Received: 31 October 2019 | Revised: 16 May 2020 | Accepted: 26 May 2020

DOI: 10.1002/fes3.220

REVIEW

Food and Energy Security Open Access | WILEY

Underutilized African indigenous fruit trees and food–nutrition security: Opportunities, challenges, and prospects

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Funding information
National Research Foundation, Grant/Award Number: 109508

Abstract

The diverse range of indigenous fruit trees in Africa is a source of untapped potential for food and nutrition security. Here, we review information on 10 indigenous fruit trees that are considered to be underutilized and explore their occurrence, distribution, nutritional components, phytochemicals, and medicinal potentials, as well as their associated challenges and prospects. The indigenous fruit trees, which occur across different ecological zones in Africa, are rich sources of vitamins, minerals, protein, and valuable phytochemicals. They also have recognized medicinal value and used as diverse therapeutic remedies by many ethnic groups in Africa. The key challenges to fruit tree sustainability include indiscriminate and illegal logging, low accessibility, and low acceptability, as well as inadequate research on their cultivation. We proposed a scheme to increase the value chain of underutilized fruit trees, which can contribute to the livelihoods of smallholder farmers and other stakeholders mainly through income generation. In addition to the concerted efforts of multidisciplinary research teams encompassing plant breeders, botanists, molecular biologists, food scientists, and horticulturists, there is an urgent need for governments and other international stakeholders to provide incentives and encourage the domestication, commercialization, and agro-processing of underutilized fruit trees for future economic prosperity of Africa.

KEYWORDS

agro-processing, ethno-medicine, food security, hidden hunger, livelihood, phenolics, phytonutrients

1 | INTRODUCTION

The increasing world population, deforestation, and climate change are some of the key driving forces of food–nutrition insecurity in the developing countries (Bvenura & Sivakumar, 2017; Mabhaudhi, Chimonyo, & Modi, 2017; Narjes & Lippert, 2019; Shumetie Ademe, Goshu, Kassa, & Mwanjalolo, 2017). Food insecurity indicates an inability to access good, healthy, and appropriate food. Delivering enhanced food security which is the basic right of people is one key global challenge (Black et al., 2017). There is much concern about an increase in global hunger as the human population, urbanization, and climate variability are exponentially increasing thereby, exacerbating food insecurity in areas currently vulnerable to hunger and undernutrition (Wheeler & Von Braun, 2013; Willett et al., 2019). In 2017, the number of undernourished people increased to 821 million which translates into one out of every nine individuals globally (Fouberg, Murphy, & De Blij, 2020)

Another critical dimension of food insecurity is "hidden hunger" which is recognized as micronutrient deficiencies that affects over 2 billion people globally (Fortin, 2018; Hodge, 2016). The effect of hidden hunger can be devastating, leading to poor health, or even death. The negative effects of this dimension of food insecurity on the survival rate of a child are acute, especially within the early years of life, resulting in serious physical and cognitive consequences (Britto et al., 2017; Mngadi, Moodley, & Jonnalagadda, 2019). In addition to the threat to health, hidden hunger can hinder socioeconomic development, particularly in the developing countries (von Grebmer et al., 2014). However, the scientific target for nutritionally sufficient or healthy diets should be largely composed of fruits and vegetables, grains, legumes, nuts, and unsaturated oils; low to moderate consumption of seafood and poultry; and zero to low consumption of red meat, processed meat, added sugar, refined grains, and starchy vegetables (Afshin et al., 2019; Willett et al., 2019). Whereas the current average food intake of healthy foods by individuals is far below recommended levels while overconsumption of unhealthy foods is increasing globally (Willett et al., 2019).

The importance and possible contribution of indigenous fruit trees to food-poverty reduction has been recognized (Schreckenberg et al., 2006), and several authors have explored the nutritional and economic potentials of underutilized fruit trees in Africa and suggested their role for mitigating malnutrition and "hidden hunger" (Ashraf, Ashraf, & Ozturk, 2018; N'Danikou, Vodouhe, Bellon, Sidibé, & Coulibaly, 2017). In Africa, many indigenous fruit trees have lost their natural habitat to deforestation resulting from exponential human population growth (Cemansky, 2015; Estrada & Coates-Estrada, 1996; Fischer & Lindenmayer, 2007). FAO (2010) and Nkosi et al. (2020) highlighted the great potentials of indigenous fruits in the local and international economy.

TABLE 1 Overview of the 10 selected indigenous fruit trees in different regions of Africa

Scientific name	Family	Common name	Period of fruit availability	Region(s) of availability in Africa
Adansonia digitata L.	Malvaceae	African baobab	April–October (Akinnifesi et al. 2007)	1, 2, and 4 (Awodoyin et al., 2015)
Balanites aegyptiaca (L.) Delile	Zygophyllaceae	Balanite	April–June (Bvenura & Sivakumar, 2017)	1, 2, 3, 4, and 5 (Stadlmayr et al., 2013)
Dovyalis caffra (Hook.f. & Harv.) Sim	Salicaceae	Kei-apple	December–May (http://www.worldagroforestrycentre.orglSitesJTreeDBS/AFf/AFf.htm)	1 (Awodoyin et al., 2015)
Garcinia livingstonei T. Anderson	Clusiaceae	Imbe	No information found	1, 2, 3, and 4 (Awodoyin et al., 2015)
Mimusops zeyheri Sond.	Sapotaceae	Transvaal red milk wood	April–September (http://pza.sanbi.org/mimusops-zeyheri)	1 (Orwa et al., 2009)
Parinari curatellifolia Planch.ex Benth.	Chrysobalanaceae	Mobola-plum	October–January (Bvenura & Sivakumar, 2017)	1, 2, and 4 (Awodoyin et al., 2015)
Sclerocarya birrea (A.Rich.) Hochst. subsp. caffra (Sond.) Kokwaro	Anacardiaceae	Marula	February–March (https://www.daff.gov.za/Daffweb3/Portals/0/Brochures%20and%20Production%20guidelines/Production%20Guidelines%20Marula.pdf)	1, 2, 3, and 4 (Stadlmayr et al., 2013)
Strychnos spinosa Lam.	Loganiaceae	Monkey orange	July–December (Bvenura & Sivakumar, 2017)	1, 2, 3, and 4 (Awodoyin et al., 2015)
Uapaca kirkiana Müll.Arg.	Phyllanthaceae	Wild loquat	October–January (Bvenura & Sivakumar, 2017)	1, 2, 3, and 4 (Stadlmayr et al., 2013)
Vangueria infausta Burch.	Rubiaceae	Wild medlar	January–April (http://pza.sanbi.org/vangueria-infausta)	1, 3, and 4 http://tropical.theferns.info/viewtropical.php?id=Vangueria+infausta

Note:: Availability of underutilized fruit in different region(s) in Africa—Southern Africa [1], West Africa [2], Central Africa [3], East Africa [4], and North Africa [5].

Consuming more than seven type of fruits daily evidently lowers the risk of death from any cause, yet many individuals in developing countries living below the poverty line have a low or even zero intake of fruits (Kucich & Wicht, 2016; Wilkinson & Pickett, 2020). Better understanding of the occurrence and nutritional qualities as well as the economic potential of these indigenous fruit species can be important for enhanced food security in Africa.

This review makes the case for strengthening food–nutrition security with evidence from existing literature by exploring 10 indigenous fruit trees regarded as underutilized for their potential contribution to food and nutrition security. The selection of the indigenous fruit trees was based on scarcity of existing literature focusing on these underutilized fruit trees in several regions of Africa despite their enormous potentials (Awodoyin et al., 2015; Bvenura & Sivakumar, 2017). In addition, the key challenges limiting the potential of these selected fruit trees were highlighted. The prospects of refocusing research efforts and resources in a concerted manner were articulated as a means to unlock the full potential in the selected indigenous fruit trees.

2 | OCCURRENCE AND DISTRIBUTION OF THE 10 SELECTED INDIGENOUS FRUIT TREES

The 10 selected indigenous fruit trees have diverse distribution, duration of fruiting and occurred in different region(s) in Africa (Table 1). For instance, African baobab (*Adansonia digitata* L) is found in Southern African countries such as Botswana, Namibia, and Mozambique and other tropical African countries. The plant is known by several names in different geographical locations. Some of these names include "magic tree," "chemist tree," "symbol of the earth," and "monkey bread of Africa" (Diop, Sakho, Dornier, Cisse, & Reynes, 2006; Diop, Franck, Grimm, & Hasselmann, 1988;

General uses	Morphological description
The pulp is eaten as snacks after roasting. It is a good flavoring agent, oil derived from it can be a thickening agent in soups (Rahul et al., 2015)	A medium-sized, bulging, short trunked and bottle-shaped deciduous tree usually not more than 20 m height but trees reaching 30 m have been recorded (Kamatou et al., 2011)
The fruit is edible (Amadou & Le, 2017). Leaves and flowers are also edible (http://tropical.theferns.info/viewtropical.php?id=Balanites+aegyptiaca)	The tree reaches 10 m in height, narrow and long branches, green spines which are arranged in spirals (Shalaby, El Namaky, Kandil, & Hassan, 2018)
The ripe fruit is edible, can be used to make cake, jam, drink, and jelly or added to fruit salad (Minnaar, Jolly, Paulsen, Du Plessis, & Van Der Rijst, 2017)	Reaches a height of 6–9 m (Orwa et al. 2009)
It is mainly grown as an ornamental fruit, but is sometimes eaten (Joseph,).	An evergreen small tree, ranging from 6 to 18 m in height. Leaves are borne in opposite pairs, 3 to 5.5 cm broad
It is rich source of vitamin c. (Chivandi, Davidson, Pretorius, & Erlwanger, 2011)	It is a large, evergreen plant that may reach 15 m in height. (Department of Agriculture Forestry and Fisheries (DAFF), 2012; Mabhaudhi, Chimonyo, Chibarabada, et al., 2017)
Ripe fruits are often edible. It can also be cooked or fermented into beer. The oil-rich nuts are high in important nutrients (Crown et al., 2017)	It a tropical fruit tree with a shape like mushroom and grows up to 20 m height
Fruit is eaten fresh or processed into beverages. Leaves are good sources of fodder (Prins et al., 2010)	It is a fairly large sized tree, usually with 9 m height but can grow up to 18 m. It is single stemmed, with a dense, spreading foliage (Mojeremane & Tshwenyane, 2004)
Ripe fruits are consumption fresh but can also be sun-dried (Ngadze, Linnemann, Nyanga, Fogliano, & Verkerk, 2017)	The tree is a small, spiny plant that can grow from 2 to 6 m height (Van Wyk, 2013)
Fruits can be eaten in its raw form and could be fermented into wine (Kadzere et al., 2006)	It is a wide rounded crown tree with many branches that grow up to 12 m in height (Liu et al., 2019)
It is edible and also used as beverage, juice, and vinegar (Van Wyk, 2011a,b)	Deciduous tree of 3–7 m in height with a short trunk (Chiau, Francisco, Bergenstaring, & Sjouml, 2013).

Vermaak, Kamatou, Komane-Mofokeng, Viljoen, & Beckett, 2011). In South Africa, the African Baobab is found mostly in the warm parts of the Limpopo Province (Venter & Witkowski, 2010).

Balanite (*Balanites aegyptiaca* (L.) Delile) is prevalent in the south of the Sahel-Savannah region across Africa, especially in West African countries including Mali, Benin, Senegal, Nigeria, and Burkina Faso (Buchmann, Prehsler, Hartl, & Vogl, 2010; Sanchez, Osborne, & Haq, 2011). Furthermore, Balanite is peculiar to dry lands south of the Sahara, extending southward to Malawi in the Rift Valley (Chothani & Vaghasiya, 2011). It is a lowland plant that can thrive under 1,000 m above sea level, temperature of 20–30°C, and low rainfall (Chadha, 1976). On the other hand, the Kei-apple (*Dovyalis caffra* (Hook.f. & Harv.) Sim) is a native of the Southern African region and found in countries such as Mozambique, Malawi, Swaziland, Lesotho, Zimbabwe, and Namibia (Orwa, Mutua, Kindt, Jamnadass, & Simons, 2009; Aremu et al. 2019). It is an evergreen tree with aromatic apricot-like fruit and indigenous to the Kei river area (Schmidt, Lotter, & McCleland, 2002). The fruit of Kei-apple is round-shaped and small-sized measuring around 2.5–3.8 cm in length with 5–15 seeds. The plant thrives at 200–2450 m above sea level as well as in dry and sandy soils (Orwa et al., 2009; Omotayo et al. 2019).

Imbe (*Garcinia livingstonei* T. Anderson) occurs in the tropical African nations such as Uganda, Swaziland, South Africa, Somalia, Angola, and Congo. The tree ranging from 4 to 6 m bears an edible plum-like fruit and usually has several trunks, which arch away from the main axis and produce a number of short, thick, side branches. Likewise, Transvaal red milk wood (*Mimusops zeyheri* Sond.) occurs in South Africa, Mozambique, Zimbabwe, and Swaziland. The plant thrives well on the dry woodland and bushveld of the Southern Africa. The plant occurs naturally on rocky outcrops, riverine, wooded hillsides, and forest fringes. The wide range of natural occurrence suggests that it would be suited to cultivation in summer rainfall areas of low to medium altitude areas where frost is minimal.

Mobola plum (*Parinari curatellifolia* Planch.ex Benth.) is widespread in Swaziland, Zimbabwe, Uganda, and South Africa (Table 1). Another African indigenous fruit tree with great potential is the Marula (*Sclerocarya birrea* (A.Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro). It is found in Niger, Burkina Faso, and Benin (Gouwakinnou, Kindomihou, Assogbadjo, & Sinsin, 2009). Monkey orange (*Strychnos spinosa* Lam.) occurs in South Africa, Mozambique, Swaziland, Zimbabwe, Zambia, Botswana, Namibia, Angola, Guinea Bissau, and Madagascar. It can be found growing singly in well-drained soils, bushveld, riverine fringes, sand forest, and coastal bush.

Wild loquat (*Uapaca kirkiana* Müll.Arg.) occurs in Angola, Democratic Republic of Congo, Burundi, Malawi, Tanzania, Mozambique, Zimbabwe, and Zambia (Ngulube, Hall, & Maghembe, 1995). The tree bark is dark gray or gray-brown, thick and deeply fissured. The young shoot of the growing tree is covered with creamy-brown hairs. Leaves are simple and alternately arranged in clusters which are concentrated at the ends of branchlets. The young leaves are covered with curly hairs on the under surface. Fruit is round, skin tough, yellow-brown, and contains an average of 3–4 white seeds. Wild medlar (*Vangueria infausta* Burch.) is found in Uganda, Kenya, Tanzania, Malawi, Mozambique, Zimbabwe, Namibia, Botswana, Swaziland and South Africa where the fruit tree is commonly found in open and exposed grassland.

3 | POTENTIAL BENEFITS ASSOCIATED WITH THE 10 SELECTED INDIGENOUS FRUIT TREES

These underutilized fruit trees are currently characterized by inadequate exploration relative to their potential. However, these fruit trees are gradually receiving more recognition due to their health nutritional and economic opportunities. Some of these aforementioned attributes are discussed below:

3.1 | Diverse ethno-medicinal uses

Based on the diverse medicinal properties of the 10 selected indigenous fruit trees, they currently play important roles in the healthcare systems in different parts of Africa, especially among rural communities (Table 2). Most African people still rely on traditional medicine which is often the first and last line of defense against wide range of diseases (Cheikhyoussef, Shapi, Matengu, & Ashekele, 2011; Sophy & Mavis, 2008). The fruit, seed, leaf, tuber, root, and flower of many indigenous fruit trees are used for different medicinal purposes. The benefits of ethno-medicine are well-recognized by the majority of the rural communities in Africa (Donini, 2012). Indigenous knowledge on medicinal plants and their use by indigenous people are useful for conservation of cultural traditions and biodiversity as well as for community healthcare (Cheikhyoussef & Embashu, 2013; Cheikhyoussef et al., 2011). Ecological information on the conservation of these valuable resources remains pertinent. These fruit trees which are often considered as “minor” contributors to the agricultural outputs can be fully explored to become major crops through propagation and systematic cropping.

TABLE 2 Ethno-medicinal uses of different plant parts of the 10 selected indigenous fruit trees in Africa

Scientific name	Plant part	Disease conditions treated in folk medicine
Adansonia digitata L.	Bark	The tree bark is boiled and used as steam bath for relieving shivering, influenza, and body pains other fever symptoms (DeFilipps & Krupnick, 2018)
		It is believed that drinking of infusion from the fibrous bark of the tree improves immunity
	Leaves	The fresh leaves are prepared as concoction for hyposensitive, antihistamine, treat kidney, bladder disease, fatigue, diarrhea, guinea worm, and asthma. The leaves are also used as remedy against insect bites and several other health issues
	Flower	The flower and leaf infusions are used to treat respiratory and digestive problems as well as eye inflammatory (Zahra'u, 2014)
	Fruit pulp	The pulp is prepared to combat fevers and treat dysentery
	Gum	The gum from the tree bark is used for cleaning sores. It is also used as an expectorant and a diaphoretic
	Root	Boiled roots are taken as a remedy for lassitude, impotence, and kwashiorkor (http://tropical.theferns.info/viewtropical.php?id=Adansonia+digitata)
Balanites aegyptiaca (L.) Delile	Bark	The bark decoction is used as spasmolytic and an antidote for arrow poison in West African traditional medicine (Chothani & Vaghasiya, 2011)
	Leaves	The leaves help in preventing worm infections and can be used to treat liver and spleen disorders (Sagna, Niang, Guisse, & Goffner, 2014)
	Fruit	Fruits are used to treat dysentery and constipation
	Seed	The seeds are used to treat tumors and wounds, as laxative, also in treatment of stomach-ache, yellow fever, hemorrhoid, jaundice, and syphilis (Chothani & Vaghasiya, 2011).
Dovyalis caffra (Hook.f. & Harv.) Sim	Root and thorns	To treat different form of chest pain and amenorrhea (Cumes, Loon, & Bester, 2009)
	Bark and root	To treat rheumatism and pain-related problem (Watt & Breyer-Brandwijk, 1962)
Garcinia livingstonei T. Anderson	Root	The root is processed into powder state and used as an aphrodisiac
	Fruit	The fruits can be fermented into a pleasant alcoholic beverage which could help in improving health (http://pza.sanbi.org/garcinia-livingstonei)
Mimusops zeyheri Sond	Bark	The bark is ground and boiled with water to treat ulcer and wounds (Amusan, Dlamini, Msonthi, & Makhubu, 2002)
	Leaves	To treat diabetes mellitus (Semenya & Potgieter, 2014; Semenya, Potgieter, & Erasmus, 2012)
	Root	To treat syphilis, stomach-ache, and gynecological infections (Mongalo & Makhafola, 2018)
Parinari curatellifolia Planch.ex Benth.	Bark	To treat pneumonia, cataracts, and ear-ache
	Leaves	Pound and used in dressing dislocated bones, broken bones as well as in wound healing. Also used for pneumonia treatment (http://southafrica.co.za/mobola-plum-fruit.html)
Sclerocarya birrea (A.Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro	Leaves	To alleviate heartburn, intestinal problems, and constipation (Ojewole, 2003)
	Bark	Inhaling the boiled steam helps in treating dysentery, malaria, and diarrhea (Deutschländer et al., 2009)
Strychnos spinosa Lam.	Leaves	Ground leaves are used for treating sore (Ngadze et al., 2017)
	Root	The roots are prepared as tea and use against cold symptoms, cough, gonorrhea, and malaria (Kone et al., 2004)
Uapaca kirkiana Müll. Arg.	Bark	The bark is used as medicine against dysentery and indigestion
	Leaves	Leaves are used as fodder for cattle and help against dysentery and intestinal-related problems
	Root	An infusion of the roots is boiled as a local remedy for indigestion, dysentery and intestinal problems (Ngulube et al., 1995)
Vangueria infausta Burch.	Root	Used in treating roundworm, malaria, pneumonia, and chest related problems
	Leaves	The ground leaf powder is applied to tick bite spots on livestock, dogs, and other animals in order to enhance their healing http://tropical.theferns.info/viewtropical.php?id=Vangueria+infausta

3.2 | Sources of high nutritional and phytochemical pools

The selected fruits are diverse in colour, texture, and shape (Figure 1) and contain fiber, minerals, carbohydrates, organic acids, fats, proteins, iron (Fe), calcium (Ca), magnesium (Mg), sodium (Na), zinc (Zn), and vitamins. At any particular time of the year, the availablity of fruits is guaranteed because of the different fruiting periods for these indigenous trees (Table 1), thereby meeting the food and nutrition needs of the local communities. In addition, these fruits can be consumed fresh or in dried form. They are mainly low in fat and calories, rich in carbohydrate and fiber as well as vitamins. These selected fruits have a potential dynamic role for providing a healthy diet (Stadlmayr, Charrondière, Eisenwagen, Jamnadass, & Kehlenbeck, 2013; Vincente, Manganaris, Ortiz, Sozzi, & Crisosto, 2014; Nkosi et al. 2020). Common organic acids found in the indigenous fruits are citric, malic, tartaric, oxalic, lactic, acetic and iso-citric acid (Table 3). These constituents are known to play a main function in the sugar to acid ratio of the human blood (Chidi, Bauer, & Rossouw, 2018). In addition, dietary fibers such as pectin, beta-glucans, hemicellulose, cellulose, lignin, and fructans which are known to improve body immune function and reduce the chances of acquiring many non-communicable diseases (NCDs; Matallana-González & Morales, 2019; Ötles & Ozgoz, 2014).

Furthermore, amino acids such as proline, alanine, asparagine, arginine, cystine, glutamic, aspartic, and glycine are abundant in the fruits. Vitamins cannot be sufficiently synthesized by humans but are obtained from food (Vincente et al., 2014). The vitamins found in the underutilized fruits include vitamins A (retinol), B_1 (thiamine), B_2 (riboflavin), B_3 (niacin/nicotinic acid), B_5 (pantothenic acid), B_6 (pyridoxine), B_9 (folate/folic acid), C (ascorbic acid), D_3 (cholecalciferol), E (α-tocopherol), and K_1 (phylloquinone). These make an important vitamin input to diet and nutrition, as they have specific nutritional roles in human body functionalities and performance (Bvenura & Sivakumar, 2017; Govender, Pillay, Siwela, Modi, & Mabhaudhi, 2016; Kucich & Wicht, 2016). Furthermore, phytochemicals which are non-nutritive plant chemicals that have protective or disease preventive properties are abundant in the selected fruit trees (Table 3). Some of the well-known phytochemicals are saponins, flavonoids, alkaloids, tannins, cardiac glycosides, terpenes, anthraquinones, steroids, and phenolics (Bvenura & Sivakumar, 2017; Doughari, 2012).

FIGURE 1 Examples of African underutilized fruit trees with potentials for food and nutrition security: Kei-apple (*Dovyalis caffra* (Hook.f. & Harv.) Sim) (a, b, c, d); Marula (*Sclerocarya birrea* (A.Rich.) Hochst. subsp. *caffra* (Sond.) Kokwaro) (e, f); Mobola-Plum (*Parinari curatellifolia* Planch.ex Benth.) (g, h); African Baobab (*Adansonia digitata* L.) (i); Monkey Orange (*Strychnos spinosa* Lam.) (j, k); Transvaal Red Milk wood (*Mimusops zeyheri* Sond.) (l, m); and Wild medlar (*Vangueria infausta* Burch.) (n, o)

3.3 | High economic value

Indigenous fruit trees can make varieties of contributions to livelihood and profitability of small-scale and commercial farmers. Despite the low state of commercial development, indigenous fruit trading and marketing are important for economic development. Evidence of few organizations trading in indigenous fruit products which range from fruit juice to seedlings currently exists (Ham et al. 2007). Indigenous fruits are sold in both urban and rural markets and provide a substantial income to the small-scale farmers. However, the adoption of large scale cultivation of indigenous fruits by farmers will remain low until the economic returns on investment associated with the domestication of underutilized fruit tree are profitable.

Existing studies revealed that the trading of fruits collected from the wild is a profitable enterprise (Akinnifesi et al. 2007). Indigenous fruit tree collection is an efficient labor allocation strategy and its returns to labor are considerably higher than that of crop production (Mithöfer and Waibel, 2003). For example, the collection of *Uapaca kirkiana* generated an average of $50 in Zimbabwe and $78 for *Sclerocarya birrea* in South Africa (Akinnifesi et al. 2007). Furthermore, studies in Malawi, Tanzania, and Zimbabwe found that the percentage of net profit of indigenous fruit products reached 28% with higher profits being obtained in locations that are close to the markets (Akinnifesi et al. 2007). In South Africa, communities collectively harvested about 2000 tons of *Sclerocarya birrea* and earned $180,000 annually, representing more than 10% of average household income in the communities (Ham, 2005). In addition, the members of a popular southern African Natural Products Trade Association reported gross revenue of $629,500 from the sale of fruit tree products. The key fruit tree products were obtained from *Sclerocarya birrea* and *Adansonia digitata* that generated $126,420 and $44,120, respectively (Akinnifesi et al. 2007; Mithofer 2005). Based on a recent market projection, the potential market of baobab was valued at $960 million. Studies in Zimbabwe revealed that improvements in tree yield and earlier fruiting of indigenous fruit trees will create incentives for farmers to cultivate indigenous fruits (Mithofer et al. 2006).

4 | CHALLENGES ASSOCIATED WITH UNLOCKING THE POTENTIAL OF THE 10 SELECTED INDIGENOUS FRUIT TREES

There is still scarcity of research investment and development for the improvement of underutilized fruit trees. Many of these indigenous fruits are still sourced from the wild and natural environments which have generally limited their potential for higher yield and growth (Awodoyin et al., 2015). The various factors that have hindered the exploration of the 10 selected indigenous fruit trees are highlighted below:

a. **Inadequate baseline data on the nutritional properties of individual indigenous fruit tree:** There is still scarcity of proper, organized baseline information on the nutritional properties of the selected indigenous fruit plants (Styger, Rakotoarimanana, Rabevohitra, & Fernandes, 1999). The existing data on many of the selected indigenous fruit tree are based on few collections from specific location which may vary considerably when compared to collections from other geographical areas. Increasing evidence suggests that the quality and quantity of chemical metabolites in plants are influenced by a multitude of factors especially the environmental conditions (Ncube, Finnie, & Van Staden, 2012).
b. **Indiscriminate and illegal logging:** Indiscriminate cutting of trees is a common act in the rural communities in Africa, and this has immeasurably contributed to the depletion of the population of indigenous fruit trees (Sardeshpande & Shackleton, 2019). This unregulated tree felling may be attributed to poverty, food insecurity, and high rate of unemployment among the young populations (Baldermann et al., 2016). Hence, there is a need for investment in the propagation and establishment of plantations for these selected fruit trees as well as the enactment and effective implementation of rules and regulations against illegal logging.
c. **Low level of acceptability and accessibility of indigenous fruits:** This is a major challenge facing underutilized indigenous fruit trees, and it is mostly borne out of general lack of interest and neglect of the wild fruits (Bvenura & Sivakumar, 2017). Hence, most of the fruit trees still grow in the wild and/or are cultivated on a small scale due to lack to proper access to capital for investment or fear of the risk involved in plantation (Nkosi et al. 2020). Hence, the production as well as availability and accessibility is often limited. Therefore, timely marketing campaign and promotion of the underutilized fruit trees is pertinent.
d. **Insidious domination and preference for the exotic fruit tree species**: The over-reliance of the majority of the African populace on the popular exotic fruit species such as apples and strawberry is a key problem in Africa (Byron & Arnold, 1999; Shackleton, Shackleton, Buiten, & Bird, 2007). This has in turn slowed down the expected growth needs that should have ensued through commercialization of the fruit tree cropping and marketing for food and nutrition security (Nkosi et al. 2020). This has also somewhat contributed to the limited income generated for the local farmers contributing to the low level of rural development in most countries in Africa (Rogan, 2016).

TABLE 3 Nutritional compositions and phytochemicals of the 10 selected indigenous fruit trees in Africa

Scientific name	Common compounds
Adansonia digitata L.	**Amino acids**: Arginine, alanine, cysteic acid, glutamic acid, aspartic acids, glucine, histidine, isoleucine, leucine, lysine, phenylalanine, tyrosine, prolamine, serine, proline, threonine, valine, and tyrosine (Yazzie, VanderJagt, Pastuszyn, Okolo, & Glew, 1994; Zahra'u et al., 2014) **Fatty acids**: Caprylic, lauric, mystiric, palmitic, palmitoleic, stearic, oleic, linoleic, linolenic, arachdic, and gadoleic acid (Chadare, Linnemann, Hounhouigan, Nout, & Van Boekel, 2008) **Phytochemicals:** Saponins, flavonoids, alkaloids, tannins, cardiac glycosides, terpenes, anthraquinones, steroids, and phenolics (Doughari, 2012)
Balanites aegyptiaca (L.) Delile	**Amino acids**: Lysine, threonine, valine, methionine, cysteine, isoleucine, leucine, thyrosine, phenylalanine, arginine, histidine, aspartic acid, histidine, glutamic acid, proline, glycine, serine, and alanine (Kubmarawa et al., 2008) **Fatty acid**: Palmitic, stearic, oleic, and linoleic acids (Chothani & Vaghasiya, 2011) **Phytochemicals:** Alkaloids, saponins, tannins, phenols, and anthraquinones (Doughari et al. 2007)
Dovyalis caffra (Hook.f. & Harv.) Sim	**Organic acids**: Maleic acid, citric acid, succinic acid, oxalic acid, lactic acid, propionic acid, formic acid, fumaric acid, acetic acid, butyric acid, and tartaric acid (Taher, Tadros, & Dawood, 2018) **Phytochemicals:** Hesperidin, rutin, rosmarinic acid, quercitrin, luteolin, catechin, gallic acid, pyrogallol, protocatechuic acid, coumarin, catechol, isoferulic acid, resveratrol, ellagic acid,3,4,5-trimethoxycinnamic acid, *p*-coumaric acid, and cinnamic acid (Mpai, Du Preez, Sultanbawa, & Sivakumar, 2018; Taher et al., 2018)
Garcinia livingstonei T. Anderson	**Fatty acids**: Palmitic acid, myristic acid, stearic acid, oleic acid, linoleic acid, palmitoleic acid, arachidic acid, heptadecanoic acid, and behenic acid (Joseph et al.,) **Antinutrient**: Tannin, oxalate, phytate, and trypsin inhibitor (Adesuyi, Elumm, Adaramola, & Nwokocha, 2012) **Phytochemicals**: Phenol, saponin, alkaloids, flavonoids, and glycosides (Adesuyi et al., 2012)
Mimusops zeyheri Sond	**Fatty acid:** Palmitic acid, oleic acid, and linoleic acid (Chivandi et al., 2011) **Amino Acids:** Arginine, serine, aspartic acid, glutamic acid, glycine, threonine, alanine, tyrosine, proline, hydroproline, methionine, valine, phenylalanine, isoleucine, leucine, histidine, and lysine (Chivandi et al., 2011)
Parinari curatellifolia Planch.ex Benth.	**Phytochemicals:** Saponins, carbohydrate, alkaloids, tannins, cardiac glycosides, flavonoids, phenol, terpenes, and steroids (Peni et al., 2010); 1-phenyl-2-butanone, benzophenone, dibenzyl ketone, and vanillin (Joulain et al., 2004)
Sclerocarya birrea (A.Rich.) Hochst. subsp. caffra (Sond.) Kokwaro	**Essential amino acids**: Histidine, isoleucine, arginine lysine, leucine, methionine, threonine, tryptophan, and valine (Hiwilepo-van Hal, Bille, Verkerk, van Boekel, & Dekker, 2014) **Nonessential amino acids:** Alanine, aspartic acid, cysteine, glutamic acid, glycine, hydroxyl-proline, proline, serine, and tyrosine (Malebana et al., 2018) **Fatty acid:** Myristic acid, lauric acid, pentadecyclic acid, margaric acid, eicosanoic acid, palmitic acid, heneicosylic acid, stearic acid, trycosylic acid, lignoceric acid, and behenic acid (Malebana et al., 2018) **Phytochemicals:** Flavonoids, alkaloids, polyphenols, catechin, gallic acid, quinones, saponins, sterols and terpenes and coumarins (Virginie, Pierre, Francois, & Franck, 2016)
Strychnos spinosa Lam.	**Phytochemicals:** Alkaloids, saponins, tannins, flavonoids, terpenoids, steroids, phenols, and glycosides (Fentahun, Makonnen, Awas, & Giday, 2017)
Uapaca kirkiana Müll. Arg.	No information found
Vangueria infausta Burch.	**Fatty acid:** Hexanoic acid, octanoic acid (Raice, Sjoholm, Wang, & Bergenståhl, 2015); Methylcylohex-1-ene (Maroyi, 2018; Mbukwa, Chacha, & Majinda, 2007) **Fatty acid ethyl and methyl esters:** Ethyl hexanoate, ethyl octanoate, methyl hexanoate, and methyl octanoate (Raice et al., 2015; Riahi-Chebbi et al., 2019) **Phytochemicals:** Apigenin-7-O-rutinoside, dihydrokaempferol, dihydroquercetin-3′-O -O-glucoside, epiafzelechin, (−)-epicatechin, genistein, luteolin, luteolin-7-O-rutinoside, luteolin-4-O-glucoside, quercetin, and quercetin-3-O-glucoside (Abeer, 2011; Mbukwa et al., 2007); Tomentosolic acid and Vanguerolic acid (Würger, McGaw, & Eloff, 2014)

e. **Value addition and market demand issue:** For most of these selected indigenous fruit trees, standardized agro-techniques for production, harvesting, storing the value-added products and improved processing are not common or still at infantry stage (Awodoyin et al., 2015). Furthermore, there is still a low market demand problem for the selected underutilized fruit trees. Lack of proper awareness and low market development for the selected fruit trees is still a problem to be solved in Africa.

f. **Inadequate knowledge on effective harvesting and storage technique as well as processing facilities:** Better understanding of specific harvesting techniques and storage methods for different fruits is needed. In addition, there is inadequate storage and processing of these fruits during the season when there is surplus, and this often leads to large scale wastage (Maruza et al., 2017).
g. **Inadequate research and innovation:** Knowledge of the potential of underutilized fruit trees remains mostly anecdotal with limited, and there is often incoherent evidence available to support the development of particular crops (Mabhaudhi, Chimonyo, Chibarabada, & Modi, 2017). This situation could be attributed to lack of clear research goals and limited funding for indigenous fruit trees.

5 | PROSPECTS OF UNLOCKING THE POTENTIALS IN THE 10 SELECTED INDIGENOUS FRUIT TREES

Approaches aimed at unlocking the potential of indigenous fruit trees are currently receiving increasing attention globally (Nkosi et al. 2020). In order to derive benefits from the 10 selected indigenous fruit, the following areas need to be actively pursued.

5.1 | Promotion of the consumption of indigenous fruits for health benefits

In the last few years, there has been much attention given to promoting sustainable agriculture and food–nutrition security (Frison, Cherfas, & Hodgkin, 2011; Heywood, 2011; Kennedy & Smith, 1995). According to Willett et al. (2019), the current average intake of healthy fruits intake is far below recommended levels while overconsumption of unhealthy foods is increasing. This is contributing to a rising prevalence of diverse health issues especially NCDs (Liu, Zhang, Wang, & Liu, 2014; Lock, Pomerleau, Causer, Altmann, & McKee, 2005). Humans need to eat more fruits, nuts, and seeds given the associated health benefits. However, this diet needs to be provided without further damaging the planet, which calls for sustainable agriculture for a sustainable food system.

5.2 | Promoting an effective value chain for the 10 selected indigenous fruit trees

Investment in the propagation and establishment of plantations for the underutilized fruit trees has been strongly recognized. The domestication of indigenous fruit trees will help in land management system that can serve as a viable option to climate change adaptation and mitigation. For a successful value chain promotion on the selected underutilized fruit trees, key variables that need to be considered include the following:

a. High quality fruits which entails the physical appearance, taste, nutritional value, storability
b. Robust production, handling, and processing (cultivation, yield, harvesting, transport, storage, and processing technologies)
c. Reliable marketing and associated economic attributes (consumer preferences and trends, distribution technologies, and trade concentration)
d. Awareness of environmental factors and conditions (adaptability to different and/or changing environmental conditions)

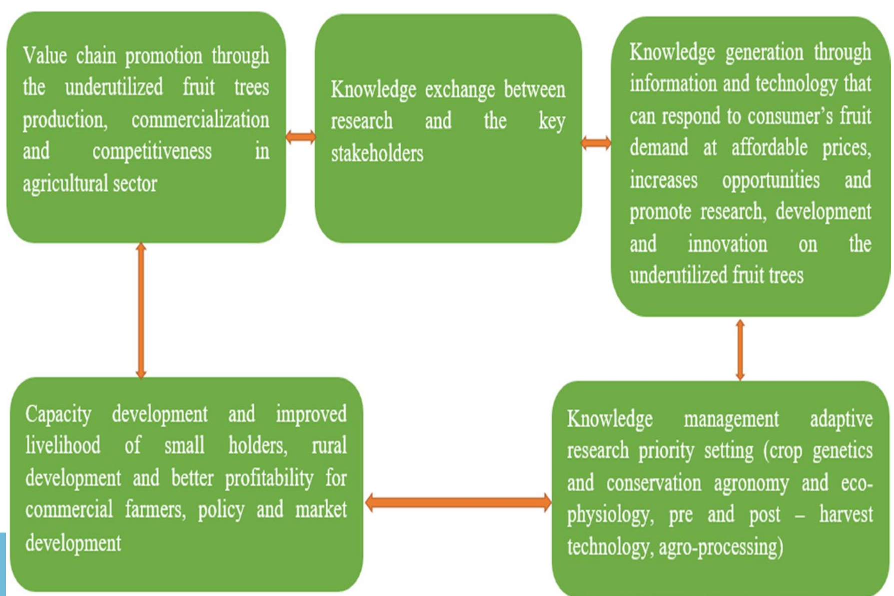

FIGURE 2 A schematic illustration for research strategy on value chain promotion for the 10 selected indigenous fruit trees

e. Increased research, innovation, and knowledge exchange among stakeholders (potential uses, production, and processing technologies) and
f. Globalization effects (trade liberalization and acceptability).

The scale and complexity of focus areas is large making it challenging to develop a well-articulated value chain strategy for the selected underutilized fruit trees. However, the main focus is to consolidate existing information and establish new priorities that cater for specific underutilized fruit trees (Figure 2). It is widely recognized that priority setting is a critical step for any efficient and coherent strategic plan (Mabhaudhi, Chimonyo, Chibarabada, et al., 2017). The value chain helps with the formulation of specific policies for the selected underutilized fruit trees, potentially strengthens investment and encourages equitable resource allocation for research development. Another key resource is the agricultural knowledge about the characteristics and cultivation methods of these indigenous fruit trees. Local farmers have the advantage of traditional expertise on how to grow these indigenous plants under field conditions with low input costs. This has the potential to translate into the low production cost for the fruits, leading to higher income and general livelihood benefits for the smallholder farmers. All this can help to broaden the rural food baskets, which currently lack dietary diversity. Lastly, the fact that the value chains for these fruits are underdeveloped creates opportunities for developing autonomous pathways out of poverty through their promotion in rural areas of Africa (Mabhaudhi, O'Reilly, Walker, & Mwale, 2016).

5.3 | Agro-processing prospect of the 10 selected indigenous fruit trees

Agro-industry transforms agricultural materials into semi-finished products in an effort to reduce spoilage or waste of produce (Shaheen, Wani, & Kubrevi, 2019). In addition, agro-processing involves a set of techno-economic activities carried out on agricultural commodities for diverse purposes (Mhazo, Mvumi, Nyakudya & Nazare, 2012). In relation to the selected indigenous fruit trees, the agro-foods processing industry could play a fundamental role in the creation of income and employment opportunities in developing countries (Giraudo, 2020; Ren, Zhang, Zhang, Mao, & Li, 2020). The agro-processing sector is a significant component in the agro-food industry and covers a broad area including postharvest activities, packaged agricultural raw materials, industrial and technology-intensive processing of intermediate goods, and the fabrication of final products (UNDP 2012). In most developed countries, 15% of their national earnings are generated from agro-based industries. Despite the low percentage that agriculture contributes to total earnings the majority of African countries, agricultural performance in the economy continues to decline when compared to the contribution of other nonagriculture sectors of the economy.

Furthermore, agro-processing industry is still struggling in the majority of countries where food insecurity remains the bane of their societies (Olaoye, 2014). Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life (Pinstrup-Andersen, 2009; Smith & Gregory, 2013). A more purposeful exploration of the agro-processing of the selected indigenous fruit trees has the potential to ensure food and nutrition security based on the following approaches:

a. Production of fortified food
b. Year-round availability of affordable, safe and nutritious food
c. Enhanced agricultural productivity and increased farm household's income
d. Job creation for rural and urban youth
e. Establishment of food standards for the indigenous fruits
f. Transformation of underutilized fruit waste into useful products.

5.4 | Efficient cultivation protocols and agronomy of the 10 selected indigenous fruit trees

Indigenous fruit propagation and establishment are important for economic development. The existing production gaps require adequate knowledge of the agronomy of fruit trees. Presently, the cultivation of indigenous fruit trees is still an unpopular investment, unlike the exotic counterparts with many plantations. The longevity required for trees to reach fruiting stage is a major bottleneck and may significantly affect the livelihood especially for small-scale farmers (Bello-Bravo, Lovett, & Pittendrigh, 2015; Leakey, 2012). Therefore, the investment in the improvement of the plants for ease of domestication remains pertinent. An effective way of up-scaling the cultivation of the selected indigenous fruit trees is to involve farmers in the entire process of participatory selection, propagation, nursery, tree establishment, and management of superior planting materials. This will shorten the time required to produce and disseminate the planting materials from centralized nurseries to the small-scale farmers. For instance, these farmers can be organized to produce high-quality seed, seedlings, and vegetative propagule as evidenced in small-scale nursery enterprise managed by farmer groups in West Africa and Southern Africa (Akinnifesi et al., 2006; Tchoundjeu et al., 2006). In addition, grafting techniques, which is central to the domestication program or management of own commercial nurseries, need to be enhanced (Degrande et al., 2013).

In the domestication of indigenous fruit trees, the extent to which the establishment of nursery by small-scale farmers can be strengthened through training to ensure their success and sustainability. This includes training small-scale farmers to collect quality germplasm from superior trees in a way that ensures genetic quality, efficient establishment and management of nurseries, tree establishment and management on-farm, harvest, and postharvest handling activities, and marketing of germplasm and tree products. On the other hand, intensive research remains to be conducted in tropical silviculture, including regeneration methods fruit tree breeding and improvement, effects of intensive culture on soils and moisture regimes, measurement of growth and yield and their response to various silvicultural treatments, the protection, and care of these potential fruit tree plantation. Hence, the selection, management, and cultivation of the indigenous fruit trees require the integration of silvicultural and horticultural approaches (Akinnifesi et al. 2007).

5.5 | Application of molecular technologies for development of the 10 selected indigenous fruit trees

The commercial potentials of these selected indigenous fruit trees can be immensely promoted if cultivars that can be adapted to commercial focused investment. In addition, the breeding of indigenous fruit trees needs significant resources for the development of entirely new cultivars that can equally conform to the modern form of transportation and storage requirements (Arias et al. 2012; Badenes, Fernandez Marti, Ríos, & Rubio-Cabetas, 2016). As a result, genomic science and molecular technology can play a role in improving nutritional quality and increase these African fruit tree production. Thus, the domestication of the fruit trees with food value can be improved if plant breeders can tap into the power of low throughput DNA markers such as polymerase chain reaction (PCR-based single sequence repeats) or high throughput markers such as single nucleotide polymorphisms (SNPs) to select desirable genotypes or counter-select undesirable ones. Study designs should use transcriptome sequencing to build a catalogue of expressed genes for important African trees, toward discovering genes involved in fruit quality, yield, pest, and drought resistance (Daru, Berger, & van Wyk, 2016). Furthermore, in cases of barriers to conventional breeding, the power of genetic modification (GM) can be harnessed through genomics.

6 | CONCLUDING REMARKS

There is a strong possibility that the key to future food–nutrition security on the continent of Africa may lie in the untapped potential of indigenous fruit trees. The nutritional composition of the 10 selected indigenous fruits revealed a potential contribution to human diet which is consistent with the important proposals made by Willett et al. (2019). An array of valuable phytochemicals are present in most of the selected fruit trees. With the world's population inadequately nourished and diet of many in the region is nutritionally inadequate, many of the environmental systems that regulate the state of the planet has pushed beyond safe boundaries by food production, the need for a global transformation of the food system remain urgent. Therefore, exploring the potentials of theseselected indigenous fruit trees remain a good starting point toward achieving the UN Sustainable Developments Goals (UN SDG, 2030). Due to their inherent traits such as disease and pest resistance as well as drought tolerance, these 10 indigenous fruit trees may have some advantages over many exotic fruit species which are heavily marketed and commercially developed. However, the major restrictions to their inclusion in the diet of many are diverse and include inadequate baseline information on several aspects of plant growth and development, fruit processing including storage challenges, low-value addition, low accessibility, and a general lack of interest from researchers. It is also evident that the domestication of indigenous fruit trees in Africa is still in its infancy. We propose that further exploring, domesticating, and commercializing these 10 selected indigenous fruits can be economically and socially significant. Such developments can help ensure a steady supply of fruit, nutrients, and associated products to consumers, traders, and processing industries that will impact the economic and health sectors in the region. There should also be a concerted effort by scholars focusing on research around the entire value chain of underutilized species to help deliver to the market for enhanced visibility, nutritional benefits, commercialization, and sustainability. The future of the 10 selected indigenous fruit trees is promising for Africa provided the co-operation among the different stakeholders is secured.

ACKNOWLEDGMENTS

AOO appreciate the Postdoctoral Fellowship from the North West University, Mmabatho, South Africa. AOA thank the National Research Foundation (NRF Research Development Grants for Y-Rated Researchers, Grant UID: 116343 and Incentive Funding for Rated Researchers, Grant UID: 109508), Pretoria, South Africa for funding. We appreciate the financial support (including the payment of Article Processing Charge) from the Food Security and

Safety Niche Area, Faculty of Natural and Agricultural Sciences, North West University, Mmabatho, South Africa. We are sincerely grateful to Ms Moloko Mojapelo (Department of Agriculture, Forestry and Fisheries, Pretoria, South Africa) for providing the photographs used in this review article. We declare that the opinions, findings, and conclusions/recommendations expressed in this work are that of the authors, and that the funder (NRF) accepts no liability whatsoever in this regard. NRF had no role in the design of the study or collection, analysis, and interpretation of data and in writing the manuscript.

CONFLICT OF INTEREST

The authors of this work declare that there is no conflict of interest.

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How to cite this article: Omotayo AO, Aremu AO. Underutilized African indigenous fruit trees and food–nutrition security: Opportunities, challenges, and prospects. *Food Energy Secur*. 2020;9:e220. https://doi.org/10.1002/fes3.220