Indigenous knowledge on the uses and morphological variation among *Strychnos gerrardii* N.E.Br. morphotypes at Emkhandlwini area, KwaZulu-Natal, South Africa

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Abstract

Background: Strychnos gerrardii N.E.Br., a member of the Loganiaceae family, is primarily known in rural communities for its edible fruits. However, indigenous knowledge on the uses and morphological diversity of native fruit trees such as S. gerrardii has not received much research. This study aimed to document the existing ethnobotanical knowledge on local uses and morphological diversity of S. gerrardii morphotypes growing in the Emkhandlwini area.

Methods: The existing indigenous knowledge were collected from 100 randomly selected participants using a structured questionnaire. Simple random sampling method was used for selection of participants.

Results: Different food uses of *S. gerrardii* include direct fruit consumption as well as fruit processing into fermented beverages and food products called **umbhantshi, ujwembe, amahewu, umnkwankwa** in isiZulu local language, and alcohol. Therapeutic reports of *S. gerrardii* include its use to treat stomach disorders, influenza virus, high blood pressure, diabetes, and respiratory problems, as well as increasing milk production in females and cleansing of the body system. Other uses of *S. gerrardii* include its importance as a homestead defence against thunderstorms and lightning, treatment for livestock diseases, ornament making, and controlling traditional spiritual problems. *S. gerrardii* varied morphologically according to its leaf, fruit, and organoleptic traits. Leaf colours varied from light green, green, dark green, and grey. Most leaves were roundish followed by elongated, round and heart-shaped, and elongated and heart-shaped leaves. Fruit shapes ranged from roundish, wedged, and pear-shaped, with the wedge-shaped fruits being reported sweeter than others.

Conclusion: Indigenous knowledge will benefit future breeding initiatives and the selection of desired traits for domesticating the species as a food crop.

Keywords: edible fruits, ethnomedicine, ethnofood, indigenous knowledge, morphological variation, organoleptic properties, *Strychnos gerrardii*.

Background

Strychnos gerrardii N.E.Br., commonly called coastal monkey orange (Van Rayne *et al.* 2021), belongs to the Loganiaceae family of section Densiflorae (Zharare *et al.* 2022). *Strychnos gerrardii* is a shrub with narrow and smooth elliptic leaves (Adebowale *et al.* 2014; 2016). It is one of the *Strychnos* plant species that produces medium-sized fruits (Van Rayne *et al.* 2021). The genus name "*Strychnos*" comes from the Greek word "Strukhnos" which describes the presence of properties in the poisonous nightshade (Asuzu 2020). Hence, the seeds of the *Strychnos* fruits are toxic due to the presence of strychnine (Zharare *et al.* 2022).

Indigenous knowledge is any knowledge or understanding derived from a local culture (Sillitoe 2006). People from distinct communities have their unique cultural traditions and experiences, which have a significant impact on how people perceive their environment, deal with health-related issues, and behave in social situations (Sillitoe 2006). Local people have a deep understanding of morphological traits that make variations within and across indigenous plants (Mbhele et al., 2022). Morphological markers play a critical role is studying morphological diversity using phenotypic traits such as seed size, flower colour, and fruit traits such as colour, shape, and texture (Chesnokova *et al.* 2020).

African developing countries face food insecurity due to different contributing factors such as climate change, poverty, and biodiversity loss (Kunene *et al.* 2020). Indigenous fruit plants are the main contributors to in-situ conservation because of their ability to withstand different environmental conditions (Kunene *et al.* 2020). Indigenous plants have been the source of food and medicine for ages (Rana *et al.* 2015). The majority of South African rural populations, especially women and children, rely on indigenous fruits such as monkey orange fruits because of their delicious flavour (Ngadze *et al.* 2017b).

Native fruits are collected during different seasons and are highly recommended as a nutrient supplement for local communities (Ngadze 2018). These fruits have health benefits, as they offer high levels of energy, fiber, zinc, iron, and vitamin C (Ngadze *et al.* 2017b; Ngadze 2018). In Zimbabwe, it is believed that about 30% of pregnant and lactating women lack iron in their bodies, and maternal anaemia is a leading contributor to high mortality of mothers and newborn babies (Ngadze *et al.* 2017b). The majority of African people use indigenous plants for different purposes, such as consumption and therapeutic purposes, without replacing the cut trees, hence leading to poor conservation of the species and decreased fruit production in the following years (Kunene *et al.* 2020). Despite their significance for consumption and therapeutic uses, native trees have not received much research and development attention toward becoming fruit crops for broader cultivation (Kunene *et al.* 2020). Therefore, the objective of this study was to document the existing ethnobotanical knowledge on traditional uses and morphological variation of *Strychnos gerrardii* morphotypes at Emkhandlwini area, KwaZulu-Natal, South Africa. This knowledge will benefit future breeding initiatives and the selection of desired traits for domesticating the species as a food crop. The study hypothesised that the Emkhandlwini community have intense knowledge about indigenous uses and morphological variation of *Strychnos gerrardii.*

Materials and Methods

Study area

The study on Indigenous knowledge of the uses and morphological variation among *Strychnos gerrardii* morphotypes was conducted at Emkhandlwini area with a geographical location of 28°28'41.2"S; 31°42'19.1"E in the northern KwaZulu-Natal, South Africa (Fig. 1). It is located under King Cetshwayo district municipality, at Mthonjaneni local municipality, under the tribal leadership of Inkosi (Chief) Biyela. This area has a Savanna biome with sandy and rocky soils that favour the growth of S. gerrardii trees. Emkhandlwini area has a subtropical climate and records an average monthly rainfall of 20 and 144 mm in winter and summer, respectively. The warmest months in this area are January to March, with an average daily temperature of 22-23˚C, and the coldest months are typically June to August, with a daily average temperature ranging from 16-17˚C. The letter requesting permission to use the area as the study site was submitted to Biyela tribal court in June 2023 and the approval was granted back by the relevant tribal leaders.

Indigenous Knowledge Survey Data collection

A survey on Indigenous knowledge and morphological variation among *S. gerrardii* morphotypes was conducted by randomly choosing local participants from 100 homesteads. Simple random sampling was used in the current study. Simple random sampling method refers to a technique where everyone in a population has an equal opportunity on being chosen for the sample (Makwana *et al.* 2023). The study's objectives were explained to all interviewees well using the mother tongue (isiZulu). Each participant per homestead was requested to sign a consent form before the interview to indicate their willingness to partake in the survey. The participants were interviewed using questionnaires. Interviews and discussions were conducted using the mother tongue language (isiZulu) to facilitate simple communication with the local participants. Questionnaires were categorized into different sections. The first category was socio-demographic information, which included the gender and age of the interviewee. Gender included males and females, and age was divided into three classes, categorized as young (18-34 years), adults (35-54 years), and seniors (55 and above years). Morphological variation and importance of the isiZulu name **umkhuhlu** for *S. gerrardii* was discussed. Information on morphological variation included leaf traits (size, colour, and shape), fruit traits (fruit size, pericarp colour and texture, pulp colour and texture), and variation

in fruit taste. Colour traits were visually determined using the natural colour system® (NCS; http://www.ncscolour.com/en/natural-colour-system/). The final information on indigenous uses of *S. gerrardii* included details about different food and medicinal uses, plant part(s) used, and mode(s) of preparation and/or application.

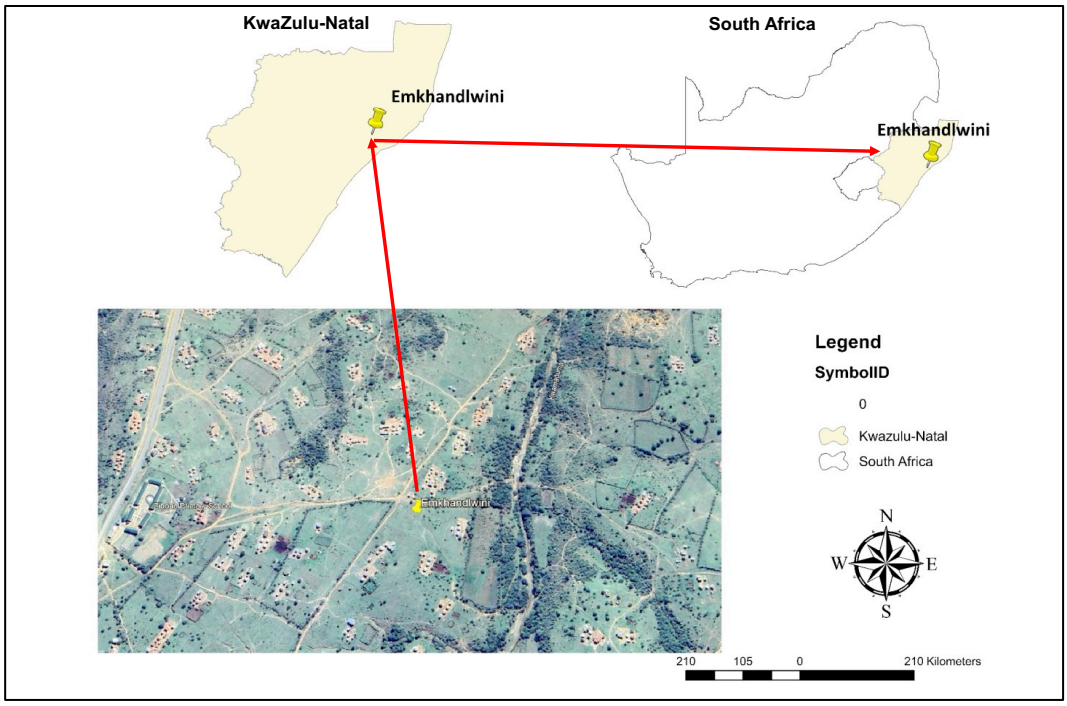

Figure 1. Study area map of Emkhandlwini in northern KwaZulu-Natal, South Africa (Source: adapted from Google Earth Pro, Google Earth).

Data analysis

Among 100 participants in the study who were knowledgeable about different uses, morphological, and organoleptic variation among *S. gerrardii,* the frequency was calculated using a mathematical formula developed by Mashile *et al.* (2019).

Frequency Index (FI) = $\frac{FC}{N} \times 100$

Where FI represents the frequency index, which expresses the percentage of frequency of use and morphological variation of *S. gerrardii* by the participant, FC represents the number of participants that mentioned a use or morphological variation of *S. gerrardii*, and N represents the total number of participants. The percentage of each gender within a particular use and morphological trait was calculated by using the number of participants within the number of a particular gender divided by the total number of participants per category.

Results

The significance of "umkhuhlu", the isiZulu name of *Strychnos gerrardii*

Many local people in the Emkhandlwini area did not understand the meaning of **umkhuhlu**. However, some people reported that **umkhuhlu** literally means "**khuhla**", which refers to removing any dirtiness from the body or cleaning the body. The minority of males (2%) mentioned the significance of the name as associated with cleansing the body through either colon hydrotherapy, **"ukuchatha"**, purging **"ukuphalaza"**, and other means. It was also mentioned that *S. gerrardii, "***umkhuhlu***"* plant parts are used for medicinal purposes.

Socio-demographic information of the participants

Among 100 people in the Emkhandlwini area, KwaZulu-Natal, who participated in an Ethnobotanical survey on local uses and morphological variation of *Strychnos gerrardii*, 59 and 41% were males and females, respectively (Fig. 2). More males than females were interviewed for both young and adult age categories. Still, the case was the opposite for the seniors/elderly

group. The younger age (18 to 34) group had the greatest number of participants, followed by the middle-aged and, lastly, the elders.

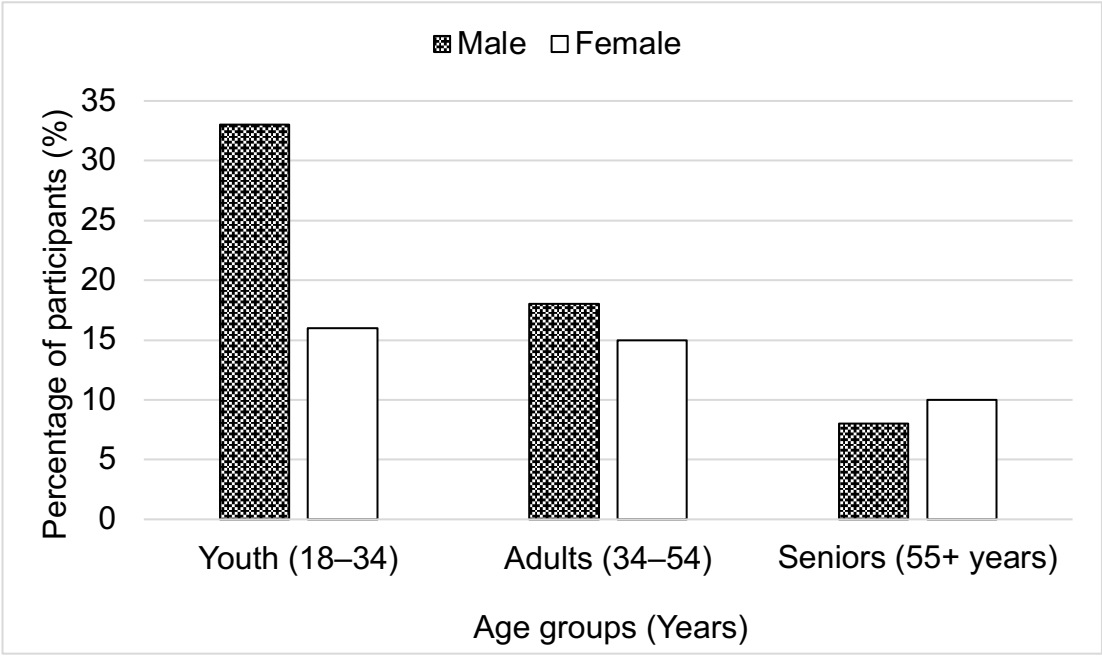

Figure 2. Socio-demographic information (gender and age) of local participants at Emkhandlwini area (*n* = 100).

Food uses of *Strychnos gerrardii*

Fruit

In Emkhandlwini area, the ripe fruit is consumed directly after being cracked. Participants collect ripe fruits from the tree or when they have fallen on the ground (Table 1). The change in fruit colour and smell are the main indicators of fruit ripening. Due to the hard *S. gerrardii* pericarp*,* respondents crack fruits by striking them against hard rocks. The tightly packed seeds have their fleshy and edible seed coats sucked until the sweetness is finished, and thereafter the seeds are discarded. The cattle herders, hunters, and wood gatherers mentioned that the fruits are more enjoyable when they are resting under tree shades on sunny days. Furthermore, it was mentioned that direct fruit consumption gives more energy. According to participants, *S. gerrardii* trees are found around their homes, but the majority of them grow in the bush. All the participants were informative about the direct consumption of *S. gerrardii* fruits. Among the knowledgeable respondents, 59% were males, whereas 41% were females. The males were more informative than females across all ages except the elderly group where women had more knowledge than men.

Fermented maize meal (umbhantshi)

In the Emkhandlwini area, **umbhantshi**, also known as *S. gerrardii* fermented maize meal, refers to a mixture of a cooked maize meal (**uphuthu**) and fleshy pulp of *S. gerrardii* (Table 1). The preparation of **umbhantshi** involves direct removal of pulp and mixing it with a cooked maize meal (**uphuthu**). The fleshy seed coat is removed for the fruits with minimal pulp, and the resulting juice is mixed with cooked maize meal. Depending on the texture of a pulp, the water is also added to achieve the desired consistency. This combination is allowed to ferment for approximately 24 hours and served thereafter. Respondents mentioned that the sugar is added if the mixture turns out to be more bitter than expected. Only a few respondents (10%) were knowledgeable about fermented maize meals in the Emkhandlwini area. Males (50%) and females (50%) had equal knowledge on fermented maize meal. Younger males (60%) and older women (60%) were more knowledgeable than the opposite genders of their age groups.

Table 1. Ethnobotanical uses of *Strychnos gerrardii* at Emkhandlwini area, KwaZulu-Natal, South Africa.

Category	Use	Resp	Gender	Age (years)		
			F [N (%)]	18-34 N(TFI; SFI)	35-54 N(TFI; SFI)	≥55 N(TFI; SFI)
Food	Fruit	100	M [59 (59)]	33 (33; 56)	18 (18;31)	8 (8; 14)
			F [41 (41)]	16 (16; 39)	15 (15; 37)	10 (10; 24)
	Umbhantshi	10	M [5 (50)]	3 (30; 60)	1 (10; 20)	1 (10; 20)
			F [5 (50)]	1 (10; 20)	3 (30; 60)	1 (10; 20)
	Ujwembe	23	M [12 (52)]	6 (26; 50)	5 (22; 42)	1 (4; 8)
			F [11 (48)]	3 (13; 27)	6 (26; 55)	2 (9; 18)
	Amahewu	2	M [1 (50]	0 (0; 0)	0 (0; 0)	1 (50; 100)
			F [1 (50)]	1 (50; 100)	0 (0; 0)	0 (0; 0)
	Umnkwankwa	4	M [3 (75)]	0 (0; 0)	3 (75; 100)	0 (0; 0)
			F [1 (25)]	0 (0; 0)	0 (0; 0)	1 (25; 100)
	Alcohol	1	M [1 (100)]	0 (0; 0)	1 (100; 100)	0 (0; 0)
			F [0 (0)]	0 (0; 0)	0 (0; 0)	0 (0; 0)
Medicinal	Cleansing of body system	18	M [15 (83)]	6 (33; 40)	7 (39; 47)	2 (11; 13)
			F [3 (17)]	0 (0; 0)	2 (11; 67)	1 (6; 33)
	Stomach problems	19	M [8 (42)]	2 (11; 25)	6 (32; 75)	0 (0; 0)
			F [11 (58)]	9 (47; 82)	0 (0; 0)	2 (11; 18)
	Influenza virus (Flue)	7	M [4 (57)]	1 (14; 25)	3 (43; 75)	0 (0; 0)
			F [3 (43)]	1 (14; 33)	2 (29; 67)	0 (0; 0)
	High blood pressure and diabetes	3	M [3 (100)]	0 (0; 0)	1 (33; 33)	2 (67; 67)
			F [0 (0)]	0 (0; 0)	0 (0; 0)	0 (0; 0)
	Respiratory problems	1	M [1 (100)]	0 (0; 0)	1 (100;100)	0 (0; 0)
			F [0 (0)]	0 (0; 0)	0 (0; 0)	0 (0; 0)
	Milk production	1	M [0 (0)]	0 (0; 0)	0 (0; 0)	0 (0; 0)
			F [1 (100)]	0 (0; 0)	1 (100;100)	0 (0; 0)
Other	Homestead defense	3	M [2 (67)]	2 (67; 100)	0 (0; 0)	0 (0; 0)
			F [1 (33)]	1 (33; 100)	0 (0; 0)	0 (0; 0)
	Homestead building	5	M [4 (80)]	3 (60; 75)	1 (20; 25)	0 (0; 0)
			F [1 (20)]	0 (0; 0)	1 (20; 100)	0 (0; 0)
	Traditional spiritual problems	1	M [0 (0)]	0 (0; 0)	0 (0; 0)	0 (0; 0)
			F [1 (100)]	0 (0; 0)	0 (0; 0)	1 (100;100)
	Ornaments	3	M [2 (67)]	0 (0; 0)	2 (67; 100)	0 (0; 0)
			F [1 (33)]	0 (0; 0)	1 (33; 100)	0 (0; 0)
	Livestock	11	M [7 (64)]	4 (36; 57)	3 (27; 43)	0 (0; 0)
			F [4 (36)]	1 (9; 25)	4 (36; 100)	0 (0; 0)

Legend:

Resp = Respondents, F = Female, M = Male, N = Number, FI = Frequency Index expressed as percentage (%), TFI = Total Frequency Index, SFI = Specific Frequency Index

Juice (ujwembe)

Respondents described *S. gerrardii* fruit juice (locally known as **ujwembe** in isiZulu) as a mixture of water and pulp and/or fleshy seed coats. This juice can be prepared at home or in the bush during wood gathering and cattle herding. When **ujwembe** is prepared at home, the hard pericarp of *S. gerrardii* fruit is cracked; seeds and pulp are removed from the fruit and mixed with water through vigorous starring. Thereafter, the cloth or a sack is used to separate the drinkable mixture from the seeds. The mixture is then exposed to the sun for 30 minutes to an hour to release the toxic acid. The sugar is also added for taste. During wood gathering and cattle herding, respondents used the bowl-shaped rocks in the river as a container for mixing water and pulp. These bowl-shaped rocks made removing the flesh surrounding the seeds easy. Twenty-three (23%) participants were informative about **ujwembe**. Among them, the males (52%) were knowledgeable than females (48%). The younger males (50%) are overnumbered by younger females (27%) in terms of how the juice is prepared. However, the opposite was obtained in the other age groups where women had more knowledge than men.

Fermented porridge (amahewu)

Preparation of *S. gerrardii* fermented porridge (**amahewu**) at the eMkhandlwini area starts by straining juice from the pulp and/or fleshy seed coats of *S. gerrardii* fruit (**ikhuhlu**) and mixing it with the freshly prepared warm porridge. The mixture is cooled down and allowed to ferment for approximately 24 hours before drinking. Only a minority (2%) was aware of this fermented porridge combination, which was younger females (100%) and elderly men (100%).

Sundried and ground fruits (umnkwankwa)

In the Emkhandlwini area, **umnkwankwa** is a local name used to describe the powder of the ground seeds and pulp of S. Gerrard. The fruits of *S. gerrardii* are cracked and the seeds plus pulp are removed from the fruit. The seeds and pulp are exposed to the sun to dry and ground into powder using different tools. The resulting mixture can be eaten directly or mixed with other food such as porridge. According to participants, this mixture is mostly useful by people with diabetes and high blood pressure. In the Emkhandlwini area, **umnkwankwa** is believed to lower blood pressure and diabetes levels due to its bitterness. Only four (4%) participants were aware of **umnkwankwa**. Men (75%) were more familiar with **umnkwankwa** than women (25%). Ground fruits were more popular in older males (100%) and elderly women (100%) compared to than other age groups.

Strychnos gerrardii alcohol (ugologo wamakhuhlu)

Strychnos gerrardii alcohol, also known as **ugologo wamakhuhlu** in the Emkhandlwini area, refers to a mixture of fruit, water, and brown sugar. In preparation of *S. gerrardii* alcohol, two (2) liters of water and brown sugar are mixed with the fruit content and buried on the ground with the yeast for approximately six months. Only one (1%) respondent, an older man (100%), was knowledgeable about *S. gerrardii* alcohol.

Medicinal uses of *Strychnos gerrardii*

Cleansing of body system

Respondents defined the cleaning of the body system as the removal of toxic or unwanted substances from the body using natural or artificial methods. Different methods of cleaning the body systems that are systems used at the Emkhandlwini area include colon hydrotherapy (**ukuchatha**) and purging (**ukuphalaza**). The variety of *S. gerrardii* plant parts are used to clean body system, namely, bark (9%), roots (4%), leaves (4%), and fruits (1%). The roots, bark, and leaves can be boiled with water and the resulting mixture can be used as an emetic, for colon hydrotherapy, and purging, respectively. The half-ripe *S. gerrardii* fruit is licked for cleaning the body system. Eighteen (18%) participants mentioned this medicinal use of *S. gerrardii*. This information was more popular amongst men (83%) than among females (17%).

Stomach problems

According to the respondents, stomach issues refer to discomfort in the belly or abdomen. Stomach problems can be treated using *S. gerrardii* leaves (13%), bark (4%), and roots (2%). The leaves are boiled with water, and the resulting liquid can be sipped. Tiny pieces of *S. gerrardii* bark are cooked in water and used as an emetic. Similar to the preparation of leaves decoction, the roots are boiled with water and taken orally by a person suffering from stomach problems. About 19% of respondents shared information about this remedy; among them, females (58%) were more informative than males (42%).

Influenza virus/ flue (umkhuhlane)

At Emkhandlwini area, bark (4%), leaves (2%), and roots (1%) are used to treat **umkhuhlane**. The bark and leaves can be boiled with water to treat flue. The small portions of roots are mixed with water for purging. Only 7% of local people were aware of this remedy. Males (57%) were more knowledgeable than women (43%). Knowledge of the preparation of this decoction was popular amongst older males (75%) and older females (67%).

High blood pressure and diabetes

Respondents defined high blood pressure, also known as hypertension, as the blood pressure that is higher than normal. Fruits (2%) and roots (1%) were amongst the *S. gerrardii* plant parts that help lower high blood pressure and diabetes. At Emkhandlwini area, a person with hypertension is required to lick a half-ripe bitter fruit to reduce his/her blood pressure. The roots are also boiled with water, and a person suffering from high blood pressure is required to must drink the resulting mixture. At Emkhandlwini area, these plant parts are recommended for lowering blood pressure due to their bitterness. As per the responses from Emkhandlwini residents, a similar way used to lower high blood pressure is also used to manage sugar levels. About three (3%) participants were aware of these ethnobotanical uses, where 100% of the information was obtained from males and zero women contributed. Among the knowledgeable males, elderly men (67%) contributed more information than middle-aged men (33%)

Respiratory problems (isifo sofuba)

According to Emkhandlwini residents, respiratory problems are associated with difficulties in gaseous exchange in humans. Emkhandlwini local people use the roots to treat respiratory problems. The roots are cooked with water and the resulting drinkable mixture is taken by the person with respiratory problems. Only one (1%) participant knew about this decoction. Adult males (100%) were informed about this decoction.

Increase of milk production in females

Participants used *S. gerrardii* leaves to increase milk production in lactating women. The leaves were mixed with boiled water, then removed and used to touch the outside skin (**ukuthoba**) of the breast. Only one (1%) adult female (100%) participant was knowledgeable about this use.

Other uses

Homestead defence against thunderstorms and lightning

As per the response from Emkhandlwini local people, a thunderstorm, sometimes called a lightning storm, is a type of storm characterized by lighting and sound waves it produces in the atmosphere. If the homestead is not protected, thunderstorm can bring hazardous impacts to the homestead. Therefore, respondents use the leaves of *S. gerrardii* to protect homestead against lightning. The pure water and *S. gerrardii* leaves are mixed in a bucket and can be used to sprinkle (**ukuchela**) around the whole homestead. This use was only known by three (3%) participants, where 67% were males and 33% were female. Younger males and females (100%) contributed more information than the other age groups.

Building of a homestead

In the Emkhandlwini area, a homestead refers to any built house where people live. Local people of this area collect S. gerrardii sticks to build rondavels (4%) and fence (1%) their homesteads. About 5% of participants use *S. gerrardii* sticks as a building material. Males (80%) were more informative than females (20%). Among the informative participants, more information was mostly obtained from adult females (100%) and younger males (75%).

Traditional spiritual problems (umtombo wamagobongo)

In the Emkhandlwini area, spiritual problems refer to life difficulties that are caused by different spiritual factors, including ancestral influences and evil spirits, to name a few. Furthermore, traditional spiritual problems strictly refer to spiritual difficulties that can only be addressed by traditional methods like rituals, herbs, and prayers. The roots of *S. gerrardii* is used in combination with other traditional herbs to make **umtombo wamagobongo** for the person with traditional spiritual problems. Only one (1%) elderly woman was aware of this use.

Ornaments

The hard shell of *S. gerrardii* is used for decoration purposes in the Emkhandlwini area. Hard shells are also used to make knobkerries (**amawisa**), which are used either as drumsticks or weapons during traditional ceremonies. Dried seeds are used to make necklaces. This information was obtained in 3% of homesteads, whereby 67 % of participants were middle-aged males and 33% were middle-aged females.

Livestock

In addition to directly humans feeding on *S. gerrardii* fruits, the livestock, donkeys, and monkeys also feed on these fruits at the Emkhandlwini area. Respondents mentioned *S. gerrardii* fruits as another food source for livestock during the winter season when the grass is dry. The roots and leaves of *S. gerrardii* are used to treat illness in goats. This information was obtained from most males (64%) than females (36%). This knowledge was mostly obtained from adult females (100%) and younger males (57%).

Variation in morphological and organoleptic components of *Strychnos gerrardii.*

Leaf traits

Leaf colour

Most participants mentioned green leaves (46%), whereas dark green (28%), light green (20%), and greyish leaves (6%) were known by the minority, respectively. The green colour was mostly known by young males, followed by middle-aged females. Both men (53%) and women (47%) of the younger group were aware of dark green leaves. However, middle-aged (47%) and elderly (18%) men outnumbered women (33% and 16%, respectively) of similar age groups in mentioning dark green leaves.

Leaf shape

The shape of *S. gerrardii* leaves mentioned by local people of the Emkhandlwini area varied from roundish (50%); followed by elongated (30%), then the round heart-shaped (8%), until the least elongated heart-shaped (3%) leaves (Table 2). Young and middle-aged (60%) males were knowledgeable of roundish leaves over the females across all age classes except elderly females.

Table 2. Morphological and organoleptic variation of *Strychnos gerrardii* morphotypes at Emkhandlwini area, KwaZulu-Natal, South Africa.

Category		**Resp**	**Gender**	**Age (years)**		
		FI	**F [N (%)]**	**18-34 N(TFI; SFI)**	**35-54 N(TFI; SFI)**	**≥55 N(TFI; SFI)**
Leaf traits						
Colour	Light green	**20**	M [12 (60)]	7 (35; 58)	5 (25; 42)	1 (5; 8)
			F [8 (40)]	4 (20; 50)	1 (5; 13)	2 (10; 25)
	Green	**46**	M [27 (59)]	18 (39; 67)	5 (11; 19)	4 (9; 15)
			F [19 (41)]	6 (13; 32)	9 (20; 47)	4 (9; 21)
	Dark green	**28**	M [17 (53)]	6 (21; 35)	8 (29; 47)	3 (11; 18)
			F (12 (47)]	6 (21; 50)	4 (14; 33)	2 (7; 16)
	Greyish	**6**	M [3 (50)]	2 (33; 67)	1 (17; 33)	0 (0; 0)
			F [3 (50)]	0 (0; 0)	1 (17; 33)	2 (33; 67)
Shape	Roundish	**50**	M [30 (60)]	18 (36; 60)	9 (18; 30)	3 (6; 10)
			F [20 (40)]	9 (18; 45)	8 (16; 40)	5 (10; 25)
	Elongated	**39**	M [23 (59)]	12 (31; 52)	7 (18; 30)	4 (10; 17)
			F [16 (41)]	7 (18; 44)	7 (18; 44)	2 (5; 13)
	Round & heart-shaped	**8**	M [6 (75)]	3 (38; 50)	2 (25; 33)	1 (13; 17)
			F [2 (25)]	0 (0; 0)	0 (0; 0)	2 (25; 100)
	Elongated & heart-shaped	**3**	M [2 (67)]	0 (0; 0)	2 (67; 100)	0 (0; 0)
			F [1 (33)]	1 (33; 100)	0 (0; 0)	0 (0; 0)
Fruit traits						
Size	Small	6	M [6 (86)]	4 (57; 67)	1 (14; 17)	1 (14; 17)
			F [1 (14)]	1 (14; 100)	0 (0; 0)	0 (0; 0)
	Medium	74	M [44 (59)]	24 (32; 55)	15 (20; 34)	5 (7; 16)
			F [30 (41)	11 (15; 37)	11 (15; 37)	8 (11; 27)
	Large	20	M [13 (54)]	7 (29; 54)	3 (13; 23)	3 (13; 23)
			F [11 (46)]	4 (17; 36)	5 (25; 45)	2 (8; 18)
Shape	Roundish	86	M [53 (62)]	30 (35; 57)	17 (20; 32)	6 (7; 11)
			F [33 (38)]	15 (17; 45)	11 (13; 33)	7 (8; 21)
	Wedged	10	M [7 (58)]	3 (25; 43)	1 (8; 14)	3 (25; 43)
			F [5 (42)]	0 (0; 0)	2 (17; 40)	3 (25; 60)
	Pear	4	M [1 (25)]	1 (25; 100)	0 (0; 0)	0 (0; 0)
			F [3 (75)]	1 (25; 33)	2 (50; 67)	0 (0; 0)
Colour	Light yellow	20	M [9 (45)]	5 (25; 56)	3 (15; 33)	1 (5; 11)
			F [11 (55)]	5 (25; 45)	5 (25; 45)	1 (5; 9)
	Yellow	25	M (19 (70)]	10 (37; 53)	5 (19; 26)	4 (15; 21)
			F [8 (30)]	1 (4; 13)	5 (19; 63)	2 (7; 25)
	Orange yellow	55	M [32 (58)]	18 (33; 56)	10 (18; 31)	4 (7; 13)
			F [23 (42)]	10 (18; 43)	6 (11; 26)	7 (13; 30)
Texture	Rough	29	M [15 (52)]	8 (28; 53)	4 (14; 27)	3 (10; 20)
			F [14 (48)]	5 (17; 36)	6 (21; 43)	3 (10; 021)
	Smooth	71	M [44 (62)]	25 (35; 57)	14 (20; 32)	5 (7; 16)
			F 27 (38)]	11 (15; 41)	8 (11; 30)	7 (10; 26)
Pulp colour	Light yellow	18	M [11 (61)]	9 (50; 82)	2 (11; 18)	0 (0; 0)
			F [7 (39)]	4 (22; 57)	3 (17; 43)	0 (0; 0)
	Yellow	34	M [20 (53)]	11 (32; 55)	6 (18; 30)	3 (9; 15)

			F [14 (47)]	5 (15; 36)	7 (21; 50)	2 (8; 14)
	Orange yellow	48	M [28 (58)]	13 (27; 46)	10 (21; 36)	5 (10; 18)
			F [20 (42)]	7 (15; 75)	5 (10; 25)	8 (17; 40)
Organoleptic traits						
Pulp texture	Watery	40	M [27 (68)]	16 (40; 59)	9 (23; 33)	2 (5; 7)
			F [13 (32)]	5 (13; 42)	7 (18; 54)	1 (3; 8)
	Sticky	60	M [35 (54)]	19 (29; 54)	10 (15; 29)	6 (9; 17)
			F [30 (46)]	12 (18; 40)	9 (14; 30)	9 (14; 30)
Fruit taste	Very sweet	09	M [5 (56)]	2 (2; 40)	2 (2; 40)	1 (11; 20)
			F [4 (44)]	0 (0; 0)	1 (11; 25)	3 (33; 75)
	Sweet	81	M [51 (63)]	31 (38; 61)	16 (20; 31)	4 (5; 8)
			F [30 (37)]	14 (17; 47)	10 (12; 33)	6 (7; 20)
	Sour	10	M [4 (33)]	0 (0; 0)	1 (8; 25)	3 (25; 75)
			F [8 (67)]	2 (17; 25)	5 (42; 63)	1 (8; 13)

Legend:
Resp = Respondents, F = Female, M = Male, N = Number, FI = Frequency Index expressed as percentage (%), TFI = Total Frequency Index, SFI = Specific Frequency Index

Fruit traits

Fruit size

Sizes of *S. gerrardii* fruits varied from small, medium, and large with an estimated diameter of 5, 8, and 10 cm, respectively (Table 2). The majority of participants were knowledgeable about medium-sized fruits (74%), followed by large (20%), and the least knew small fruits (5%). Small fruits were known by more young males in all age groups except the older group. Medium-sized fruits were mostly mentioned by young (55%) and middle-aged males (34%). Large fruits were known by the young males (54%), older women (45%), and elderly males (23%).

Fruit shape

Strychnos gerrardii fruit shape varied from roundish (86%), wedge-shaped (10%), and pear-shaped (4%) fruits as stated by respondents (Fig. 3). Information on round-shaped fruits was mostly obtained from males (62%) compared to females (38%). Wedge-shaped fruits were mostly mentioned by males (58%) than females (42%), whereas elderly women (60%) were more knowledgeable about wedge-shaped fruits. Younger males (100%) and adult women (67%) were more informative about pear shaped fruits.

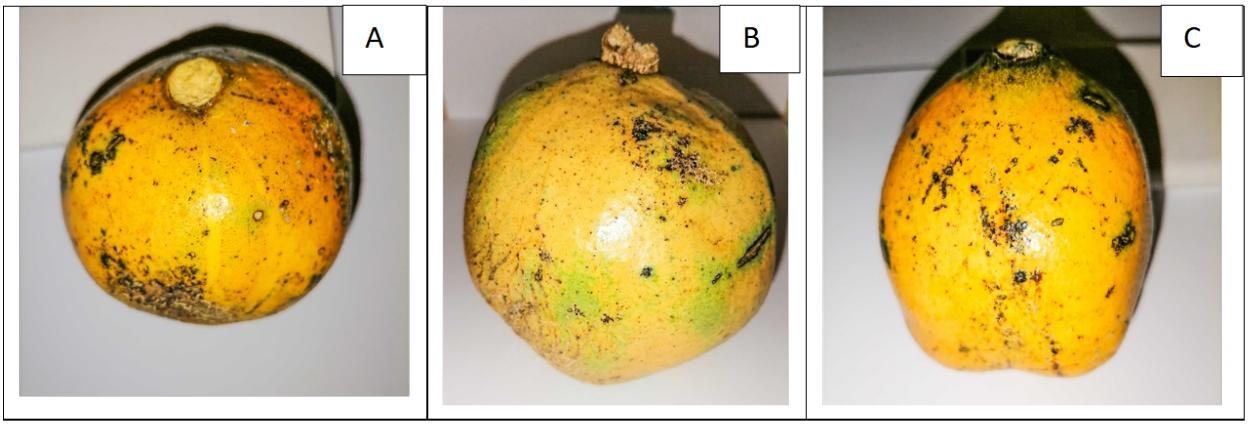

Figure 3. Variation in fruit shapes: round-shaped fruits (A), Wedge-shaped fruits (B), Pear-shaped fruits (C).

Fruit colour

The diverse pericarp colours of *S. gerrardii* mentioned by respondents included the famous orange-yellow (55%), followed by yellow (25%), and less mentioned light yellow (20%) (Table 2). Among the variety of mentioned pericarp colours, orange-yellow was mentioned mainly by young (56%) and middle-aged men (31%) than females of the same age group. However, elderly women (30%) were more knowledgeable about orange-yellow fruit's pericarps than elderly men (13%). The yellow-colored fruit pericarp were mostly known by men (70%) than women (30%) across all age groups. Women (55%) identified

light yellow fruits more than males (45%). The middle-aged (45%) women identified more light-yellow fruits than men (33%) whereas the equal gender distribution was obtained across other age groups.

Pericarp texture of the fruits

Participants mentioned the pericarp texture of *S. gerrardii* fruits as varying between smooth (71%) and rough (29%) (Table 2). Smooth fruits were mostly mentioned by young (57%), middle-aged males (32%), and elderly women (26%) per age group. Rough-textured fruits were more popular amongst younger men (53%) and older women (43%).

Pulp colour

According to the respondents, the pulp colour ranges from orange-yellow (48%), yellow (34%), and light yellow pulp (18%) (Table 2). The younger males were more informative than the females of the same age group for all pulp colour categories. Middle-aged women (50%) and elderly women (40%) were more knowledgeable about yellow and orange-yellow fruit's pulp, respectively.

Organoleptic traits

Pulp texture

Respondents were more knowledgeable about the sticky (60%) than the watery (40%) pulp texture of *S. gerrardii* fruits (Table 2). The younger males and females were more familiar with the sticky pulp texture in each gender category. The younger males (54%) and elderly women (30%) were more knowledgeable about sticky pulp than the men of a similar age group. Information on watery fruit pulp was more popular amongst males (68%) than females (32%).

Fruit taste

Participants mentioned the taste of *S. gerrardii* fruits to range from very sweet, sweet, and sour, where sweet taste (81%) was the most famous, followed by sour (10%) and the very sweet (9%) taste was the least (Table 2). Elderly women (75%) were more familiar with the very sweet fruits than men (20%) of the same age group. More information on sweet fruit was obtained from males (63%) than females. Elderly men (75%) were more aware of sour fruits than elderly women (13%).

Discussion

Socio-demographic information of the participants

The higher contribution of *Strychnos gerrardii* ethnobotanical knowledge by the younger generation, particularly males in the Emkhandlwini area, KwaZulu-Natal (Fig. 2), suggested that they get plant knowledge during different community and/or traditional gatherings. People gain indigenous knowledge through informal learning and that knowledge is transmitted from one generation to another during hunting, farming, harvesting and gathering wild foods (O'Brien 2010). Younger boys gain more traditional knowledge during cattle herding (Ntombela 2019). Generations access knowledge from traditional knowledge systems rather than Western scientific systems. Hence, families play a significant role in the traditional education of the youth (Ugulu & Aydin 2011).

Significance of umkhuhlu, the isiZulu name of *Strychnos gerrardii*

The significance of **umkhuhlu**, the isiZulu name of *S. gerrardii* as referring to "**khuhla**" which means to remove any dirtiness from or clean the body, can be attributed to the isiZulu names that are coined from the use of plants (Ntombela 2019). Body cleansing refers to the process of removing toxins from the body and promoting wellness (Blaak et al., 2023). IsiZulu names given to medicinal plants are generally derived from names referring to animals, body parts of animals, behaviour of a plant, particular traditional use of the plant, and global location of the plant (Ntombela 2019). Similarly, in the Oyemeni area, South Africa, Strychnos spinosa Lam. is called **umhlala** in isiZulu, the name which means to stay (**hlala***)* (Mbhele *et al.* 2022). Again, *Portulaca quadrifida* L. or *Portulaca formosana* (Hayatta) Hayatta is called **phunyukabemphethe** or **nkunzengenampondo** in isiZulu, which are praise explanations that the plant is traditionally used to win a court case (Ntombela 2019). Another example is *Mentha Aquatica Linnaeus, which is called embolism in isiZulu, a direct translation of a compound that enhances the rotting process because this plant is traditionally used to degrade into small pieces the internal lumps called idlis* (Ntombela 2019). However, the information on the significance of **umkhuhlu**, the isiZulu name of *S. gerrardii* was obtained amongst few participants, probably because urbanization in this area has led to a decline in knowledge about useful plants amongst the communities (Ugulu & Aydin 2011).

Food uses of *Strychnos gerrardii*

Direct consumption of fruits

Emkhandlwini participants collect ripe *S. gerrardii* fruits either directly from the tree or once they have fallen on the ground (Table 1), which is a similar way of collecting ripe *Strychnos spinosa* fruits for direct consumption at Oyemeni area, South Africa (Mbhele *et al.* 2022). It was also common for both *S. gerrardii* (Table 1) and *S. spinosa* (Mbhele *et al.* 2022) to determine fruit ripeness and readiness for consumption through colour change from green to yellowish and the emission of a sweet smell from fruit peduncle-attachment scar. The falling of *S. gerrardii* fruits from the tree upon ripening is possibly caused by increased hormones such as auxin and abscisic acid that generally promote fruit abscission in plants (Gupta *et al.* 2022). The change in fruit colour from green to yellow/orange indicates the degradation of chlorophyll to carotenoids or anthocyanins, and the biosynthesis of volatile organic compounds as influenced by ethylene in ripening fruits (Iqbal *et al.* 2017). The production of ethylene during the repining phase in fruits is controlled by different regulations of various 1-aminocyclopropane-1-carboxylic acid synthase and 1-aminocyclopropane-1-carboxylic acid oxidase genes (Kumar *et al.* 2014). The sweet smell that is emitted by ripening *S. gerrardii* fruits can be attributed to the emission of volatile compounds such as terpenoids, phenylpropanoids, benzenoids, fatty acid derivatives, and amino acid derivatives which are normally produced at fruit ripening (Mostafa *et al.* 2022). Notably, these volatile organic compounds play a crucial role both for defence and attractive mechanisms (Mostafa *et al.* 2022).

The exposure of fruit internal content for direct consumption through cracking the fruit pericarp by striking them on rocks is similar for both *S. gerrardii* (Table 1) and *S. spinosa* (Mbhele *et al.* 2022) fruits. In other *Strychnos* species such as *Strychnos cocculoides* Baker*., Strychnos innocua* Del.*, Strychnos madagascariensis* Pior*., Stryncos spinosa* Lam*.,* and *Strychnos pungens* Solored., fruits are eaten raw as a snack (Van Rayne *et al.* 2021). In Zimbabwe, rural communities collect *S. cocculoides* fruits for consumption during periods of food scarcity (Ngadze 2018). *Strychnos* species are also recommended for direct consumption as they have high nutrient content such as iron (70-140 mg), zinc (29 mg), and vitamin C (34-88 mg) (Ngadze *et al.* 2018).

Fermented maize meal (umbhantshi)

Residents from Emkhandlwini area mix cooked maize meal with *S. gerrardii* pulp or the extracted juice from fleshy seed coats to prepare **umbhantshi** in a similar way as the same dish is prepared at Oyemeni area using *S. spinosa* fruit pulp (Mbhele *et al.* 2022). In Zimbabwe, pulp of *S. cocculoides* and *S. spinosa* fruits is mixed with stiff maize meal to prepare a dish locally known as **sadza** (Ngadze *et al.* 2017a). It is, therefore, possible that pulp and seed coats of Strychnos species have either high acidity or are fortified with microorganisms that promote the fermentation process (Voidarou *et al.* 2021), but this needs further research. During natural food fermentation, metabolites produced by different microorganisms, including lactic acid, acetic acid, carbon dioxide, ethanol, hydrogen peroxide, bacteriocins and antimicrobial peptides, prevent the development of spoilage organisms (Voidarou et al., 2021). Fermentation refers to a process whereby organic compounds are broken down by microorganisms to produce new edible products (Kunene et al., 2020). Fermentation helps increase the shelf life of indigenous fruit, thus avoiding fruit erosion (Kunene *et al.* 2020). Every culture uses its methods to prepare food from indigenous fruits (Mbhele *et al.* 2022).

Juice (ujwembe)

In the current study, juice from *S. gerrardii* fruits is prepared by manual separation of seeds from the pulp, mixing the pulp with water and then allowing the mixture to ferment for 30 to 60 minutes before consumption. Similarly, the preparation of juice from *S. cocculoides* fruits in Zimbabwe (Ngadze *et al.* 2017a), and S. spinosa fruits in South Africa (Mbhele et al. 2022) and Zimbabwe (Ngadze et al. 2017a) involves the separation of seeds and flesh and addition of water, but with the exclusion of fermentation stage. The ability of *Strychnos gerrardii* to produce fermented juice suggests the presence of lactic acid bacteria like the *Leuconostoc mesenteroides* 12b which favours the antioxidant activity of the fermented juice (Kunene *et al.* 2020). *Strychnos madagascariensis* and *S. spinosa* fruit juice is recommended by many people of Eswatini compared to juices from other indigenous fruit trees such as *Boscia albitrunca*, *Ximenia caffra,* and *Vangueria infausta* (Kunene *et al.* 2020).

Fermented porridge (amahewu)

The local use of *Strychnos gerrardii* fruit content to produce fermented alcoholic and non-alcoholic beverages in the Emkhandlwini area is like practices in Eswatini, where the pulp is manually separated from *S. spinosa* and *S. madagascariensis* seeds and mixed with the porridge to give a tangy taste (Kunene *et al.* 2020). *Strychnos gerrardii* is used as a porridge ingredient, possibly because it might contain abscisic acid and pectin, which gives a brighter colour in a porridge and acts as a thickening agent, respectively (Kunene *et al.* 2020). The same preparation method is used in the Oyemeni area to prepare fermented porridge (**amahewu***)* from *S. spinosa* fruits (Mbhele *et al.* 2022). Similarly, in Mozambique, the flour of S.

cocculoides is mixed with porridge to make a drink that is locally known as *Bozo* (Ngadze *et al.* 2017b). In Zimbabwe, **mahewu** is prepared by mixing the sorghum flour with *S. cocculoides* and *S. spinosa* pulp and allowing it to ferment for approximately 12 to 24 hours (Ngadze *et al.* 2017a). Furthermore, in Zimbabwe, the pulp of S*. cocculoides* and *S. spinosa* fruits is soaked in water for 30 to 120 minutes to produce a juice, which is thereafter mixed with cooked maize meal to produce **mutandabota** *(Zea mays*-based porridge) (Ngadze *et al.* 2017a). In Eswatini, fruit juice extracted from other indigenous fruit species such as *Ximenia caffra* Sond. and *Vangueria infausta* Burch*.* subsp. *infausta* is also used to add flavour to the porridge (Kunene *et al.* 2020).

Sundried and ground fruits (umnkwankwa)

The preparation method of sundried and ground *S. gerrardii* fruit pulp and seeds, locally known as **umnkwankwa** at Emkhandlwini area, is similar to the preparation method in Zimbabwe, where *S. innocua or S. madagascariensis* seed coats and seeds are sundried via a process locally called **kurovera** (Ngadze *et al.* 2017a). The resulting mixture is locally consumed in a powder form or added as an ingredient in the preparation of porridges and other beverages (Ngadze *et al.* 2017a; Shai *et al.* 2020). Emkhandlwini residents highly recommend sundried and ground fruit pulp and seeds for people with high blood pressure and diabetes due to their bitter taste. The fruit pulp and seed coat of *S. madagascariensis* and *S. innocua* have high natural bioactive chemicals, antioxidant, and anti-diabetic activities, hence they are recommended for managing hypertension and diabetes in South Africa and Zimbabwe (Oboh *et al.* 2020).

Strychnos gerrardii alcohol (ugologo wamakhuhlu)

In the current study, the preparation method of *Strychnos gerrardii* alcohol, locally known as **ugologo wamakhuhlu**, involves mixing fruit content, water, and brown sugar, which is a similar way used in Oyemeni area to prepare alcohol from *S. spinosa* fruits (Mbhele *et al.* 2022). It is possible that the pulp of *Strychnos gerrardii* and other *Strychnos* fruits is accumulated with the microorganisms such as yeast and lactic acid bacteria which govern alcohol fermentation (Voidarou *et al.* 2021). Fermented alcoholic beverages, locally referred as **kashipembe**, are produced from *S. cocculoides* fruit pulp in Namibia (Marenga 2021). Other fruit trees such as *Sclerocarya birrea* (A. Rich.) Hochst. subsp. *caffra* (Sond.) **Kokwaro** are also used to prepare alcohol in Eswatini and Namibia (Kunene *et al.* 2020). Local people from Eswatini and Namibia traditionally give the marula alcohol to the King and Chief as a gift (Kunene et al., 2020).

Medicinal uses of *Strychnos gerrardii*

Cleansing of body system

Emkhandlwini participants use decoction from roots, bark, and leaves of *S. gerrardii* as an enema for general body cleansing. Similarly, in Limpopo, tiny pieces of the bark of other Indigenous species, such as *Trichilia dracaena* Sond. are prepared as an enema for general body cleansing (Constant & Tshisikhawe 2018). Each culture has its traditional way of cleansing ceremony, as it is popular at Eswatini, where seawater fetched with **lihlutho** (traditional calabashes) is used for the incall cleansing ceremony (Pullanikkatil *et al.* 2021).

Stomach issues

Local participants in Emkhandlwini area use *S. gerrardii* and Marula bark decoction to treat running stomachs. The roots, bark, and leaves of *Strychnos decussata* (Pappe) Gilg. are used to cure stomach problems (Van Rayne *et al.* 2021). In the Oyemeni area, S. spinosa bark is cooked with water, and the resulting mixture is taken orally to treat stomach pains (Mbhele et al., 2022). In Namibia, the juice of immature *S. cocculoides* fruit is drunk by a person suffering from stomach ache (Elago & Tjaveondja 2015). *Strychnos gerrardii* has variously reported medicinal uses in Emkhandlwini area including treating stomach problems, hence this species remains helpful in rural and developing communities with poor access to Western medical care (Ayantunde *et al.* 2009).

Influenza virus (flu)

At Emkhandlwini area, roots, bark and leaves decoction is used to treat flue. Similarly, in Lesotho and South Africa (KwaZulu-Natal), tiny pieces of *Alepidea amatymbica* Eckl. and Zeyh. (**ikhathazo***)* roots are boiled with water and the decoction is sipped to treat colds and influenza (Cock & Van Vuuren 2020). This suggests that S*. gerrardii* plant parts have anti-influenza activities, but more research is needed. The usage of traditional plants with anti-influenza activities remains helpful for treating influenza virus around the world (Cock & Van Vuuren 2020).

Furthermore, local people from KwaZulu-Natal also burn tiny pieces of *Alepidea amatymbica* Eckl. and Zeyh. stem and inhale the smoke to cure colds (Cock & Van Vuuren 2020). Leaf decoction of *Artemisia afra* Jacq. ex Willd. (**umhlonyane**) is drunk to cure coughs (Cock & Van Vuuren 2020). Additionally, influenza is also treated by directly inhaling the freshly crushed

leaves of *A. afra* (Cock & Van Vuuren 2020). Influenza, also known as flu, caused by the influenza virus, is a very contagious disease that spreads through the air (Mehrbod *et al.* 2018; Cock & Van Vuuren 2020).

Diabetes and high blood pressure

At Emkhandlwini area, managing high blood pressure and diabetes involves direct consumption of unripe *S. gerrardii* fruits and orally taking root decoction. Similarly, in northern Maputaland, South Africa, *S. madagascariensis* fruit and seed decoction is taken orally to treat hypertension (De wet *et al.* 2016). Roots of *S. spinosa* are mixed with the bulbs of *Tacca leontopetaloides* (L.) Kuntze to treat diabetes in Togo (Tittikpina *et al.* 2020). The seed coat and fruit pulp of *S. madagascariensis* have high anti-diabetic activities (Van Rayne *et al.* 2021). However, immature fruits of *Strychnos* species, including *S. cocculoides, S. madagascariensis, S. pungens* and *S. spinosa*, are confirmed to contain poisonous strychnine and brucine (Van Rayne *et al.* 2021). Therefore, it is not recommended for Emkhandlwini residents to take too much of unripe *S. gerrardii* fruits, as it was also not recommended for Maputaland residents to orally take more seeds of *S. madagascariensis* because they cause vomiting when overdosed (De wet *et al.* 2016).

Respiratory problems

Emkhandlwini residents use a root decoction to treat respiratory problems, which is also similar to the traditional use of *S. spinosa* roots to treat respiratory problems in Benin (Tittikpina *et al.* 2020). Roots and leaves of *S. spinosa* are boiled together and decoction is drunk to unblock respiratory issues in Sudan (Avakoudjo *et al.* 2021). The ability of *Strychnos* species to treat respiratory problems confirms that plant parts of these species have inhibitory activity against viral respiratory pathogens (Cock & Van Vuuren 2020). Other species that are traditionally used to cure inflammatory and respiratory diseases include, *Clerodendrum glabrum* E.Mey. var. *glabrum, Cussonia spicata* Thunb.*, Pittosporum viridiflorum* Sims.*, Rapanea melanophloeos* (L.) Mez.*,* and *Tabernaemontana ventricosa* Hochst. ex A. DC. (Mehrbod *et al.* 2018).

Increase of milk production in females

Emkhandlwini breastfeeding females use *S. gerrardii* leaves soaked in hot water to increase their milk production. The roots and bark of *S. spinosa* are also used to stimulate milk production in nursing mothers (Tittikpina *et al.* 2020). The ability of leaves, roots, and bark of *Strychnos* species to stimulate milk production suggests the presence of galactagogue or lactation inducer substances which promote lactation and milk production in humans (Sibeko *et al.* 2021). Similarly, *Moringa oleifera* Lam. leaves are used for galactagogue production in females during the postpartum (Sibeko *et al.* 2021). Furthermore, it can be suggested that there is a common accumulation of phytochemicals containing iron elements in fruits and other parts of *Strychnos* species, but this needs further research. *Strychnos* species fruits have high iron content of approximately 140 mg/100 g which serves as an implement for iron deficiency in breastfeeding mothers (Ngadze *et al.* 2017b).

Other uses of *Strychnos gerrardii*

Homestead defence against thunderstorms and lightning

Home defence against lightning and thunderstorms in the Emkhandlwini area is ensured by sprinkling the whole homestead with pure water and S. gerrardii leaves. However, in the Oyemeni area, homestead protection is achieved by strategically placing four ripe fruits of *S. spinosa* around the homestead (Mbhele *et al.* 2022). This is done with the belief that the homestead will be protected against witchcraft and evil spirits (Mbhele et al., 2022).

Homestead building

Poles from *S. gerrardii* trees are used for fencing and building rondavels. *Caesalpinia decapetala* (Roth) Alston is a security fence around homesteads and kraals (Semenya *et al.* 2012). *Eucalyptus paniculata* Sm. plants have strong wood used for charcoal and poles for fencing (Semenya *et al.* 2012). The strength and fire resistance of *Strychnos gerrardii* wood for fencing and building material suggests the presence of graphite and carbon which makes the wood to be stronger and fire resistant (Tributsch & Fiechter 2008).

Traditional spiritual problems (umtombo wamagobongo)

Strychnos gerrardii roots, in combination with other traditional herbs, are used to address the traditional spiritual problems in people. Similarly, *Cissampelos torulosa* E. Mey. ex Harv. leaves and stems are traditionally used for spiritual cleaning in Vhavenda communities in Limpopo (Constant & Tshisikhawe 2018). People from KwaZulu-Natal and Eastern Cape use different modes of spiritual cleansing such as washing, purging, and sprinkling (Hutchings 2007).

Ornaments

The use of *S. gerrardii* fruits and seeds to make different ornaments in the current study relates to the general use of hard shells from *Strychnos* species to prepare different musical instruments and ornaments in Zimbabwe (Ngadze 2018). Ornaments and instruments made from *S. gerrardii* possibly have cultural and traditional significance in the Emkhandlwini area (Pullanikkatil *et al.* 2021), similar to how *Cucurbita moschata* Duch ex Poir is used to make calabashes (commonly known as **lihlutho***)* in Eswatini, which is traditionally used for brewing homemade beer. The wood obtained from *Strychnos* species is used for making tools and firewood (Ngadze 2018). Fully matured fruits of *Lagenaria siceraria* (Molina) Standley are cleaned up by removing a papery pulp and seeds from a fruit, leaving a strong hollow shell that is used for making musical instruments, cups, utensils, bowls, and beer containers (Silverman *et al*. 2021).

Livestock

Livestock and other wild animals feed on ripe *S. gerrardii* fruits during pastures' feed scarcity seasons. Livestock relies on fruits and leaves of Strychnos species during the dry season (Ngadze 2018). Leaves of woody species are more resistant to drought and lack of humidity (Ayantunde *et al.* 2009); hence, leaves of S. gerrardii act as a supplement during the winter season. The roots and leaves of *S. gerrardii* are used to cure different diseases in goats. Leaves of *S. spinosa* and *Crossopteryx febrifuga* (G. Don) Benth. are used to treat dermatitis and skin diseases in livestock (Tittikpina *et al.* 2020). *Strychnos gerrardii* can treat several diseases alone and independently, hence this confirms that undomesticated plants with medicinal properties play a crucial role in the prevention and controlling of various diseases in livestock (Asfaw *et al.* 2022).

Variation in morphology of *Strychnos gerrardii*

Leaf traits

In the current study, *S. gerrardii* leaf colour varied from light green, green, dark green, and greyish (Table 2). Similarly, the leaf colour of *S. madagascariensis* (Maroyi 2021) and S. spinosa from the Oyemeni area (Mbhele et al. 2022) varied from green and dark green. Variation in the leaf colour of *S. gerrardii* is due to leaf pigments such as chlorophyll, carotenoids, and anthocyanins (Tang *et al.* 2020). Green leaves in plants are due to high chlorophyll content and this pigment plays an important role during photosynthesis (Tang *et al.* 2020).

A variation of *S. gerrardii* leaf shapes at Emkhandlwini area from roundish, elongated to heart-shaped leaves (Table 2) was similar to roundish and elongated *Strychnos spinosa* leaf variation recorded among morphotypes at Oyemeni area (Mbhele *et al.* 2022). This suggests that these species are closely related, where the similar leaf shape between certain *Strychnos* species indicates retention of a trait from their recent common ancestor (Adebowale *et al.* 2012). Furthermore, *Strychnos madagascariensis* leaf shape varies from elliptic to oval (Adebowale *et al.* 2012, Maroyi 2021).

Fruits traits

Distinct fruit sizes obtained at Emkhandlwini area varied in terms of diameters which included small (5 cm), medium (8 cm), and large (10 cm) fruits, which are in a similar diameter range (6.48-8.07 cm) as *S. madagascariensis* fruits collected from Bushbuckridge and Shongweni, South Africa (Van Rayne *et al.* 2022). However, according to Van Rayne *et al.* (2021), fruit diameter of *S. cocculoides* and *S. gerrardii* vary from 5-7 cm. Diameter of *S. spinosa* fruits from Oyemeni area varied from 12 to 16 cm (Mbhele *et al.* 2022), showing that they are bigger than *S. gerrardii* fruits. The *S. gerrardii* fruit shape variation between roundish, wedged, and pear-shaped (Table 2) was different from globose and roundish shape of *Strychnos madagascariensis* fruits (Maroyi 2021), probably because species are different. Rough and smooth *S. gerrardii* fruit texture found at Emkhandlwini area was like *S. spinosa* fruit texture from Oyemeni area (Mbhele *et al.* 2022).

The variation of pericarp colour on ripe *S. gerrardii* fruits from Emkhandlwini from yellow, light yellow, and orange-yellow (Table 2) was comparable to orange-yellow and yellow colour of mature *S. gerrardii* and *S. madagascariensis* fruits (Maroyi 2021; Van Rayne *et al.* 2021). The ripe *S. spinosa* from Oyemeni area showed variation in pericarp colour that varied from pale green, green, pale yellow, yellow, and intense yellow (Mbhele *et al.* 2022). Change in pericarp colour from green to intense yellow suggests higher concentration of carotenoids, carotene and xanthophylls at maturity stage (Van Rayne *et al.* 2022).

Variation in organoleptic properties of *Strychnos gerrardii*

In the current study, fruit pulp colour of *S. gerrardii* varied from light yellow, yellow, and orange yellow (Table 2), which confirms that *S. gerrardii* and *S. madagascariensis* have orange pulp at maturity (Van Rayne *et al.* 2021). In the Oyemeni area, the fruit pulp of S. spinosa varies from light yellow and yellow to brown at the ripening stage (Mbhele *et al.* 2022). The variation of *S. gerrardii* fruit pulp texture between watery and sticky texture (Table 2), was related to a variation from thick to juicy texture in the pulp of *S. spinosa* fruits (Mbhele *et al.* 2022). *Strychnos cocculoides* and *S. pungens* from Southern

Africa have jelly-like and juicy pulp textures, respectively (Ngadze *et al.* 2017b). Variation in pulp texture of *S. gerrardii* can be due to natural plant enzymes such as polygalacturonase, pectinmethylesterase, lyase, as well as rhamnogalacturonase which partially breakdown pectin and cellulose upon fruit ripening, affecting the texture and juiciness of fruits (Mbhele *et al.* 2022). Organoleptic properties refer to sensory components of a fruit that contribute to an individual's experience through senses such as taste, texture, and smell (Yi *et al.* 2016).

The range in fruit taste between very sweet, sweet, and bitter was similar in both *S. gerrardii* (Table 2) and *S. spinosa* (Mbhele *et al.* 2022) morphotypes. This variation in fruit taste among *S. gerrardii* morphotypes can be caused by differences in the accumulation of sugar and conversion of sucrose to glucose and fructose (Ngadze *et al.* 2017b) as well as in the presence of sweet proteins (Harker & Johnston 2008) upon ripening. *Strychnos cocculoides* and *S. innocua* are reported to have sweeter and bitter fruit taste, respectively (Ngadze *et al.* 2017b). In Cameroon, fruits are selected for cultivation based on their taste, size, and yield (Kunene *et al.* 2020).

Taste in *Strychnos* fruits is affected by the ripening stage and environmental factors such as habitat and different climatic conditions (Ngadze *et al.* 2017b). However, the environmental factor did not affect the studied *S. gerrardii* fruits because these morphotypes were exposed to the same climatic conditions. The sweeter *S. gerrardii* fruits from Emkhandlwini had a bitter taste that caused vomiting as the consumer approached the seed, which suggests the presence of toxic alkaloids in the seeds, such as strychnine or brucine (Van Rayne *et al.* 2022). Seeds of *S. madagascariensis* are not consumed due to the presence of poisonous alkaloid strychnine in the seeds (Van Rayne *et al.* 2022).

The wedge-shaped *S. gerrardii* fruits were very sweet when compared with the others, which is a similar case of very sweet, rough-textured and small *S. spinosa* fruits compared to sickly-sweet, smooth and larger fruits (Mbhele *et al.* 2022). Future studies on the relationship between fruit shape, texture and size with the taste, are essential among morphotypes of *Strychnos* species. The relationship between the texture and taste of the fruit is based on two factors (Harker & Johnston 2008). The first key factor is the release of taste components in the fruit cellular and tissue structure of the pulp as well as how the structure is broken down during chewing (Harker & Johnston 2008). Secondly, the natural ripening stages in the fruit involve a temporal correlation between softening and flavour development (Harker & Johnston 2008).

Conclusion

Strychnos gerrardii is a native species with various potential uses including food, medicinal, and ornamental uses. In addition to the nutritional benefits of its fruits, there is an opportunity for economic contribution and local community development through value-added processes. However, a lack of information on processing methods leads to the erosion of fruits in rural communities. Detailed research on morphological variation amongst *S. gerrardii* morphotypes is needed to recommend these fruits for improvement, future breeding, and conservation purposes. Roots, bark, leaves, and fruits of *S. gerrardii* possess important medicinal properties, hence suggesting the commercialization of this plant in health departments. Furthermore, future studies should focus on phytochemical analysis of *S. gerrardii* as various parts exhibit similar therapeutic effects, hence suggesting the presence of similar compounds in these parts.

Declarations

Ethics approval and consent to participate: The study was conducted in accordance with the Declaration of Helsinki in compliance with Nagoya Protocol on Access and Benefit Sharing, and approved by the Institutional Ethics Committee of UNIVERSITY OF ZULULAND (protocol code: UZREC 171110-30 Dept. 2016/120 and date of approval: 7 September 2016).
Informed consent statement: Informed consent was obtained from all subjects involved in the study.
Conflicts of interest: The authors declare no conflict of interest.
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Authors' contributions: Conceptualization, ACM, NRN, GEZ, and CZ; methodology, ACM and NRN; software, ACM; validation, NRN, GEZ, and CZ; investigation and formal analysis, ACM; resources, ACM; data curation, ACM; writing: original draft preparation, ACM; review and editing, NRN; supervision, NRN, GEZ, and CZ; project administration, ACM; funding acquisition, NRN. All the authors have read, reviewed, and approved the final version of the manuscript.

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