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REVIEW

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Unconventional Food Plants (UFPs): an approach to the nutritional and functional properties of nasturtium (*Tropaeolum majus* L.)

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Abstract
Unconventional food plants (UFPs) are little-explored plant species that can be used in human nutrition. In addition to the low cost of production, these plants can add nutritional value to food products, so their use as a raw material may be feasible within the food industry. Among the UFPs is the nasturtium (Tropaeolum majus L.), an easy cultivation species with all edible parts except the roots. Its flowers can be used in various culinary preparations besides having antioxidant potential; therefore, their consumption may benefit human health. Furthermore, the leaves, stalks and seeds can also be used in different ways in food; however, few studies have been reported on these parts of the plant. This review brings an approach to the nutritional and functional properties of edible parts of nasturtium, aiming at adding value with potential applications for the development of new nutritious and functional food products, thus valuing biodiversity.

Keywords: PANC, biodiversity, phytochemicals, flowers, leaves, stems.

Graphical Abstract

Nasturtium is an unconventional plant whose flowers, leaves and stems are edible

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1 Introduction

Unconventional food plants (UFPs), or "plantas alimentícias não convencionais" (PANC) in Portuguese, is a term that Brazilian biologist Valdely Ferreira Kinupp created in 2008 and refers to underutilized plant species showing food potential for human consumption, which have spontaneous growth but generally have low market value, being sold only on a small scale. In addition, UFPs can also refer to species that are common and cultivated in a specific region but are underexplored and unconventional in other regions in the same country (Leal et al., 2018; Jesus et al., 2020).

Among the UFPs is *Tropaeolum majus* L., popularly known as nasturtium or capuchinha in Portuguese, whose species belongs to the Tropaeolaceae family, native to Central and South America (GBIF, 2022; Callegari & Matos Filho, 2017). This plant has rounded leaves, flowers with a color that varies between yellow, orange, and red tones with dark internal spots, and greenish fruits. This plant can be grown at any time of the year, growing in moist soil rich in organic matter, with all its parts considered edible, except the roots (Callegari & Matos Filho, 2017).

The nasturtium has diverse uses, which vary according to the country. For instance, its use in foods in India includes all parts of the plant. On the other hand, flowers, leaves, and fruits are used to decorate sophisticated dishes in France. Furthermore, due to its herbal properties, the juice of its leaves can be used as a natural expectorant in Brazil (Franzen et al., 2016).

Considering that knowledge about this UFP is still on the rise, this review article presents an approach to the nutritional and functional properties of edible parts of nasturtium, aiming at adding value with potential applications for the development of new nutritious and functional food products, thus constituting a strategy for valuing biodiversity.

2 Unconventional Food Plants (UFPs)

Unconventional food plants (UFPs) are mainly native, exotic, or naturalized species, whose leaves, roots, flowers, or stems are edible but not usually used in human nutrition (Sartori et al., 2020). UFPs are often referred to as bush, weeds, or invasive plants. They grow in areas of commercial agricultural production and may cause competition with cultivated species. They usually have spontaneous growth and require simple, undemanding cultivation, high genetic variability, and adaptation to different environments, enabling their cultivation and low environmental impact. However, they have nutritional potential still unknown by most of the population. In addition, they are not part of the list of commonly consumed vegetables, mainly due to a lack of habit and/or knowledge. For this reason, they are called UFPs (Kinupp & Lorenzi, 2014).

In nature, it is possible to find a diversity of edible plants. It is estimated that there are approximately 30,000 species with food potential (Kinupp & Lorenzi, 2014). According to data from the Food and Agriculture Organization of the United Nations (FAO), it is estimated that, across the planet, the number of plants consumed by man has dropped from 10,000 to 170 in the last hundred years (Lira, 2018). However, only a tiny part of all the plants that humans can consume are known and produced.

For the environment, producing a UFP means recognizing native species whose use is disappearing and valuing biodiversity because many of them are still underutilized as food. In addition, due to their resistance and varied production, many unconventional plants can safely provide healthy food, available all year round and at no high cost (Ranieri et al., 2017).

Such vegetables that are important representatives of Brazilian culture include azedinha (*Rumex acetosa*), purslane (*Portulaca oleracea*), nasturtium (*Tropaeolum majus*), dandelion (*Taraxacum officinale*), peixinho (*Stachys byzantina*), milkweed (*Sonchus oleraceus*), taioba (*Xanthosoma taioba*), nettle (*Urtica dioica*), among others. Some of them are native, while others were introduced by European (mainly Portuguese) settlers or by enslaved Africans (Brazil, 2009).

According to the Food Guide for the Brazilian Population (Brazil, 2014), traditional eating patterns developed and transmitted over generations are essential sources of knowledge for formulating recommendations to promote adequate and healthy eating. Besides, these standards result from the accumulation of knowledge about the varieties of plants and animals that best adapted to the conditions of the climate and soil, about the production techniques that proved to be more productive and sustainable, and about the combinations of food and culinary preparations that were well suited to human health and taste.

Several species of these vegetables can exert beneficial physiological effects regarding the digestive tract, as they act on the intestinal microbiota, which plays a fundamental role in the health and balance of the intestine (Paschoal & Souza, 2015).

Current research has identified that, in general, UFPs have a nutritional composition superior to some conventional vegetables. As a result, UFPs can also significantly contribute to the daily intake of vitamins and minerals, which are essential for human development (Liberato et al., 2019).

It is worth mentioning that the usually not consumed parts of conventional plants, such as chayote leaves, pumpkin, and sweet potato, are also considered UFPs. In this way, these edible portions present a range of diversity, versatility, and variety of nutrients, contributing to an adequate, healthy, environmentally, and culturally responsible diet.

3 Nasturtium: nutritional and functional properties

Nasturtium is characterized as an ornamental flower, in addition to having an attractive visual aspect to the consumer and is considered one of the pioneers in the use of flowers in human food (Franzen et al., 2016). It is a subtropical plant that adapts well to partially shaded environments as long as it is irrigated in the driest periods and can also be grown throughout the year. In **Fig. 1,** it is possible to observe the flowers, leaves and stems of the plant.

Flower Leaf Flowers, leaves and stems

Fig. 1 Edible parts of nasturtium

Although the flower is the most explored part of scientific works, the chemical composition of the nasturtium is still not fully known. Available studies show the presence of some chemical components in certain parts of the plant. However, the data presented in the literature are varied, probably due to different plant cultivation conditions, such as sun exposure, soil type, fertilization, or even the plants can be of different varieties (Jakubczyk et al., 2018).

As can be seen in **Table 1**, stalks have a high moisture and fiber content compared to other parts. On the other hand, the leaves have higher protein contents, which is a highlight for potential application in developing new food products.

Table 1 Mean values of the proximal composition (g 100 g^{-1}) of nasturtium edible parts.

Edible parts	Moisture	Carbohydrates	Proteins	Lipids	Ashes	Fibers
Flower[1]	91.91	4.73	1.48	0.33	0.78	0.77
Leaf[2]	87.41	1.58	6.13	0.10	0.97	2.23
Stalk[2]	95.09	0.65	1.22	1.13	0.45	2.79
Seed[3]	-	7.14	1.99	0.33	0.63	-

Source: [1]Franzen et al. (2016); [2]The authors, according to AOAC (2005); [3]Jakubczyk et al. (2018).

Nasturtium has several biologically active compounds, such as flavonoids (isoquercetin, kaempferol) and carotenoids belonging to the group of phenolic compounds. In addition, this plant is also rich in micronutrients like potassium, phosphorus, calcium, magnesium, zinc, copper and iron. Moreover, due to these characteristics, it has numerous beneficial properties for health, having antioxidant, hypotensive, antibacterial, and anticancer action (Jakubczyk et al., 2018).

The antioxidant capacity of foods is related to the presence of phenolic compounds, vitamin C, carotenes, and other pigments. Furthermore, the action of these components depends on their concentrations in food. Silva et al. (2021) determined the antioxidant activity and the contents of phenolic compounds and vitamin C in nasturtium leaves and flowers, as summarized in **Table 2**.

Table 2 Mean values for antioxidant activity, phenolic compounds and vitamin C of nasturtium flowers and leaves.

Edible parts	Antioxidant activity (% SRL)	Phenolic compounds (mg 100 g^{-1})	Vitamin C (mg 100 g^{-1})
Flower	68.32	23.39	175.93
Leaf	93.58	167.84	188.55

% SRL: percentage of free radical scavenging. Source: Silva et al. (2021).

Table 3 Mean values for bioactive compounds and antioxidant activity of nasturtium flowers.

Parameter	Red	Orange	Yellow
TPC (mg GAE 100 g^{-1})	908.7	687.7	538.4
ORAC (μmol TE 100 g^{-1})	18719	11790	7111
CTA (mg C3G 100g^{-1})	114.5	58.2	31.9
THA (mg CAE 100 g^{-1})	33.3	81.2	235.6
Quercetin (mg 100 g^{-1})	16.1	9.7	5.6
Kaempferol (mg 100 g^{-1})	40.9	167.0	29.6
Flavonols (mg ME 100 g^{-1})	315.1	1.2	0.8

TPC, total phenolic compounds, expressed in mg gallic acid equivalents (GAE) per 100 grams wet basis; ORAC, oxygen radical absorbance capacity, expressed in μmol Trolox equivalent per 100 g wet basis; TAC, total anthocyanin content; C3G, expressed in mg of cyanidin-3-O-glucoside equivalents per 100 g wet basis; THA, total hydroxycinnamic acids, expressed in mg of chlorogenic acid equivalents (CAE) per 100 grams on a wet basis; flavonols expressed as mg of myricetin equivalents (ME) per 100 grams wet basis. Source: Garzón et al. (2015).

3.1 Flowers

It is worth mentioning that the leaves stand out due to the high concentration of phenolic compounds and vitamin C; therefore, they also have greater antioxidant activity.

Edible flowers can be considered a non-traditional food, and their consumption can be recommended due to their antioxidant capacity, which is often similar or superior to traditional fruits (Benevenuti, Bortolotti & Maggini, 2016).

According to Ebert et al. (2021), nasturtium flowers present diversity in their color and can be red, yellow and orange. Depending on the color, these flowers can provide greater antioxidant capacity, for example, the red nasturtium due to a higher concentration of anthocyanins, which is associated with a reduced risk of chronic diseases, provided that it is combined with a healthy lifestyle. Yellow flowers have higher levels of total carotenoids, such as lutein, and their consumption is related to eye health. Orange flowers contain intermediate values of phenolics and carotenoids when compared to red and yellow flowers (Souza et al*.,* 2020).

Table 3 presents the composition of the main bioactive compounds and *in vitro* antioxidant activity by the ORAC method of the different colors of the nasturtium flower.

In general, nasturtium flowers have a high content of carotenoids, flavonoids (quercetin, kaempferol, myricetin, rutin and catechin) and anthocyanins (delphinidin, cyanidin and pelargonidin), which are substances with significant antioxidant, anti-inflammatory, and hypotensive potential. Therefore, the consumption of *Tropaeolum majus* L. can provide beneficial effects on human health (Souza et al., 2020; Ebert et al., 2021).

The flowers have a spicy flavor, similar to watercress, can be eaten fresh or dried, and are mainly used to decorate dishes (Franzen et al., 2016; Callegari & Matos Filho, 2017). In a sensory analysis of different species of edible flowers, carried out by Benevenuti, Bortolotti and Maggini (2016), the *Tropaeolum majus* L. species was considered the most attractive, obtaining the highest score from the evaluators. Its flavor was associated with the radish and presented a strong spicy flavor, sweetness, softness, and aroma.

3.2 Leaves, stems, fruits, and seeds

Regarding nasturtium leaves and stems, there is still little data available in the literature about their nutritional properties. However, some studies show that the leaves have minerals, mainly zinc, and can be used to prepare salads, omelets, stews or even infusions (Botrel et al., 2020; Souza et al., 2020). In addition, the leaf extract helps treat urinary infections and has antihypertensive and anticoagulant effects (Souza et al., 2020). The stalks can also be used along with the leaves in various culinary preparations (Callegari & Matos Filho, 2017).

A study by Barrantes-Martínez et al. (2022) supplemented pre-diabetic patients for 4 weeks with 15 g per week of freeze-dried nasturtium leaves. The intervention did not cause effects on glycemic parameters and insulin resistance; however, the results demonstrated a beneficial potential of supplementation, as they suggested an improvement in the lipid profile of these individuals.

From the seeds of nasturtium (**Fig. 2**), also known as a fruit, Lorenzo's Oil can be extracted, which is indicated for the treatment of adrenoleukodystrophy, a severe and degenerative disease (Franzen et al., 2016; Ebert et al., 2021). The oil extracted from the seeds has a high content of monounsaturated fatty acids (>96%), and the erucic acid content reaches 80% in some varieties of the plant (Jakubczyk et al., 2018).

Fig. 2 Nasturtium seed. Source: Adapted from Sartori et al. (2020).

In addition, immature fruits can be preserved and immersed in white vinegar for approximately 12 days, with a typical caper taste (Sartori et al., 2020). Finally, ripe seeds can be toasted and ground and later used to replace black pepper (Callegari & Matos Filho, 2017).

4 Final considerations

Nasturtium represents a promising food category as well as an important source of micronutrients and phytochemicals. Its edible parts, such as flowers, leaves, stems, and seeds, have nutritional characteristics that can be added to developing new food products with functional and sensory properties. In addition, it contributes to the appreciation of food cultures and may be an alternative to promote food and nutritional security and food sovereignty.

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D.C.: Data curation; formal analysis; investigation; methodology; writing - original draft. G.N.: Writing - review & editing. L.O.M.: investigation; writing - original draft. L.G.L.: Writing - review & editing. V.C.I.: Conceptualization; data curation; formal analysis; Writing - review & editing.

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Conflicts of Interest

The authors declare no conflict of interest.

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