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Review

Suitability of *Amaranthus* species for alleviating human dietary deficiencies

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ABSTRACT

Nearly all essential nutrients for humans are available in plants. Among vegetables, amaranths are rich sources for micronutrients and dietary minerals; an interesting group of crops to answer mounting demand for food. They are a promising group of crops with unique nutritional compositions that could enhance the biological value of processed foods. Compared to other grains, amaranths have the highest amount of gluten free protein, calcium, dietary fibers and essential amino acids required for a healthy living. By the estimation of the United States National Academy of Science of 1975, *Amaranthus* species were ranked major potential crops with the most promising economic values among the 36 underexploited tropical plants indicating that there are untapped prospects and potentials in their utilization. Worthy of mention is the menace of dietary deficiencies threatening public health and quality of life in developing worlds due to little attention being paid to one of the world's most promising vegetables. This paper therefore reviews existing literatures on the use of *Amaranthus* species as sources of food and medicine; their evolutionary history and overlapping roles in dietary fortification; nutraceutical properties; availability and wide-ranging adaptability to adverse environments; their global endorsement and how bioavailable their nutrients are with a view to finding a lasting solution to hidden hunger and nutrient deficiencies ravaging developing countries and the world at large.

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1. Introduction

In the recent time, much attention has been given to micronutrient malnutrition owing to the realization that it plays a significant role in global disease menace. In addition to the more proven indices, micronutrient deficiencies are responsible for a wide range of non-specific physiological damages, leading to reduced resistance to infections, metabolic

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complications, and delayed or compromised physical and mental development. While micronutrient deficiencies are certainly more frequent and severe among disadvantaged populations, they pose a threat to public health in some industrialized countries (Flyman and Afolayan, 2006; Gletsu-Miller and Wright, 2013; Venskutonis and Kraujalis, 2013).

In the year 2000, the World Health Report acknowledged iron, iodine, vitamin A and zinc deficiencies as being among the world's most serious health risk factors. Consequences of dietary deficiencies on public health are potentially huge and exclusively significant when it comes to mapping out strategies for the control and prevention of diseases such as malaria, HIV/AIDS, tuberculosis, and chronic diseases associated with poor diets (World Health Organization, 2000). This is particularly true for iodine deficiency in Europe, where it was generally assumed to have been eradicated, and of iron deficit, which is currently the predominant micronutrient deficiency around the world populations (World Health Organization, 2000). In addition, the increased consumption in industrialized countries (especially those in social and economic transition) of highly-processed energy-dense, but micronutrient-poor foods is likely to adversely affect micronutrient intake and status. Measures to correct micronutrient deficiencies at least the major ones are, however, well known, and moreover relatively cheap and easy to implement. The control of iodine deficiency disorders through salt iodization, for example, was a major accomplishment in public health nutrition over the last 30 years (World Health Organization, 2000).

The presence of mineral nutrients in all body tissues and fluids is necessary for the maintenance of certain physicochemical processes which are essential to life (Hels et al., 2004; Soetan et al., 2010). Mineral nutrients can be divided into major, secondary and micro or trace minerals based on their requirement by humans and almost the entire nutrient minerals and organic nutrients established as essential for human nutrition is available in plant foods. All foods contain several mineral nutrients; however, some are higher in certain minerals than other minerals. The recommended doses vary considerably as established by various agencies related to regulation of mineral nutrients in various foods. A dietary requirement is defined as the lowest continuing intake of a nutrient that, for a specified indicator of adequacy, will maintain a defined level of nutritive need of an individual (Sutherland et al., 1998).

Humans have different daily nutritional requirements and these vary depending on sex, size, age and activity levels. The term reference intakes (RI) refers to daily amounts recommended for an average person to achieve a healthy, balanced diet for maintaining rather than losing or gaining weight. The RIs for fat, saturated fats, sugars and salt are all maximum amounts, while those for carbohydrates and protein are to be met each day. There is no RI for fiber although health experts recommended between 21 and 38 g daily depending on age and sex (Food and Nutrition Board, Institute of Medicine, 2002; https://www.bbcgoodfood.com/).

The functional roles of protein in food enhancement are critical for developing protein based ingredients which increase the biological value of food. Proteins play a central role in regulating different activities at cellular, tissue and organ levels of the body given the right hydrolytic environment (Panyam and Kilara, 1996).The nutritional value of each food can be determined by the quantity and the quality of the several amino acids present or absent. If a certain food supplies enough of seven of the eight essential amino acids, the lacking amino acid is defined as the “limiting amino acid”. In addition to its richness, meat protein distinguishes itself because of its richness in all the essential amino acids with no limiting amino acids (Williams, 2007). Vegetarians have to combine cereal and legumes to get all the essential amino acids. Cereals like rice and wheat are especially poor in lysine, while legumes have lower contents of methionine (Elango et al., 2009) (Table 1).

For the past two decades, the determination of amino acid requirements in humans has been an active area of research due to advances made in the development of stable isotope based carbon oxidation methods. Nutritional application of experimentally derived amino acid requirement estimates depends upon the capacity of food proteins to meet the amino acid requirements in humans. Hence, there is a need to know the proportion of dietary amino acids, which are bioavailable, or metabolically available to the body for protein synthesis following digestion and absorption using the indicator amino acid oxidation method to determine almost all indispensable amino acid requirements in adult humans (Elango et al., 2009). Although this concept is widely applied in animal nutrition, it has not been applied to human nutrition due to lack of data, however, it is a major step forward in defining the protein quality of food sources and integrating amino acid requirement data with dietary amino acid obtainable in foods (Elango et al., 2009).

Table 1
Reference intakes of some nutrients and energy for adults.
Adapted from https://www.bbcgoodfood.com/.

S/N	Nutritional requirements	Quantity
1	Energy (kcal)	2000
2	Carbohydrates (g)	260
3	Protein (g)	50
4	Sugar (g)	90
5	Fat (g)	70
6	Saturated fats (g)	20
7	Salt (g)	6

Therefore, vegetables form an important component of a balanced diet (Agte et al., 2000). They vary markedly in their nutritional values depending on different parts of the plant consumed and it has been proven that in vegetables, more health promoting ingredients such as vitamins, amino acids and sugars have long been recognized for their health benefits to humans. As technology and research techniques are improving, other substances in vegetables that were previously ignored are getting the attention (Rai et al., 2012). Thus, the hope of reclaiming lost dietary requirements resides in plants and leafy vegetables have the wherewithal to fix the nutrient gap affecting vulnerable populations of the world.

2. Human dietary deficiencies

Deficiency in minerals and vitamins has become a threat to wellbeing of over 2 billion people in the world. The effects of this is more pronounced in pregnant women and children as it impairs resistance to infections, fetal and child growth and cerebral development of acute magnitude which is found among low income earners, food insecure and vulnerable households in developing countries who either lack access to variety of foods or unaware of their suitable dietary needs thereby resulting in high incidence of infectious diseases. Dietary deficiency therefore contributes largely to vicious circle of underdevelopment due to its demeaning effects on health, learning ability and productivity especially on the already disadvantaged groups (World Health Organization, 2000). The dietary requirement refers to lowest continuing intake of a nutrient that will maintain a defined level of nutritive need in an individual for a specified indicator of adequacy while the essential dietary component is one that the body cannot synthesize in sufficient quantities to maintain health (Sutherland et al., 1998).

The use of leaves in human nutrition is not considered in general with the importance it deserves in some low protein diets. When limiting amino acid of main foods is lysine (as is seen in cereal based diets) the protein of leaves may be of a great importance in its supplementation. As reported in other works, the main problem in leaf protein utilization is the content in non-digestible glucoside matter, which may be limiting the digestibility and absorption of nutriments (Barba de la Rosa et al., 2009; Venskutonis and Kraujalis, 2013). Amaranths, despite having been neglected over many years, are a promising food crop, mainly due to their resistances to heat, drought, diseases and pests. In addition, the nutritional value of both the seeds and leaves is excellent. With regard to their high grain protein concentration, they are superior