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Plant-based traditional foods and beverages of Gumare Village, Botswana

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Abstract

The consumption of traditional and indigenous foods and beverages varies across different ethnic communities and is often influenced by geographical location. However, the diversity of edible plants is rapidly declining due to climate change, leading to a loss of knowledge about useful plants used by different communities before the plant itself becomes extinct. This research investigated the edible plant types and investigated the processing steps of plant-based traditional foods/dishes and beverages of Gumare village, located in the catchment area of the Okavango Delta in the northwest of Botswana. Questionnaire interviews and focus group discussions (FGD) were used to collect data. The study identified 52 wild and 19 domesticated edible plants used in the preparation of traditional foods/dishes and beverages of Gumare village. Maize, sorghum, millets, beans, melon, watermelon, pumpkin, bottle gourd and sweet potato are widely used domesticated crops. The wild edible plants are either directly used after minor processing or as recipes in traditional dishes and/or as an inoculum in the fermentation, as a substrate in traditional beverages and some as medicinal plants. However, some taboos and food safety challenges were observed in the use of certain plants. The study highlighted a decline in the use of traditional foods/dishes and beverages, particularly among the young generation. The youth indicated that they have a low interest in gathering traditional foods and beverages due to the time-consuming nature during harvesting and the labour-intensive processing. In addition, they indicated the dangers of attacks by wild animals from veld by reptiles (for example snakes and pythons) and alligators (crocodiles) from rivers during the harvesting of raw materials used in traditional foods and dishes. For the communities, the diverse edible wild plants documented are a source of nutrients and bioactive compounds such as dietary fibers, phenolics, terpenes, essential oils, carotenoids, and alkaloids that help to combat malnutrition and for use as traditional medicines to support health and wellness. In conclusion, the significant diversity of wild edible plants and domesticated crops in Gumare village, likely due to its location in the catchment area of the Okavango Delta, plays a crucial role in diet diversification and can contribute to food and nutrition security. However, for most wild edible plants of Botswana, information on their nutrient and bioactive compounds are still limited. This study provides baseline information for further chemical investigation and development of resources in the formulation of functional foods and nutraceuticals.

Keywords Bogobe Jwa Babu, Bogobe Jwa Torobela, Bogobe Jwa Nxoko, Botswana, Gumare, Indigenous foods, Wild edible plants

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Graphical Abstract

Introduction

Plants (domesticated or wild) used in the traditional/indigenous foods and beverages by different ethnic communities vary with geographical locations. Different plant parts (grains/seeds, fruits/berries, stems, leaves, roots/tubers, stem pith juice, barks, twigs, spices, and herbs) are used as sources of nutrients, bioactive compounds, and medicines. They significantly contribute to the food and nutrition security, health, and well-being of the communities where they are found.

The contribution of edible wild plants to Botswanans' indigenous foods is known to be significant (Bultosa et al. 2020; Denbow and Thebe 2006). However, due to urbanization and lifestyle changes, there is a shift towards the consumption of western style processed foods and the purchase of imported foods and beverages, particularly among the youth and civil servants (Brown et al. 2015; Kasimba et al. 2017). As a result, there is a surge of non-communicable diseases in Botswana (Brown et al. 2015) and most urban African countries (Lopes et al. 2022). Wild edible plants are naturally grown in their suitable ecology and their sustainability is affected by several factors, among others by anthropogenic activities and climate changes (Salami et al. 2022; Willett et al. 2019).

The transformation of global food systems require action for protection, preservation, and promotion of indigenous food systems for them to be sustainable and resilient to deliver a diversified diet, for biodiversity

conservation, human, and planetary health (FAO 2021; Willett et al. 2019). FAO (2021) further reported that about 80 percent of the remaining global biodiversity systems are found in the regions where indigenous people are found. According to Shenzhen Declaration on plants, with the ongoing rate of accelerated changes on our planet and societies, more than half of the land plant species could be extinct by the end of the present century, and traditional local knowledge on wild plants may rapidly disappear even before the plants themselves become extinct (Crane et al. 2017). As a remedy, the need to value, document, and protect such knowledge of ethnic communities about the plants including their use as foods, feeds and medicine was emphasized (Lugo-Morin 2020; Sarkar et al. 2020). Such documentation efforts in southern African regions were reviewed (Welcome et al. 2019) and it was found that gaps still exist in different ethnic communities regarding description of processing stages of indigenous foods/dishes and beverages. Such documentations of edible plants used by different ethnic communities are important for the restoration and sustainability of indigenous food systems, to create awareness for further preservation and exploration for use in combating food and nutrition insecurity, and for medicinal purposes to promote health and wellness as well as preserving the plants.

Bultosa et al. (2020) reported and documented 50 wild edible plants and the description of the processing of plant-based traditional foods and beverages for Ramotswa village. Ramotswa village is in the South-East District of Botswana, 35 km to the South of Gaborone, which is the capital city of Botswana, situated at latitude 24° 52′ 14.034" S and longitude 25° 51′ 50.4216" E. The annual precipitation in Ramotswa is about 536 mm. The average yearly temperature is 29℃, January being the warmest (about 31℃) month of the year which can be as high as 31.7℃. June is the coldest month, with an average temperature of 25℃, but the minimum can be as low as 4.5℃. In terms of topography, Ramotswa is in plains that range from 1000 to 1050 m above sea level (m.a.s.l) with some gently undulating valleys with almost flat pediments. There are hilly areas at 1068 to 1189 m.a.s.l. with undulating pediments, while some areas are almost flat to gently undulating plain with kopjes and associated pediments (Bekker & De Wit 1990; Staudt 2016). Ramotswa sits on a hardveld with massive moderately deep well-drained dark brown to yellowish red sandy clay loam to sandy clay. The soils are the eutric regosols (Nachtergaele & De Wit 1990) and major woody species include *Peltophorum africanum*, *Vachellia tortilis*, *Vachellia karoo*, and *Ziziphus mucronata* (Bekker & De Wit 1990). Majority of the residents in Ramotswa are the Balete ethnic group.

Gumare village where this study was conducted, in contrast to Ramotswa is in the North-West District of Botswana, on the western edge of the Okavango Delta at about 1005 km from Gaborone. Gumare lays at the latitude of 19°35′62″S, the longitude of 22°15′49″E and an altitude of about 965 m.a.s.l. The annual average precipitation ranges from 400 to 600 mm. Most of the rains fall between November and March. The average maximum temperature is 35 °C occasionally reaching a maximum of 41 °C during summer. In winter, the minimum average temperature is 7 °C. The Okavango Delta is an inland permanent water body that provides a habitat for diverse species of plants, arachnids, large herbivores, and birds (Darkho & Mbaiwa 2014). Gumare village and its immediate surroundings are characterized by deep sandy Kalahari soils which support woody savannah vegetation and grassland (Dube & Pickup 2001). The woody savannah vegetation types in the area are riparian woodland, mopane woodlands, mixed shrubland, acacia woodlands, grasslands, and floodplains toward Tubu village (Bennitt et al. 2015). The major woody species are *Terminalia sericea*, *Lonchocarpus nelsii*, *Vachellia erioloba*, *Combretum imberbe*, and *Colophospermum mopane* (Bekker & De Wit 1990; Dube 2008; Ringrose et al. 2005). Gumare and the surrounding villages have abundant animal life which include cattle, goats, donkeys, horses, and wild herbivores such as elephants and hippopotami. It also has a variety of birds and carnivores. The majority of Gumare village residents who participated in this study are from Moyei, Mosarwa, Mbukushu and Mosubiya tribes.

Because of locations, ecological vegetations, climates, and ethnic variation between Gumare and Ramotswa, the knowledge experience and heritage of indigenous foods/dishes and beverages are not alike even though there can be some similarities because of cultural exchange in the country. Hence in this paper, the type of edible plants used and descriptions of the processing of plant-based foods/dishes and beverages of Gumare village in Botswana are reported.

Methodology

The study was conducted in Gumare village of which the map is shown in Fig. 1 (Mosothwane 2015).

A qualitative research methodology was followed (Bultosa et al. 2020; McCune & Kuhnlein 2011). Details on the questionnaire for a survey, focus group discussion (FGD) and criteria used in the selection of participants are described in Bultosa et al (2020).

A letter was written to the District Authority and the Chief of Gumare village to get a permit and consent to carry out the study. On a pre-visit to the Chief of the village, consultations on the objectives of the research, the FGD schedule and the methodology of the study, as well

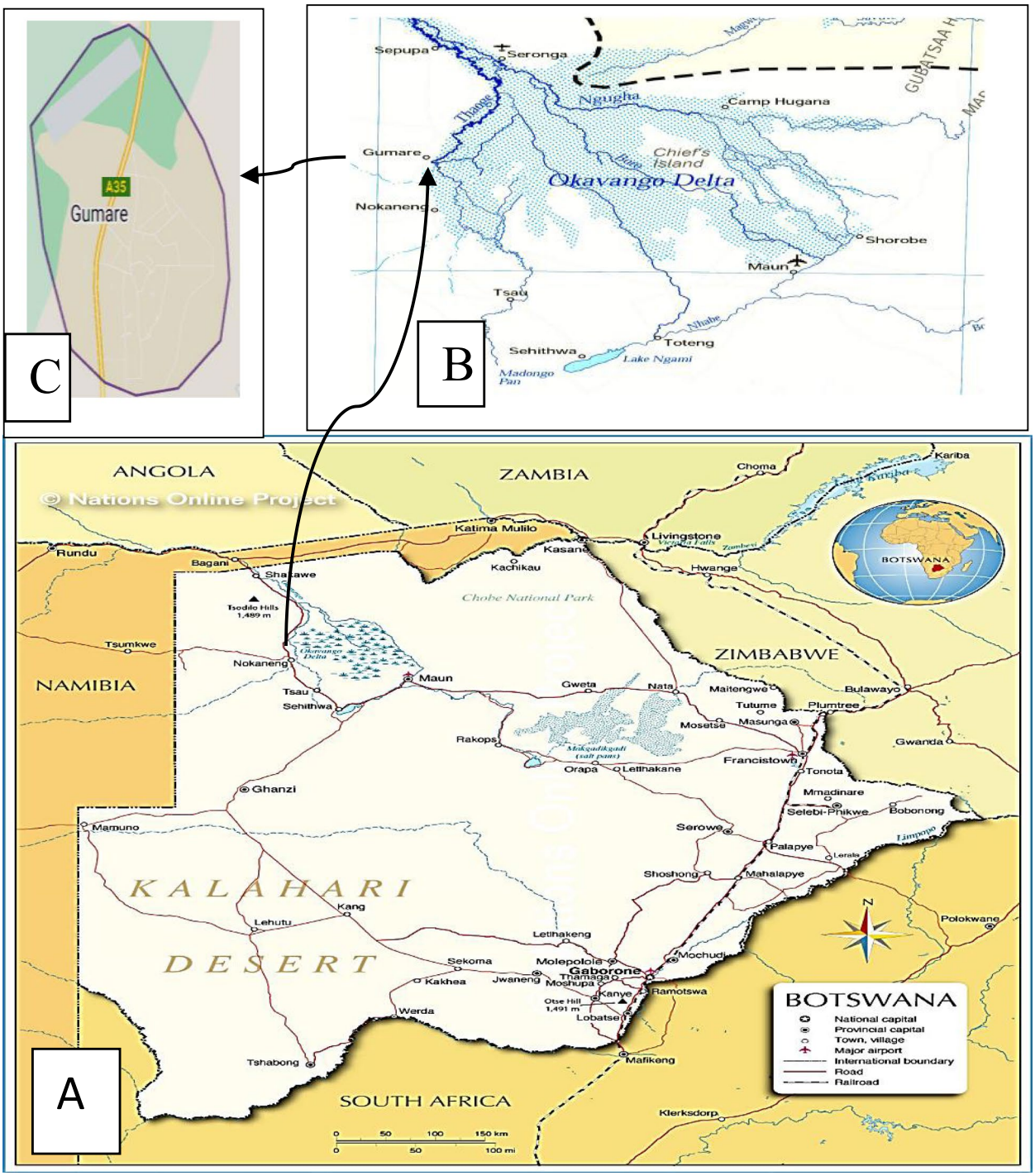

Fig. 1 Maps of **a** Botswana and **b** Botswana's Okavango Delta region where Gumare village is located and **c** Gumare village, map "b" is adapted from Mosothwane (2015)

as assistance with the selection of FGD participants were discussed and agreed upon. The criteria used in the selection of FGD participants were residents in the village, having full knowledge and skills on traditional foods/dishes and beverages of the village, processing for family consumption and/or for sale, having past experiences, and ability to judge current scenario, knowledge in the culture and language of the communities, both male and female participation, and aged between 40 and 87 years. The FGD involved 12 participants and was facilitated by

a rural sociologist who specialized in participatory methodologies. When there was consensus among FGD participants about a topic under discussion, the information generated was captured on a flip chart by the facilitator and two rapporteurs on notebooks. The rapporteurs were provided with guidelines on how to capture the information. A tape recorder was also used to capture audio information for cross-checking with written notes.

The one-to-one interview with respondents on the developed questionnaires was conducted by a trained enumerator, who was a resident of Gumare village. The enumerator was trained using the guidelines. The respondents were selected randomly based on the following criteria: being residents of the area, having knowledge of indigenous foods/dishes and beverages of the communities, and involved in collecting, preparing, preserving, and serving indigenous foods/dishes and beverages of the communities. Vernacular language and where possible, English language were used and the scientific names on the list of edible plants were generated by a Botanist at the Botswana University of Agriculture and Natural Resources (BUAN), Botswana. The data from 34 questionnaires were decoded in a Microsoft Access, 2013, responses were extracted and reconciled information with FGD are reported.

Results and Discussion

The ethnic groups that participated in the Gumare village were: Moyei > Mosarwa > Mbukushu > Mosubiya > Morotshi > Motawana = Mo Angola (Table 1). Most of the participants were Christians, subsistence farmers and household food processors.

Wild food plants

The study generated 52 wild edible plants in the Gumare village used in the indigenous foods/dishes and beverages (Table 2). In most cases, fruits, tubers/roots and in some cases, stems and stem pith extracts, leaves, seeds, and fruiting bodies are used. Most of the edible parts of the plants are used for their nutrients and some are also indicated to have both nutritional and medicinal use.

The market potential for Mokolwane (*Hyphaene petersiana* Klotzsch ex Mart), Tsaro (*Phoenix reclinata* Jacq.), Moretlwa (*Grewia flava* DC), Mogorogoro (*Strychnos* spp), Mowana (*Adansonia digitata*), Mogwana (*Grewia bicolor* Juss.), Moxwi, Kwena (*Mentha aquatica* L.) were indicated as high probably because most of them are used for processing of indigenous beverages and Kwena is widely used as a herb. For others, the market potential was described as poor and for some it was not described. The months/seasonal availabilities vary for some short (fruits) and some nearly throughout the year (tubers and

Table 1 Demographic characteristics of the study participants from Gumare village, Botswana

Demography		Interview	Focus group discussion (FGD)
Gender	Male	14	6
	Female	20	6
Ethnicity	Moyei	16	9
	Herero	2	0
	Mbukushu	4	0
	Mosubiya	3	0
	Motawana	1	0
	Morotshi	2	0
	Mosarwa	5	1
	Mo Angola	0	1
	Blank	1	0
Religion	Christian	22	12
	African traditional religion	8	0
	Not given	4	0
Age (years)	11- 20	0	0
	21–30	2	0
	31–40	10	0
	41–50	10	1
	51–60	6	7
	61–70	3	1
	> 70	3	3
Education	Cannot read or write	6	0
	SUB B	1	2
	Primary education	8	6
	Secondary education	10	3
	Certificate	6	0
	Diploma	1	0
	Bachelor`s degree	2	0
	Not given	0	1
Occupation	Subsistence farmer/Molemi	11	10
	Household food processor	10	0
	Cottage Type Food Processor	1	0
	Public Administrator	1	0
	Councillor	1	0
	Welder	1	0
	Storekeeper	1	0
	School Cook	1	0
	Plumber	1	0
	Taxi Driver	1	0
	Domestic Worker	1	0
	Shop Attendant/Small business	1	1
	IT Technician	1	0
	Hospital orderly	0	1
	Not given	2	0

Table 2 List (names) of wild edible plants used in indigenous foods, dishes and beverages of Gumare village along with parts and forms used, value, food safety, taboos, market potential, seasonal availability and perishable nature of the edible plants

No	Ver. N	Eng. N	Sci. N	Parts U	Forms U	Value/Use K	Food Saf. C	Taboo	Market P	Month. A. (Perish. N.)
1	Tsaro/Nkadi/ Moxinxa	Wild date palm, feather palm	*Phoenix reclinata* Jacq	Fruits & Roots/ tubers, buds as vegetable, stem sap for wine	IF (stem sap juice fermented for wine)	NP MD		-	P	N- D (P)
2	Mokolwane/ Mokolane	Ilala palm	*Hyphaene petersiana* Klotsch ex Mart	Fruits, Palm heart, stem sap wine, Roots	IB (stem sap juice fermented for wine)	NP MD	Its beverage may cause diarrhoea	-	H	A – O (P)
3	Moretlwa/ Moretwa	Raisin tree/Velvet raisin/Wild currant	*Grewia flava* DC	Fruits fresh or dried	IB (fermented to beer)	NP		-	H	A –M (P)
4	Mogwana	Bastard/false brandybush	*Grewia bicolor* Juss	Fruits, Tubers	IB	NP		-	H	M – J (SP)
5	Mokgompha-tha/ Motsot-sojane	Donkey berry/rough-leaved raisin	*Grewia flavescens* Juss	Fruits, seeds	IF	NP/MD		-		A-M (D)
6	Mowana	Baobao	*Adansonia digitate* L	Fruits, Seeds	IF IB	NP MD		-	H	M (P, seed = D)
7	Morula	Marula tree/ Cider tree	*Sclerocarya birrea*(A. Rich.) Hochst. *subsp. Caffra* (Sond.) Kokwaro	Fruits	IF IB	NP	Its beverage may cause diarrhoea	-		F-M (P)
8	Motsentsela/ Motsintsila	Bird plum, brown ivory	*Berchemia discolour* (Klotzsch) Hemsl.)	Fruits, Fruits juice fermented	IF	NP MD		-		F-M (P)
9	Mochaba/ Motshaba	Sycomore fig	*Ficus sycomoros* L	Fruits & Stem exudates		MD		-		JUL (P)
10	Mochabacha-bana		*Ficus* spp	Fruits	IF	MD		-		D – J (P)
11	Mogorogor-wane	Wild orange/Monkey orange	*Strychnos cocculoides* Baker	Fruits/pulp juice	IB					(P)
12	Mogorogoro		Strychnos spp	Fruits & Seeds	IF	NP		-	H	O-N (P, seed = D)
13	Moqowa		*Unidentified*	Grape fruits		MD		-		N-D (P)
14	Moretologa		*Ximenia* spp	Fruits	IF	NP MD		-		S–N (P)
15	Motsaodi	African mangosteen, wild plum	*Garcinia livingstonei* T. Andrers	Fruits	ID	NP MD		-		S- N (P)

Table 2 (continued)

No	Ver. N	Eng. N	Sci. N	Parts U	Forms U	Value/Use K	Food Saf. C	Taboo	Market P	Month. A. (Perish. N.)
16	Mmupudu-people in Gumara call mmilo as mmupudu. Mmilo is *Vanguera infausta*. In the South East of Botswana mmupudu is *Mimusops zeyheri*		*Vanguera infausta*	Fruits				-		A—JUN (P)
17	Dikgobe tsa Badisana	African stachys, wild sage	*Stachys aethiopica* L	Fruits, Leaves	IF	NP		-		J-D (P)
18	Mampimpin-yane	African cucumber/balsam apple/ southern balsam pear	*Momordica balsamina* L	Fruits & Roots	IF	NP MD		Only eaten by women; Do not use a knife to cut it	P	J-D (P)
19	Morupaphiri	Kalahari currant	*Rhus tenuinervis* Engl. synonym *Searsia tenuinervis* (Engl.) Moffet	Fruits	IF	NP		-	P	J—JUL (P)
20	Maphate		*Unidentified*	Fruits	IF	NP	Cannot be swallowed, may cause constipation	-		A—M (P)
21	Motuu		*Unidentified*	Fruits	IF	NP	Cannot be swallowed, may cause constipation	-		J-D (P)
22	Mokgalo		*Ziziphus mucronata* Willd	Fruits	IF	MD		-		J—JUL (P)
23	Xaatu		*Unidentified*	Fruits	IF	NP	Cannot be swallowed, may cause constipation	-		J-D (P)
24	Moka-manawa/ Mokopakopa	Velvet sweet-berry	*Bridelia mollis* Hutch. Synonym#	Fruits	IF	NP		-		A – M (D)
25	Mokhut-somu/ Mokut-shumo/ Mokochong	African ebony/Monkey guava	*Diospyros mespiliformis* Hochst. Ex A. DC	Fruits dried, crushed/flour						(D)
26	Nakgwa/ Shequcomo		*Unidentified*	Tubers	IF	NP		-		A-JUN (SP)
27	Chada		*Unidentified*	Tubers	IF	NP MD		-		J-D (SP)

Table 2 (continued)

No	Ver. N	Eng. N	Sci. N	Parts U	Forms U	Value/Use K	Food Saf. C	Taboo	Market P	Month. A. (Perish. N.)
28	Tswii/water lily	Egyptian blue lily, sacred blue lily	*Nyphaeae Burm.f. var.caerulea* (Savigny) Verdc	Tubers	IF	NP		-		J-D (SP)
29	Monakaladi		*Unidentified*	Tubers	ID	NP		-		F (SP)
30	Sesepasepa		*Unidentified*	Tubers	IF	NP		-	P	J-D (SP)
31	Segokgwe		*Unidentified*	Tubers	IF	NP MD		-	P	J-D (SP)
32	Lerusa		*Unidentified*	Tubers	IF	NP		-	P	J-D (SP)
33	Serowa		*Ceropegia rendallii* N.E. Br	Tubers/Roots						
34	Moxwi		*Unidentified*	Tubers	IF IB	NP MD		-	H	J-D (SP)
35	Moanja		*Unidentified*	Tubers & Leaves	IF		Poisonous	Single leaf is not allowed to be eaten as it may cause death		J-D (SP)
36	Tjita		*Unidentified*	Roots	IF	NP		-		J-D (SP)
37	Koma	Papyrus, paper plant	*Cyperus papyrus* L	Roots & Stem	IF	NP		-		J-D (SP)
38	Tsita	Bulrush/Love reed	*Typha capensis* (Rohrb.) N.E.Br	Rootstalks (Rhizomes)		MD				
39	Kwena	Water mint/Lavander mint	*Mentha aquatica* L	Leaves	IB (tea, flavorant, preservative)	MD		-	H	J—D (SP)
40	Leketa/ Rothwe		*Cleome gynandra* L	Leaves	IF	NP		Not harvested with nails as it may become bitter because of pricking by nails the tissue		F-A (SP)
41	Thepe (Bokoxhono)		*Amaranthus thunbergii* Moq	Leaves	ID	NP		Not harvested with nails as it may become bitter		F- A (SP)
42	Ntsongwa		*Unidentified*	Grasses		NP		-		J-D (SP)
43	Ngarara		*Unidentified*	Seeds	IF IB	NP		-	P	A – M (D)
44	Phoka	Grass	*Urochloa trichopus* (Hochst.) Stapf			MD		-		M-J (SP)
45	Maxixino/ Moporota	Sausage tree/ cucumber tree	*Kigelia africana*	Flowers, fruits		MD		Harvested early mornings only		S (P)
46	Mabowa	Fungi (Mushroom)	*Unidentified*	Fungi fruiting body	ID			Very dangerous for children		F- M (P)

Table 2 (continued)

No	Ver. N	Eng. N	Sci. N	Parts U	Forms U	Value/Use K	Food Saf. C	Taboo	Market P	Month. A. (Perish. N.)
47	Motlopi	shepherd's tree	*Boscia albitrunca* (Burch.) Gilg & Benedict							
48	Sexhowa		*Unidentified*							
49	Xandramo-shoro		*Unidentified*							
50	Monxhoni		*Unidentified*							
51	Nxhoma		*Unidentified*							
52	Makhungara		*Unidentified*							

Where: *Ver. N.* Vernacular name, *Eng. N* English name, *Sci. N* Scientific name, *Parts U.* Forms used, *IF* Indigenous food, *ID* Indigenous dish, *IB* Indigenous beverages, *MD* Medicinal value, *NH* Nutrient for health, *Use K.* Use knowledge, *Food Saf. C.* Food safety challenge, *Month. A.* Months available, *Market P.* Market potential, *HM* High market, *H* = High, *P* = Poor, *Perish. N.* Perishable nature, *Du* Durable, *Pe* Perishable, *Sp* Semi-perishable, *N-D* November-December, *A-O* April-October, *A-M* April-March, *M* March, *F-M* February- March, *JUL* July, *D-J* December-January, *O-N* October- November, *N-D* November—December, *S-N* September-November, *A-JUN* April-June, *J-D* January-December, *J – JUL* January-July, *A – M* April-March, *A – M* April-May, *M-J* May-June, *F* February, *F-A* February-April, *S* September. Synonym# = *Bridelia duvigneaudii* Wilki., *Bridelia scadens* Wilki., *Bridelia stipularis* Blume., *Bridelia ferruginea* Benth., *Bridelia katangensis* J. Leonard

leaves). This shows how wild edible plants are important in supporting the food and nutrition security of the communities throughout the year.

Domesticated food plants

There are 19 domesticated edible plants used (Table 3). Maize, sorghum, pearl millet and sweet reed grains are used in traditional foods/dishes and beverages. Cowpeas, groundnuts, and Bambara groundnuts are used as legumes in traditional foods/dishes. Melon, watermelon, babu, nquoko, leraka, bottle gourd, sego, pumpkin fruits/pulps, and their seeds as nuts are used in traditional foods/dishes. Leaves from cowpea, melon, babu, leraka, bottle gourd, sego, sweet potato and ngolo are used as vegetables. Most domesticated plants are used in two ways either in the indigenous foods, dishes, or beverages for the nutrient supply.

On both wild and domesticated foods and beverages some taboos and food safety concerns were indicated (Tables 2 and 3, respectively). Past studies on taboos associated with foods indicated negative impact on foods and nutrition security since some nutrient-dense food resources are avoided by some segments of the population because of taboos (Angsongna et al. 2016). The food safety challenges are related to contamination with undesirables, improper handling and processing, post-processing cross-contamination, and in some because of failure to suppress the inherent undesirables by proper processing.

The market potential for all edible domesticated plants was high and most of the domesticated plants were indicated to be available from February to April. The fresh harvested edible parts of high moisture content and those prepared (cooked) were classified as perishable, and those with protective epicarp (melon, bottle guard and sego) and dry grains were classified as semi-perishable and/or durable.

Wild plants use as food nutrient sources and medicinal value

Most wild edible plants listed were specified to be used in various indigenous foods/dishes, beverages and/or for their medicinal purposes. Palm (*Phoenix reclinata* Jacq. and *Hyphaene petersiana* Klotzsch ex Mart.) fruits, stem saps, and palm hearts (young stem) are used in the indigenous foods system. The fruit pulps of *H. petersiana* have been reported to bear significant levels of ash (6.0%), carbohydrates (5.3%), proteins (3.1%), minerals (mg/kg) (K 245.94, Na 11.65, P 9.46, Mg 8.94, Ca 5.01, and S 2.93) and anti-nutrients (saponins, tannins and phytates) (Nyambe et al. 2019). Even though the palm sap extract is used for wine production, studies on the physicochemical properties of the extract used as brew raw materials are still limited. In addition to making traditional wine and being used as fruits and vegetables, African palms are used for various medicinal purposes (Gruca et al. 2015). For example, *P. reclinata* is used to treat different ailments (infections, injuries, inflammation, and various disorders: digestive, genitourinary, nervous, nutritional, and sensory systems), for veterinary medicine and magical purposes. From the roots of *P. reclinata* alkaloids, tannins, steroid glycosides, saponins, anthraquinones and reducing sugars were detected; tannins- epigallocatechin-3–0-gallate and steroid glycosides were identified to be protective against tenofovir induced kidney damage in Wistar albino rats (Namuleme et al. 2017). *H. petersiana* is used to treat infections, respiratory system disorders, and injuries, and for veterinary medicine (Gruca et al. 2015). Despite such knowledge of the medicinal uses of plants by communities, characterization of bioactive compounds from both plants in Botswana is still limited.

The fruits from *Grewia flava* and *Grewia bicolor* were reported to have the potential to produce jam, juice, wine, and dried and processed products (Welcome & Van Wyk 2019). In the study area, the fruits are consumed fresh, can be dried for later use, and eaten as a snack like raisins and/or used to process traditional khadi (alcoholic) beverages. Despite the fruits' wide use being acknowledged, information on the chemical composition is limited. Studies on the seed oils of *Grewia bicolor* indicated the yield is low, but from fatty acid profiles, it was suggested that it is possible to use it in the manufacturing of soaps, pharmaceutical products, and cosmetics (Nyakudya et al. 2017). Mokgomphatha (*Grewia flavescens* Juss.) fruits and seeds are used fresh or dried. In Sudan, it is used as a juice drink and in light porridge preparations (Elhassan et al. 2010).

Baobab (*Adansonia digitata*) is one of the highly valued trees because the fruits, seeds, leaves, barks, flowers, and taproot of the seedlings and young saplings are used either for nutritional, medicinal, and/or cosmetic purposes. In Gumare, its fruits and seeds are edible and medicinal. A detailed review of the nutrient profiles of Baobab fruits pulp, leaves and seeds was described by Chadare et al. (2010). The fruits pulp is reported to bear (mg/100 g) vitamin C 280–300, Ca 293.0, P 96.0–118.0, carbohydrates 75.6, fibers 52.0, K 2.31, protein 2.30 and lipids 0.27 (Rahul et al. 2015). The young leaves are rich sources of provitamin A carotenoids (0.9 to 2.7 mg/100 g as retinol equivalents), quality proteins and minerals (Eltahir & Elsayed 2019). The Baobab's seeds, oil fatty acids are 32 to 38% monounsaturated (oleic acid), 22 to 26% polyunsaturated (linoleic acid), and 17 to 22% saturated (palmitic acid) shown to be useful for the cosmetic industry (Muthai et al. 2019). Major bioactive compounds identified include flavonoids, phytosterols and

Table 3 List (names) of domesticated edible plants used in indigenous foods, dishes and beverages of Gumare village along with parts used, value, food safety, taboos, market potential, seasonal availability and perishable nature

No	Ver. N	Eng. N	Sci. N	Parts U	Forms U	Value/Use K	Food Saf. C	Taboo	Market P	Month. A. (Perish. N.)
1	Mmidi /Semanga	Maize	*Zea mays* L	Grains	IF ID IB	NP MD	May cause constipation	After crushing grains using mortar and pestle, remove the pestle to prevent body/stomach pains The maize cover is discarded a day after harvest On beverage: people are not allowed to pass near pots with salt as the maize beverage may lose its taste	H	D-M (P = when soft and cooked and when prepared as a dish, D = when dried, SP = flour)
2	Mabele	Sorghum	*Sorghum bicolor* (L.) Moench	Grains	ID IB	NP MD		-	H	F – A (SP)
3	Mabelebele (Mahangu)	Millet	*Pennisetum glaucum*	Grains	ID IB	NP MD		-	H	F- A (SP)
4	Ntšhê	Sweet reed (sweet sorghum)	*Sorghum bicolor* (L.) Moench	Grains & stem piths	IF IB	NP		Not to be eaten until ripe to avoid introducing pests	H	F – A (D)
5	Dinawa	Cowpea	*Vigna unguiculata* [L.] Walp	Grains (pulse) & leaves	ID	NP		The pods must not be opened with teeth to prevent infestation or attack by rodents	H	F—A
6	Thonga (Manoko)	Groudnuts	*Arachis hypogaea* L	Grains (nuts)	IF	NP		-	H	F—A
7	Ditloo	Jugo beans/ Bambara groundnuts	*Vigna subterranean* (L.) Verdc	Grains (nuts)	IF ID	NP MD		-	H	F—A
8	Lerotse (Torobela)	Melon	*Citrullus lanatus* var. citroides (L. H. Bailey) Mansf	Seeds, leaves, pulps & rinds	IF ID	NP		The terminal buds are cut and put in the centre to increase its yield	H	(D)
9	Thotse	Melon seed	*Unidentified*	Seeds	IF	NP		Boys are not allowed pass through thotse because they have no womb	H	
10	Babu		*Unidentified*	Seeds, leaves, pulps & rinds	IF ID	NP		-	H	F – A (P)
11	Nquoko		*Unidentified*	Seeds, pulps & rinds	IF ID	NP	May cause diarrhea	-	H	(P)

Table 3 (continued)

No	Ver. N	Eng. N	Sci. N	Parts U	Forms U	Value/Use K	Food Saf. C	Taboo	Market P	Month. A. (Perish. N.)
12	Leraka		*Unidentified*	Seeds, fruits & leaves	IF ID	NP MD		Fermented milk and 3 legged black pots are not allowed into the storage room to avoid quick spoilages	H	F—A
13	Legapu	Watermelon	*Citrullus lanatus* (Thunb.) var. lanatus	Pulp & seeds	IF IB	NP	May cause diarrhea when eaten rotten	-	H	F—A
14	Segwana	Bottle gourd/Calabash	*Lagenaria siceraria* (Mol.) Standl	Whole fruits, leaves & seeds	IF ID	NP		The terminal buds are cut and put in the centre to increase its yield	H	(D)
15	Sego		*Unidentified*	Whole fruits, leaves & seeds	IF ID	NP		The terminal buds are cut and put in the centre to increase its yield	H	(D)
16	Sembokoma	Sweet potato	*Ipomoea batatas*	Roots& leaves	IF ID	NP	May cause diarrhea and heartburn	It is not shared People who plough it, must be naked to yield great produce	H	M-JUL (P = when cooked, SP = when raw)
17	Maraka		*Unidentified*							
18		Pumpkins	*Cucurbita pepo* L	Pulp	IF					
19	Ngolo		*Unidentified*	Roots & leaves	IF ID	NP	May cause diarrhea and heartburn	It is not shared People who plough it must be naked to yield great produce	H	M-JUL (P = when cooked, SP = when raw)

Where: *Ver. N.* vernacular name, *Eng. N* English name, *Sci. N* scientific name, *Parts U.* parts/forms used, *IF* indigenous food, *ID* indigenous dish, *IB* indigenous beverages, *FR* fermented, *Use K.* use knowledge, *NP* nourishment potential, *Food Saf. C.* food safety challenge, *N/A* not available, *VH* very high, *H* high, *P* poor, *Month. A.* months available, *Perish. N.* perishable nature, *Du* durable, *Pe* perishable, *Sp* semi-perishable, *D-M* December-March, *F—A* February-April, *M-JUL* March-July

alkaloids implicated to have antioxidants, anti-inflammatory, anti-microbial, anti-malarial, anti-diarrhoea, anti-anaemia, anti-asthma, anti-viral effects, immunostimulant and have been regarded as a panacea to treat different ailments (Ismail et al. 2021; Kamatou et al. 2011). Baobab leaves decoction/infusion were reported to treat diarrhoea, fever, inflammation, kidney and bladder diseases, blood clearing, asthma, diaphoretic, and insect bites. Fruits are used to treat microbial diseases and hyper-lipidaemia (Ismail et al. 2021); and seeds to treat fever, diarrhoea, coughs, and wounds (Rahul et al. 2015). The Food and Drug Administration (FDA) of the USA and the European Union (EU) have approved the Baobab fruits pulp as generally recognized as safe (GRAS) for use as functional food ingredients for the benefit of dietary fibers, high vitamin C, phenolics and minerals (Kamatou et al. 2011). From the dried Baobab fruits pulp, six iridoid glycosides, four hydroxycinnamic acid glycosides and three phenylethanoid glycosides isolated were purported contributors of antioxidants, anti-inflammatory, anti-microbial and anti-viral effects for health benefits (Li et al. 2017). Baobab fruit pulp and the Baobab fruit shell were reported to be good sources of bio-accessible polyphenolics (quercetin, proanthocyanidin, proanthocyanidins B1 and B2) antioxidants (Ismail et al. 2021).

The morula (*Sclerocarya birrea* (A. Rich.) Hochst. subsp. Caffra (Sond.) Kokwaro) fruits and fruit kernels are used in the indigenous food systems of Botswana. Fresh fruits, juice, fermented wine, Amarula (a creamed liquor), jams, jelly, fruit peel essential oils, and kernel/nut oils are commercialized (Hiwilepo-van Hal et al. 2013). The fruit pulp is high in vitamin C (62–400 mg/100 g) and sugars (11.8%) (Hiwilepo-van Hal et al. 2013; Mashau et al. 2022). The fruits bear sesquiterpene hydrocarbon and are high in total phenolic and flavonoid contents (Ngemakwe et al. 2017). The fruit seed nut is rich in proteins (with essential amino acids) and oils (rich in oleic, stearic acid, and palmitic acid) (Mashau et al. 2022). The antioxidant, anti-diabetic, anti-bacterial and anti-fungal activities of the morula fruits are attributed to its high vitamin C, phenolic acids (ferulic acid, caffeic acid, vanillic acid, *p*-hydroxybenzaldehyde, *p*-hydroxybenzoic acid and *p*-coumaric acid), flavonoids (procyanidins, galloyl derivatives of flavonoid glycosides) and tannins content (Mashau et al. 2022).

Motsentsela /motsintsila, brown ivory or bird plum (*Berchemia discolour* (Klotzsch) Hemsl.) fruits are consumed as fresh, dried, and fermented beverage. The fruits bear about 30% sugars, vitamin C (45 to 65 mg/100 g), pro-vitamin A carotenoids (83 RE) and significant minerals (mg/100 g, DM) (K 1240.0, Ca 98.0, Fe 84.0, Mg 53.0 and Na 16.0) (Cheikhyoussef & Maroyi 2017; Feyssa et al. 2012). The *Berchemia discolour* fruits are used in traditional medicine for the treatment of bleeding gums, infertility, barks for infertility, love charm, malaria, bleeding nose, itching skin, and toothache were reported (Cheikhyoussef & Maroyi 2017). In Namibia, tannins, cardiac glycosides, flavonoids, saponins, tannins, and terpenoids were detected from the fruits and bark extracts. In addition, anthraquinones phlobatanins and steroids were detected from the bark extracts (Cheikhyoussef et al. 2010). The traditional medicinal use such as for the treatment of bleeding gums could be attributed to vitamin C and other bioactive compounds from the fruits. However, nutrients and bioactive compounds information from Botswana on *Berchemia discolour* fruits is limited.

Ripe fruits of *Ficus sycomoros* L. are directly consumed, dried for later use, fermented into beverages and medicinal use was indicated. From the fruits, vitamin C (285.0 mg/100 g, FW) (Braide et al. 2018), total -phenolics (33.6 to 51.9 mg of GAE/g, DM), -flavonoids (2.5 to 8.6 mg as QE/g DM), -tannins (4.9 to 7.1 as tannic acid equivalents/g DM), -anthocyanins (86.2 to 113.4 mg as cy-3-glu /100 g FW) and -alkaloids (3.1 to 4.0 g/100 g) (El-Beltagi et al. 2019) were reported. Different parts (fruits, leaves, barks, and roots) of *Ficus* spp. were indicated to be used as an anti-microbial, anti-diarrheal, antioxidant, neuroprotective, hepatoprotective, hypotensive and anti-diabetic (Oghenesuvwe et al. 2018). From the fruits, major phenolic acids (benzoic acid, vanillic acid, caffeine, syringic acid, salicylic acid, *p*-coumaric acid, vanillin and caffeic acid) and flavonoids (kaempferol, neringenin, myricetin, rosmarinic acid, quercetin), alkaloids, tannins, saponins, steroids (*β*-sitosterol, stigmasterol, campesterol) and major fatty acids (linoleic, oleic, linolenic, stearic, and palmitic acids) were reported (El-Beltagi et al. 2019). The anti-bacterial, antioxidant and anti-cancer activities of the fruit extract were implicated to be related to the synergetic effects of the bioactive compounds found in the fruits (El-Beltagi et al. 2019). Excessive intake of the fruits may be deleterious since saponins, oxalates and hydrogen cyanides were recorded from the fruits (Braide et al. 2018; Oghenesuvwe et al. 2018).

Monkey orange (*Strychnos cocculoides* Baiker) fruits are widely consumed in the Southern African regions as fresh ripened immediately on harvest or processed (dried leather, jams, juices, fermented to wine and beer, fritters, muffins, cooked with maize meal porridge) forms (Ngadze et al. 2017). From the fruit, major phenolic acids (caffeoylquinic, caffeic, benzoic, chlorogenic acids), flavonoids (quercetin, naringening, kaempferol, rutin), iridoid glucosides (secoxyloganin, sweroside, acetylloganic acid isomers) and phenolic apioglucoside (kelampayoside A) of anti-oxidants, anti-inflammatory,

anti-diabetic effects were reported (Ngadze et al. 2018). Iridoid glucosides are known for lowering blood glucose and inhibition of advanced glycation end products that help in the suppression of inflammation and insulin resistance in type 2 diabetes mellitus (West et al. 2016). Because of its high fiber 4.6 g/100 g, vitamin C 34.2 mg/100 g, minerals (mg/100 g) (Fe 70.5, Mg 137.2, and K 959.2) (Ngadze et. al. 2017) and bioactive compounds, fortification of maize porridge with the Monkey orange fruits pulp was reported to enhance bioactive compounds and mineral bio-accessibility with a significant reduction in the *in-vitro* digestion of starches to combat malnutrition (Ngadze et al. 2019).

Motsaodi (*Garcinia livingstonei* T. Andrers.) fruits are consumed in indigenous foods and can be fermented into pleasant-flavoured alcoholic beverage. The fruits are reported to have anti-cancer, anti-viral, anti-parasitic and effects on the central nervous system (Joseph et al. 2017; Magadula & Suleimani 2010). Motsaodi fruit seeds were reported to be rich in carbohydrates, proteins, and fats; minerals (mg/100 g) (Na 680–1188, K 275.3–1083.0, Ca 420–760, Mg 144–290, P 39.2–57.8, Fe 15.7–35.5) (Joseph et. al. 2017). From the fruits phenolics, flavonoids, glycosides, alkaloids, and anti-nutrients (oxalate and tannins) below the deleterious levels were reported (Joseph et al. 2017; Omotayo & Aremu 2020).

Stachys aethiopica L. leaves are used as herbal tea to treat internal haemorrhoids, influenza, women's gynaecological make-up and liver problems (VanWyk & Gorelik 2017). Despite such use, information on bioactive compounds from the plant is limited.

African cucumber, balsam apple or southern balsam pear (*Momordica balsamina* L.) leaves, fruits pulp and roots are used as food and/or medicine. The young leaves are cooked and used as a relish with porridge and are indicated to be useful for the supply of amino acids and other nutrients: potassium, calcium, magnesium, phosphorus, zinc, iron, and manganese (Nagarani et al. 2014). Different parts of the plants (leaves, barks, fruits, and seeds) were reported to have anti-oxidant, anti-inflammatory, anti-microbial, anti-viral (anti-HIV), anti-bacterial, anti-malarial (anti-plasmodial), shigellocidal, anti-diarrheal, anti-septic, analgesic, anti-diabetic (hypo-glycaemic) and hepatoprotective properties (Ramalhete et al. 2022). From the plant, alkaloids, flavonoids, glycosides, steroids, triterpenoids, cardiac glycosides, saponins and resins were reported (Nagarani et al. 2014; Thakur et al. 2009). Several cucurbitacins oxygenated triterpene compounds found in free or glycosidic form from the leaves and stems were reported effective as apoptosis agents on multidrug-resistant cancer cells by inhibiting *p*-glycoprotein in the overexpressing cancer cells (Ramalhete et al. 2022). A ribosome-inactivating protein, balsamin from the seeds of *M. balsamina* was indicated to have anti-viral properties toward human immunodeficiency virus 1 (HIV-1) (Ramalhete et al. 2022). The active metabolite isolated (momordins) from the fruit pulp extract was shown capable of inhibiting the multiplication of HIV and other viruses (Thakur et al. 2009).

Rhus tenuinervis Engl. synonym *Searsia tenuinervis* (Engl.) Moffet fruits are consumed fresh or dried. The leaves, roots and barks were reported to have anti-bacterial properties and used to treat gastrointestinal infections- diarrhoea and in the extracts, the presence of flavonoids, terpenoids, saponins, alkaloids and tannins was reported (Dushimemaria et al. 2012).

Mokamanawa (*Bridelia mollis* Hutch) (synonym *Bridelia duvigneaudii* Wilki., *Bridelia scadens* Wilki., *Bridelia stipularis* Blume., *Bridelia ferruginea* Benth., *Bridelia katangensis* J. Leonard) fresh fruits or dried are consumed and processed into jam or juice. From the fruit's pericarp (a thin layer that surrounds the seeds), and seeds on a dry matter basis (g/100 g) carbohydrates 38.8 and 33.5, proteins 8.9 and 44.4, fibers 3.9 and 2.8, ash 1.9 and 1.2, respectively, oil from the seeds 9.1; phenolics, flavonoids, tannins for the fruits' pericarp and seeds 125.59 and 9.84 mg GAE/g, 44.67 and 7.17 mg QE/g and 15.4 and 17.71 mg TAE g, respectively were reported (Murthy et al. 2021). The barks are consumed as vegetables, the leaves are used to treat burning, itching, dysentery, emetic, piles, skin blisters and wounds and the roots to treat cough, diarrhoea, fever, malaria, parasitic worms, and stomach pains (Maroyi, 2019b). However, information on the nutrients and bioactive compounds of the fruits from Botswana is limited.

Mokhutsomu, jackal berry (*Diospyros mespiliformis* Hochst. Ex A. DC.) fruits are consumed fresh, fermented as alcoholic beverages, dried, and crushed into flour (Welcome & Van Wyk 2019). In Saudi Arabia, from the fruits (moisture 80.3%, fibers 4.8%, protein 9.3%, lipids 4.6%, total carbohydrate 15.9%, sugars 9.8%), bioactive compounds (phenolic 20.69 mg GAE/g, total tannins 3.84 mg/g, anthocyanins 0.26 mg/g, carotenoids 23.82 mg β-carotene equivalents/g, vitamin C 709.5 µg/100 mg and vitamin A 597.41 µg/100 mg) and minerals (mg/100 g) (Na 26.92, K 389.38, Ca 89.50, Mg 23.95, P 42.69 and Fe 4.59) were reported (Hegazy et al. 2019). From the fruit, anti-nutrients (phytates, oxalates, saponins and tannins) below the harmful effects were reported (Nyambe et al. 2019). Elsewhere *Diospyros mespiliformis* fruits chewing or infusion/decoction was indicated to be used for treating gingivitis, toothache, dysentery, menorrhagia and wound dressing (Ahmed & Mahmud 2017). The healing effects from the fruit is most probably due to the presence of bioactive compounds in it. The fruits' high

antioxidant activities and carotenoids are attractive for the development of functional foods.

Tswii (*Nyphaeae* Burm. *f. var. caerulea* (Savigny) Verdc.) and Serowa (*Ceropegia rendallii* N.E. Br.) tubers are cooked and consumed as vegetables. Tubers and stems of Koma (*Cyperus papyrus*) are consumed as snacks. However biochemical information from them is limited.

Tsita (*Typha capensis* (Rohrb.) N.E.Br.) rhizomes were indicated to have medicinal value to treat male reproductive dysfunctions, for easy delivery of pregnancy, venereal diseases, menstrual cramps, dysentery, diarrhoea, and from the rhizomes' quercetin and naringenin were identified as bioactive compounds (Ilfergane 2016).

Kwena, water mint (*Mentha aquatica* L.) is a herb that is used in indigenous beverages such as tea, for flavour imparting, -preservatives and -medicinal purposes. The leaf's essential oils have been widely used in different parts of the world in culinary as flavourings, preservatives, medicines, and cosmetics. A total of 34 compounds of which major compounds were mentofuran (oxygenated monoterpene), 1,8-cineole, limonene, β-caryophyllene, menthone, linalyl acetate, α-pinene, linalool with anti-bacterial and antioxidant activities (Getahun et al. 2008; Truong et al. 2022) of high total phenolic and total flavonoid contents were reported (Benabdallah et al. 2016; Truong et al. 2022). The major phenolic acids (caffeic, cinnamic, ferulic, and oleanolic) and other phenolic compounds (rosmarinic acid, luteolin, eriocitrin, naringenin-7-O-glucoside, luteolin-7-O-glucoside isorhoifolin, eriodictyol, and apigenin) were among others reported (Naureen et al. 2022; Truong et al. 2022). Since ancient times, because of its essential oils and phenolic compounds *Mentha aquatica* herbs have been used as therapeutics for human physiological conditions such as digestive health, oral health, anti-cancer activity, skin, brain and, cardiovascular health (Naureen et al. 2022).

Thepe (*Amaranthus thunbergii* Moq.) is used as a leafy vegetable. Elsewhere nutrients (Ca 2.3, K 5.8, Mg 2.7, P 0.67, S 0.85 mg/g fresh weight basis), bioactive compounds as mg/g fresh weight (vitamin C 1.1, phenolic 3.8 mg GAE, flavonoids 1.8 mg CE) with anti-oxidant activities of 61 µmol TE/g fresh weight were reported (Jiménez-Aguilar & Grusak 2017). The leaves can contribute significant K, Ca, Mg and phenolics toward human nutrition.

Rothwe (*Cleome gynandra* L.) leaves and young shoots are consumed as vegetables. The leaves are noted to bear significant mineral nutrients (mg/100 g dry matter basis) (K 3100.0, Ca 2300.0, Mg 400.0, P 700.0, S 400.0, Fe 360.3, Mn 39.3 and Zn 6.0) (Omondia et al. 2017). The high Fe content observed was indicated in part that contributed by the soil contamination (Omondia et al. 2017). Bioactive compounds: phenolics, flavonoids (kaempferol, quercetin and isorhamnetin), glucosinolates (the major compound being 3-hydroxypropyl glucosinolate), vitamin C and carotenoids were reported as significant in *Cleome gynandra* leaves (Omondia et al. 2017).

Phoka (*Urochloa trichopus* (Hochst.) Stapf) is a grass from the *Poaceae* family and was indicated to have medicinal value. Even though information on the chemical composition of the grains is limited, in Tanzania, Sudan, Botswana, and Zimbabwe the grains are sometimes grounded into flour and cooked with water, milk or melon juice to porridge, made into cakes or for processing of traditional beers.

Motlopi (*Boscia albitrunca* (Burch.) Gilg & Benedict) fruits and roots are used as foods, roots as coffee substitutes and inoculum in traditional fermented dairy products. The traditional fermented buttermilk called *Omashikwa* in Namibia produced by placing the roots of *Boscia albitrunca* in the calabash was reported to have positive roles in controlling the microbial profile for better consistency and sensory quality (Bille 2013). The leaves, roots barks and fruits are used in traditional medicine to treat different ailments (constipation, diarrhoea, ear problems, emetic, epilepsy, eye problems, galactagogue, haemorrhoids, headache, HIV/AIDS, hypertension, magical purposes, muscular pain, respiratory infections, skin diseases: chickenpox and rash, -snakebite, -syphilis, and ethnoveterinary medicine: anthrax, chicken diseases, fertility problems, retained placenta, eye, liver, and lung infections) (Maroyi, 2019a). Information on *Boscia albitrunca* bioactive compounds is limited.

Fruits and flowers of Maxixino, African sausage tree (*Kigelia africana* (Lam.) Berth.) were indicated to have medicinal value. Pharmacological studies conducted on different parts of *Kigelia africana* (fruits, barks, leaves, roots) showed significant antioxidant, anti-inflammatory, analgesic, and anti-cancer activities. Because of these in many parts of Africa, the plant parts are used for the treatment of infectious diseases, skin diseases, fainting, anaemia, epilepsy, complications related to sexual organs (enlargement of genital), firming of breast, as an anti-diabetic agent, for HIV and respiratory ailment treatments (Bello et al. 2016; Gupta & Jain 2019). From *Kigelia africana* about 145 phytoconstituents of which the majority belong to the class of flavonoids, phenyl ethanoglycosides, phenylpropanoids, naphthoquinones, iridoids, coumarins, coumaric acids, and its derivatives, terpenes, terpenoids, steroids and sterols have been reported (Bello et al. 2016). From *Kigelia africana* fruits of hexane extracts, 91 compounds were reported of which 2,4-ditertbutylphenol was the most potent anti-diabetic agent recommended to serve as a lead compound in the new anti-diabetic drugs development (Fagbohun et al. 2020).

The wild edible plants are sources of various bioactive compounds among others different polyphenolic compounds (phenolic acids, flavonoids, tannins, lignans), dietary fibers, carotenoids, essential oils, terpenoids, steroids, glucosinolates, alkaloids, vitamins C and E. Such bioactive compounds were known to impart diverse antioxidant roles (free radical scavengers, proton donors, electron acceptors, quenchers of singlet oxygen, peroxides inactivators, pro-oxidant metal ion chelators, quenchers of secondary oxidation products and inhibitors of pro-oxidative enzymes), bolstering of antioxidant enzymes in the prevention of unsaturated lipids sensitive to oxidation in foods and human cell membranes (Shahidi & Zhong 2015). Such anti-oxidants' role, protect cells' integrity from oxidative stress injury (damages to cell membranes, DNA, proteins, lipids, and other compounds of the cells) and the development of inflammation which is the hallmark of degenerative human diseases (various cardiovascular diseases, type 2 diabetes mellitus and cancers). Also, the anti-microbial effects of the prevention of infectious diseases by the edible plants' bioactive compounds were highlighted. These edible plants are making parts of regular diets in the indigenous foods/dishes and beverages and in the coming section processing of such traditional diets are described.

Gumare village plant-based traditional foods/dishes

The list of traditional foods/dishes extracted from the 34 respondents interviewed from Gumare village is given in Table S1. The information described below is the synthesis of the respondents' responses as well as the FGD finding.

Tswii

This is prepared from water lily (*Nyphaeae* Burm. *f. var. caerulea* (Savigny) Verdc.) tuber (Fig. 2A), meat, salt, and edible cooking oil. The black outer cover of the tuber is peeled off using a knife, the tuber is cut into small pieces to increase surface area and speed up cooking. Meat (with bones) is cut into small pieces and then placed at the bottom of a cooking pot. The tuber pieces are then placed on top of the meat and water is added. If the meat is lean, edible cooking oil can be added otherwise the product can be prepared without cooking oil. The meat and tuber are cooked together over an open fire until they are soft, and the meat starts to fall apart off the bones. Once the mixture of meat and tuber have cooked and become soft, they are left to cool for some time. Then salt is added to taste, and the meat and the tuber are crushed into smaller even pieces. Once the meat and tuber pieces have well mixed, the nutrient-dense product is ready to be served on its own or with maize or sorghum porridge (Fig. 2B). No taboos were indicated but some participants informed that it could cause diarrhoea in some people. The diarrhoea is probably caused because of contamination due to improper product handling, processing, or storage. This product can be functional in that the meat products were enhanced from waterlily tubers dietary fibers and other carbohydrates with the possible potential of prebiotic effects (Zhu 2017). The product can be stored at room temperature for 24 h and is available all year round, but the most reliable time is between May and August when the rivers are running for *Tswii* tuber harvest.

Roasted groundnuts snack

Dried groundnuts are cleaned and roasted in a pot while being turned continuously until they turn light brown, and salt is added. This product was said to be dense in nutrients with no taboos, or food safety challenges indicated. It can be stored for up to five days and is available throughout the year.

Bogobe Jwa Mabele and sardines

This dish is prepared from sorghum flour, sardine fish, and water. The sardines are first cooked in water until soft, sorghum flour is mixed with the sardines making sure that the product does not become thick. The mixture is then cooked for an extra 30 min and then served. Sorghum porridge cooked with sardine fish in such a manner will be anticipated to improve the protein quality in which sorghum's major protein kafirin is known to be inherently poor for its digestibility as well on omega-3 fatty acids profiles of the porridge supplied from fish. No taboos were indicated, the product can be stored at room temperature for 12 h and is available throughout the year.

Morula kernel snack

The morula tree fruit seeds are cut open using a sharp hacking tool to remove the edible white nut. The product is usually eaten raw and is rich in oils (high in oleic mono-unsaturated fatty acid) and proteins with essential amino acids (Mashau et al. 2022). It can be stored for a week and no food safety or taboos were indicated and are available throughout the year.

Roasted pumpkin seeds snack and soup

The pumpkin seeds are roasted in a pot until brown and consumed as a snack. The roasted seeds can be further processed into a soup by pounding using a mortar and pestle. The soup is usually cooked in water for about 30 min. As a nut, the product is rich in oils, proteins, and antioxidants (tocopherol, polyphenols, flavonoids, and beta-carotene) (Gargi et al. 2022). No food safety and taboo challenges were indicated. Roasted seeds can be stored for a day at room temperature. The soup is

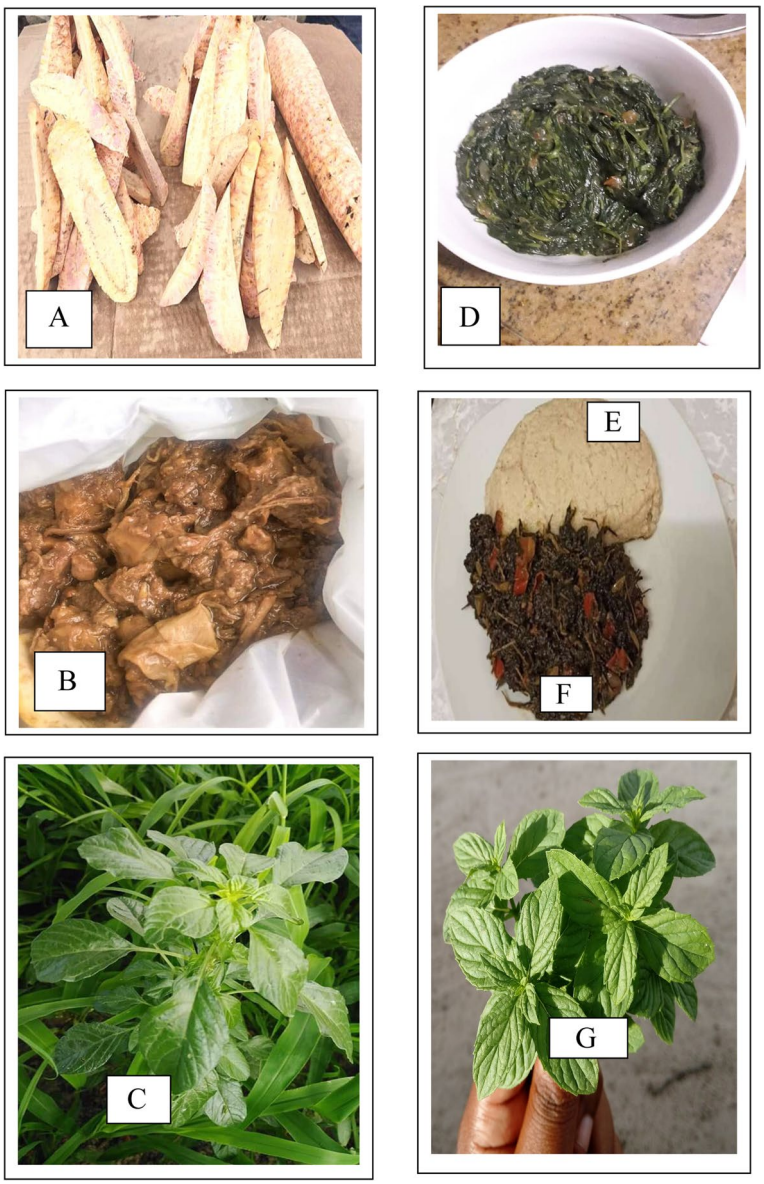

Fig. 2 Traditional foods/dishes **A** uncooked Tswii, **B** cooked Tswii, **C** Thepe leaves, **D** cooked Thepe, **E** Bogobe Jwa Mabele, **F** cooked leketa leaves, **G** Kwena leaves

reported to be safe for the whole family and can be stored at room temperature for the whole day. The products are available from January to February.

Bogobe jwa Babu

This dish is prepared from Babu melon, sour milk, and sorghum flour. Melon is washed, sliced, the seeds removed, and the pulp is sliced, and cooked in water in a pot until very soft. To the soft pulp cooked, sour milk is added, followed by sorghum flour and then the mixture is simmered for some minutes. The product was indicated to be nutrient-dense, but in some people, it causes indigestion (stomach upset) and pain in the upper stomach area. The sorghum porridge consumed in such a manner can be described as improved with nutrients and bioactive compounds contributed from sour milk and melon pulp. It can be stored for 24 h at room temperature and is available during harvest season or from March to June.

Thepe

This is a traditional vegetable dish prepared from *Thepe* (*Amaranthus thunbergii*) leaves (Fig. 2C), lemipi (animal

fat), salt and water. The leaves are thoroughly washed to remove dirt and soil, cooked in a pot by adding some water for a while, then a bit of animal fat (pounded), salt and further cooked for about 30 min (Fig. 2C). This product was indicated to be nutrient-dense, and no taboos or food safety issues were indicated. As a cooked leafy vegetable, this product will contribute toward mineral (notably Ca, K and Mg) and antioxidant (polyphenolic and flavonoids) intake (Jiménez-Aguilar & Grusak 2017). Under room temperature, the product can be kept for 24 h and is available from January to March.

Lebowa (mushroom)

This is a snack prepared using wild mushrooms and milk. Soft particles from the mushroom are first removed by dusting and then cooked with milk in a pot for about 20 min. This nutrient-dense product was indicated free of taboos. Mushrooms are recognized for desirable nutrients and bioactive compounds for use in functional foods and nutraceuticals (Rathore et al. 2017). When cooked with milk in such a manner it could be anticipated to significantly improve the health and wellness of the people. Under room temperatures, the snack can be stored for a day and is available from January to May.

Boiled Lephutse (pumpkin; *Cucurbita pepo* L.)

The pumpkin is first washed and sliced, and the seeds are removed. The seedless slices are cut into medium-sized pieces and cooked with a little bit of water for 20 min. Then pumpkin fruits are valued for their nutrients and bioactive compounds notably cucurbitacins, carotenoids (beta-carotene, lutein and beta-cryptoxanthin) and pectins, and with cooking the bioavailability of carotenoids is enhanced (Hussain et al. 2022; Montesano et al. 2018). Consumption of this product could be anticipated to contribute toward pro-vitamin A and antioxidant intakes. No taboos are indicated, and the product can be stored as cooked fresh for 24 h under room temperatures and is available from March to July.

Cooked dried sorghum

This dish is prepared from dried sorghum grains, water, cooking oil /animal fat and salt. Sorghum grains are cleaned, washed, and cooked in water until soft, cooking oil or pounded animal fat are added before adding salt for taste. This product was indicated to help with constipation most probably because of dietary fibers from whole grains and oils used in the cooking as well the contribution toward whole grains intake and phenolic antioxidants from whole sorghum grains could be significant (Rashwan et al. 2021; van der Kamp et al. 2022). No food safety issues, and taboo were reported. The product can be stored at room temperature for 24 h. This product can be available throughout the year depending on the quantity of sorghum harvested and stored.

Nkadi (tsaro tuber/root)

Freshly dug nkadi (*Phoenix reclinata* Jacq) tuber/root is used to make nkadi. The outer cover of the tuber is removed, washed, cut into medium-sized pieces, and cooked in water until soft, after then ready for consumption. Elsewhere, extracts from *Phoenix reclinate* were described to treat epilepsy, erectile dysfunction, stomach-ache, and kidney damage (Namuleme et al. 2017) and whether the intake of this diet would have such roles demand further investigation. No food safety and taboo challenges were indicated, and the product is usually eaten immediately, and is available throughout the year.

Roasted ghao

Roasted ghao is made from the inner part of a young palm (*Phoenix reclinata* Jacq. and *Hyphaene petersiana* Klotzsch ex Mart.) tree stem. The stem covers are removed leaving the inner part, put directly on the fire and more firewood is piled on top. It is left in between the firewood for three hours, then taken off and the remaining covers removed until the inner soft tissues called *ghao* are exposed. After cooling, the *ghao* is eaten. Roasted ghao may cause diarrhoea for some individuals, but no taboos were indicated. The reason that causes diarrhoea requires further investigation, whether it has chemical aetiology because of ghao compositions or is by contamination of pathogenic microorganisms since during processing of ghao, there is firewood use and after processing it may be also infected by pathogenic microorganisms because of poor hygiene and sanitation on handling and storage. *Phoenix reclinate* was reported to treat digestive system and nutritional disorders in traditional medicine (Gruca et al. 2015) and whether these effects are related to diarrhoea requires further investigation. The product can be stored for a day at room temperature and is available all year round.

Morogo wa Lephutshe

This is processed from baby pumpkin leaves, small pumpkins, salt, and water. The pumpkin is cut into small pieces and put at the bottom of a pot, leaves are washed, and placed on top of the pumpkin before adding water and cooked for about 30 min. Salt is added when the pumpkin is soft. This product is said to be nutrient-dense, and no food safety nor taboos were indicated. The pumpkin (*Cucurbita pepo*) leaves because of protein, fiber, pro-vitamin A carotenoids (194 µg RE/100 g), folates (36 µg/100 g) (Uusiku et al. 2010), mineral (potassium, calcium, magnesium, iron and zinc), bioactive cucurbitacins and phenolic compounds, beneficial health effects

as a booster of haemoglobin in the red blood cells (Gargi et al. 2022), anti-oxidants, anti-inflammatory, prevention of arthritis, anti-cancer and anti-microbial effects (Montesano et al. 2018) were reported. Morogo wa lephutshe can be stored for a day at room temperature and is available from January to February.

Dried Lephutshe (pumpkin) seeds soup

This is processed from lephutshe melon, salt, and water. The melon seeds are roasted until turned brownish, cooled, and pounded using a mortar and pestle and cooked in a pot in a small amount of water for at least 30 min, salt is added for taste and then served. The product was indicated to provide satiety for the family and no taboos were indicated. As seed oils soup, it could provide fatty acids, proteins, and from seeds coats dietary fibers (Gargi et al. 2022). The product can be kept at room temperature for a day and available for the whole year.

Leketa

Leketa is a leafy vegetable prepared from the *leketa/rothwe* (*Cleome gynandra* L) leaves, animal fat, salt, and water. The leaves are cleaned, washed, and boiled in water together with animal fat for about 10 min (until both are completely cooked). Salt can be added along with other ingredients or during the boiling step and then served as a relish with *Bogobe Jwa Mabele* (Fig. 2E) or alone (Fig. 2F). The product is indicated to be rich in vitamin C and good for digestion; and this diet could be beneficial for the supply of minerals, phenolics, flavonoids, carotenoids and glucosinolates (Omondia et al. 2017). The product was indicated to cause diarrhoea in some individuals. It is highly advised that during harvesting, the leaves are not crushed as it can result in a bitter tasting cooked product. Crushing the leaves can lead the substrate to react with enzymes, probably resulting in compounds that create a bitter and unpleasant taste.

Bogobe Jwa Nxoko

The raw materials for this gruel are mabele (sorghum) flour, nxoko melon, fresh milk, and water. During preparation, the melon is washed, sliced to remove seeds, and cooked in a pot until very soft. Thereafter, mabele flour is added and mixed with the pulp, the mixture is left to simmer for a while and the milk is poured when the sorghum melon pulp is well cooked. The ingredients are then mixed and left to simmer for 10 min. Although this product is nutrient-dense, it may not go well with lactose-intolerant individuals. For individuals who are lactose intolerant, sour milk can be used. No taboos were indicated, the product can be stored at room temperature for a day and is mostly available from February to July.

Gumare village plant-based traditional beverages

The list of traditional beverages extracted from the 34 respondents interviewed from Gumare village is given in Table S2. The information described below is the synthesis of the respondents' responses as well as the FGD finding.

Motlopi drink

Motlopi (*Boscia albitrunca* (Burch.) Gilg & Benedict) fruits are washed, the skin from each fruit is removed and the fruits are placed in a different container. Milk is poured into the fruits and whisked until a thick orange drink is achieved. The liquid drink is decanted leaving the seeds and then consumed immediately. The beverage is indicated to be high in vitamin C with no food safety and taboos challenge. In the product, the possibilities of both water and milk soluble nutrients extraction from the fruits are high. This product is like an industrially processed milkshake fruit product. The product can be stored for a day at room temperature and is available from February to June when motlopi fruits are in season. Some also indicated it is available throughout the year probably from motlopi fruits preserved by drying (Maroyi 2019a, 2019b).

Ghao powder + Cow's milk drink

The inner part of a young palm tree stem (ghao) is cooked/boiled and pounded with mortar and pestle until powder forms. The powder is mixed with cow milk and served. The beverage may cause diarrhoea to some people, but no taboos are indicated. Diarrhoea may be caused by contamination in the processing probably during pounding ghao conversion into powder. The ghao powder processed from young palm stem can add fibers and sugars to the milk and probably with beneficial pre-biotic effects. The beverage is immediately consumed and is available throughout the year.

Kwena milk

In the processing, Kwena (*Mentha aquatica* L.) leaves (Fig. 2G) are washed and boiled with milk in a pot for about 10 min, after which it will be then immediately consumed while hot. The beverage is said to lower blood pressure, and relieve cough, influenza, and bad breath. Likely, bioactive compounds (essential oils and phenolic compounds) (Benabdallah et al. 2016; Getahun et al. 2008) from Kwena leaves are leached into the beverages for health support. The beverage is refreshing and can be stored for about 8 to 12 h at room temperature. The dried leaves of Kwena can be stored for about a year. No food safety and taboos were indicated. The beverage is available from October to June. The

Kwena leaves tea can be also made using brown sugar and water.

Lengangale drink

The dried melon [*Citrullus lanatus* var. citroides (L. H. Bailey) Mansf] fruits pulp and rind are boiled in water in a pot for about 10 min, and the decanted liquid is served immediately while warm. The drink is indicated to be refreshing with no food safety issues and taboos reported. The drink is available throughout the year because lengangale is a dried preserved product.

Moretologa drink

Moretologa (*Ximenia* spp.) fruits are cleaned, and skins are removed and transferred into a different container. Milk is poured and whisked together until a thick consistency is achieved. The seeds of the fruits are removed, and the drink is consumed immediately. Also, moretologa fruits drink can be made using water without milk. The moretologa fruits are valued for their high total phenolic, flavonoids, vitamin C, carbohydrates (fibers and sugars) and mineral (potassium, phosphorus and magnesium) contents (Goosen et al. 2018), and when consumed with milk it could abundantly supply such bioactive compounds and significant nutrients as diet. No food safety and taboos challenges were indicated except to some it can cause setshwabu (seizures) in some people. The beverage is available from October to July.

Mowana drink

Mowana (*Adansonia digitata* L.) fruits are cleaned, their powder is removed and put in the bowl to which cow milk is poured, and whisked together until the mixture turns into yoghurt, mowana seeds are removed and then the beverage is served. No food safety and taboos were indicated. Consumption of *Adansonia digitata* fruits in this manner makes the product nutrient-dense (vitamin C, dietary fibers and minerals Ca and K), functional foods enriched with bioactive compounds among others by phenolic compounds from the *Adansonia digitata* fruits (Chadare et al. 2009; Ismail et al. 2021). The beverage can be stored for a day at room temperature. The beverage was indicated to be available from April to July when the fruits are in season.

Motlopi coffee

Motlopi (*Boscia albitrunca* (Burch.) Gilg & Benedict) roots are cleaned and roasted in a pot until it becomes brownish. The roasted roots are pounded with mortar and pestle until are powder. Water is boiled and motlopi root powder is added and boiled for 10 min, milk is added, further boiled for another 5 min and then the beverage is served with sugar. The beverage helps in the reduction of high blood pressure presumably because of its fibers from the roots (Maroyi 2019a, 2019b). No food safety and taboo challenges were indicated. The beverage can be stored for a day at room temperature and is available throughout the year.

Ipwaka

Sorghum bran along with water and sugar in a container is covered with a blanket for warming and allowed to ferment for about 24 h. After that, it is decanted, and the alcoholic beverage is collected in a clean container and then served. The sorghum bran supplies micronutrients and contributes somewhat free amino nitrogen and fermentable substrates to the sugar brew (Rashwan et al. 2021). The beverage is refreshing with no taboos indicated. But on food safety, it was indicated in some individuals it causes diarrhoea. The beverage can be stored for about 2 to 3 days and is available throughout the year.

Moxhinxha juice

Moxhinxha/tsaro/moxinxa-mokulane (*Phoenix reclinata* Jacq) is cleaned, sun-dried for two days, pounded nicely to powder without crushing the seeds and sieved to separate seeds from the powder. The powder is placed in a bowl to which milk is added and whisked after then immediately consumed. The *Phoenix reclinate* fruits in this product could contribute significant total phenolics of high antioxidant capacity, fibers and different sugars (Amorós et al. 2014). As a diet, it can be regarded improved both in terms of bioactive compounds and nutrient supply. No food safety and taboos were indicated. The beverage can be stored for a day at room temperature and is available from November to April.

Mokgalo coffee

Mokgalo (*Ziziphus mucronata* Wild.) fruits are cleaned and roasted in a pot with a lid on until they turn brownish. The roasted mokgalo fruits are put in a pot, water is added, and boiled until the brew becomes brownish, milk is added and further boiled for 3 min, then served immediately with sugar while hot. The *Ziziphus mucronate* fruits are known to taste bitter probably this aspect is one driving factor for its use as a coffee substitute; and from the different parts of the plant cyclopeptide alkaloids, from the fruit carotenoids, vitamin C, flavonoids, tetracyclic triterpenoid saponins, from the seed minerals (potassium, phosphorus, calcium, magnesium, sodium, iron, and zinc) were reported (Mongalo et al. 2020). No food safety and taboos were indicated. The beverage is available from March to August.

Fig. 3 Traditional beverages. **A** juice tapping from palm (Mokolwane), **B** beverage from palm stem sap extract

Mokolwane/Motjema drink

The peels from the mokolwane (*Hyphaene petersiana* Klotsch ex Mart) stem are removed using a knife to get the fleshy part and then the exudates are tapped in bottles (Fig. 3A). The collected sap is fermented into palm wine (Fig. 3B). The palm wine is one of the traditional beverages in Botswana that support the livelihood of palm exudate tappers and cottage wine producers. The contents obtained can be also dried in the sun for about two days, and pounded using mortar and pestle until powder, cow milk is added and whisked together until a thick consistency is achieved (like a fruit juice milkshake) and then served. In this aspect different sugars from mokolwane stem sap of different sweetening properties are incorporated replacing table sugar. No food safety and taboos were indicated. The drink can be stored at room temperature for one day and is available from August to October.

Challenges indicated

The preparation of most of the products is time-consuming, tedious, and labour-intensive. Furthermore, for those raw materials collected from veld or rivers, attacks from wild animals and youngsters' limitations in farming activities were the challenges (Table 4). For fermented alcoholic beverages, fermentation takes a long time and no regulations on alcohol content were mentioned. Intervention for example through the development of guidelines and youngster education on precautions will be beneficial to maximize the exploitation of the resources and for safety. Studies on fermentation nature to optimize recipes, processing parameters and development of starter culture could be a remedy for challenges observed in the fermented products. Nursery development for the cultivation of wild plants around the homestead is another option to avoid searching from the area that can predispose to wild animals' attack.

The respondents indicated that in their village, 60% and 62% of the people still eat traditional foods/dishes and drink beverages, respectively, while 40% and 38%, respectively do not eat and drink them. Some 53% of respondents indicated that there is still knowledge on both the preservation of traditional foods/dishes and beverages in their community. Whereas 47% have indicated that such knowledge is fading away. The reasons mentioned for the decline in the preservation and eating of traditional foods/dishes, and beverages drinking include a preference for readily available exotic foods, limited interest in agriculture as well as traditional foods and beverages among the youth. In addition, respondents indicated the decline of raw material in the environment, traditional food and dishes being less tasty compared to exotic foods, length of time taken to prepare traditional food and beverages and limited opportunity for the youth to learn how to prepare traditional foods and beverages from their parents. Other reasons raised were the influence of urbanization and the decline in the number of people who grow crops due to ageing, conflict with the law as some people add toxic and/or harmful substances to traditional beverages leading to fatalities.

Table 4 Challenges concerning particular indigenous foods/dishes and beverages- response from Gumare village

Challenges	Indigenous foods/dishes and beverages																											
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	1	2	3
Time consuming		+	+		+		+	+		+		+	+	+	+	+		+			+			+		+	+	+	+
Time consuming and tedious																		+											
Labour intensive	+					+					+	+	+					+				+							
Seasonal ingredients						+						+								+					+	+			
Uses a lot of firewood																	+												
Risk from Alligators/Reptiles attacks when collecting fish			+						+																				
Danger from attack by reptiles e.g. snakes																			+				+						
Danger from attack by wild animals														+															
Danger from attack by predators when collecting raw materials in the veld				+									+																
Danger from attack by wild animals when collecting fruits												+						+											
Fermentation takes long time												+																	
Alcohol content not monitored												+						+											

Where A = Beans (ditloo), B = Bogobe Jwa Phoka (grass), C = Bogobe Jwa Tlhapi, D = Bogobe Jwa Torobela (pumpkin), E = Boiled maraka, F = Dikgobe (beans and lechotlho), G = Dikgobe (beans, maize/samp), H = Dinawa + Thonga (groundnuts), I = Fish, J = Ghao powder + cows milk drink, K = Ipwaka, L = Khadi, M = Kwena, N = Leketa, O = Lengangale, P = Leswabi, Q = Maize beverage, R = Mberera, S = Mokolwane drink, T = Moretologa drink, U = Morula beer, V = Motlopi drink, W = Moxhinxha juice, X = Mushroom (Iebowa), Y = Nkadi (Tsaro tuber), Z = Nyebu, 1 = Roasted ghao, 2 = Thepe (morogo/ relish), 3 = Tswii (water lily) and "+" = indicate challenge described toward a given indigenous foods/dishes and beverages

Conclusions

In Gumare village, the study showed that there were 52 wild and 19 domesticated edible plants used for processing traditional foods/dishes and beverages. The wild edible plant parts were either used directly after minor processing or as recipes in traditional dishes and/or beverages. There was a wide diversity of wild edible plants and domesticated crops because Gumare village is in the Okavango River Delta catchment area. The diversity shows, contributions towards diet diversification for food security and to combat malnutrition.

However, for most wild edible plants from Botswana, nutrient information and bioactive compounds are limited. The community elders in the village indicated that there is a decline in the use of traditional foods/dishes and beverages, particularly among the young generation. Among others, the time-consuming nature of processing and the risk of attacks by wild animals when acquiring the raw materials were reported as challenges for the readily available traditional foods and beverages. This study provided baseline information for a further chemical investigation, and the development of resources, for example, through planting backyard nurseries.

Gumare village plant-based traditional foods/dishes and beverages also include the following foods/dishes and beverages, the processing descriptions of which were already published (Bultosa et al. 2020).

Foods/dishes

Bogobe Jwa Mabele (Mosokwane), Borekhu, Beans/Nyebu (Ditloo or Letlhodi cooking), Samp mixed with beans (Setampa sa dinawa), Morogo wa dinawa, Dried maize and bean (Dikgobe), Bogobe Jwa Mmidi, Ntshwatshwa (Lechotlho), Bogobe Jwa Torobela (Bogobe Jwa Lekatane/lerotse), Lengangale, Leswabi, Leowane, Lerotse/Lekatane/Makatane/Marotse, Lekgomane/ Legodu/Makgomane/Maraka.

Beverages

Bojalwa Jwa Ila, Khadi, Mberera (traditional sorghum beer), Morula beer, Mosukujwane tea.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s43014-023-00142-3.

Additional file 1: Table S1. Frequency among 34 respondents described on the nature (processing, value, safety, taboos, storage, availability) of different indigenous plant-based foods/dishes of Gumare village.

Additional file 2: Table S2. Frequency among 34 respondents described on the nature (processing, value, safety, taboos, storage, availability) of different indigenous plant-based beverages of Gumare village.

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Authors' contributions

NT conducted FGD and edited the manuscript (MS). GB led the research, participated in FGD, drafted, and edited the MS. GM supplied photographs of foods/dishes and extracted descriptions of traditional foods/dishes and beverages from survey questionaries. MM served as the co-team leader and participated in FGD. SM provided the scientific names and edited MS. RKL, GDH, ES and BSM edited the MS. KS participated in FGD and served as rapporteur on FGD. All authors contributed as members of the research team, read, and approved the MS.

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Availability of data and materials

All data are included in this manuscript. Further details can be available from the corresponding author upon request.

Declarations

Ethics approval and consent to participate

The research was approved by Research and Publication Committee (RPC) currently called the Research Technology Development & Transfer Committee (RTDTC) of Botswana University of Agriculture and Natural Resources (BUAN). The survey was conducted after getting verbal consent from the participants and the permit from the District Authority and the Chief of Gumare village.

Consent for publication

Not applicable.

Competing interest

The authors declare that they have no competing interests.

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References

Ahmed, A. H., & Mahmud, A. F. (2017). Pharmacological activities of *Diospyros mespiliformis*: A review. *International Journal of Pharmacy and Biological Sciences, 7*(4), 93–96.

Amorós, A., Rivera, D., Larrosa, E., Obón, C. (2014). Physico-chemical and functional characteristics of date fruits from different Phoenix species (*Arecaceae*). *Fruits*, *69*,315–323: https://doi.org/10.1051/fruits/2014020.

Angsongna, A., Armah, F. A., Boamah, S., Hambati, H., Luginaah, I., Chuenpagdee, R., & Campbell, G. (2016). A systematic review of resource habitat taboos and human health outcomes in the context of global environmental change. *Global Bioethics, 27*(2–4), 91–111. https://doi.org/10.1080/11287462.2016.1212608.

Bello, I., Shehu, M.W., Musa, M., Asmawi, M.Z. & Mahmud, R. (2016). Review: *Kigelia africana* (Lam.) Benth. (Sausage tree): phytochemistry and pharmacological review of a quintessential African traditional medicinal plant. *Journal of Ethnopharmacology*, *189*, 253–276. https://doi.org/10.1016/j.jep.2016.05.049.

Bekker, B. P. & De Wit, P. (1990). *Vegetation Map of the Republic of Botswana. Soil Mapping and Advisory Services Project*. AG: DP/BOT/85/011. FAO, Ministry of Agriculture, Gaborone.

Benabdallah, A., Rahmoune, C., Boumendje, M., Aissi, Q., & Messaoud, C. (2016). Total phenolic content and antioxidant activity of six wild Mentha species (*Lamiaceae*) from northeast Algeria. *Asian Pacific Journal of Tropical Biomedicine, 6*(9), 760–766. https://doi.org/10.1016/j.apjtb.2016.06.016.

Bille, P. G. (2013). Effect of *Boscia albitrunca* (Omukunzi) root on the bacteriology and viscosity of Omashikwa, traditional fermented buttermilk from Namibia. *African Journal of Food, Agriculture, Nutrition and Development, 13*(4), 7927–7943.

Braide, W., Dokubo, K. O., Adeleye, S. A., Uzoh, C. V., & Akobundu, C. I. (2018). Phytochemical properties, toxicological screening and antibacterial qualities of various parts extracts of *Ficus sycomorus*. *Journal of Medicinal Plant and Herbal Therapy Research, 6*, 1–8.

Brown, C., Shaibu, S., Maruapula, S., Malete, L., & Compher, C. (2015). Perceptions and attitudes towards food choice in adolescents in Gaborone, Botswana. *Appetite, 95*, 29–35. https://doi.org/10.1016/j.appet.2015.06.018.

Bultosa, G., Molapisi, M., Tselaesele, N., Kobue-Lekalake, R., Haki, G. D., & Makhabu, S.,… Nthoiwa, G.P. (2020). Plant-based traditional foods and beverages of Ramotswa Village, Botswana. *Journal of Ethnic Foods, 7*(1), 1–15. https://doi.org/10.1186/s42779-019-0041-3.

Chadare, F.J., Linnemann, A.R., Hounhouigan, J.D., Nout, M.J.R. & Van Boekel & M.A.J.S. (2009). Baobab food products: A review of their composition and nutritional value. *Critical Reviews in Food Science and Nutrition, 49*(3), 254–274, https://doi.org/10.1080/10408390701856330.

Cheikhyoussef, A., Naomab, E., Potgieter, S., Kahaka, G., Raidron, C. & Ashekele, H.M. (2010). Phytochemical properties of a Namibian indigenous plant; Eembe (*Berchemia discolor*). In: proceeding of the first national research symposium, Windhoek, Namibia, pp 313–321.

Cheikhyoussef, A. & Maroyi, A. (2017). Bird plum; *Berchemia discolor* (Klotzsch) Hemsl: A review of its ethnobotany, phytochemistry and pharmacology. In M. Neffati, H. Hanen & A. Máthé (Eds.), *Medicinal and Aromatic Plants of the World - Africa* (pp143–155), Volume 3, Springer Nature, The Netherlands, https://doi.org/10.1007/978-94-024-1120-1.

Crane, P.R., Ge. S., Hong, D.Y., Huang, H.W., Jiao, G.L., Knapp, S.,…Zhu, Y-X. (2017). (Shenzhen Declaration Drafting Committee). The Shenzhen declaration on plant sciences -uniting plant sciences and society to build a green, sustainable Earth. *PhytoKeys*, 86, 3–7, https://doi.org/10.3897/phytokeys.86.20859.

Darkoh, M.B.K. & Mbaiwa, J.E. (2014). Okavango delta – a Kalahari Oasis under environmental threats. *Journal of Biodiversity and Endangered Species*, 2(4), 1–6, https://doi.org/10.4172/2332-2543.1000138.

Denbow, J., & Thebe, P. C. (2006). Chapter 5 - Cuisine and Traditional Dress. In T. Falola (Ed.), *Culture and Customs of Botswana* (pp. 107–133). Greenwood Press.

Dube, O. P., & Pickup, G. (2001). Effects of rainfall variability and communal and semi- commercial grazing on land cover in Southern African rangelands. *Climate Research, 17*, 195–208.

Dube, O.P. (2008). Estimating woody plant density from aerial photographs in communal and leasehold land tenure systems in Northwest Botswana. *Journal of Environmental Informatics*, 11(2), 131–145, https://doi.org/10.3808/jei.200800117.

Dushimemaria, F., Mumbengegwi, D.R., Du Preez, I. & Bock, R. (2012). Qualitative phytochemical screening and *in vitro* antimicrobial effects of plant extracts of *Searsia tenuinervis*. *Journal of Research in Microbes*, 1(2), 088–095, https://jmicrobes.com, https://jmicrobes.com.

El-Beltagi, H.S., Mohamed, H.I., Abdelazeem, A.S., Youssef, R. & Safwat, G. (2019). GC- MS analysis, antioxidant, antimicrobial and anticancer activities of extracts from *Ficus sycomorus* fruits and leaves. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 47(2), 493–505, https://doi.org/10.15835/nbha47211405.

Elhassan, G.O.M. & Yagi, S.M. (2010). Nutritional composition of Grewia species (*Grewia tenax* (Forsk.) Fiori, *G. flavescens* Juss and *G. Villosa* Willd) fruits. *Advance Journal of Food Science and Technology*, 2(3), 159–162.

Eltahir, M.E.S. & Elsayed, M.E.O. (2019). Chapter 11. *Adansonia digitata*: phytochemical constituents, bioactive compounds, traditional and medicinal uses. In A.A. Mariod (Ed), *Wild Fruits: Composition, Nutritional Value and Products* (pp133–142), Springer Nature Switzerland, https://doi.org/10.1007/978-3-030-31885-7_11.

Fagbohun, O.F., Oriyomi, O.V., Adekola, M.B. & Msagati, T.A.M. (2020) Biochemical applications of *Kigelia africana* (Lam.) Benth. fruit extracts in diabetes mellitus. *Comparative Clinical Pathology*, 1–15, https://doi.org/10.1007/s00580-020-03179-9.

FAO. (2021). *Alliance of Biodiversity International and CIAT. Indigenous Peoples' Food Systems: Insights on Sustainability and Resilience in the Front Line of Climate Change*, Rome, pp. 1–420, https://doi.org/10.4060/cb5131en.

Feyssa, D.H., Njoka, J.T., Asfaw, Z. & Nyangito, M.M. (2012). Nutritional value of *Berchemia discolor*: a potential to food and nutrition security of households. *Journal of Biological Sciences*, 12, 263–271, https://doi.org/10.3923/jbs.2012.263.271.

Gargi, A., Sharma, M., Surapaneni, B.R. & Gowda, S. (2022). Cucurbita: a cavernous account of bioactive compounds and potential therapeutic agents. *The Pharma Innovation Journal*, 11(6): 1836–1842, www.thepharmajournal.com.

Goosen, N. J., Oosthuizen, D., Stander, M. A., Dabai, A. I., Pedavoah, M.-M., & Usman, G. O. (2018). Phenolics, organic acids and minerals in the fruit juice of the indigenous African sourplum (*Ximenia caffra*, Olacaceae). *South African Journal of Botany, 119*, 11–16. https://doi.org/10.1016/j.sajb.2018.08.008.

Getahun, Z., Asres, K., Mazumder, A. & Bucar, F. (2008). Essential oil composition, antibacterial and antioxidant activities of *Mentha aquatica* growing in Ethiopia. *Ethiopian Pharmaceutical Journal*, *26*, 9–16, https://doi.org/10.4314/epj.v26i1.35128.

Gupta, A.K. & Jain, A. (2019). Phyto-chemical and therapeutic briefing of *Kigelia Africana* (Lam.) Benth. *Indian Journal of Pharmaceutical and Biological Research*, 7(1),14–23, https://doi.org/10.30750/ijpbr.7.1.4.

Gruca, M., Blach-Overgaard, A., & Balslev, H. (2015). Review: African palm ethno- medicine. *Journal of Ethnopharmacology, 165*, 227–237. https://doi.org/10.1016/j.jep.2015.02.050.

Hegazy, A.K., Mohamed, A.A., Ali, S.I., Alghamdi, N.M., Abdel-Rahman, A.M. & Al- Sobeai S. (2019). Chemical ingredients and antioxidant activities of underutilized wild fruits. *Heliyon*, *5*, e01874, https://doi.org/10.1016/j.heliyon.2019.e01874.

Hiwilepo-van Hal, P., Bille, P. G., Verkerk, R., & Dekker, M. (2013). The effect of temperature and time on the quality of naturally fermented marula (*Sclerocarya birrea* subsp. Caffra) juice. *LWT - Food Science and Technology, 53*, 70–75. https://doi.org/10.1016/j.lwt.2013.02.021.

Hussain, A., Kausar, T., Sehar, S., Sarwar, A., Ashraf, A. H., & Jamil, M.A.,…Majeed, M.A. (2022). A comprehensive review of functional ingredients, especially bioactive compounds present in pumpkin peel, flesh and seeds, and their health benefits. *Food Chemistry Advances, 1*, 1–10. https://doi.org/10.1016/j.focha.2022.100067.

Ilfergane, A. (2016). Investigations on the effects of *Typha capensis* on male reproductive functions. A dissertation submitted in fulfilment of the requirements for the degree of Philosophiae Doctor (PhD), Department of Medical Biosciences University of the Western Cape, South Africa.

Ismail, B. B., Guo, M., Pu, Y., & Çavus, O.¸ Ayub, K.A., Watharkar, R.B.,… Liu, D. (2021). Investigating the effect of *in vitro* gastrointestinal digestion on the stability, bioaccessibility, and biological activities of baobab (*Adansonia digitata*) fruit polyphenolics. *LWT - Food Science and Technology, 145*, 1–8. https://doi.org/10.1016/j.lwt.2021.111348.

Jiménez-Aguilar, D., & Grusak, M. A. (2017). Minerals, vitamin C, phenolics, flavonoids and antioxidant activity of *Amaranthus* leafy vegetables. *Journal of Food Composition and Analysis, 58*, 33–39. https://doi.org/10.1016/j.jfca.2017.01.005.

Joseph, K.S., Bolla, S., Josh, K., Bhat, M., Naik, K., Patil, S.,…Murthy, H.N. (2017). Determination of chemical composition and nutritive value with fatty acid compositions of African mangosteen (*Garcinia Livingstonei*). *Erwerbs-Obstbau*, 59, 195–202, https://doi.org/10.1007/s10341-016-0311-9.

Kamatou, G. P. P., Vermaak, I., & Viljoen, A. M. (2011). An updated review of *Adansonia digitata*: A commercially important African tree. *South African Journal of Botany, 77*, 908–919. https://doi.org/10.1016/j.sajb.2011.08.010.

Kasimba, S.N., Motswagole, B.S., Covic, N.M. & Claasen, N. (2017). Household access to traditional and indigenous foods positively associated with food security and dietary diversity in Botswana. *Public Health Nutrition*, 21(6), 1200–208, https://doi.org/10.1017/S136898001700369X.

Li, X.-N., Sun, J., Shi, H., Yu, L. L., Ridge, C. D., & Mazzola, E.P.,…Chen, P. (2017). Profiling hydroxycinnamic acid glycosides, iridoid glycosides, and phenylethanoid glycosides in baobab fruit pulp (*Adansonia digitata*). *Food Research International, 99*, 755–761. https://doi.org/10.1016/j.foodres.2017.06.025.

Lopes, T., Zemlin, A. E., Erasmus, R. T., Madlala, S. S., Faber, M., & Kengne, A. P. (2022). Assessment of the association between plant-based dietary exposures and cardiovascular disease risk profile in sub-Saharan Africa: A systematic review. *BMC Public Health, 22*, 361. https://doi.org/10.1186/s12889-022-12724-w.

Lugo-Morin, D. R. (2020). Indigenous communities and their food systems: A contribution to the current debate. *Journal of Ethnic Foods, 7*(6), 1–10. https://doi.org/10.1186/s42779-019-0043-1.

Magadula, J. J., & Suleimani, H. O. (2010). Cytotoxic and anti-HIV activities of some Tanzanian *Garcinia* species. *Tanzania Journal of Health Research, 12*, 1–7. https://doi.org/10.4314/thrb.v12i2.56402.

Maroyi, A. (2019a). *Boscia albitrunca*: a review of its botany, medicinal uses, phytochemistry, and biological activities. *Asian Journal of Pharmaceutical and Clinical Research*, 12 (10): 51–56, https://doi.org/10.22159/ajpcr.2019.v12i10.35337.

Maroyi, A. (2019b). Utilization of *Bridelia mollis* as herbal medicine, nutraceutical, and functional food in southern Africa: A review. *Tropical Journal of Pharmaceutical Research.* 18 (1), 203–209, https://doi.org/10.4314/tjpr.v18i1.30.

Mashau, M. E., Kgatla, T. E., Makhado, M. V., Mikasi, M. S., & Ramashia, S. E. (2022). Nutritional composition, polyphenolic compounds and biological activities of marula fruit (*Sclerocarya birrea*) with its potential food applications: A review. *International Journal of Food Properties, 25*(1), 1549–1575. https://doi.org/10.1080/10942912.2022.2064491.

McCune, L.M. & Kuhnlein, H.V. (2011). Chapter 15. Assessments of indigenous peoples' traditional food and nutrition systems. In E.N. Anderson, D. Pearsall, E. Hunn, N. Turner (Eds), *Ethnobiology*, (pp 249–266). New Jersey: Wiley, https://doi.org/10.1002/9781118015872.ch15.

Mosothwane, M.N. (2015). A note on the demographic and health pattern of a historical sleeping sickness cemetery at Letsholathebe Memorial Hospital, Maun, Botswana. *International Journal of Osteoarchaeology*, 1–8, https://doi.org/10.1002/oa.2452.

Montesano, D., Rocchetti, G., Putnik, P., & Lucini, L. (2018). Bioactive profile of pumpkin: An overview on terpenoids and their health-promoting properties. *Current Opinion in Food Science, 22*, 81–87. https://doi.org/10.1016/j.cofs.2018.02.003.

Mongalo, N.I., Mashele, S.S. & Makhafola, T.J. (2020). *Ziziphus mucronata* Willd. (*Rhamnaceae*): its botany, toxicity, phytochemistry and pharmacological activities. *Heliyon*, 6, https://doi.org/10.1016/j.heliyon.2020.e03708.

Murthy, H.N., Dalawai, D., Mamatha, U., Angadi, N.B., Dewir, Y.H., Al-Suhaibani, N.A.,…Ali Mohsen Al-Ali, A.M. (2021). Bioactive constituents and nutritional composition of *Bridelia stipularis* L. Blume fruits. *International Journal of Food Properties*, 24 (1), 796–805, https://doi.org/10.1080/10942912.2021.1924776.

Muthai, U. K., Indieka, A. S., Muchugi, A., Karori, S. M., Mng'omba, S., Ky-Dembele, C., & Jamnadass, R. (2019). Quantitative variation of fatty acid composition in seed oil from baobab (*Adansonia digitata* L.) wild populations in sub-Sahara Africa. *South African Journal of Botany, 123*, 1–8. https://doi.org/10.1016/j.sajb.2019.01.026.

Nachtergaele, F. & De Wit, P. (1990). *Soil Map of the Republic of Botswana. Soil Mapping and Advisory Services Project FAO/BOT/85/011*. Map 2 of 2.FAO, Ministry of Agriculture, Gaborone.

Nagarani, G., Abirami, A., & Siddhuraju, P. (2014). Food prospects and nutraceutical attributes of Momordica species: A potential tropical bioresource, a review. *Food Science and Human Wellness, 3*, 117–126. https://doi.org/10.1016/j.fshw.2014.07.001.

Namuleme, C.B., Ikwap, K., Tamale, A., Tumwine, G., Kateregga, J. & Kato, C.D. (2017). Nephroprotective effect of *Phoenix reclinata* total crude root extract on tenofovir induced kidney damage in wistar albino rats. *Journal of Pharmaceutical Research International*, 17(6), 1–10, https://doi.org/10.9734/JPRI/2017/34247.

Naureen, I., Saleem, A., Sagheer, F., Liaqat, S., Gull, S., Fatima, M. & Arshad, Z. (2022). Chemical composition and therapeutic effect of mentha species on human physiology. *Scholars Bulletin*, 8(1): 25–32, https://doi.org/10.36348/sb.2022.v08i01.004.

Ngadze, R.T., Linnemann, A.R., Nyanga, L.K., Fogliano, V. & Verkerk, R. (2017). Local processing and nutritional composition of indigenous fruits: The case of monkey orange (*Strychnos* spp.) from Southern Africa. *Food Reviews International*, 33 (2), 123–142, https://doi.org/10.1080/87559129.2016.1149862.

Ngadze, R. T., Verkerk, R., Nyanga, L. K., Fogliano, V., Ferracane, R., Troise, A. D., & Linnemann, A. R. (2018). Effect of heat and pectinase maceration on phenolic compounds and physicochemical quality of *Strychnos cocculoides* juice. *PLoS ONE, 13*(8), 1–13. https://doi.org/10.1371/journal.pone.0202415.

Ngadze, R. T., Linnemann, A. R., Fogliano, V., & Verkerk, R. (2019). Monkey orange fruit juice improves the nutritional quality of a maize-based diet. *Food Research International, 116*, 870–877. https://doi.org/10.1016/j.foodres.2018.09.022.

Ngemakwe, P. H. N., Remize, F., Thaoge, M. L., & Sivakumar, D. (2017). Review: Phytochemical and nutritional properties of underutilised fruits in the southern African region. *South African Journal of Botany., 113*, 137–149. https://doi.org/10.1016/j.sajb.2017.08.006.

Nyakudya, T. T., Nosenga, N., Chivandi, E., Erlwanger, K. H., Gundidza, M., & Gundidza, E.,… Muredzi, P. (2017). *Grewia bicolor* seed oil: Putative pharmaceutical, cosmetic and industrial uses. *South African Journal of Botany, 97*, 154–158. https://doi.org/10.1016/j.sajb.2015.01.004.

Nyambe, M.M., Hakwenye, H. & Benyamen, M.S. (2019). Nutritional and anti-nutritional composition of *Diospyros mespiliformis* and *Hyphaene petersiana* fruits from Namibia. *International Science and Technology Journal of Namibia*, *13*, 2–11, https://istjn.unam.na/index.php/istjn.

Oghenesuvwe, E., Erhirhie, Ilodigwe, E.E. & Ihekwereme, C.P. (2018). *Ficus sycomorus* L. (*Moraceae*): a review on its phytopharmacology and toxicity profile. *Discovery Phytomedicine*, 5(4), 64–71, https://doi.org/10.15562/phytomedicine.2018.75.

Omondia, E. O., Engels, C., Nambafu, G., Schreiner, M., Neugart, S., Onyango, M., & M. & Winkelmann, T. (2017). Nutritional compound analysis and morphological characterization of spider plant (*Cleome gynandra*) - an African indigenous leafy vegetable. *Food Research International, 100*, 284–295. https://doi.org/10.1016/j.foodres.2017.06.050.

Omotayo, A.O. & Aremu, A.O. (2020). Underutilized African indigenous fruit trees and food–nutrition security: opportunities, challenges, and prospects. Food and Energy Security, 1–16, 9:e220, https://doi.org/10.1002/fes3.220.

Rahul, J., Jain, M.K., Singh, S.P., Kamal, R.K., Anuradha, Naz, A.,…Mrityunjay, S.K. (2015). *Adansonia digitata* L. (baobab): a review of traditional information and taxonomic description. *Asian Pacific Journal of Tropical Biomedicine*, *5*(1), 79–84, https://doi.org/10.1016/S2221-1691(15)30174-X.

Rashwan, A. K., Yones, H. A., Karim, N., Taha, E. M., & Chen, W. (2021). Potential processing technologies for developing sorghum-based food products: An update and comprehensive review. *Trends in Food Science & Technology, 110*, 168–182. https://doi.org/10.1016/j.tifs.2021.01.087.

Ramalhete, C., Gonçalves, B. M. F., Barbosa, F., Duarte, N., Maria-José, U., & Ferreira, M- J.U. (2022). *Momordica balsamina*: Phytochemistry and pharmacological potential of a gifted species. *Phytochemistry Reviews, 21*, 617–646. https://doi.org/10.1007/s11101-022-09802-7.

Rathore, H., Prasad, S., & Sharma, S. (2017). Mushroom nutraceuticals for improved nutrition and better human health: A review. *PharmaNutrition, 5*, 35–46. https://doi.org/10.1016/j.phanu.2017.02.001.

Ringrose, S., Jellema, A., Huntsmanmapila, P., Baker, L., & Brubaker, K. (2005). Use of remotely sensed data in the analysis of soil-vegetation changes along a drying gradient peripheral to the Okavango Delta. *Botswana. International Journal of Remote Sensing, 26*(19), 4293–4319. https://doi.org/10.1080/01431160500113575.

Sarkar, D., Walker-Swaney, J. & Shetty, K. (2020). Food diversity and indigenous food systems to combat diet-linked chronic diseases. *Current Developments in Nutrition*; *4*: nzz099.

Salami, S. O., Adegbaju, O. D., Idris, O. A., Jimoh, M. O., Olatunji, T. L., & Omonona, S.,… Laubscher, C.P. (2022). South African wild fruits and vegetables under a changing climate: The implications on health and economy. *South African Journal of Botany, 145*, 13–27. https://doi.org/10.1016/j.sajb.2021.08.038.

Shahidi, F., & Zhong, Y. (2015). Measurement of antioxidant activity. *Journal of Functional Foods, 18*, 757–781. https://doi.org/10.1016/j.jff.2015.01.047.

Staudt, M. (2016). *Production of Environmental Hydrogeology Maps Using GIS for the Ramotswa Project Area*, Southeast District, Botswana, https://www.researchgate.net/publication/294891820.

Thakur, G.S., Bag, M., Sanodiya, B.S., Bhadauriya, P., Debnath, M., Prasad, G.B.K.S. & Bisen, P.S. (2009). *Momordica balsamina*: a medicinal and neutraceutical plant for health care management. *Current Pharmaceutical Biotechnology*, *10*, 667–682, https://doi.org/10.2174/138920109789542066.

Truong, V.N.P., Vo, N.T.T. & Pham, T.T.M. (2022). A review on water mint (*Mentha aquatica* L.): phenolic compounds and essential oils. *Thu Dau Mot University Journal of Science*, *4* (1),41–50, https://doi.org/10.37550/tdmu.EJS/2022.01.278.

Uusiku, N.P., Oelofse, A., Duodu, K.G., Bester, M.J. & Faber, M. (2010). Nutritional value of leafy vegetables of sub-Saharan Africa and their potential contribution to human health: a review. *Journal of Food Composition and Analysis*, *23* 499–509, https://doi.org/10.1016/j.jfca.2010.05.002.

van der Kamp, J.-W., Jones, J. M., Miller, K. B., Ross, A. B., Seal, C. J., Tan, B., & Beck, E. J. (2022). Consensus, global definitions of whole grain as a food ingredient and of whole- grain foods presented on behalf of the whole grain initiative. *Nutrients, 14*(138), 1–10. https://doi.org/10.3390/nu14010138.

VanWyk, B.-E., & Gorelik, B. (2017). Review: The history and ethnobotany of Cape herbal teas. *South African Journal of Botany, 110*, 18–38. https://doi.org/10.1016/j.sajb.2016.11.011.

Welcome, A. K., & Van Wyk, B. E. (2019). An inventory and analysis of the food plants of southern Africa. *South African Journal of Botany, 122*, 136–179. https://doi.org/10.1016/j.sajb.2018.11.003.

West, B., Deng, S., Uwaya, A., Isami, F., Abe, Y., Yamagishi, S. & Jensen, C.J. (2016). Iridoids are natural glycation inhibitors. *Glycoconjugate Journal*, *33*, 671–681, https://doi.org/10.1007/s10719-016-9695-x.

Willett, W., Rockström, J., Loken, B., Springmann, M., Lang, T., & Vermeulen S.,… Murray, C.J.L. (2019). Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. *Lancet, 393*, 447–492. https://doi.org/10.1016/S0140-6736(18)31788-4.

Zhu, F. (2017). Review: Structures, properties, and applications of lotus starches. *Food Hydrocolloids, 63*, 332–348. https://doi.org/10.1016/j.foodhyd.2016.08.034.

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