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Chapter

From Neglected and Underutilized Crops to Powerful Sources of Vitamin A: Three Case Studies of Mozambican Cultivated *Tacca leontopetaloides*, Cowpea, and Cassava

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Abstract

About 1 billion people are currently suffering from chronic hunger, malnutrition, and vitamin A deficiency, while it is predicted that world food production needs to increase by 70% by 2050 to satisfy 9.9 billion predicted population in the world, relying on a natural resource base that is reaching its limits and with climate change adding further pressures on agriculture and acting as the main driver of crop diversity loss. The main goal of this chapter was to discuss the role of neglected crops (arrowroot, cassava, and cowpea) as potential sources of vitamin A with case studies of Mozambique country where the current population (30.5 million—mid-2018) is predicted to more than double by mid-2050 (67.4 million) while vitamin A deficiency and food insecurity are serious issues. Crops have an important role in rural communities and are nutrient dense and can be used in diet diversification and vitamin A alleviation. They are highly adapted to agroecological niches and marginal areas. The current research reinforces that neglected crops are potential sources of vitamin A with an extra extensive phytochemical composition that together are important in alleviating vitamin A deficiency. Their production promotion must be reinforced and incorporated in crop diversification.

Keywords: sources of vitamin A, orphan crops, famine foods, *Vigna unguiculata* L. Walp, *Tacca leontopetaloides* L. Kuntze, *Manihot esculenta* Crantz

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1. Introduction

1.1 Status of vitamin A deficiency in the world and in Mozambique

Recent statistics estimate that 821 million people in the world are undernourished and the world hunger continues to rise in recent years [1]. Undernourishment and severe food insecurity are increasing in almost all regions of Africa, as well as in South America. Actually, 237 million people are undernourished in sub-Saharan Africa (SSA) [1]. The increase in hunger and food insecurity indicates that there is considerable work to be done against malnutrition and vitamin A deficiency globally.

Vitamin A (also called retinol) is one of the fat-soluble vitamins necessary for good health. It has an important role as an antioxidant by helping to prevent free radicals from causing cellular damage and for proper function of the immune, skeletal, respiratory, reproductive, and integumentary (skin) systems and decrease the risk of certain cancers, heart attacks, and strokes [2]. It is also essential for the proper function of the retina, where it can act to prevent night blindness, as well as lower the odds of getting age-related macular degeneration [2]. As reported by Han et al. [3], vitamin A deficiency (VAD) is known to cause ocular changes, including corneal ulcers and xerophthalmia, ocular globe modifications, and loss of palpebral and pupillary reflexes.

According to GEM [4], the recommended dietary dose (RDA) for vitamin A is 1.0 mg/day for the adult man and 0.8 mg/day for the adult woman. Vitamin A can be supplied entirely via β-carotene (6 mg of β-carotene is considered to be the equivalent of 1 mg of vitamin A [4]). The deficiency of vitamin A occurs when the chronic failure to eat sufficient amounts of vitamin A or β-carotene results in levels of blood serum vitamin A that are below a defined range [4]. Globally, Low [5] reported that 190 million preschool children and 19 million pregnant women are affected by vitamin A deficiency. In sub-Saharan Africa (SSA), more than 40% of children under five suffer from VAD.

In Mozambique, 44% of children under the age of five are stunted, 4% are wasted, and 18% are underweight. The statistics indicate that 15% of infants are born with a low birth weight. The under-5 mortality rate has been estimated to be 138 per 1000 live births, and globally the ranking of stunting prevalence is the 19th highest out of 136 countries [6, 7]. Annually, Mozambique loses US$116 million to vitamin and mineral deficiencies [6, 7]. As reported by Aguayo [8], an estimated 2.3 million children below the age of 5 years are vitamin A deficient. In the absence of appropriate policy and program action, VAD is the attributable cause of over 30 000 deaths annually, representing 34.8% of all-cause mortality in this age group. Historically, Mozambique was devastated by a postindependence civil war from 1977 to 1992 which destroyed infrastructures, ruined livelihoods, and severely hampered agricultural production and economic development [9]. There is a problem of physical access in rural areas, where the majority of the population lives. Contrarily, economic access to food is a major issue, especially in times of soaring food prices in urban areas. Natural shocks such as floods and drought regularly affect agricultural production [9]. The Mozambican diet is mainly composed of cassava, maize, beans, and imported wheat. There is a low supply of micronutrient-rich foods. Eighty percent of the dietary energy supply is provided by cereals and starchy roots; this very poor level of dietary diversification has not improved for the last 40 years and is currently the lowest in the region.

Mozambique's population of almost 30 million people (30,804,450 current total population) remains one of the most vulnerable in the world, ranking 180 out of 188 countries in the United Nations Development Programme. Forty-four percent of the woman at reproductive age are anemic, and 69% of children of 6–24 months old are vitamin A deficient [10]. One-third of the population is chronically food insecure. Undernutrition in children remains at 44% while the prevalence of vitamin A and iron deficiencies at 69 and 74%, respectively. Micronutrient malnutrition, also known as hidden hunger, leads to high social and public costs, reduced work capacity, and the tragic loss of human potential. Mozambican urban dwellers are increasing at 1.5% each year, due to the migration trend from rural to urban settings. Malnutrition is affecting low-income consumers living.

VAD is a public health problem in more than half of all countries, especially in Africa and Southeast Asia, hitting hardest young children and pregnant women in low-income countries. According to the World Health Organization [11], an estimated 250 million preschool children are vitamin A deficient, and it is likely that in VAD areas a substantial proportion of pregnant women is vitamin A deficient. According to the same source, 250,000 to 500,000 vitamin A-deficient children become blind every year, half of them dying within 12 months of losing their sight. VAD is the major cause of preventable blindness in children and increases the risk of disease and death from severe infections. VAD also causes night blindness in pregnant woman and may increase the risk of maternal mortality. Supplying adequate vitamin A in high-risk areas can significantly reduce mortality and is crucial for maternal and child survival. The absence of this vitamin causes a high risk of disease and death.

According to the WHO [11], an intensified action to end and eradicate worldwide the VAD and ensure universal access to healthier and more sustainable diets for all people wherever they live is the main goals of the United Nations Decade of Action on Nutrition 2016–2025. All countries are claimed to undertake activities and nutrition actions to reduce malnutrition. Such actions will require large commitment from all institutions and communities. Such commitment implies that new interventions must be created, sustained, and strengthened over time. One of the solutions is the promotion of orphan crops in the diet of small farmer agriculture. The main goals of the chapter are to discuss the use of orphan or underutilized crops (arrowroot, cassava, and cowpea) as potential sources of vitamin A with key examples of Mozambican situation.

1.2 Global population growth: challenges in food production versus climate changes

The world population is projected to reach 9.9 billion by 2050, representing up to 2.3 billion or 29% from an estimated 7.6 billion people now, according to projections by the Population Reference Bureau (PRB) included in the 2018 World Population Data Sheet [12]. The PRB projects that Africa's populations will more than double to 2.6 billion by 2050 and account for 58% of the global population increase by that date. Particularly, the Mozambican population will increase to 36.9 million by 2050 (**Table 1**). The number of people in Asia, America, and Oceania is projected to increase about 717 million to 5.3 billion, from 1 billion now to 1.2 billion, and from 41 million to 64 million, respectively, while in Europe will decline from 746 million to 730 million.

The Global Agricultural Productivity report [13] points out that in India, national production will only meet 59% of the country's food demand in 2030. In East Asia, only 67% of food demand up to 2030 will be supported within the region. In sub-Saharan Africa, projections indicate that only 15% of food demand will be reached by 2030, which would require significant imports or food assistance or the opening of new areas for development, which may not be suitable for sustainable production [13]. The need for increased production is facing important constraints.

Region**	Current population (mid-2018, millions)	Predicted population by mid-2050 (millions)
World (total)	**7621 (≈100%)**	**9852**
Asia	4536 (59.52%)	5253
Africa	**1284 (16.85%)**	**2586**
Sub-Saharan Africa	1049 (13.76%)	22
Mozambique	**30.5 (0.4%)**	**67.4**
Americas	1014 (13.31%)	122
Europe	746 (9.79%)	730
Oceania	41 (0.53%)	64

***Current population (2018 world data sheet) and predicted growth by 2050 with focus in Africa and Mozambique Special attention is also given for sub-Saharan Africa (SSA) region and Mozambique country.*

Table 1.
Current population (mid-2018) and the predicted growth by 2050 in the world and for each region in particular.

Among them are the depletion and reduction in the productivity growth rates of the main crops, the dependence of phosphorus derived from rock, a nonrenewable resource, and climate change [14].

On the other hand, the increase in production alone is not enough to achieve economic, environmental, and socially sustainable food systems. Food and agricultural systems are vulnerable to a variety of risks, including extreme weather events and climate change, market volatility, and political instability. Climate change affects the availability, access, use, and stability of food supply, as well as work, capital, and the choice of crops intended for food production [15, 16]. Studies show that the average global yields of rice, maize, and wheat are projected to decrease between 3 and 10% by a heating degree above historical levels [17]. Climate change poses a major challenge to food security, which is very vulnerable to changes in climate patterns [18]. Food production in developing countries is negatively affected by climate change, especially in countries that are already vulnerable to climate effects (drought or floods) and that have low yields and high indices of hunger and poverty. Vulnerable populations are the most affected by climate change, and threats to these groups can interfere with their food, nutrition, access to water, and income, exacerbating conflicts [19].

There is a need for new approaches to ensure food and nutrition security. These should be sustainable, resilient, and practical solutions. Given this context, biodiversity, especially neglected crops, is essential to addressing the impacts of climate change [20]. They are nutrient-rich crops that demonstrate the potential for adaptation and production in several continents, reinforcing the importance of diversity in the face of climate change and which must be the priority in future research [21]. In addition, small farmers need support to improve agricultural production, diversifying crops such as the use of neglected or underutilized species. This chapter reinforces and calls attention for the use of neglected crops to face climate changes and as potential sources of vitamin A while combating malnutrition and vitamin A deficiency.

1.3 Neglected crops: basic concept and nutritional potential

Staple foods are facing major challenges and will continue in the near future due to climate changes. In this regard, diversification of crops including neglected crops is important if the world needs to achieve the goal of food security. Neglected crops are crop species traditionally used with local communities with great potential to contribute with food security and vitamin A deficiency issues [22].

According to the Food and Agriculture Organization (FAO) [23], neglected, underutilized, or orphan crops (NUCs) are plant species which for social, agronomic, or biological reasons have lost their importance over the 500 years. The original function of some neglected crops or their potential uses have been marginalized along the time; others have practically been forgotten. They constitute plant species which played a fundamental role in the agriculture and food supply of indigenous peoples and local communities. Their neglect was in many cases the result of the deliberate suppression of self-sufficient ways of life which characterized traditional cultures [23].

Currently, agriculture needs to explore nonconventional pathways such as underutilized crops (NUCs) as possible future crops. This is premised on reports that NUCs are adapted to a range of agroecologies and may be nutrient dense and offer better prospects in marginal production areas. Neglected crops are drought and heat stress tolerant, resistant to pests and diseases, and adapted to semiarid and arid environments and could be useful in diversifying diets and addressing micronutrient deficiencies in poor rural communities [24, 25].

Neglected crops are integral part of local culture, are present in traditional food preparations, and are the focus of current trends to revive culinary traditions; they have comparative advantages over staple crops because they have been selected to stressful conditions and can be cultivated using low input and biological techniques. These crops are generally ignored by policymakers and excluded from research and development agendas, and if we need to survive future climate changes and food production challenge, special efforts must be needed to improve their cultivation, management techniques, and harvesting and post-harvesting processes, and we need to better research the nutritional status and create secure policies and legal frameworks to regulate their use [22]. Neglected crops are represented by ecotypes or landraces which require some genetic improvement. Due to dependence of modern crops and industrialization, unfortunately, neglected crops are suffering rapid erosion of traditional knowledge [24]. These crops are represented in ex situ gene banks, but efforts are needed to rescue and conserve the genetic diversity of these underutilized species. Without better characterization and evaluation of these species, they will remain poorly understood [25]. A combination of ex situ with in situ (on-farm) conservation efforts must be implemented [24]. Another approach to promote the use of neglected crops is conservation through use. Neglected crops are also characterized by having fragile seed supply systems, and efforts need to be made to provide planting material to farmers in order to make the cultivation of underutilized species more feasible and sustainable over time [25].

Nowadays, only four main crops, i.e., maize, potato, rice, and wheat, supply more than 60% of the human's energy intake. The projected increase in the world's population has driven up the need for food and increased food demand [26]. It has become clear that the lack of diversity due to concentrating on fewer crops can have negative consequences for the human diet, which may cause malnutrition and diet-related diseases [26]. Since neglected crops are also rich in nutrients and health-promoting compounds with preventive effects against malnutrition and some chronic diseases and can survive in marginal or stressful conditions, they have a great potential in improving nutrition in local communities [26]. Diversifying the food chain by including these neglected species could be an effective tool to improve overall human nutrition and health [26].

In Africa and Mozambique to address vitamin A deficiency and malnutrition, focus must be concentrated not only on staple foods but also on diet-relevant neglected crops [27]. Currently, sub-Saharan Africa accounts for 9% of the global population and is characterized by high prevalence of food and nutrition insecurity, which is partly due to a lack of crop diversification [27]. Apart from playing an important role in the African diet, neglected crops can also contribute to the local economy and are part of traditional medicine as leaves of certain crops are used both as a food and a medical source. Most of the plants used grow indigenously in the wild or are cultivated on a very small scale [27]. Hence, production, as well as availability, is limited [27].

1.4 *Vigna unguiculata* L. (Walp): production, nutritional composition, and potential source of vitamin A

Vigna unguiculata L. Walp is an annual herbaceous plant species of the leguminous family (Fabaceae) and subfamily Papilionoideae (Faboideae). Historically, the origin and domestication of the cowpea occurred in Africa, near Ethiopia, and is now cultivated in more than 100 countries [28]. It is cultivated mainly by small farmers in many parts of the world. Cowpea is rich in nutrients and is well adapted to different edaphoclimatic regions and of vital importance for the livelihood of millions of people in Central, West, and South Africa, mainly due to its tolerance to heat and drought [28]. All these factors are particularly important because cowpea is more consumed by nutritionally vulnerable populations. In addition, it is of growing interest due to its vegetable proteins [28].

The latest productive data of updated cowpea provided by the United Nations Food and Agriculture Organization (FAO) refer to the 2016 harvest. The area cultivated worldwide was 12.3 million hectares and the production of 6.9 million tons [29]. Among all countries, the largest producers are Nigeria (3 million tons), Niger (1.9 million tons), and Burkina Faso (603 mil tons) [29]. Cowpea presents countless forms of use, being used mainly as dry grains, pods, and green grains in natura for human consumption and may vary in size, color, shape, and texture, as well as in its nutritional composition. Also, cowpea is a rich source of bioactive compounds, such as peptides, resistant starch, dietary fiber, phytochemicals, and antioxidants, as well as certain types of vitamins and minerals, important for health. The string bean contains a complex and unique protein profile, including globulins (8.2%), albumins (11.9%), glutelins (14.4–15.6%), and prolamins (2.3–5.0%) [30–32]. The protein is composed mainly of the globulin fraction (50–70%). The quality and singularity of the protein depend on the composition of amino acids; according to Gupta et al. [33], the maximum and minimum total contents of essential amino acids were 33.43 and 27.50 g/100 g of protein, respectively.

Phenolic compounds and their mechanisms of action, both in raw cowpea and cooked, have been reported in many studies. Adjei-Fremah et al. [34] observed phenolic compounds, condensed tannins, and antioxidant capacity of the seed extracts of several cowpea varieties. The folic acid and ferulic acid have been claimed to be the most abundant phenolic acids in cowpea seed, while in the seed shell, the main phenolic acid is the gallic acid, followed by the protocatechuic, P-hydroxybenzoic, and coumaric acids [35].

The cowpea contains a high amount of resistant starch and dietary fiber and can be considered a food of low glycemic index [36]. Cowpea resistant starch has been thoroughly studied by Eashwarage et al. [37] and Chen et al. [38], while total dietary fiber in cowpea was reported by Kirse and Karklina [39], Eashwarage et al. [37], and Khan et al. [40]. According to Gonçalves et al. [41], cowpea flour can be used as a supplement to provide additional vitamin A activity and zinc in cereal-based weaning foods. Carotenoids such as lutein, β-carotene, γ-carotene, and cryptoxanthin, which are precursor substances of vitamin A, are also present in the grains, pods, and leaves of cowpea [42–45].

The main limiting factors of cowpea consumption include low digestibility, deficiency of amino acids containing sulfur, and the presence of antinutritional factors. The presence of some types of phenolic compounds, such as proanthocyanidins [46], phytic acid [47], tannins [48], haemagglutinins [49], cyanogenic glycosides, oxalic acid [20], dihydroxyphenylalanine, and saponins, may be nutritionally disadvantageous for humans. In addition, enzymatic inhibitors of cowpea, such as protease inhibitors, are also considered antinutritional compounds [50]. On the other hand, α-amylase and β-glucosidase inhibitors in cowpea may be extremely beneficial for human health, as they may reduce the rate of glucose release during digestion. Ojwang et al. [43] reported that the proanthocyanidin content of cowpea varies from 2.2 to 6.3 mg/g, which is similar to other legumes, such as peas, lentils, and combs [43]. However, proper processing methods can be used to destroy these antinutritional factors and improve the levels of bioavailability, especially when used as food for infants and children [28].

In addition to phenolic compounds, proteins, peptides, and protease inhibitors, the string bean presents other functional properties responsible for the improvement in the lipid profile, control of blood glucose level, and arterial pressure and also for helping in cancer prevention. Moreover, being more than an individual compound, reports indicate that cowpea exerts positive effects on disease prevention, indicating a probability of synergistic interactions among the compounds present in the species. However, in vitro data on anticancer and anti-inflammatory properties of cowpea are inconclusive and require further studies [28].

Considering the characteristics of the species as to the nutritional aspects, a product with high social and economic value is observed. Thus, cowpea cultivation can be considered an opportunity for producers, although there are still countless challenges to be overcome in terms of research and investments in the transfer of technologies to increase the productive potential of species.

1.5 *Manihot esculenta* Crantz: production, nutritional composition, and potential source of vitamin A

Cassava belongs to the genus *Manihot* that comprises 98 species and is one of the widely cultivated species. It is a dicotyledonous, perennial, arbustive that can reach up to 4 m of height belonging to the family Euphorbiaceae [51]. Cassava is considered one of the most important cultures in the tropics and subtropics around the world being widely cultivated by possessing tuberous roots. It is the fifth most important basic culture globally after maize, rice, wheat, and potato in relation to production and caloric intake [52, 53]. Currently, cassava is produced in 103 countries, with a total global production of 270 million tons, in approximately 25 million hectares worldwide. Thirty countries located in Africa, Latin America, and Asia are considered large global cassava producers, together producing more than 50 million tons annually [54]. Nigeria, Thailand, Indonesia, Brazil, and Congo dominate 60% of the world's cassava production [55].

Estimates suggest that cassava is a staple food for 800 million people living in South America, the Caribbean, Africa, and Asia [56]. It is cultivated by poor farmers, many of them women, often in marginal lands. The main product of the cassava plant is its amylaceous roots; however, the leaves are consumed in at least 60% of the countries of sub-Saharan Africa, providing an important source of proteins, vitamins, and micronutrients [57]. The nutritional content of cassava can vary depending on the part of the plant that is consumed (leaves or root), variety, age of the plant, place of cultivation, and environmental conditions. The root of cassava is considered a great source of energy due to a large amount of carbohydrates present. The carbohydrate content varies from 32 to 35% of its fresh mass and from

80 to 90% of its dry mass [58]. Eighty percent of the carbohydrates produced is starch, mainly in the form of amylopectin (83%) and amylose (17%) [59]. The fiber content is approximately 1.5%, and this value may vary according to the variety and stage of root development. The lipid (0.1–0.3% root dry mass) and protein (1–3% root dry mass) contents are considerably lower than those shown by other crops, such as corn and sorghum [60].

The essential amino acids lysine, cysteine, leucine, methionine, threonine, and tryptophan are present in low amounts. On the other hand, arginine, aspartic acid, and glutamic acid are the amino acids that appear in larger amounts in the cassava roots [61]. The calcium, iron, potassium, magnesium, copper, zinc, and manganese contents are compared to those found in many legumes. The calcium content is relatively high compared to other basic crops and may reach approximately 360 mg/100 g of root [60].

In the regions where cassava is cultivated, the roots are mainly of white pulp possessing low levels of vitamins including vitamin A [62]. The vitamin C content is relatively high, ranging from 15 to 45 mg/100 g of root [61]. On the other hand, cassava varieties with yellow pulp root have a higher content of β-carotene; this carotenoid is important in human food because it is a precursor of vitamin A [53]. Breeding programs are focused on the development of biofortified varieties with the presence of carotenoids as β-carotene in the roots of yellow coloration [63]. The new varieties of root cassava with yellow pulp have the potential to provide up to 25% of the vitamin A needed daily by children and women [64]. The cassava roots of biofortified yellow pulp have starch and flour with physicochemical characteristics and functional properties similar to those found in the roots of cassava of white pulp; however, the values of provitamin A are higher [53]. Cassava is the staple foods of millions of people in the world; the consumption of biofortified cassava with β-carotene can help fight vitamin A deficiency which is a serious public health problem in many parts of the world [65]. This plant plays a key role in food security and income generation.

1.6 Case study 1: *Tacca leontopetaloides* as source of vitamin A in Mozambique

Hunger and malnutrition have serious ramification in humans, and an example is the increase of dietary-related diseases globally. *Tacca leontopetaloides* tubers are known to be a staple food in Mozambique, mainly in Inhassunge District, Zambézia Province (center region of Mozambique). Previous research has demonstrated that most rural dwellers depend largely on *Tacca* to meet up with shortages in nutrients like minerals, proteins, lipids, carbohydrates, and vitamins [66, 67]. Despite the nutritional content, it is also known to contain high levels of antinutritional factors which could be toxic to the body. Therefore, knowledge of the nutritional status and toxic levels is imperative in order to encourage its cultivation and consumption. Regarding its vitamin A contents, there is a lack of information in the literature. The principal amino acids present in the protein are arginine, glutamic and aspartic acids, leucine, lysine, and valine. In the study of Bosha [68], the presence of reducing sugars, tannins, flavonoids, steroids, glycosides, and hydrogen cyanide was observed. The presence of potassium, sodium, magnesium, selenium, manganese, vanadium, and some heavy metals like lead, aluminum, arsenic, and mercury was also reported including vitamins A, B1, B2, B3, C, and E. The proximate analysis showed moisture, ash, fats, fiber, crude protein, and carbohydrates.

According to USDA National Nutrient Database for Standard Reference Release 1 Basic Report November 21 [69], arrowroot contains vitamins in (mg/100 g) such as vitamin C (0.143), riboflavin (0.059), niacin (1.693), vitamin B-6 (0.266), folate

(338 μg/100 g), and vitamin A—RAE (1 μg/100 g). In a study of Upkabi et al. [67], *Tacca* presented dry matter in average of 29%, starch content in average of 26%, ascorbic acid and proteins (1.1%), ash (2.7%), 0.5% fiber, 0.1% fat, 95% total carbohydrates, 10% of starch moisture content, starch with water absorbing content around 5.6 g/g, and oil absorbing capacity around 7%.

The results of Vu [70] indicated that high total phenolic content and total flavonoid contents were presented in leaves of *Tacca*. The chemical compositions of *Tacca* flour showed 0.66% total of nitrogen, 0.91% lipid, 0.05% ash, and 85.7% starch content on dried weight. The extract of peels showed to possess potential antimicrobial activity against different microorganisms. *Tacca* is a promising crop for food and pharmaceutical excipient industries. Jagtap and Satpute [71] while studying the flavonoid fingerprinting of *Tacca* revealed the presence of diosmin, rutin, epigenin, saponin, hesperidin, phenolic acid, chlorogenic acid, quercetin, and isoquercetin with strong medicinal value. Despite the antinutrional content, its starch can also be explored in the pharmaceutical industry.

1.7 Case study 2: cassava as source of vitamin A in Mozambique

In sub-Saharan Africa, the major cassava-producing countries include Nigeria (53 million mt in 2013), Democratic Republic of Congo (16 million mt), Angola (16.4 million mt), Ghana (15.9 million mt), and Mozambique (10 million mt [72]). Mozambique has a world share of 3.3% [73]. The Mozambican diet is mainly composed of cassava—a staple with low protein content. With the exception of green leafy vegetables which often accompany the staples, the supply of micronutrient-rich foods (other vegetables, fruit, and foods of animal origin) is dramatically low [74]. The consequences of malnutrition should be a significant concern for policy-makers in Mozambique where chronic malnutrition (stunting or low height for age) affects more than 2 million children under 5 years (43%—[75]). Food insecurity together with poor diet quality is among the main problems in Mozambique, resulting in insufficient micronutrient intake. In the rural areas of the northern part of the country, households consume mostly maize and green leafy vegetables consumed as infrequently as 2–3 days per week. Due to poor diet, there are high levels of micronutrient deficiencies, such as anemia, which affects 69% of children under 5 years and 54% of women of reproductive age [75]. Efforts are being made; for example, in 2017, Mozambique created the National Council for Nutrition and Food Security (CONSAN) with the aim of having a high-level, institutionalized coordination structure for nutrition and food security to support the reduction of food insecurity and chronic malnutrition and to promote the effective implementation of nutrition and food security policies [75].

Poor nutrition contributes also to high rates of childhood mortality in Mozambique. Those who are nutritionally deficient are more susceptible to diseases, which further complicate the situation [76]. Forty-four percent of children in Mozambique under five are stunted due to poor diet and suffer chronic illness. Iron, iodine, and vitamin A deficiencies are among the main perpetrators at the microlevel. Deficiency in iron in Mozambique affects 75% of the children who grow anemic and are apathetic, anorexic, and energyless. Iodine deficiency has mental and physical repercussions [76]. Vitamin A deficiency weakens the body's immunity to infections by 69% of children. It also affects 11% of mothers, who find it hard to breastfeed their children because they are also undernourished [76].

Vitamin A deficiency is a major challenge of public health in Mozambique, and on the other hand, yellow cassava or provitamin A-rich cassava has great potential to alleviate vitamin A deficiency and can be used as a complementary approach to other interventions [77]. Considering the high prevalence of vitamin A deficiency, supplementation of this nutrient by neglected crops even in small quantities is likely to result in major public health gains [77].

Many cassava varieties cultivated in Africa have white roots with virtually no provitamin A. New developed yellow cultivars are rich of carotenoids and have provitamin A activity. These yellow varieties have been crossbred with African cassava varieties, by using conventional techniques, to increase provitamin A content [77]. Yellow cassava contains provitamin A carotenoids primarily as beta-carotene, which humans absorb and convert to retinol (vitamin A). Cassava is a nutty flavored, starch tuber in the spurge family (Euphorbiaceae) of plants. Cassava is one of the highest value calorie food for any tropical starch-rich tubers and roots. It has been argued that 100 g root provides 160 calories. Their calorie value mainly comes from sucrose which accounts for more than 69% of total sugars and 16–17% amylose, another major source of complex carbohydrates. Cassava has more protein than other tropical root tubers and is free of gluten. The leaves are also a good source of dietary proteins and vitamin K as they are consumed in Africa, Asia, and Latin America. Cassava presents also B-complex group of vitamins such as folates, thiamin, pyridoxine (vitamin B-6), riboflavin, and pantothenic acid and minerals such as zinc, magnesium, copper, iron, manganese, and potassium [78]. According to an in-depth analysis of nutrients, cassava root, raw, has the following nutrients per 100 g [75]: energy value (160 Kcal), carbohydrates (38.06 g), protein (1.36 g), fat (0.28 g), and fibers (1.8 g). According to this in-depth analysis, cassava presents also vitamins such as folates; niacin; pyridoxine; riboflavin; thiamin; vitamins A, C, E, and K; electrolytes such as sodium and potassium; and minerals (calcium, iron, magnesium, manganese, phosphorus, and zinc).

Globally, between 250,000 and 500,000 vitamin A-deficient children become blind every year; half of them are reported to die within 12 months of losing their sight. Rather than fortifying the cassava after it is grown, the cassava naturally grows with high levels of vitamin A [79]. Annually, 150 000 children die of vitamin A deficiency because it makes them more susceptible to infections [80]. A promotion of neglected crops such as yellow cassava in Mozambican environment can help reduce the problem of vitamin A deficiency.

1.8 Case study 3: *Vigna unguiculata* as source of vitamin A in Mozambique

Mozambique lies along the southeastern coast of Africa with an extensive coastline of 2470 km and an area of 801,590 km^2. It has about 36 million hectares of arable land, suitable for agriculture. At present, approximately 3.9 million hectares, which make about 10% of the arable land, are under cultivation with 97% cultivated by smallholder farmers [81, 82]. Maize, cassava, and cowpeas are the most common food crops, cultivated by 79, 73, and 50% of the farmers, respectively [82]. Currently, crop diversification has been promoted through different strategies such as capacity building and practical demonstrations at school garden and community levels. Seventeen percent of total legume area (752,000) in Mozambique is destined to cowpea [83].

Cowpea is widely grown in Mozambique, and currently 63,000 million tonnes are produced annually on about 126,000 ha. Consumers in Mozambique eat the green grain (pods), dried grains, and tender leaves. Farmers generally grow spreading varieties, which are photosensitive and low grain yielding but have high biomass that serves as vegetable produce over a long period. It is due to the importance that farmers give to the leaves for their household consumption as well as for the market. Higher importance is given to leaves than the grain in different regions of the country [83–85].

According to Chiulele [85], cowpea is one the most widely grown food crops in Africa. It is estimated that more than 90% of the world cowpea grain production of 5.7 million tonnes is produced in about 10 million hectares in Africa. The crop is most important in the semiarid and hot areas of Africa where other crops may fail due to poor adaptation to heat, drought, and low soil fertility conditions. Cowpea is an important crop in Mozambique where the grain and leaves are major sources of food and family income, particularly for resource-poor households. The crop has a high protein content of about 25% in the grain (dry weight basis) and serves as a cheap source of protein, vitamins, and minerals. The crop enhances the quality of the cereal-based diets when its high lysine content is combined with the high content of methionine and cysteine of cereals. In addition, the crop improves the cropping systems and soil fertility by reducing soil erosion, suppressing the weeds, and fixing atmospheric nitrogen which contributes to increased yields of nitrogen-demanding crops [85].

According to Gerrano [86], in southern Africa, cowpea can be used as a food for humans as well as for fodder production and for weed control in forestry plantations. The seeds contain small amounts of β-carotene (precursor of vitamin A), thiamin, riboflavin, niacin, folic acid, and ascorbic acid. It is a major source of inexpensive protein in human diets with grains containing about 23–25% protein, 1.8% fat, and 60.3% carbohydrates, and it is a rich source of calcium and iron [86].

Globally, cowpea is cultivated on about 12 million hectares worldwide out of which more than 98% is located in Africa [87]. Africa contributes to 96.4% of the world production followed by 2% Asia, 1.2% Americas, and 0.4% Europe. At African level, East and West Africa together contribute 94.2% in terms of harvested area [86]. Currently, the top ten world producers are Nigeria (3,027,596 tonnes), Burkina Faso (1,987,100 tonnes), Cameroon (603,635 tonnes), Tanzania, Sudan, Kenya, Mali, and Myanmar and Mozambique (82,931 tonnes) [87].

Cowpea (*Vigna unguiculata* L. Walp) has shown several agronomic, environmental, and economic advantages, contributing to further improve the diets and incomes of peasant farming across Africa, Asia, and South America. Cowpea can grow in semiarid regions with low input requirements. Due to its high protein and low fat content, cowpea is considered to be a multipurpose crop [71, 88]. According to USDA Food Composition Database [81], cowpea is a powerful source of vitamin A. For example, leaf tips contain 36 μg/100 g of vitamin A, young pods with seeds (68 μg/100 g), mature seeds (2 μg/100 g), mature seeds boiled or cooked (1 μg/100 g), and leaf tips cooked or boiled (29 μg/100 g) of vitamin A. As reported by [88, 89], cooking and sprouting of legumes greatly influence nutritional quality by increasing bioavailability of nutrients as well as enhancing digestibility and utilization of nutrients. As demonstrated in its multipurpose functions, cowpea can be promoted and used as in food diversification to supply vitamin A and contribute fighting the malnutrition in Mozambique.

2. Conclusions and future outlook

Extensive literature available on neglected crops and in situ/in vivo experience with rural communities until today prompt us to claim that neglected crops have great potential not only as a source of vitamin A but by their ability to adapt to different environments and marginal areas. Despite the extensive works in neglected crop promotion, more real and practical actions have to be taken if we want to halt the continuous rise in vitamin A deficiency in the world and food insecurity. Scientists and policymakers are urged to recognize the potential of neglected crops and create real alternatives and technologies to promote the sustainable use of neglected crops while contributing to fight hunger, malnutrition, and food insecurity. Cassava, cowpea, and arrowroot are crops of the future; their use must be maximized to help eradicate vitamin A problems and food insecurity in Mozambique, in Africa, and in the world.

Orphan crops have been overlooked by research, extension services, and policy-makers; governments rarely allocate resources for their promotion and development which results in small farmers planting them less often and due to reduced access to high-quality seeds, with consequences in loss of traditional knowledge. Currently, the world uses a mere 30 species to feed the world from 30,000 available. Yet these neglected and underutilized crops can help to increase the diversification of food production, adding new species to our diets that can result in a better supply of particular nutrients. Neglected and underutilized crops can also provide economic and environmental benefits as farmers can use them as part of crop rotation systems or interplant them with other crops, protecting and enhancing agro-biodiversity at the field level.

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