

Review

Biochemical constituents and the role of African wild medlar (*Vangueria infausta*) in human nutrition: a review

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Abstract

This publication presents the biochemical components, the botanical characteristics, and the significance of African medlar to human nutrition and developments on the fruits' uses in biotechnology and the food industry. African wild medlar (*Vangueria infausta* subsp *infausta*) is one of the multitudes of underutilised wild edible indigenous fruit trees that grows naturally throughout Southern Africa. Available literature shows that almost every part of the tree, have known nutritional or medicinal benefits. In-depth literature search using keywords (*Vangueria infausta* subsp *infausta*, African wild medlar, biochemical constituents, underutilised crops of Africa, human nutrition and recommended daily intake) was used to source credible literature accessible from online sources such as Scopus, ResearchGate, Web of Science, Google Scholar, and Science Direct. The degree of relevance to each item linked to the review were used as an inclusion and exclusion criteria for suitable literature and for data analysis purposes. The results of the study reveal that fresh or processed African wild medlar fruit is consumable. The fruit contains significant levels of vitamins, phenols, macro and micro-nutrients, that humans require in both large and small amounts. Due to its richness in biochemical constituents such as flavonoids, phenols, proteins, vitamin C and zinc, African medlar fruit has a potential to meet the human recommended daily intake (RDI), thus can be considered a potential functional food crop. Rural communities in Southern Africa use African medlar fruit as a raw material for value-added products including jam, juice, alcohol-based products, and medication. Therefore, commercialization of this crop could play a pivotal role in accelerating the sustainable development goals SDG 1 (no poverty), subsequently addressing SDG 2 (Zero hunger). The study unearthed a need for further research, in particular empirical studies and highlights a great potential for government interest in entrepreneurial projects of commercialisation and agro-processing of African medlar fruit tree.

Keywords Macro-nutrients · Micro-nutrients · Recommended daily intake · SDG goals · Underutilised crop · Zero hunger

1 Introduction

Food and nutritional security continue to be a serious threat in most developing countries, due to factors such as accessibility and affordability [1]. The utilisation of underutilised indigenous crops to assist their mainstream counterparts is one of the best promising approaches for attaining the (Zero Hunger) target set by the sustainable development goals (SDGs), but underutilisation of these crops has also created significant obstacles for achieving those set goals across the African continent [1]. An ongoing quest for "new" crops that may be added to the food supply and/or are commercially

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viable is essential in addressing the world's food and medicinal crisis [2]. This emphasizes the necessity of introducing alternative crops that thrive in challenging environments to satisfy global demand for food and medicine [3]. African wild edible fruit crops are those that grow organically without routine access to agricultural inputs like irrigation and fertilizer [4]. Studies on climate change adaptation have recently placed a significant emphasis on the production and consumption of underutilized food crops, especially edible wild fruit species. Because of this, the sustainable development goals (SDG) have increased research interest in ending hunger under the motto (Zero hunger). African wild medlar (*Vangueria infausta*), belonging to Rubiaceae family is one commonly known species in South Africa and its neighbouring countries such as Zimbabwe, Swaziland, and Mozambique. It is one of the underutilised crops that has a potential to become a mainstream crop due to its nutritional abundance [5]. African wild medlar grow well in woodland, preferable on a stony to moderate sandy valleys [6]. The genus name *Vangueria*, according to [5], was derived from the Madagascan word for *Vangueria edulis*. The Latin word *infausta*, which means unlucky, alludes to the magical abilities it is thought to possess but is rarely used. The African wild medlar fruit tree is believed to thrive best in warm climates with temperatures between 20 and 36 °C, moderate rainfall, under loamy to sandy loam soil and the crop is draught resistance [7]. African wild medlar fruit harvesting helps rural to semi-rural communities to generate money through sales and increase household consumption of the fruit and its by-products [8]. Many communities in South Africa, particularly in the lowveld, like to harvest them when they are fully ripe [6]. When the fruit turns from green to brownish or yellowish in colour and sometimes detaches from the tree, the ripening process is complete [9]. Several authors such as [7, 10] have noted that the African wild medlar's plant parts can be used for a variety of purposes, including, (i) eating the fruit raw or dried and (ii) using the fruits as the raw material for alcoholic and juice beverages. The roots and leaves can treat several ailments, including ringworm, toothaches, malaria, pneumonia, and swelling of the limbs [11]. This review compared the biochemical components of African wild medlar fruit, its value in human nutrition towards fulfilment of daily intake (RDI) for potential commercialization of the crop. To help authors produce the article, the following research questions were developed, namely; (i) What body of knowledge is available regarding the biochemical components of African wild medlar fruit?, (ii) What are the botanical characteristics of the fruit tree called the African wild Medlar?, (iii) What are the biochemical constituents of African wild medlar and its significance to human nutrition?, and (iv) How are African medlar fruit tree is used in biotechnology and food industry?.

2 Materials and methods

Between January and March 2023, the following databases were searched: Scopus, Web of Science, Google Scholar, and Science Direct as followed by [4]. These key phrases were used: *Vangueria infausta*, African medlar fruit, underutilized African fruit crops, biochemical components, fruit value-added products and the function of fruits in human health. Authors chose works that were released between 1972 and 2023 for this review. Only 31 of the 150 articles that were found through the search engines were cited in this review. The literature was used to arrange the document's sections, sub-components, and selection was based on relation to the manuscript's title. The review was prepared strictly in compliance with UNISA, the College of Agriculture and Environmental Sciences Research and Higher Degree Committee (Ethical number/Reference #: 2022/CAES HREC/104), and other local and global relevant regulations.

3 Results and discussion

3.1 Botanical characteristics and geographical distribution of *V. infausta*

Vangueria infausta, commonly known as (African medlar, Table 1) is a plant species that is indigenous to Southern to Eastern Afro-tropics and belongs to the Rubiaceae family [12]. The plant grows in woodland regions, stony terrain, loamy to sandy valleys and occurs most frequently in exposed, open grassland [12]. It spreads from the Northern Cape to the Eastern Cape via the Free State, KwaZulu-Natal, Mpumalanga, Gauteng, and Limpopo province, South Africa [2]. Depending on the habitat, African wild medlar is deciduous shrub or small tree which can grow to a height of 3 to 7 m [13]. Sometimes, the tree has one stem or many, but commonly has more than one. The bark is smooth, ranging in colour from grey to yellowish brown, and it peels off in unreliable manner, with thin strips [12]. The short, fuzzy hairs cover the branchlets, especially when they are young [7]. Like other members of this family, the leaves are single and oriented in opposition as shown in Fig. 1. When they are young, the leaves have small, silky, and velvety hairs covering them and

Table 1 South African common names of *Vangueria infausta* subsp. *Infausta*

	Common names of <i>Vangueria infausta</i> (South Africa)	References
Afrikaans	Wilde mispel	[29]
English	Wild medlar	[6]
Northern Sotho	Mmilo	[23]
Tsonga & Shangaan	Matswila	[10]
Ndebele	Umviyo	[18]
Venda	muzwilu	[5]
Tswana	Mmilo	[15]
Swati	Amantulwane	[30]
Zulu	Umtulwa	[12]

have a pale green colour [14]. The leaves form ranges from elliptic to ovate, and its net veining is clearly visible below. The leaves become twisted and harsh to the touch as they age [15]. Around September to October in the spring, soft, velvety, acorn-shaped buds start to emerge either before or concurrently with the new leaves [16]. They later unfold into tiny, greenish-white to yellowish flowers as shown in Fig. 1 [3]. Along the brief lateral branches, they gather in groups. When young, the fruit is nearly spherical, glossy dark green, and when ripe, it turns light brown [12]. The leathery skin of the ripe fruit, which is soft and fleshy with 3–5 seeds embedded in soft pulp, surrounds the soft pulp as shown in Fig. 1 (Venter and Venter 1996). During January to April, the fruit which has a delicious sweet–sour, mealy flavour are available and their edible with an apple flavour [5].

3.2 Non-medicinal and ethnomedicinal uses of African medlar

African medlar is a wild fruit crop that naturally grow in several lowveld regions in South Africa. It can be eaten when taking a walk in the veld for a variety of purposes, including hunting, and watching the grazing of animals [5].

3.3 Uses of African medlar roots and leaves

The roots and leaves of the African medlar have medicinal properties, according [17]. Infusions of the roots and leaves have been used to cure diseases such as ringworms, toothaches, pneumonia, malaria, and other chest conditions. Infusions of the leaves have also been used as a cleansing. In addition, the affected areas of children with swelling limbs are soaked in a decoction of the pulverized leaves to cure swelling according to [16].

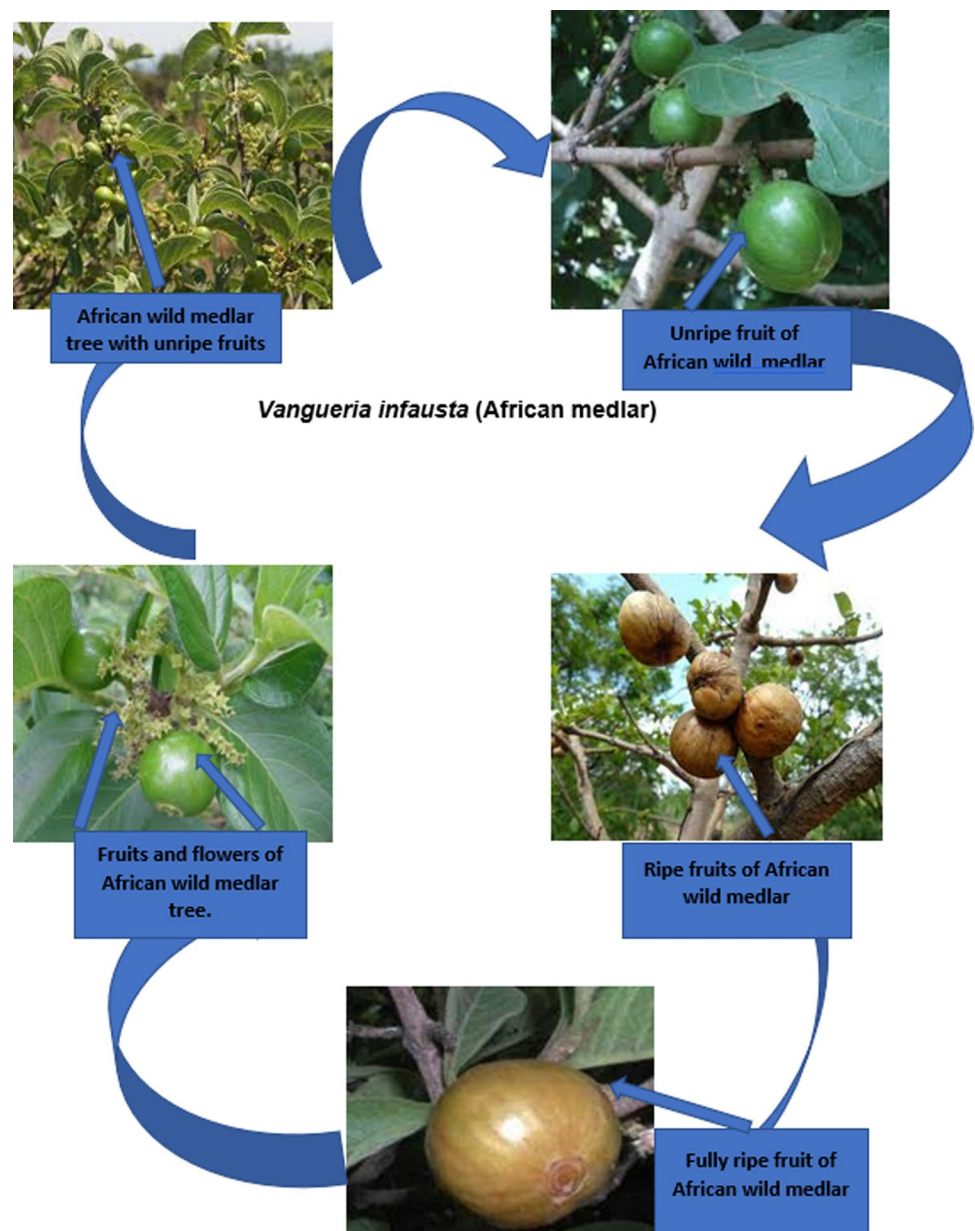
3.3.1 Uses of African medlar fruit

The African medlar fruit is primarily consumed raw, though in some regions it is dried and kept for use when they are out of season [16]. It has been reported that the fruit can be used to distil mampoer, a potent alcoholic beverage, or brandy, or that it can be fermented to make beer [16]. Furthermore, the fruit can be used to make a passable apple sauce alternative by combining it with a little water and sugar [14]. Squeezing out the fruit juice in water while removing the seed and skins create for more flavouring options, especially for porridge meals. The fruit can be used to make value-added products such as vinegar, according to [12].

3.4 Biochemical constituents of African medlar and their role in human nutrition

Due to rising unemployment rates and the global economic downturn, particularly in developing nations, the ever-increasing population and the COVID-19 pandemic have led to a rise in food goods prices, particularly fruits according to [4]. People who depend on a particular diet for their health are typically curious about the biochemical or nutritional content of the food products before consumption, while people who live in areas where there is a food shortage tend to eat for other purposes [18]. Since African medlar's prevalence is mostly in rural and semi-rural areas of South Africa, where there are frequent food scarcity issues, it is important to assess its biochemical components as a viable alternative or underutilized crop. According to [19], most indigenous fruit crops, like African medlar, bear fruit during a certain season

Fig. 1 Varying growth stages of (*Vangueria infausta*) African medlar



and are freely available to the community. These crops may play a key role by enhancing community access to food, nutrition, and medicinal ingredients [18]. Various authors such as [20], have linked chronic ailments like cardiovascular disease, high blood pressure, hypercholesterolemia, osteoporosis, several malignancies, chronic obstructive pulmonary disorders, respiratory issues, and mental health with poor fruit intake. Consequently, indigenous fruits, like the African medlar fruit, could be processed industrially, to create alternative food and medicinal products that can fight hunger, malnutrition and increase food security.

3.4.1 Crude protein and its role in human health

The human body needs protein to repair damaged cells and create new ones according to [21]. In addition, children, teenagers, and expectant women need protein for growth and development (Uusiku et al. 2010). According to [3] and [21], an average adult should consume at least 34 g of protein as recommended daily (RDI) per kilogram of body weight to prevent deficiencies such as slow healing of injuries, access fatigue, hair, and skin related problems. About (21.3 mg/100 g) of crude protein was quantified on African medlar fruit by [16]. The difference between the values quantified on the

African medlar fruit (21.3 mg) and recommended daily intake (34 mg) was (12.7 mg). Values (24 mg) reported by [7] and [16] could mean that African medlar fruit may play a pivotal role in growth, development of human being and assist women during pregnancy (Table 2).

3.4.2 Energy and its role in human health

Authors such as [20] reported that the human body uses the energy received from fruits for a variety of functions such as the basic metabolism of different organs and tissues, maintaining body temperature, and applying muscle power to maintain posture and produce motion. It also has been reported by [1] that about 20% of energy is used by brain. About (1445 kJ/100 g) were quantified from African medlar fruit by [16]. To maintain a healthy body weight, adults should consume roughly (7600 kJ) of energy each day from food. Energy values obtained from African medlar fruit could mean that the fruit has potential to prevent symptoms such as headache, weak muscles and chronic tiredness, which are symptom associated with low energy in human diet (Table 2).

3.4.3 Total flavonoids and their role in human health

Flavonoids have a variety of health advantages, such as antiviral, anticancer, antioxidant, anti-inflammatory effect, cardio-protective and neuroprotective properties [21]. The variation between Wild medlar flavonoids content (14.9 CE mg/100 g), as reported by [7] in (Table 2), when compared to recommended daily intake (225 CE mg) was (210 CE mg). Even though the flavonoids content of African medlar was lower, values reported from this study could mean that the fruit may play a potential role in curbing complications such excessive bruising, nose bleeds and haemorrhoids, which are symptoms linked to flavonoids deficiency in human diet.

3.4.4 Total phenols and their role in human health

Authors such as [20] explained the role of phenolic compounds as being antioxidants to shield the body's tissues from the harmful effects of oxidative stress. Phenols are used to treat sore throat, mouth, and canker sore discomfort as well as irritation and pain. The roots phenolic content value (368.6 GAE mg/100 g), relative to stem bark (287.2 GAE mg/100 g) and fruit (29.3 GAE mg/100 g) variation was (52.2 GAE mg/100 g) as reported by [16], while the recommended daily intake is at 500 GAE mg/100 g. Even though values obtained from African medlar fruit plant material is lower compared to the recommended daily intake, the study findings demonstrated that the African medlar plant material could be maximally utilised as raw material for varying value-added products such as juice, jam, and medicinal products (Table 2). Such products could be used to prevent various diseases related to body tissues, skin irritation, eyes, nose, throat, and nervous system, which are associated with low phenolic content in human diet [20].

3.5 Role of macro-nutrients in human health

The nutritional components of food that the body needs for energy to sustain the body's structure and systems include macronutrients like vitamins, calcium, magnesium, potassium, and phosphorus [21]. When choosing what to eat, consumers are helped by the quantified values of these nutrients in food products to make the best decision for their dietary

Table 2 Biochemical constituents of African medlar

Biochemical compound (Fruit)	Values	Functions	RDI	References
Crude protein	21.30 (mg/100 g DW)	Breakdown food, grow and repair body tissue	15 mg	[7]
Energy	1445 (KJ/100 g)	Important for human metabolism (growth, pregnancy, and lactation)	2000 kJ	[2]
Total flavonoids	14.88 (CE 100/g DW)	Anticancer, antioxidant and anti-inflammatory	225 mg	[2]
Total phenols	29.35 (GAE 100/g DW)	Promote anti-inflammation capacity	1000 mg	[7]
Vitamin C	67.7 (mg/100 g DW)	Healing wounds and skin protection	90 mg	[7]

needs. People who often rely on a certain diet for their nutritional needs and health benefits are therefore usually cautious when making decisions regarding food goods [21].

3.5.1 Vitamin C and its role in human health

According to [9], the body needs vitamin C to create blood vessels, cartilage, muscle, and collagen in bones. The body’s ability to repair depends on vitamin C as well. Additionally, it aids in cell protection and health maintenance [2]. The variation of African medlar fruit vitamin C content of value of (67.7 mg/100 g) and recommended daily intake (90 mg/100 g), as shown in Table 2, was (22.3 mg/100 g). This could mean that consumption of African medlar fruit could play a pivotal role in addressing diseases such as poor wound healing, bleeding gums and poor hair growth, which are deficiencies symptoms linked with low vitamin C in human diet [7].

3.5.2 Calcium and its role in human health

Calcium is a mineral that is most frequently linked to strong bones and teeth, but it also plays a critical role in blood circulation, assisting with muscular contraction, regulating regular heartbeats and nerve activity [20]. The calcium differences between African medlar fruit (124 mg/100 g) in relation to the recommended daily intake (1000 mg/100 g), was (879 mg/100 g) as shown in Table 3. Even though, calcium content of African medlar fruit obtained from a study conducted by [16] was lower, compared to the recommended daily intake, values show that the consumption of this fruit has a potential to address human health issues such as low blood calcium levels is possible [22]. Long-term low calcium levels, which can cause dry, brittle nails, and muscle cramps which are associated with calcium deficiencies in human diet could also be prevented through consumption of the fruit.

3.5.3 Magnesium and its role in human health

Authors such as [21] highlighted that role of magnesium as one of elements which is necessary for a variety of bodily functions, including the control of blood pressure, blood sugar levels, muscle, and neuron function as well as the synthesis of DNA, and protein. The magnesium differences between African medlar fruit (99 mg/100 g) in relation to the recommended daily intake (365 mg/100 g), was (266 mg) according to the analysis undertaken by [7] as shown in Table 3. Even though, magnesium content of African medlar fruit obtained from a study conducted by [7] was lower, compared to the recommended daily intake, values show that the fruit has a potential to address human health issues such as high blood pressure and heart disease, which are deficiency symptom diseases linked to shortage of magnesium in human diet [20].

3.5.4 Potassium and its role in human health

Many plant-based meals naturally contain potassium, and it can also be taken as a supplement [20]. Its primary function in the body is to support the maintenance of regular fluid levels inside of cells. It also aids in muscular contraction and nerve function [22]. According to [21], potassium also aids in maintaining a regular heartbeat. Potassium-rich foods assist to counteract some of the negative effects sodium has on blood pressure. The potassium content variation between African medlar fruit (1,683 mg/100 g) and recommended daily intake (2000 mg/100 g) was (317 mg) as shown in Table 3. The potassium concentration of African medlar fruit reported by [7] is a suggestive proof that the fruit has potential mineral

Table 3 Mineral composition of African medlar (mg/100 g DW)

Mineral composition (mg/100 g DW)		RDI (mg/g)	References
Calcium	124	1000	[7]
Copper	10.1	10	[7]
Iron	0.09	13	[7]
Magnesium	99	365	[7]
Potassium	1683	2000	[7]
Phosphorus	128	4000	[7]
Sodium	13.7	2300	[7]
Zinc	0.016	11	[7]

strength, and thus when consumed, could play a key part in preventing several disorders like weak muscles, paralysis, camping, irregular heart problems, which are associated to potassium deficiency in human diet.

3.5.5 Phosphorus and its role in human health

Phosphorus is one of the most prevalent minerals in human body, which makes up about 85% of human bones and teeth [21]. Phosphorus and calcium work together to develop and maintain the health of bones and teeth, which is one of their major responsibilities. Authors such as [21] reported all human tissues and cells require phosphorus for their growth and repair, as well as for the synthesis of DNA and RNA, the genetic building blocks [3]. The variation between African medlar fruit phosphorus content (128 mg/100 g) and recommended daily intake (4000 mg/100 g) was (3872 mg) as shown in Table 3. Even though, phosphorus content of African medlar fruit obtained from a study conducted by [7] was lower, compared to the recommended daily intake, values show that the fruit has a potential to play a pivotal role in curbing diseases such as muscle weakness, which is associated to potassium deficiencies in human diet.

3.6 Role of micro-nutrients in human health

3.6.1 Role of iron in human health

Approximately 70% of the iron in the body is found in the red blood cells called haemoglobin and the muscle cells called myoglobin, both of which are necessary for the creation of blood [21]. For the blood to carry oxygen from the lungs to the tissues, haemoglobin is necessary (Uusiku et al. 2010). The iron content of African medlar fruit (10 mg/100 g) determined by [7] was equivalent to the amount recommended for the daily intake by human (10 mg/100 g) as shown in Table 3. This could mean that consumption of African medlar fruit will result in 100% supply of iron required by human daily. This may imply that eating African medlar fruit will provide a person with the entire recommended daily allowance of iron. Additionally, diseases like anaemia that prevent the body from producing enough red blood cells, which are essential for delivering oxygen, could be avoided through the consumption of African medlar fruit.

3.6.2 Role of zinc in human health

The body only needs low amounts of zinc; hence it is called micro mineral [21]. Zinc benefits the human immune system and metabolism; hence it must be provided daily to all body cells [21]. Additionally, it plays a crucial role in tissue repair, immune system upkeep, cell proliferation, DNA synthesis, and protein synthesis [4]. In addition, zinc is important for wound healing and the ability to taste and smell. African medlar fruit has a very low zinc content (0.016 mg/100 g), according to analysis done by [7], when compared to recommended daily intake (11 mg/100 g), the difference was (10.9 mg) in Table 3. Even though, zinc content of African medlar fruit obtained from a study conducted by [21] was lower, compared to the recommended daily intake, the fruit could play a vital role in curbing diseases such as loss of taste, smell, and poor wound healing, which are associated with zinc deficiency in human diet.

3.7 Other uses and potential value-added products of African medlar

Although the fruit is often consumed raw, some regions store it as dried fruit for use during times of food crisis. It is rumoured that it can be used to distil mampoyer, a potent alcoholic beverage, or brandy, or that it can be fermented to make beer [6] and [8] as shown in Table 4. It can be used to make a passable apple sauce alternative by combining it with a little water and sugar. Squeezing out the fruit juice in water while removing the seed and skins allows for more flavouring options. This is

Table 4 Different uses of African medlar plant materials

Different uses of African wild medlar		
Plant part	Uses	References
Roots	Medicine (Malaria, chest pains and ringworm)	[6]
Stem bark	Medicine (sexually transmitted diseases and toothache)	[16]
Fruits	Food (edible fruit, dried fruit, alcohol beverage and juice)	[17]

frequently done to flavour oatmeal. The fruit can be used to make vinegar, according to [16]. This herb also has therapeutic benefits as shown in Table 4.

3.7.1 Alcohol

According to [18], alcohol may play a pivotal role in deducing human chance of passing away from heart disease, which is just one of the health advantages of moderate alcohol intake as shown in Table 3. Authors such as [18] is of a view that low intake of alcoholic beverage could lower the risk of having an ischemic stroke (which occur when the arteries to the brain become narrowed or blocked, causing severely reduced blood flow) possibly decreasing human risk of developing diabetes. The type of alcohol found in the alcoholic beverages that is consumed by people is a substance known as ethanol [23]. Fermentation is a procedure that is normally applied through systemic storage of fruits, and grains to produce alcohol, especially when yeast or bacteria react with the sugars in food, the by-products is called ethanol [23]. There is numerous literature such as [23], that reported alcohol as one of the by-products of African medlar fruit. This could mean that the fruit has a potential to be used as a raw material in the manufacturing of alcohol beverages, which might play a pivotal role in economic emancipation of communities where this fruit is prevalent.

3.7.2 Fruit

Most of the minerals that humans need in either significant or tiny amounts daily are found in fruits [8]. Fruits include a variety of biological components that humans can consume, including water, carbohydrates, lipids, proteins, certain minerals, vitamins, and antioxidants. Most fruits can be consumed raw and are widely available throughout the year [18]. For the reasons listed above, fruits are unique in their contributions to human health and are therefore regarded as the most significant food in terms of food science and technology [9]. The African medlar fruit contains a variety of biochemical components, including vitamins, crude proteins, micro and nanoelements, potassium, phosphorus, iron, and zinc, which suggests that the crop may play a significant role in the food industry and help prevent most diseases associated with a lack of fruit consumption according to authors such as [7], shown in Table 3.

3.7.3 Juice

Juice drinks are goods that don't contain 100 percent pure fruit juice [22]. How much fruit juice each beverage contains is listed in the ingredient's information, which is frequently on the back of the packaging [24]. There are numerous products with different levels of fruit juice. These beverages could be those that are purchased in a ready-to-drink format or as cordials, also referred to as dilutable beverages [24]. The standard ratio for beverages depends on their sugar content and must be done so before consumption. The African medlar fruit has the potential to be used as a raw material for juice, which has economic and nutritional advantages for society, as is evident from findings reported from numerous literatures such as [22].

3.7.4 Medicine

Plant-based compounds are regarded as a key source of modern medications and play a crucial biological function in the fight against several pathogenic organisms [15, 25]. Because they strongly believe in using only natural remedies and have limited access to allopathic drugs, rural residents of developing nations rely heavily on the traditional herbal medical system [26]. About 80% of people in underdeveloped countries, according to the World Health Organization (WHO), use conventional herbal remedies [27]. Due to a lack of contemporary medical facilities, the efficacy of traditional medicines, as well as cultural goals and preferences serve as a low-cost alternative for basic healthcare in most underdeveloped nations. The use of African medlar fruit as medicine in numerous studies, including [28], [29,30], suggests that this plant has the potential to be used as a raw material for the production of a variety of bio-medical products that can enhance societal health, particularly in places where access to medicine is limited or non-existent (Table 4).

4 Conclusion

The African wild medlar fruit, which is underutilised is abundant in several biochemical components, including calcium, flavonoids, magnesium, potassium, and phenols, which are crucial for preventing most diseases and enhancing human health and nutrition. The fruit processing business still has a lot of room to grow and use the bioactive components of the African medlar fruit. Consuming African medlar fruit, which is rich in several biochemical substances, is linked to both the prevention and treatment of several diseases, including heart disease, wound healing, gum bleeding, and wound healing. The health benefits of African medlar fruit have not been established, little is known about the growth, yield, biochemical and metabolite profile of this fruit tree when grown under various agronomic conditions, such as varying irrigation levels, fertilizer types, and soil types. Therefore, more research in this area is still necessary. Furthermore, it is important to extract the biochemical constituents of the African medlar fruit and utilise them as potential functional ingredients in a variety of culinary items. By promoting the commercialisation of items from African medlar crop, this will benefit both human health and the struggling rural economy, where food scarcity is still a challenge through economic emancipation.

Author contributions Dr. M.K.M was involved in article review, analysis and manuscript write-up. Ms. T. R. was involved in article review and write-up. Prof. M.M was involved in article review and write-up.

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Data availability Data generated for this study is available from the corresponding author on formal request.

Declarations

Competing interests Authors declare no competing interests.

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