

We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

4,800

Open access books available

122,000

International authors and editors

135M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.

For more information visit www.intechopen.com



Nutritional Functional Value and Therapeutic Utilization of Amaranth

Manuel Soriano-García and Isabel Saraid Aguirre-Díaz

Abstract

Amaranthus is a dicotyledonous pseudocereal and one of the New World's oldest crops, having originated in Mesoamerica, and was a major food crop of the Aztecs who named it Huautli or Xtes. Popularity in the cultivation and consumption of *Amaranthus* seed in the modern era began in the mid-1970s with the rediscovery and promotion of amaranth due to its superior nutritional attributes as compared to cereal grains. Today, amaranth is still included in the human diet because of its nutraceutical relevance. Amaranth is considered as a “superfood” because it contains high nutraceutical values such as a high-quality protein, unsaturated oils, squalene, dietary fiber, tocopherols, tocotrienols, phenolic compounds, flavonoids, vitamins, and minerals. Compared to other grains, amaranth has a higher amount of protein, dietary fiber, calcium, iron, and magnesium; therefore although it is an ancient crop nowadays, it is considered a millennium crop or superfood with relevant nutraceutical values and its agronomic versatility. This comprehensive chapter is focused on amaranth composition and antioxidant properties and provides several potential medical benefits of its valuable components.

Keywords: *Amaranthus* spp., *Amaranthus hypochondriacus*, superfood, nutritional functional value, therapeutic utilization

1. Introduction

Amaranthus is a dicotyledonous pseudocereal and one of the New World's oldest crops, having originated in Mesoamerica. The family Amaranthaceae is generally considered as the “amaranth family.” The word *Amaranthus* is basically derived from the Greek word “anthos” (flower) which means everlasting or unwilting. Amaranth (*Amaranthus* spp.) has been consumed throughout history, by the Inca, Maya, and Aztec civilizations. Amaranth was a part of the daily diet, in addition to corn and beans. At the present time, it is also called the third millennium crop plant [1]. Currently it is widely cultivated and consumed throughout India, Nepal, China, Indonesia, Malaysia, and the Philippines; whole of Central America, Mexico; and Southern and Eastern Africa. The species grown for human consumption are *Amaranthus hypochondriacus*, *A. cruentus*, and *A. caudatus*. Since pre-Hispanic time, every part of the *Amaranthus hypochondriacus* plant has been broadly used in Mexico, especially the seeds. Amaranth is a plant with annual growth, fast-growing with several different colors, and is reproduced by self-pollination by the wind. This plant has a high resistance to drought and a variety of weather conditions.



Figure 1.
Amaranthus hypochondriacus plant.



Figure 2.
Amaranth grain from which a nutritional beverage is prepared.

The domesticated species is *A. hypochondriacus* which is mainly harvested in the States of Guerrero, Morelos, Michoacán, Queretaro, Puebla, and Tlaxcala [2].

There has been an increased interest in amaranth since it appeared in the 1980s, when the US National Academy of Sciences carried out a research project entitled *Underexploited Tropical Plants with Promising Economic Value*, at that time amaranth was elected from among 36 of the world's most promising crops and identified as a major potential crop; since then, extensive research has been carried out [3]. Research has been performed on the grain which has allowed to describe its high nutritional value and agronomic potential [4].

Figure 1 shows the *Amaranthus hypochondriacus* plant and can be easily recognized among other crops as each plant has an “immortal colorful flower” that, based on our own experience, contains more than 1 kg of seeds each big flower. **Figure 2** shows that amaranth grain morphology is smooth, with slightly golden color, shiny, and slightly flattened with a lens-shaped form. Its size varies between 1.1 and 1.4 mm in length and 1.0 and 1.3 mm in width, while its weight is around 0.6 and 1.0 mg.

2. Amaranth description and composition

Amaranth (*Amaranthus hypochondriacus*) belongs to the Amaranthaceae family: the seeds are rich in macronutrients including proteins, dietary fiber, and fats (**Table 1**) and micronutrients such as vitamins and minerals (**Table 2**). Extensive reviews of the past two decades have shown that amaranth seeds have abundant protein content ranging from 13 to 19% with an outstanding balance of essential amino acids [5]. Besides, the amaranth seeds contain higher levels of oils rich in squalene, have high lipid and starch, and also contain a high amount of antioxidants [6].

It is known that celiac disease is a serious autoimmune disease that occurs in genetically predisposed people where the ingestion of gluten leads to damage in the small intestine. It is estimated to affect 1 in 100 people worldwide. Amaranth seed is gluten-free and may be used to prepare nutritious and suitable food products for people with this type of food allergy.

Herein essential amino acids, fatty acid composition, and phytonutrients of amaranth grain are given in **Tables 3–5**, respectively.

The essential amino acid profile of amaranth grain is given in **Table 3**.

The lipid contents in amaranth grain is around 7–9% higher as the values found in other cereals such as wheat and maize with values of 2.1 and 4.5%, respectively. Amaranth grain contains mainly unsaturated fats, containing linoleic (or omega-6) fatty acid (25–62%) and alpha-linolenic (or omega-3) fatty acid (0.3–2.2%) [7]. The fatty acid composition of amaranth grain is given in **Table 4**.

Amaranth grain flour contains mainly polyphenols (flavonoids) and phenolic acids with relatively high antioxidant activity. Both flavonoids and phenolic acid composition of amaranth grain are given in **Table 5**.

The amaranth grain contains more protein than other crops as corn and rice [13] and a relatively high content of several essential amino acids as shown in **Table 3**. Lysine is the principal component which limits amino acid in cereals like maize, wheat, and rice. Lysine in protein ranges from 40 to 50 g/kg. The essential amino acid index (EAAI) value of 90.4% showed that amaranth's protein is comparable

Component	Amaranth grain (value per 100 g)
Protein	13.56
Lipids	7.02
Carbohydrates	65.25
Dietary fiber	6.70
Ash	2.88
Water	11.29
Energy (kcal; kJ)	371; 1554

Table 1.
Nutrient composition and energy content of amaranth grain [7].

Amaranth grain (g per 100 g)	
Minerals	
Calcium	159 mg
Copper	0.53 mg
Iron	7.61 mg
Magnesium	248 mg
Manganese	3.33 mg
Phosphorus	557 mg
Potassium	508 mg
Sodium	4 mg
Zinc	2.87 mg
Selenium	18.7 mcg
Vitamins	
Ascorbic acid	4.20 mg
Riboflavin	0.20 mg
Folate	82 mcg
Niacin	0.92 mg
Thiamin	0.12 mg
Vitamin A	2 IU
Pantothenic acid, vit. B55	1.46 mg
Vitamin B-6	0.59 mg
Vitamin E (alpha-tocopherol)	1.19 mg
Vitamin E (beta-tocopherol)	0.96 mg
Vitamin E (delta-tocopherol)	0.69 mg
Choline	69.8 mg
Betaine	67.6 mg
Lutein	28 mcg

Table 2. Minerals and vitamins composition of amaranth grain [7].

with egg protein and can be used as a substitute for a meal [14]. Also there is a high amount of protein in amaranth's leaves [15]. Additionally, in amaranth's grain, besides omega-6, omega-3, oleic, palmitic, and stearic acids (**Table 4**), also another nutraceutical constituent is squalene [16]. As shown herein through **Tables 1–4**, amaranth grain contains a well-balanced proportion as relevant nutrient for human diet. Starch is the main component of amaranth grain and has been used in many healthy and organic food preparations [17]. As compared to the starch in corn and wheat, the starches of *A. cruentus* and *A. hypochondriacus* both have a higher swelling power or absorbance capacity, lower solubility, greater uptake, lower susceptibility to amylases, and lower amylase content (4.7–12.5%) [18].

Besides proteins, carbohydrates, and lipids, amaranth seeds contain various other constituents (**Tables 4 and 5**), making amaranth a superfood because it also counts with elevated levels of vitamin E, vitamin B2 (riboflavin), and vitamin C (ascorbic acid). It is also important to mention that saponins are found in very low levels (0.1%) in amaranth grain which makes it completely safe for human consumption [19].

Components	Amaranth grain (g per 100 g)
Arginine	1.06
Histidine	0.39
Isoleucine	0.58
Leucine	0.88
Lysine	0.75
Methionine	0.23
Phenylalanine	0.54
Threonine	0.56
Tryptophan	0.18
Valine	0.68

Table 3.
 Essential amino acid profile of amaranth grain [7].

Component	Amaranth grain (value per 100 g)
Palmitic acid (C16:0)	1.154
Stearic acid (C18:0)	0.223
Oleic acid (C18:1)	1.671
Linoleic acid (C18:2) ω -6	2.736
Linolenic acid (C18:3) ω -3	0.042

Table 4.
 Fatty acid composition of amaranth grain oil [7].

Components	Amaranth grain (mcg/g)
Flavonoids (polyphenols)	
Quercetin	68 ^a (18)
Nicotiflorin	6 ^b (6)
Rutin	6.15 ^b (6)
Phenolic acids	
Ferulic acid	310 ^c (9)
Gallic acid	41 ^d (5)
Caffeic acid	6.5 ^c (9)
p-Coumaric acid	1.2 ^c (9)
Isoquercitrin	0.4(6)
Anthocyanins	35.2 ^e (17)
Syringic acid	0.8 ^b (6)
Vanillic acid	1.7 ^b (6)

^aKalinova and Dadakova [8]

^bBarba de la Rosa et al. [9]

^cGorinstein et al. [10]

^dKlimczak et al. [11]

^eLópez et al. [12]

Table 5.
 Phytonutrients in amaranth grain.

Among other relevant facts that convert amaranth into a superfood is that it is considered as a good source of insoluble fiber with a content of 4.2% [17]. Both insoluble and soluble fibers have known health benefits such as reducing cholesterol and promoting gut health. Amaranth flours have been shown to have antioxidant activity due to flavonoids (polyphenols from secondary metabolites) found in the seed. Three flavonoids have been identified, rutin, isoquercitrin, and nicotiflorin, and several health benefits are known to be caused by these compounds [8] (see **Table 5**).

3. Amaranth benefits

3.1 High source of protein

Mexican consumers are looking for natural products that improve their health. However, our modern society tends to consume processed foods. These foods typically contain increased amounts of salt, sugar, fat, additives, or preservatives in order to improve their taste and texture or to extend shelf life—all of which are known as harmful. In my research group, we have special interest in using plants that were used in our ancient civilizations. This is the case of *Amaranthus hypochondriacus* which has a high concentration of protein, oil, minerals, vitamins, and antioxidants.

The protein contained in amaranth is of an unusually high quality due to its outstanding balance and high content of essential amino acids (**Table 3**). The essential amino acids in amaranth grain are ideal according to the World Health Organization (WHO) and Food and Agriculture Organization of the United Nations (FAO). For instance, the amount of lysine and tryptophan present in amaranth grain are relatively higher than those found in wheat, rice, and maize grains, but it is deficient in leucine.

Protein is used in every single cell in our bodies and is critical for building muscle mass, supporting neurological function, aiding in digestion, helping to balance hormones naturally, and keeping an upbeat mood which suggests that this protein is useful for muscle recovery and the immune system for athletic performance [20, 21].

3.2 Reduce inflammation

It is well documented that inflammation is a normal immune response designed to protect the body against injury and infection. If the inflammation process continues in your body, this could contribute and be associated with chronic diseases, such as cancer, diabetes, and autoimmune disorders.

The intake of amaranth could help to avoid diseases caused by inflammation because it has been described that extruded amaranth protein hydrolysates prevented inflammation by the activation of bioactive peptides that reduced the expression of several pro-inflammatory markers [22]. That is the reason why consumption of amaranth grain could help to reduce inflammation [23]. In this context, it is recommended to include amaranth grain in the diet in order to reduce inflammation and may help to prevent chronic diseases derived from inflammation process.

3.3 Bone health

Calcium is a key player in the generation and maintenance of healthy bones as it supports mineralization [24]. Amaranth contains more calcium than other seeds, which makes it a valuable food that helps to have a healthy development of bones helping to prevent osteoporosis [25, 26]. Therefore, the intake of extruded amaranth products could help to improve the proper intake of calcium to support healthier bones [27].

3.4 Amaranth as a cardioprotective

It has been proven that amaranth's oil can reduce total and bad cholesterol (LDL) increasing good cholesterol as tested in animal models by Berger et al. [28]. Also it has been proven that amaranth affected absorption of cholesterol and bile acids, cholesterol lipoprotein distribution, hepatic cholesterol content, and cholesterol biosynthesis [29].

3.5 Fights duodenal peptic ulcer

It is well known that various plant-originated "gastroprotectors" with different compositions have been used in clinical and folk medicine due to their beneficial effects on the mucosa of gastrointestinal tract. Ethanolic and ethyl-acetate leaf extracts of *A. tricolor* showed gastric-ulcer healing effect in acetic acid-induced chronic gastric ulcers and gastric cytoprotective effect in ethanol and indomethacin-induced gastric ulcers in pylorus-ligated rats [30]. A combined use of this extract with two other herbs will help to improve the antiulcer properties [31].

It has been found that duodenal peptic ulcer and chronic gastritis caused by *Helicobacter pylori* can be treated with amaranth oil [32].

3.6 Fights diabetes

Diabetes is a metabolic disorder where the body does not produce insulin or does not use it efficiently during the body's ability to process blood glucose. Consequently, it can lead to dangerous complications, including stroke, heart disease, kidney failure, and diabetic retinopathy, among other problems, it has been reported that amaranth grain and oil have an antioxidative effect on streptozotocin-induced diabetic rats [33]; grains and oils used as supplements may be beneficial for correcting hyperglycemia as part of an antioxidant therapy.

Manganese, besides regulating blood glucose, can boost the immune function [34]. Also it is known that manganese is needed in adequate levels to avoid abnormalities in cholesterol levels, skin and bone health [35], and renal health [36]. Another relevant benefit obtained when amaranth is included in diet is that due to its high amount of manganese, it represents a good option for regulating sugar levels. In the organism as manganese helps during gluconeogenesis, in this way, when manganese is obtained in a sufficient amount by consuming amaranth, it is possible to protect against diet-induced diabetes [37].

It has been shown that the influence of dietary therapy which uses sunflower and amaranth oils on parameters of immune reactivity in patients with diabetes mellitus type 2 [38] and the activation of aerobic metabolism by amaranth oil improve heart rate variability both in athletes and patients with diabetes [39].

3.7 Amaranth is gluten-free

Celiac disease is a serious disorder in which eating gluten, a protein found in wheat, barley, and rye, triggers an immune response in the body, causing inflammation and damaging the lining of the small intestine. The damage of the small intestine's lining causes a poor absorption of some nutrients, diarrhea, fatigue, weight loss, poor memory, joint pain, bloating, and anemia, among other symptoms.

Recently amaranth grain has gained more relevance because it is a gluten-free pseudocereal being an alternative option when cereals, such as wheat, barley, and rye, which do contain gluten, cannot be consumed because they cause food allergies. Amaranth is also an excellent protein choice for a healthier life and better

performance for athletes, vegans, vegetarians, and those persons that had acquired allergies or have celiac disease.

Amaranth is an excellent protein source for persons that are non-celiac gluten sensitivity (NCGS) who later on acquire gluten intolerance and also for those that born with celiac disease [40–42].

3.8 Helps pregnant women

Folic acid is the synthesized stable oxidized form of an essential water-soluble B9-complex vitamin that occurs naturally as various folates, usually in reduced form. Folic acid is very important for the development of a healthy fetus. Folic acid can be taken as a supplement tablet and food fortification, while folates are found naturally in foods. Folates play an important role in single-carbon transfer reactions, in several metabolic pathways including the synthesis of purines and pyrimidines, and, hence, in the formation of DNA and RNA. These actions have complex relations with other essential vitamins, especially vitamin B12 [43]. Prior to 1996, the principal food sources for folates were dark green leafy vegetables, organ meats, eggs, and citrus fruits. A severe deficiency of folate manifests as an anemia characterized by many large immature and dysfunctional red blood cells (megaloblasts).

For pregnant women, a folate deficiency can lead to neural tube defects such as spina bifida. A deficiency can also cause defects such as heart and limb malformations. The folate in amaranth helps the body make new cells, specifically by playing a role in copying and synthesizing DNA. There is 88.0 mcg of folate in amaranth grain (see **Table 2**). Fortification of foods with folate by the FDA has decreased the risk for neural tube defects by 26% [44].

3.9 Amaranth prevents constipation

Amaranth is an excellent source of high soluble fiber. The daily recommended dietary fiber intake for men and women are 38 and 25 g, respectively. Dietary fiber may help prevent constipation, making one's bowel movement easier to manage. Constipation clearly means the gut is overburdened, so it helps to combine amaranth grain with dark leafy greens, specially spinach; most nuts; seeds, specially pumpkin and sunflower seeds; fish; beans; whole grains; avocados; yogurt; bananas; dried fruit; eggplant; and unsweetened cocoa.

Amaranth starch binds water and thus helps to prevent constipation. The large content of fiber in amaranth grain is of great advantage [45]. Fiber is an important part of human nutrition. In developed industrial countries, i.e., to the Czech Republic, there is lack of dietary fiber in food, and the content of fiber corresponds to the figures recommended by the World Health Organization (WHO) [46].

3.10 Amaranth has antioxidant activity

Antioxidants are substances that reduce the effect of free radicals. These compounds inhibit oxidation; they help your heart health and may lower your risk of infections and some forms of cancer and degenerative disorders. Antioxidant potential has been attributed to the presence of appreciable levels of phenolics and flavonoids. Leaves and flowers of *Amaranthus* as well as their extracts were shown to possess the highest antioxidant activities compared to other parts, rutin being the major radical scavenger [47]. From a practical point of view, these antioxidants may also be used to counteract the deterioration of stored food products.

3.11 Amaranth has antimicrobial activity

An antimicrobial is a natural or synthetic agent that kills microorganisms or slows the spread of microorganisms such as bacteria, fungi, and algae. *Amaranthus* sp. antimicrobial properties have been studied and exploited by mankind for several decades. The roots, leaves, and seeds of *Amaranthus* spp. have been used in the evaluation of its antimicrobial activities against Gram-positive and Gram-negative bacteria, such as *Bacillus subtilis*, *B. bronchiseptica*, *Bacillus cereus*, *B. pumilus*, *Micrococcus flavus*, *S. aureus*, *Sarcina lutea*, *E. coli*, and *P. vulgaris*, among others [48, 49]. For the last 10 years, our research group has been working in antimicrobial peptides due to great interest to overcome the growing problem of antimicrobial resistance. An antifungal peptide called Ay-AMP was isolated from *Amaranthus hypochondriacus* seeds by acidic extraction and then purified by reverse-phase high-pressure liquid chromatography [50].

3.12 Amaranth as a hepatoprotective

A study carried out by Zeashan et al. [51] showed the hepatoprotective and antioxidant activity of 50% ethanolic extract of a whole plant of *Amaranthus spinosus* using carbon tetrachloride-induced hepatic damage in rats. Furthermore, this study suggests that possible mechanism of this activity may be due to the presence of flavonoid and phenolic compound in the *A. spinosus* which may be responsible to hepatoprotective activity [51]. Additional study was carried out using the ethanolic extract of *Amaranthus tricolor* L. leaves, to test its efficacy against CCl₄-induced liver toxicity in rats. The results indicate that *A. tricolor* extract significantly increases the activities of nonprotein sulfhydryl (NP-SH) and total protein (TP) in liver tissue supporting the evaluation of the liver histopathology in rats [52].

3.13 Amaranth as an anticancer

According to the Cancer Research Institute, cancer is the name given to a collection of related diseases. In all types of cancer, some of the body's cells begin to divide without stopping and spread into surrounding tissues. Cancer can start almost anywhere in the human body, which is made up of trillions of cells. Normally, human cells grow and divide to form new cells as the body needs them. It happens that when cells grow old or become damaged, they die, and new cells take their place. When cancer develops, however, this orderly process breaks down. As cells become more and more abnormal, old or damaged cells survive when they should die, and new cells form when they are not needed. These extra cells can divide without stopping and may form growths called tumors.

In vitro assay of antiproliferative potential of *Amaranthus cruentus* aqueous extract on human peripheral blood lymphocytes has been reported by Gandhi et al. [53]. Later on it has been reported that hexane, ethyl-acetate, and methanolic extracts of *A. tristis* Roxb. showed antiproliferative properties with minimum side effects as determined in human colon adenocarcinoma cell line (COLO-320-DM) [54].

Recently, Peters and Gandhi reported more experimental evidence regarding the antitumor potential of various amaranth leaf extracts using different solvent with significant antitumor potential. These authors stated that leaf extract should further be explored as a novel source of cancer therapy [47].

3.14 Amaranth as an antimalarial

Malaria is an infectious disease caused by protozoan parasites from the *Plasmodium* family that can be transmitted by the bite of the *Anopheles* mosquito or by a contaminated needle or transfusion. In this context, *falciparum* malaria is the most deadly type. The symptoms of malaria include cycles of chills, fever, sweats, muscle aches, and headache that recur every few days. There can also be vomiting, diarrhea, coughing, and yellowing (jaundice) of the skin and eyes. Persons with severe *falciparum* malaria can develop bleeding problems, shock, kidney and liver failure, central nervous system problems, coma, and death. Travelers to areas with malaria are advised to take medications to prevent infection if exposed [55].

Extracts obtained from two Burkinabe folk medicine plants, both spiny amaranth (*Amaranthus spinosus* L., Amaranthaceae) and erect spiderling (*Boerhavia erecta* L., Nyctaginaceae) were screened for antimalarial properties with the aim of testing the validity of their traditional uses. The plant extracts showed significant antimalarial activities in the 4-day suppressive antimalarial assay in mice inoculated with red blood cells parasitized with *Plasmodium berghei* [56].

A combination of two plant extracts of *Launaea taraxacifolia* and *Amaranthus viridis* is used by people of Western Africa in the treatment of malaria and related symptoms. This study assessed for their antiplasmodial value against the chloroquine-sensitive strain of *Plasmodium berghei*. This study showed that the methanolic extracts of *A. viridis* and *L. taraxacifolia* possess antiplasmodial activity [57].

3.15 Amaranth with an antianemic effect

Anemia is defined as a low level of hemoglobin in red blood cells. The major clinical symptom of anemia and iron deficiency shows a pale color of the skin, and its physical symptom is fatigue. According to the UNICEF, anemia has an impact on the intellectual development of children; it reduces learning ability and growth and damages the immune system.

Mexico is an underdeveloped country with malnutrition conditions. In our country, anemia is a public health problem generalized in all social socioeconomic status. *Amaranthus* has been rediscovered as a promising food crop mainly due to its resistance to heat, drought, diseases and pests, and the high nutritional value of both seeds and leaves. They are rich in proteins and micronutrients such as iron, calcium, zinc, vitamin C, and vitamin A shown in **Tables 1** and **2**.

Iron deficiency anemia is a major public health problem in young children in developing countries and is associated with impaired cognitive development and morbidity. Our research group had been developing a nutraceutical formulation in a powder form that treats the prevalence of anemia in Mexican children, adolescents, and in general all adults in México. The nutraceutical formulation is called “Naturalmente Alegría” (Naturally Joy) (**Figure 3**), and it has been approved by the Federal Committee for Protection from Sanitary Risks in Mexico (COFEPRIS). The product has been consumed by several thousands of Mexicans with anemia to date.

3.16 Amaranth as a nutraceutical/supplementary food

Extracts of all plant parts of *Amaranthus* seem to have medicinal benefits; hence the focus of recent studies has been to identify therapeutic constituents of *Amaranthus* from roots, plant stem, leaves, flowers, and seeds. Due to its high content of quality proteins with nine essential amino acids, unsaturated fatty acids, and squalene, high antioxidant activity (tocopherols and tocotrienols) of most *Amaranthus* spp., along with anti-inflammatory property, has increased



Figure 3.
*Naturalmente Alegría (Naturally Joy), a nutraceutical product from *Amaranthus hypochondriacus*.*

interest in investigating its nutraceutical and clinical potential as a functional food. *Amaranthus hypochondriacus* seed has proteins with very high levels of tryptophan and lysine which are unique compared to other grains. More nutraceutical/supplementary food information is described by Peter and Gandhi [47].

3.17 Other properties

Since pre-Hispanic time, every part of the *Amaranthus hypochondriacus* plant has been used in Mexico, especially the seeds. Nowadays, some oligopeptides and proteins have already been isolated in our laboratory, such as nonspecific lipid-transfer protein (nsLTP1) with 9.7 kDa [58], which plays a role in the plant defense, and a globulin of 34.9 kDa [20] which is a storage protein very important in nutrient conservation; an oligopeptide derived from enzymatic digestion of globulins from amaranth shows strong affinity binding to the replication origin of *Tomato yellow leaf curl virus* reducing viral replication in *Nicotiana benthamiana* [59].

4. Discussion

The importance of amaranth as a functional food has resurged in the last years. *Amaranthus hypochondriacus* grain has an excellent nutrient composition with a high concentration of proteins (13–19%) and bioactive peptides [60]. As a matter of fact, amaranth helps as antihypertensive, antioxidant, antithrombotic, and antiproliferative biological activities, among others. These peptides are encrypted within the proteins, and only after the enzymatic digestion or food processing are they released. Some studies using amaranth flour and protein isolates reported the

occurrence of peptides with biological activities such as antihypertensive, antioxidant, antithrombotic, and antiproliferative, among others [61, 62].

The Amaranthaceae family consists of 60 genera and about 800 species. Sixty of these species are cosmopolitan and grow particularly in areas of human activities where they are regarded as weeds. Of these 60 species, only 3 are considered good seed producers: *Amaranthus hypochondriacus* (the main variety grown in Mexico), *A. cruentus*, and *A. caudatus*. In these three *Amaranthus* species, both leaves and seeds contain protein of high quality. The grain is milled for flour or popped like popcorn. The leaves of both species may be eaten raw or cooked. Amaranth is a fast-growing crop, and because of its low production cost, it is one of the cheapest plants. This plant grows under varied soil and agroclimatic conditions and is also resistant to heat and drought with no major disease problems [63].

The amaranth composition includes carbohydrates, dietary fiber, lipids and proteins, and other important constituents, such as squalene, tocopherols, phenolic compounds, flavonoids, phytates, vitamins, and minerals. This comprehensive chapter is focused on amaranth composition and antioxidant properties and provides several potential medical benefits of its valuable components. Thus, amaranth and their products should be considered as a future crop with nutritional and medical purposes in many countries.

5. Conclusions

Existing evidence suggests that nutrition, especially staple-based foods such as amaranth, when part of a balanced pattern, contributes with important protein, polyunsaturated fatty acids, minerals (calcium, zinc, iron, magnesium, and manganese, among other minerals), appropriate dietary fiber, vitamins, and antioxidants that can help mitigate or reduce the risk of several diseases.

This chapter is based on scientific knowledge and personal experience working with amaranth plant. I would like to apologize to anyone who finds my description of his or her work inadequate or whose work I have accidentally omitted on this chapter.

It is obvious that amaranth seed surpasses traditional cereals in a number of nutritional and therapeutical values. Amaranth is considered as a millennium superfood with high nutraceutical values as it is used for several clinical/medical applications because it is a reasonably well-balanced food with functional properties that have been shown to provide clinical/medicinal benefits. Thanks to its properties, amaranth gives us a wide range of possibilities for using it in human nutrition, including active health support. Also it can be applied when we need more easily digestible quality proteins, e.g., in children, sportsmen, and the elderly. Further studies using more sophisticated and appropriate in vivo model systems are needed to draw solid conclusions on the subject of a nutritional functional value and therapeutic utilization of amaranth.

Conflict of interests

Authors declare that there is no conflict of interest.

IntechOpen

IntechOpen

Author details

Manuel Soriano-García* and Isabel Saraíd Aguirre-Díaz
Chemistry of Biomacromolecules Department, Chemistry Institute,
National Autonomous University of Mexico, Mexico City, Mexico

*Address all correspondence to: soriano@unam.mx

IntechOpen

© 2019 The Author(s). Licensee IntechOpen. This chapter is distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/3.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited. 

References

- [1] Rastogi A, Shukla S. Amaranth: A new millennium crop of nutraceutical values. *Critical Reviews in Food Science and Nutrition*. 2013;**53**(2):109-125. DOI: 10.1080/10408398.2010.517876
- [2] Espitia-Rangel E. Breeding of grain amaranth. In: Paredes-Lopez O, editor. *Amaranth. Biology, Chemistry and Technology*. Boca Raton, USA: CRC Press; 1994. pp. 23-38
- [3] National Academy Press. *Amaranth: Modern Prospects for an Ancient Crop*. Washington, DC: National Academic of Sciences; 1984
- [4] Ulbricht C, Abrams T, Conquer J, Costa D, Grims-Serrano JM, Taylor S, et al. An evidence-based systematic review of amaranth (*Amaranthus spp.*) by the natural standard Research collaboration. *Journal of Dietary Supplements*. 2009;**6**(4):390-417. DOI: 10.3109/19390210903280348
- [5] Venskutonis PR, Kraujalis P. Nutritional components of amaranth seeds and vegetables: A review on composition, properties, and uses. *Comprehensive Reviews in Food Science and Food Safety*. 2013;**12**(4):381-412. DOI: 10.1111/1541-4337.12021
- [6] Jahaniaval F, Kakuda Y, Marcone MF. Fatty acid and triacylglycerol compositions of seed oils of five *Amaranthus* accessions and their comparison to other oils. *Journal of the American Oil Chemists' Society*. 2000;**77**(8):847-852. DOI: 10.1007/s11746-000-0135-0
- [7] USDA. Subset, Food, and All Foods. National Nutrient Database for Standard Reference, Amaranth grain. Release 28; 2016
- [8] Kalinova J, Dadakova E. Rutin and total quercetin content in amaranth (*Amaranthus spp.*). *Plant Foods for Human Nutrition*. 2009;**64**(1):68-74. DOI: 10.1007/s11130-008-0104-x
- [9] Barba de la Rosa AP et al. Amaranth (*Amaranthus hypochondriacus*) as an alternative crop for sustainable food production: Phenolic acids and flavonoids with potential impact on its nutraceutical quality. *Journal of Cereal Science*. 2009;**49**:117-121. DOI: 10.1016/j.jcs.2008.07.012
- [10] Gorinstein S et al. Comparison of composition and antioxidant capacity of some cereals and pseudocereals. *International Journal of Food Science and Technology*. 2008;**43**(4):629-637. DOI: 10.1111/j.1365-2621.2007.01498.x
- [11] Klimczak I, Małeczka M, Pacholek B. Antioxidant activity of ethanolic extracts of amaranth seeds. *Food/Nahrung*. 2002;**46**(3):184-186. DOI: 10.1002/1521-3803(20020501)46:3<184::AID-FOOD184>3.0.CO;2-H
- [12] López VRL, Razzeto GS, Giménez MS, Escudero NL. Antioxidant properties of *Amaranthus hypochondriacus* seeds and their effect on the liver of alcohol-treated rats. *Plant Foods for Human Nutrition*. 2011;**66**(2):157-162. DOI: 10.1007/s11130-011-0218-4
- [13] Bejosano FP, Corke H. Protein quality evaluation of *Amaranthus* whole meal flours and protein concentrates. *Journal of the Science of Food and Agriculture*. 1998;**76**:100-106. DOI: 10.1002/(SICI)1097-0010(199801)76:1<100::AID-JSFA931>3.0.CO;2-B
- [14] Pisarikova B, Kracmar S, Herzig I. Amino acid contents and biological value protein in various amaranth species. *Czech Journal of Animal Science*. 2005;**50**(4):169-174. DOI: 10.1002/(SICI)1097-0010(199801)76:1<100::AID-JSFA931>3.0.CO;2-B

- [15] Shukla S et al. Nutritional contents of different foliage cuttings of vegetable amaranth. *Plant Food for Human Nutrition*. 2003;**58**(3):1-8. DOI: 10.1023/B:QUAL.0000040338.33755.b5
- [16] Kraujalis P, Venskutonis PR. Optimization of supercritical carbon dioxide extraction of amaranth seeds by response surface methodology and characterization of extracts isolated from different plant cultivars. *Journal of Supercritical Fluids*. 2013;**73**:80-86. DOI: 10.1016/j.supflu.2012.11.009
- [17] Caselato-Sousa VM, Amaya-Farfán J. State of knowledge on Amaranth grain: A comprehensive review. *Journal of Food Science*. 2012;**77**(4):R93-R104. DOI: 10.1111/j.1750-3841.2012.02645.x
- [18] Stone LA, Lorenz K. The starch of *Amaranthus*: Physicochemical properties and functional characteristics. *Starch*. 1984;**36**(7):232-237. DOI: 10.1002/star.19840360704
- [19] Oleszek W, Junkuszew M, Stochmal A. Determination and toxicity of saponins from *Amaranthus cruentus* seeds. *Journal of Agricultural and Food Chemistry*. 1999;**47**(9):3685-3687. DOI: 10.1021/jf990182k
- [20] Vasco Méndez NL, Soriano-García M, Moreno A, et al. Purification, crystallization and preliminary X-ray characterization of a 36kDa Amaranth globulin. *Journal of Agricultural and Food Chemistry*. 1999;**47**(3):862-866. DOI: 10.1021/jf9809131
- [21] Negro M, Giardina S, Marzani B, Marzatico F. Branched-chain amino acid supplementation does not enhance athletic performance but affects muscle recovery and the immune system. *The Journal of Sports Medicine and Physical Fitness*. 2008;**48**(3):347-351
- [22] Montoya-Rodríguez A, de Mejía EG, Dia VP, et al. Extrusion improved the anti-inflammatory effect of amaranth (*Amaranthus hypochondriacus*) hydrolysates in LPS-induced human THP-1 macrophage-like and mouse RAW 264.7 macrophages by preventing activation of NF- κ B signaling. *Molecular Nutrition & Food Research*. 2014;**58**(5):1028-1041. DOI: 10.1002/mnfr.201300764
- [23] Laparra JM, Haros M. Inclusion of ancient Latin-American crops in bread formulation improves intestinal iron absorption and modulates inflammatory markers. *Food & Function*. 2016;**7**(2):1096-1102. DOI: 10.1039/c5fo01197c
- [24] Macdonald HM, New SA, Golden MH, et al. Nutritional associations with bone loss during the menopausal transition: Evidence of a beneficial effect of calcium, alcohol, and fruit and vegetable nutrients and of a detrimental effect of fatty acids. *The American Journal of Clinical Nutrition*. 2004;**79**(1):155-165. DOI: 10.1093/ajcn/79.1.155
- [25] Levis S, Lagari VS. The role of diet in osteoporosis prevention and management. *Current Osteoporosis Reports*. 2012;**10**(4):296-302. DOI: 10.1007/s11914-012-0119-y
- [26] Sacco SM, Horcajada MN, Offord E. Phytonutrients for bone health during ageing. *British Journal of Clinical Pharmacology*. 2013;**75**(3):697-707. DOI: 10.1111/bcp.12033
- [27] Galan MG, Drago SR, Armada M, José RG. Iron, zinc and calcium dialyzability from extruded product based on whole grain amaranth (*Amaranthus caudatus* and *Amaranthus cruentus*) and amaranth/Zea mays blends. *International Journal of Food Sciences and Nutrition*. 2013;**64**(4):502-507. DOI: 10.3109/09637486.2012.753038
- [28] A B et al. Cholesterol-lowering properties of amaranth grain and oil in hamsters. *International*

Journal for Vitamin and Nutrition Research. 2003;**73**(1):39-47. DOI: 10.1024/0300-9831.73.1.39

[29] Mendonça S, Saldiva PH, Cruz RJ, Arêas JAG. Amaranth protein presents cholesterol-lowering effect. Food Chemistry. 2009;**116**:738-742. DOI: 10.1016/j.foodchem.2009.03.021

[30] Devaraj VC, Krishna BG. Gastric antisecretory and cytoprotective effects of leaf extracts of *Amaranthus tricolor* Linn in rats. Zhong Xi Yi Jie He Xue Bao. 2011;**9**:1031-1038. DOI: 10.3736/jcim20110915

[31] Devaraj VC, Krishna BG. Antiulcer activity of a polyherbal formulation (PHF) from Indian medicinal plants. Chinese Journal of Natural Medicines. 2013;**11**(2):145-148. DOI: 10.1016/S1875-5364(13)60041-2

[32] Cherkas A et al. Amaranth oil reduces accumulation of 4-hydroxynonenal-histidine adducts in gastric mucosa and improves heart rate variability in duodenal peptic ulcer patients undergoing *Helicobacter pylori* eradication. Free Radical Research. 2018;**52**(2):135-149. DOI: 10.1080/10715762.2017.1418981

[33] Kim HK, Kim MJ, Yon H, et al. Antioxidative and anti-diabetic effects of amaranth (*Amaranthus esculantus*) in streptozotocin-induced diabetic rats. Cell Biochemistry and Function. 2006;**24**(3):195-199. DOI: 10.1002/cbf.1210

[34] Aschner JL, Aschner M. Nutritional aspects of manganese homeostasis. Molecular Aspects of Medicine. 2005;**26**(4-5):353-362. DOI: 10.1016/j.mam.2005.07.003

[35] Rucker D, Thadhani R, Tonelli M. Trace element status in hemodialysis patients. Seminars in Dialysis. 2010;**23**(4):389-395. DOI: 10.1111/j.1525-139X.2010.00746.x

[36] Koh ES, Kim SJ, Yoon HE, et al. Association of blood manganese level with diabetes and renal dysfunction: A cross-sectional study of the Korean general population. BMC Endocrine Disorders. 2014;**14**:24-32. DOI: 10.1186/1472-6823-14-24

[37] Lee SH, Jouihan HA, Cooksey RC, et al. Manganese supplementation protects against diet-induced diabetes in wild type mice by enhancing insulin secretion. Endocrinology. 2013;**154**(3):1029-1038. DOI: 10.1210/en.2012-1445

[38] Miroshnichenko LA, Zoloedov VI, Volynkina AP, et al. Influence dietary therapy with use sunflower and amaranth oils on parameters of immune reactivity in patients with diabetes mellitus 2 type. Voprosy Pitaniia. 2009;**78**(4):30-36

[39] Yelisyeyeva O, Semen K, Zarkovic N, et al. Activation of aerobic metabolism by Amaranth oil improves heart rate variability both in athletes and patients with type 2 diabetes mellitus. Archives of Physiology and Biochemistry. 2012;**118**(2):47-57. DOI: 10.3109/13813455.2012.659259

[40] Rahaie S, Gharibzahedi SM, Razavi SH, et al. Recent developments on new formulations based on nutrient-dense ingredients for the production of healthy-functional bread: A review. Journal of Food Science and Technology. 2014;**51**(11):2896-2906. DOI: 10.1007/s13197-012-0833-6

[41] Inglett G, Chen D, Liu S. Physical properties of gluten-free sugar cookies made from amaranth-oat composites. LWT--Food Science and Technology. 2015;**63**(1):214-220. DOI: 10.1016/j.lwt.2015.03.056

[42] Mansueto P, Seidita A, D'Alcamo A, et al. Non-celiac gluten sensitivity: Literature review. Journal of the American College of

- Nutrition. 2014;**33**(1):39-54. DOI: 10.1080/07315724.2014.869996
- [43] Butterworth CE Jr, Tamura T. Folic acid safety and toxicity: A brief review. The American Journal of Clinical Nutrition. 1989;**50**:353-358. DOI: 10.1093/ajcn/50.2.353
- [44] Feinleib M et al. Folate fortification for the prevention of birth defects: Case study. American Journal of Epidemiology. 2001;**154**(12):S60-S69
- [45] King DE, Mainous AG III, Lambourne CA. Trends in dietary fiber intake in the United States, 1999-2008. Journal of the Academy of Nutrition and Dietetics. 2012;**112**(5):642-648. DOI: 10.1016/j.jand.2012.01.019
- [46] WHO (World Health Organization). Global Strategy On Diet, Physical Activity and Health. Geneva A57/9: WHO; 2004
- [47] Peter K, Gandhi P. Rediscovering the therapeutic potential of *Amaranthus* species: A review. Egyptian Journal of Basic and Applied Sciences. 2017;**4**: 196-205. DOI: 10.1016/j.ejbas.2017.05.001
- [48] Maiyo ZC, Ngure RM, Matasyoh JC, Chepkorir R. Phytochemical constituents and antimicrobial activity of leaf extracts of three *Amaranthus* plant species. African Journal of Biotechnology. 2010;**9**:3178-3182
- [49] Sheeba AM, Deepthi SR, Mini I. Evaluation of antimicrobial potential of an invasive weed *Amaranthus spinosus* L. In: Sabu A, Augustine A, editors. Prospects in Bioscience: Addressing the Issues. India: Springer; 2012:117-123
- [50] Rivillas-Acevedo LA, Soriano-García M. Isolation and biochemical characterization of an antifungal peptide from *Amaranthus hypochondriacus* seeds. Journal of Agricultural and Food Chemistry. 2007;**55**(25):10156-10161. DOI: 10.1021/jf072069x
- [51] Zeashan H, Amresh G, Singh S, Rao CV. Hepatoprotective and antioxidant activity of *Amaranthus spinosus* against CCl₄ induced toxicity. Journal of Ethnopharmacology. 2009;**125**(2): 364-366. DOI: 10.1016/j.jep.2009.05.010
- [52] Al-Dosari MS. The effectiveness of ethanolic extract of *Amaranthus tricolor* L.: A natural hepatoprotective agent. The American Journal of Chinese Medicine. 2010;**38**(6):1051-1064. DOI: 10.1142/S0192415X10008469
- [53] Gandhi P, Khan Z, Niraj K. *In vitro* assay of anti-proliferative potential of *Amaranthus cruentus* aqueous extract on human peripheral blood lymphocytes. Current Trends in Biotechnology and Chemical Research. 2011;**1**:42-48. DOI: 10.1142/S0192415X10008469
- [54] Baskar AA, Al Numair KS, Alsaif MA, Ignacimuthu S. *In vitro* antioxidant and antiproliferative potential of medicinal plants used in traditional Indian medicine to treat cancer. Redox Report. 2012;**17**:145-156. DOI: 10.1179/1351000212Y.0000000017
- [55] Shiel WC Jr. Medical definition of malaria. Medicine Net. Visited April 30, 2019. Available from: <https://www.medicinenet.com/script/main/art.asp?articlekey=4255>
- [56] Hiloua A, Nacoulmaa OGT, Guiguemdeb R. In vivo antimalarial activities of extracts from *Amaranthus spinosus* L. and *Boerhaavia erecta* L. in mice. Journal of Ethnopharmacology. 2006;**103**(2):236-240. DOI: 10.1016/j.jep.2005.08.006
- [57] Adetutu A, Olorunnisola OS, Owoade AO, Adegbola P. Inhibition of in vivo growth of *Plasmodium berghei* by *Launaea taraxacifolia* and *Amaranthus viridis* in Mice. Malaria Research

and Treatment. 2016;**2016**:9. DOI: 10.1155/2016/9248024

[58] Ramírez-Medeles MC, Aguilar MB, Miguel RN, Bolaños-García VM, García-Hernández E, Soriano-García M. Amino acid sequence, biochemical characterization and comparative modeling of a non-specific lipid transfer protein from *Amaranthus hypochondriacus*. Archives of Biochemistry and Biophysics. 2003;**415**(1):24-33. DOI: 10.1016/S0003-9861(03)00201-7

[59] Mendoza-Figueroa JS, Kvarnheden A, Méndez-Lozano J, Rodríguez-Negrete EA, Arreguín-Espinosa de los Monteros R, Soriano-García M. A peptide derived from enzymatic digestion of globulins from amaranth shows strong affinity binding to the replication origin of Tomato yellow leaf curl virus reducing viral replication in *Nicotiana benthamiana*. Pesticide Biochemistry and Physiology. 2018;**45**:56-65. DOI: 10.1016/j.pestbp.2018.01.005

[60] Silva-Sánchez C et al. Bioactive peptides in amaranth (*Amaranthus hypochondriacus*) seed. Journal of Agricultural and Food Chemistry. 2008;**56**(4):1233-1240. DOI: 10.1021/jf072911z

[61] Sabbione AC, Scilingo A, Añón MC. Potential antithrombotic activity detected in amaranth proteins and its hydrolyzates. LWT-Food Science and Technology. 2015;**60**(1):171-177. DOI:10.1016/j.lwt.2014.07.015

[62] Quiroga A, Barrio D, Añón MC. Amaranth lectin presents potential antitumor properties. LWT-Food Science and Technology. 2015;**60**(1):478-485. DOI: 10.1016/j.lwt.2014.07.035

[63] Fuentes Reyes M, Chávez-Servín JL, González-Coria C, et al. Comparative account of phenolics,

antioxidant capacity, α -tocopherol and anti-nutritional factors of amaranth (*Amaranthus hypochondriacus*) grown in the greenhouse and open field. International Journal of Agriculture and Biology. 2018;**20**(11):2428-2436. DOI: 10.17957/IJAB/15.0786