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Analysis of Carotenoids in Sweet Potatoes Using HPLC to Help Combat Vitamin A Deficiency

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Abstract. The fascinating and diverse family of organic compounds called carotenoids is widely found in plants, as well as some bacteria and algae. These natural pigments, with vibrant colours ranging from bright yellow to deep red and flamboyant red, attract attention for their importance in plant biology and their effect on human health. One of the most common vitamin deficiencies in the world is vitamin A deficiency.
The name carotenoids come from the vegetable carrot (carrot in Latin), where there are many well-known beta-carotenoids. These compounds are essential to biological processes beyond contributing to nature's variety of colours.
A deficiency, a persistent public health problem in many parts of the world. The precise quantification of carotenoids, in particular beta-carotene, makes it possible to evaluate the specific contribution of these sweet potatoes to the intake of vitamin A in the diet.
This study offers important data that could guide efforts to promote sweet potato consumption, particularly in regions where vitamin A deficiency is a concern. These tubers can be strategically included in diets to improve the availability of vitamin A, helping to mitigate the risks associated with this nutritional deficiency.
In sum, this HPLC analysis of carotenoids in sweet potatoes provides a solid basis for the promotion of these tubers as a dietary resource rich in provitamin A, thereby contributing to the fight against vitamin A deficiency and the promotion of health. in the communities concerned.
Keywords: analysis, beta-carotene, carotenoids, pigment, potato, vitamin A.

I. INTRODUCTION

The fascinating and diverse family of organic compounds called carotenoids is widely found in plants, as well as some bacteria and algae. These natural pigments, with vibrant colours ranging from bright yellow to deep red and flamboyant red, attract attention for their importance in plant biology and their effect on human health. Their numerous occurrences in a variety of fruits, vegetables and edible plants are both a manifestation of their visual beauty and a reflection of a variety of important biological functions [1], [2].

There are many possibilities today to detect ingredients in various samples ranging from food to cosmetics. The instrumental method that is suitable for analysing carotenoids is HPLC (high performance liquid chromatography). In this report we will explore the analysis and validation of a method for measuring carotenoids by HPLC and its application to the determination of carotenoid content in ten varieties of sweet potatoes. This analysis is done to help fight vitamin A deficiency in children.

This journey through the world of carotenoids will immerse us in the diversity of these molecules by exploring their chemical structures, their food sources, their biological functions and their implications for human health. Carotenoids may play an important role in promoting overall well-being, whether in combating chronic diseases or improving vision. This study provides in-depth insight into how carotenoids have moved beyond their aesthetic function to become essential players in plant biology and human health, as research into these compounds continues.

II. MATERIALS AND METHODS.

A. Theoretical Analysis of Vitamin A Deficiency

One of the most common vitamin deficiencies in the world is vitamin A deficiency. More than 100 million people are affected and it occurs in regions where provitamin A carotenoids provide the majority of vitamin A [3]. Vitamin A deficiency affects more than 250 million children under the age of five worldwide.

A better understanding of the mechanisms of absorption and metabolism of provitamin A carotenoids could help alleviate the nutritional problems associated with vitamin A deficiency.

Vitamin A was the first essential vitamin discovered. Its chemical structure is shown in Figure 1. Vitamin A is also toxic at high levels. The toxicity of vitamin A has limited its use as a supplement, but most Western diets are rich in

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vitamin A-fortified products and preformed natural products, such as meat. Plant sources also contain high levels of vitamin A from pro-vitamin A carotenoids such as β-carotene, α-carotene, and β-cryptoxanthin, with β-carotene being the most potent source of vitamin A [4].

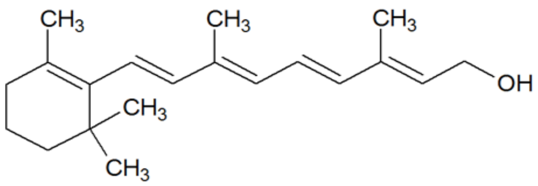

Fig. 1: Vitamin A formula [4]

Vitamin A deficiency may be due to a diet low in vitamin A or an absorption or liver disorder. Vitamin A (retinol) is necessary for the photosensitive nerve cells (photoreceptors) in the retina of the eye to function properly, allowing night vision to be maintained. In addition, it contributes to the protection of the skin, pulmonary, intestinal and urinary mucous membranes against infections.

Fig. 2: Foods rich in vitamin A, [5]/

So it is very important to consume food rich in vitamin A. The main sources of vitamin A (See Figure 2) are: fish liver oil, liver, egg yolk, butter, cream and fortified milk [6].

TABLE 1: ESTIMATION OF VITAMIN A REQUIREMENTS, BY A JOINT FAO/WHO (WORLD HEALTH ORGANIZATION) COMMISSION [4]

Groupe	Age	Basic needs	Security contribution
	Years	mg of retinol equivalent/day	
Infants	0-1	180	350
Children	1-6	200	400
	6-10	250	400
	10-12	300	500
	12-15	350	600
Boys	15-18	400	600
Girls	15-18	330	500
Men	18 +	300	600
Women	18+	270	500
Pregnant Women		370	600
Lactating Women		450	850

Seeds, nuts, vegetable oil and most dark yellow-orange or dark green leafy vegetables provide a good supply of vitamin A. A whole sweet potato, with its skin included, contains approximately 1400 micrograms of vitamin A, while half a cup of raw carrots contains more than 450 micrograms, almost 51% of the daily requirement. Other foods rich in vitamin A include spinach, broccoli, squash, watermelon, grapefruit, peaches and apricots [7]. Table 1 shows the estimated vitamin A needs of different people according to their age and sex.

The role of carotenoids

Carotenoids play a crucial role in this process. Once consumed, carotenoids are slowly transformed into vitamin A in the body. Carotenoids are optimally absorbed when they come from cooked or pureed vegetables, served with fat or oil. Good sources of carotenoids are dark green, yellow or orange vegetables, as well as yellow or orange fruits [6], [8].

Causes of vitamin A deficiency

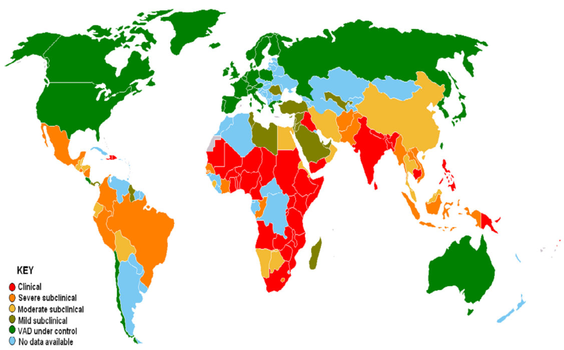

Fig. 3: Vitamin A deficiency worldwide, [9]

Vitamin A deficiency is usually caused by a diet low in the vitamin. This problem is prevalent in parts of the world where people do not consume certain foods that are good sources of vitamin A in sufficient quantities. The African continent, particularly the regions south of the Sahara, are the most affected. Indeed, of the 34 countries in the world where the WHO considers vitamin A deficiency to be a public health problem, 18 are located in West Africa, as can be seen in Fig. 3. Vitamin A deficiency is responsible for 57,000 annual deaths among children aged 6 to 59 months in French-speaking West Africa [8].

For example, in South and East Asia, where plain rice, which does not contain vitamin A, is the main food, there is vitamin A deficiency. Golden rice can prevent deficiency in vitamin A because it contains more beta-carotene. Disorders that affect fat absorption in the intestine can decrease the absorption of fat-soluble vitamin A and increase the risk of vitamin A deficiency. Chronic diarrhoea, celiac disease, cystic fibrosis, certain pancreatic disorders, and Bile duct obstruction are some of these disorders. The same effect can be produced by surgical interventions on the intestine or pancreas.

The symptoms are numerous but they can be easily overlooked. Night blindness is a first symptom. Shortly after, the white part of the eye (the conjunctiva) and the cornea may dry out and thicken. The skin becomes dry and scaly, and the mucous membranes of the lungs, intestines and urine become thick and stiff. The functioning of the immune system is disrupted, which favors the occurrence of infections, particularly in babies and children. The growth and development of children may be slowed. More than half of children with severe vitamin A deficiency may die. Diagnosis is based on symptoms and blood tests. Administering high doses of vitamin A for a few days can remedy the deficiency. Vitamin A deficiency can be prevented by eating products rich in vitamin A. Children who live in countries with high rates of food insecurity and are at risk of vitamin A deficiency should take vitamin A supplements [5].

B. Carotenoids

The name carotenoids come from the vegetable carrot (carrot in Latin), where there are many well-known beta-carotenoids. These compounds are essential to biological processes beyond contributing to nature's variety of colours. Certain carotenoids, which are precursors of vitamin A, are necessary for healthy vision, strengthening the immune system and maintaining skin health. However, many varieties of carotenoids have powerful antioxidant properties, protecting cells from free radical damage, meaning their effect is not limited to vitamin A.

More than 700 natural carotenoids have been identified [10] are two types of carotenoids: xanthophylls and carotenes [11]. Xanthophylls contain oxygen and carotenes are pure hydrocarbons. Animals do not have the ability to synthesize carotenoids and must obtain them from plant sources. Carotenoids are synthesized in plants and serve to harvest blue light in photosynthesis and to protect the plant from reactive oxygen species (ROS). Carotenoids are strongly hydrophobic compounds and are therefore associated with other lipids. In the plant cell carotenoids are located in organelles such as chloroplasts and chromoplasts. In fruits, carotenoids are more concentrated near the rind than near the stone.

Epidemiological and biological studies have implicated carotenoids as anticarcinogenic and antioxidant foods [12]. The antioxidant properties of carotenoids come from their ability to quench singlet oxygen through their conjugated double bonds. For example, lycopene has eleven conjugated double bonds and is a powerful antioxidant [13]. In the eyes, lutein and zeaxanthin protect the macula from harmful blue light and ultraviolet light. Much of the beneficial effects of carotenoids come from their vitamin A activity. There is a subclass of carotenoids that can be cleaved to produce retina. This subclass is known as provitamin A carotenoids and includes β-carotene, α-carotene, and β-cryptoxanthin. [4]

In the food industry, carotenoids are widely used as natural colorants. They are offered in food supplements because of their antioxidant properties and their potential ability to protect against the effects of the sun. They are considered capable of preventing cardiovascular diseases, certain cancers and certain eye conditions linked to aging (such as retinal degeneration) as well as strengthening the immune defenses of the elderly.

III. RESULTS AND DISCUSSION.

A. Carotenoid analysis

The most popular carotenoids

Lycopene

It is the carotenoid that we consume in the greatest quantity: between 5 and 25 mg per day. Lycopene is a carotenoid belonging to the tetraterpene family. It is widely recognized for its intense red color and is mainly found in certain fruits and vegetables, particularly tomatoes. It is the compound responsible for the red coloring of the fruit. Besides tomatoes, lycopene is also found in other fruits such as watermelons, pink grapefruit and guavas, as well as some vegetables, such as red pepper. (Fig. 4)

A distinctive feature of lycopene is its linear chemical structure (Figure 5), which gives it powerful antioxidant properties. As an antioxidant, lycopene works by neutralizing free radicals, which may help protect cells from oxidative damage. Some researchers suggest that regular consumption of lycopene may be associated with health benefits, such as reducing the risk of certain chronic diseases, including some forms of cancer and cardiovascular disease.

Fig. 4: Products rich in lycopene, [4]

Separately, studies have also explored the potential role of lycopene in skin health, suggesting that it may help protect the skin against the damaging effects of the sun's ultraviolet rays, although this does not replace conventional methods of sunscreen.

It should be noted that the bioavailability of lycopene can be improved when consumed with fat, as it is fat soluble. So, adding a small amount of fat to a meal containing lycopene sources can potentially increase its absorption.

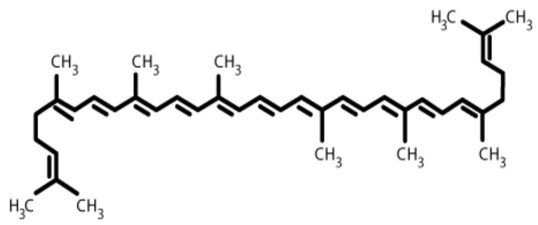

Fig. 5: Chemical structure of lycopene, [6]

Beta-carotene

Beta-carotene, one of the best known and studied carotenoids, occupies a predominant place within this family of plant pigments. It owes its name to the core, in which it was initially discovered and isolated. This reddish and orange-tinted molecule is part of the group of provitamin carotenoids, which means that it can be converted into vitamin A in the body.

Chemically, beta-carotene consists of 40 carbon atoms and is structured in two identical parts, forming a symmetrical "V" molecule. (Fig. 6) This unique structure gives beta-carotene specific properties that distinguish it within the carotenoid family.

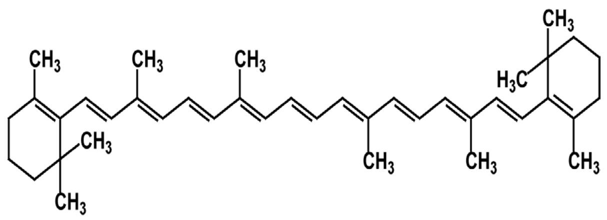

Fig. 6: Chemical structure of beta-carotene [8]

One of the most remarkable characteristics of beta-carotene is its ability to act as a precursor to vitamin A. When ingested, beta-carotene is converted in the liver to retinol, the active form of the vitamin A. This conversion is crucial for maintaining healthy vision, cell growth, reproduction, and proper functioning of the immune system.

In addition to its role as a precursor to vitamin A, beta-carotene plays a significant role as an antioxidant. By acting as a free radical neutralizing agent, it helps protect the body's cells from oxidative damage, thus playing a potential role in the prevention of certain chronic diseases.

Food sources rich in beta-carotene are varied, encompassing a multitude of colourful fruits and vegetables such as carrots, sweet potatoes, spinach, mangoes, and melons, to name a few. (Fig. 7) Including these foods in the daily diet offers a natural strategy to promote health, harnessing the benefits of beta-carotene and other carotenoids.

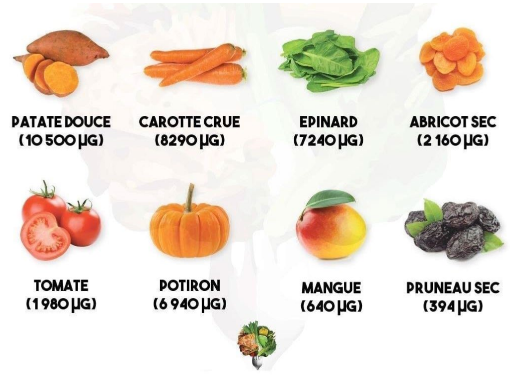

Fig. 7: Foods rich in beta-carotene, Vie Zen [6]

We consume on average 3 to 6 mg of beta-carotene per day, mainly in carrots, oranges and green vegetables. Once absorbed, it is stored in adipose tissue. When the body needs vitamin A, it draws on these reserves: 2 mg of beta-carotene provides 1 mg of vitamin A. The long-term effects of large quantities of beta-carotene have shown the major risk of increasing the lung cancer in people with risk factors, such as smoking or a diet already rich in beta-carotene.

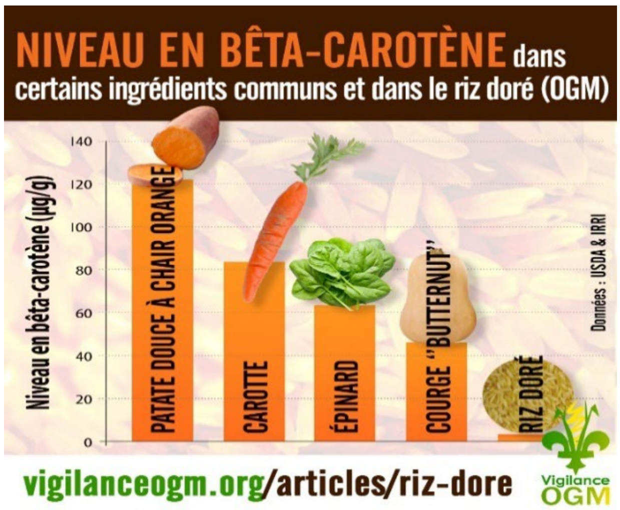

Fig. 8: Level of beta-carotene in certain foods, [6]

Astaxanthin

Astaxanthin is a carotenoid belonging to the xanthophyll class, which is a subfamily of carotenoids. This natural compound takes its name from the microalgae Haemapodous pluvial is, where it is produced in abundance. Astaxanthin is responsible for the pink to red color seen in various marine organisms such as salmon, shrimp, lobsters and crabs.

Chemically, astaxanthin has a unique structure featuring aromatic rings and conjugated double bonds. (Fig. 9) This configuration gives it exceptional antioxidant properties, making astaxanthin one of the most powerful antioxidants among carotenoids.

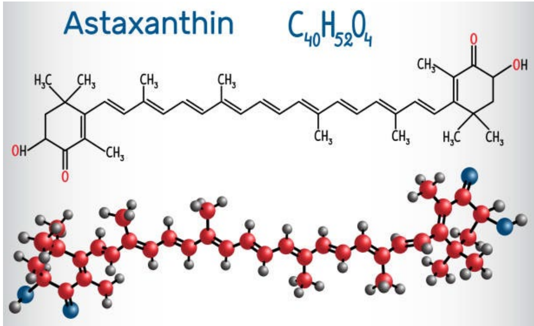

Fig. 9: Chemical structure of astaxanthin IStock, [11]

One of the best-known sources of astaxanthin is wild salmon, which acquire the substance by feeding on astaxanthin-rich marine organisms, such as shrimp and krill. (Fig. 10) The health benefits of astaxanthin are increasingly being studied, and several research studies suggest that it may play a crucial role in promoting human health.

Fig. 10: Sources of astaxanthin [11]

As an antioxidant, astaxanthin protects cells against damage caused by free radicals, helping to alleviate oxidative stress. Some researchers have explored its potential effects in preventing chronic diseases, protecting the skin from ultraviolet rays, and supporting eye functions.

Additionally, due to its anti-inflammatory properties, astaxanthin has also been studied for its potential in the management of inflammatory disorders and muscle recovery after exercise.

Lutein and zeaxanthin

Lutein and zeaxanthin are two carotenoids that also belong to the xanthophyll class. (Fig. 11) These compounds stand out for their antioxidant properties and their particularly high concentration in the retina of the eye, where they play an essential role in visual health.

Lutein:

Origin: Lutein is mainly found in green leafy vegetables such as spinach, kale and broccoli. Eggs and some other food sources also contain lutein.

Role: Lutein is particularly known for its benefits for eye health. It is concentrated in the macula of the retina, where it acts as a filter of potentially harmful blue light. By acting as an antioxidant, lutein helps protect retinal cells from oxidative damage and may help reduce the risk of age-related macular degeneration (AMD), a progressive eye disease.

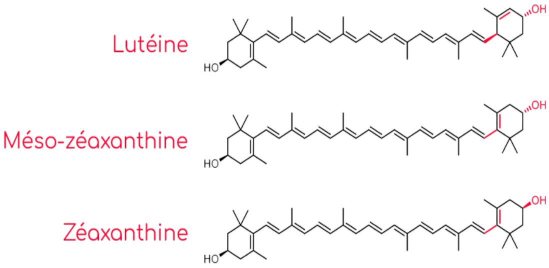

Fig. 11: Chemical structure of lutein and zeaxanthin, [14]

Zeaxanthin:

Origin: Zeaxanthin is also found in green leafy vegetables, but it is particularly abundant in foods such as corn, oranges and peppers.

Role: Zeaxanthin, like lutein, is present in the retina, and it also helps protect photoreceptor cells from the harmful effects of light rays. These two carotenoids are often associated in the scientific literature due to their common presence in the eye and their synergistic benefits for ocular health.

Research suggests that regular consumption of lutein and zeaxanthin through diet or supplements may help maintain healthy vision and reduce the risk of certain eye conditions. These carotenoids are also being studied for their potential in preventing cardiovascular disease and other disorders linked to oxidative stress.

On Table 2 you can see the main sources of carotenoids.

TABLE 2: SOME CAROTENOIDS AND THEIR FOOD SOURCES, [13]

PROVITAMINES A	BÊTA-CAROTÈNE, ALPHA-CAROTÈNE, BÊTA-CRYPTOXANTHINE	CAROTTES, ORANGES, BROCOLIS, ÉPINARDS, VERT DE BLETTES, JAUNE D'ŒUF, HUILE DE PALME ROUGE
Autres	Lutéine zéaxanthine	Choux verts, épinards, courgettes, brocolis, petits pois, maïs, kiwis, oranges, mangues, jaune d'œuf
	Lycopène	Tomates et produits dérivés (sauces, jus, etc.), pastèques, goyaves
	Astaxanthine	Crustacés (krill), algues microscopiques

Three complementary approaches are proposed to combat this problem, which is a real obstacle to progress in certain countries. These include preventive vitamin A supplementation, the enrichment of foods with vitamin A and dietary diversification through the consumption of foods rich in provitamin A carotenoids.

The organization Helen Keller International (HKI) has invested a lot of money in Burkina Faso, in collaboration with other national or international institutions, to combat the shortage of vitamin A. It has started the production of sweet potato varieties to orange flesh in the Fada region as such. Sweet potato (Ipomea batata) is a commonly consumed tuber. Promoting a specific variety requires appropriate knowledge about provitamin A carotenoid levels.

High-performance liquid chromatography is the most commonly used method for measuring carotenoids in the scientific literature. This method is used to extract carotenoids in different ways. Detection methods include ultraviolet and visible spectroscopy at fixed wavelength or with diode array detectors, electrochemistry and mass detection. [14], [15], [16], [17]

The results are presented in Table 3 [14].

TABLE 3: QUALITATIVE AND QUANTITATIVE COMPOSITION OF THE DIFFERENT VARIETIES OF SWEET POTATOES ANALYZED, (ISSA T. SOMÉ ET AL., 2004)

Sweet potato varieties	carotenoids (mg/100 g)				
	ZEA	CRYP	LYCO	ACAR	BCAR
CN	17.2 (11.2)	9.9 (11.1)	–	–	95 (83.5)
MS	19.5 (1.1)	13.5 (1.6)	–	–	6.66 (1.6)
LA	3.17 (1.51)	–	–	–	38 (8)
KA	17.2 (4)	5.1 (2.2)	17.8 (0.3)	89.8 (0.01)	429 (525)
CA	43.9 (15.2)	16.9 (2.2)	24.2 (18.4)	202 (114)	2046 (1192)
JE	38 (3.1)	15.7 (1.2)	9.6 (1.03)	136 (11)	1911 (148)
TAI	12.32 (3.6)	12.6 (2.7)	5.9 (2.9)	–	774 (357)
NA	28.4 (3.5)	17.2 (2.4)	10.4 (2.7)	151 (17)	2348 (210)
KO	6.71 (2.48)	–	–	–	170 (50)
LB	72.1 (24.8)	10.6 (6.7)	–	–	

IV. CONCLUSION

Completing this in-depth analysis of carotenoids in sweet potatoes by high-performance liquid chromatography (HPLC), which is not the subject of this article, it is clear that these tubers represent a significant source of provitamin A-rich compounds, especially beta-carotene. Research and laboratory analyzes by a number of independent authors have established that the HPLC method is a reliable and sensitive tool for the accurate quantification of the various carotenoids present in sweet potato samples, providing a detailed understanding of the specific composition of these pigments.

The significance of this analysis in the paper goes beyond simple chemical characterization. Sweet potatoes, as a natural source of beta-carotene, show significant potential in combating vitamin A deficiency, a persistent public health problem in many parts of the world. Precise quantification of carotenoids, in particular beta-carotene, makes it possible to estimate the specific contribution of these sweet potatoes to dietary vitamin A intake.

This analysis leads us to conclusions and offers important data that could guide efforts to promote sweet potato consumption, especially in regions where vitamin A deficiency is a problem. Areas with fewer sunny days (Northern Europe, Canada, Russia) and vitamin A deficiency are well suited for conducting research with increased consumption of sweet potatoes. These tubers can be strategically incorporated into diets to improve vitamin A availability, helping to mitigate the risks associated with this nutritional deficiency.

It is also good to do research based on this analysis by extending the sampling to different sweet potato cultivars, taking into account the environmental and agronomic factors that may affect the carotenoid content. This will allow a better understanding of potential variations in carotenoid composition and guide further dietary recommendations.

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