agronomy

MDPI

Review

Review of the Underutilized Indigenous *Portulacaria afra* (Spekboom) as a Sustainable Edible Food Source

Alba du Toit *, Rozanne MacDonald, Elmay Steyn, Zamancwane P. Mahlanza, Ayanda B. Zulu and Maryna de Wit

Department of Sustainable Food Systems and Development, University of the Free State, Bloemfontein 9300, South Africa

* Correspondence: dutoita1@ufs.ac.za; Tel.: +27-401-7656

Abstract: Southern Africa faces numerous challenges, such as increasing biodiversity loss and environmental degradation. Additionally, poor and vulnerable communities suffer from undernourishment and are food insecure. Therefore, Southern Africa must adopt inclusive, sustainable food systems that support food security, even under harsh climatic conditions. Wild edible plants can potentially strengthen South African communities' diets, as they are nutritious, freely available and adapted to survive in marginal conditions. *Portulacaria afra*, colloquially known as spekboom, is an indigenous succulent to South Africa. This edible plant is resilient even when exposed to weather extremes and is exceptionally easy to grow. Spekboom can potentially contribute to food security since food-insecure communities can access the plant in a socially acceptable way. However, spekboom awaits culinary development to increase its consumption. This review presents the current knowledge of spekboom. As there is limited published research, the review aims to stimulate research in food science and nutrition on this undervalued plant and introduce it as a new food and ingredient.

Keywords: *Portulacaria afra*; sustainable crops; underutilized product; undervalued food source; indigenous plants; wild edible plants; new-ingredient indigenous edible flora; climate-change-combatting plants

Citation: du Toit, A.; MacDonald, R.; Steyn, E.; Mahlanza, Z.P.; Zulu, A.B.; de Wit, M. Review of the Underutilized Indigenous *Portulacaria afra* (Spekboom) as a Sustainable Edible Food Source. *Agronomy* **2023**, *13*, 1206. https://doi.org/10.3390/agronomy13051206

Academic Editors: Purushothaman Chirakkuzhyil Abhilash, Ajeet Singh, Rama Kant Dubey, Hailin Zhang and Othmane Merah

Received: 6 March 2023
Revised: 20 April 2023
Accepted: 21 April 2023
Published: 25 April 2023

1. Current Challenges in the World

There are more than one billion undernourished people worldwide; thus, there is an urgency to improve food security and agriculture globally [1]. Agriculturally led economic growth and enhanced nutrition practices and programmes halved the proportion of undernourished people between 1990 and 2015. Nevertheless, undernourishment increased again after this period of steady decline [2,3] despite enough food being produced to feed everyone on Earth. A holistic approach must be adopted beyond the economic means of agricultural productivity to ensure global food security. Subsequently, the United Nations (UN) dedicated the second Sustainable Development Goal (SDG) in the 2030 Agenda for Sustainable Development to "end hunger, achieve food security and improved nutrition and promote sustainable agriculture" [2]. The SDG-2 recognizes the societal, economic, and environmental factors threatening the four food security pillars (availability, access, utilization, and stability) [4].

The prevalence of undernourishment peaked with the COVID-19 outbreak in 2020. Conflicts, climate change, economic recessions and collapse, and a history of persistent inequality, intensified by the COVID-19 pandemic, were identified as underlying issues of poverty and food insecurity [5]. In 2021, the UN convened to facilitate progress towards the 2030 Agenda SDGs following the regressive effects of COVID-19. The summit focused on "building back stronger" food systems since the current ways in which "food is grown, produced, traded, transported, processed, stored and marketed" are jeopardizing the future of global food security (SDG2 Advocacy for COVID-19 | SDG2 Advocacy Hub, 2020).

Inclusive, sustainable food systems are more productive and resilient, enabling countries to counteract hunger in the long run and manage future shocks imposed by climate change and disease outbreaks [3].

2. The Situation in Sub-Saharan Africa and South Africa

The countries most affected by food insecurity are the subregions of Africa. About a fifth (22.8%) of people in Sub-Saharan Africa are undernourished. The number of severely food-insecure people in Sub-Saharan Africa for the period 2018–2020 was determined to be 276.6 million. In 2019, people in Sub-Saharan Africa who were unable to afford a healthy diet were estimated to be 84% or 875.2 million, with a 5.6% increase from 2017 [5,6]. In the context of population growth, taking a holistic food-systems approach is the only way to increase sustainability in Sub-Saharan Africa. It should include economic, social, and environmental dimensions [6]. In addition to population growth, the agricultural sector faces the challenges of climate change [1,7]. This has led to a shift in farming systems to restore soil and increase crop yields. Producing more food for the future is one of the challenges in alleviating poverty and hunger in Africa [8].

About fifty percent of South Africans are food insecure or have a high risk of food insecurity. The South African National Health and Nutrition Examination Survey (SANHANES) found that 28% of South Africans in urban areas have a possibility of hunger [9]. Even though South Africa produces sufficient food and remains food secure at a national level, it still needs to guarantee food security at a household level [10]. For people to be regarded as food secure, they must be able to purchase or grow enough food [10]. Food security in most countries depends on local food production. Rural households primarily rely on local food production; thus, local agricultural production is significant to both food security and the country's economy [11].

Developing new food crops and products is one way of ensuring food security [11]. Indigenous edible South African plants were known and used by the San (Khoisan-speaking indigenous hunter-gatherer groups of Southern Africa) for medicine and consumption [12]. Indigenous edible plants can contribute to food crops used internationally and address food and nutrition security [13,14].

3. Indigenous Edible Plants in South Africa

Africa has many indigenous species that could contribute to agricultural crops [14]. Hunter-gatherers used indigenous edible plants, as did the Khoi-Khoi indigenous people [14]. In the Cape floristic region, the Khoisan use indigenous plants as part of their diet and in traditional medicine [15].

Van Wyk [14] listed South African indigenous plants with the potential to develop into products. According to van Wyk [14], at least 120 species are fit for this purpose, and 85 edible species are suitable for human consumption. Most of these species are commercialized, but only 16 are indigenous to Southern Africa, including gum Arabic; baobab; rooibos tea; honeybush tea; African potato; marula; sorghum, and cowpea [14]. Half of the 69 Cape Floristic species were used as a fruit, and a quarter as vegetables. Some fleshy plants could be used as a vegetable in speciality restaurants, *Portulacaria afra* (spekboom) being one of the plants [14]. Indigenous foods and flavours could form part of smaller industries that produce functional foods, health drinks, beers, fruit wines, herbal teas, and spices. These foods and beverages would reflect the cultural diversity of South Africa while local communities benefit from the resources. Such products could show diversity based on indigenous plants and be offered to tourists and restaurants [14].

Indigenous plants are generally disregarded by commercial farming, research, and development, making them less competitive for becoming economically viable than established crops, resulting in a loss of plant diversity and related traditional knowledge [16]. A critical characteristic of some indigenous plants is their ability to grow in arid and semiarid areas; this means they require little care and can survive under extreme temperatures [12,17].

4. Aim

Food security in Southern Africa is precarious; thus, an inclusive, sustainable food system that supports food security under harsh climate conditions must be adopted. Wild edible plants can enhance the South African diet, as they are nutritious, freely available, and adapted to survive in marginal conditions [18]. Reintroducing edible indigenous plants could increase food production to ensure that even poverty-stricken people have enough nutritious food daily [18]. Spekboom could contribute to this end, but it has yet to be discovered as a food source that can be developed into a consumer-acceptable product [19].

The aim of this review was to compile a comprehensive collection of sources on *Portuacaria afra*. In the course of our studies on the subject, we had difficulties finding credible information on edible or nutritional content. In order to minimize the future frustration of anyone looking for credible sources, this paper offers general, nutritional, pharmaceutical and other uses, as well as the sources categorized according to themes in a table (Table 1). We also aim to address misleading online information and provide credible sources presenting true facts.

Table 1. A summary of sources, categorized according to themes.

Descriptor	Date	Title	Type of Source	Link or Journal Details	No	Citation
Synonyms of *Portulacaria afra*	2021	Portulacaria monograph, the elephant's food or spekboom	Website	https://magiminiland.org/Portulacaria.html	[20]	Baran, 2021
	2019	*Portulacaria afra*	Website	https://treesa.org/portulacaria-afra/	[21]	Becking, 2019
	2009	*Portulacaria afra*	Website	http://pza.sanbi.org/portulacaria-afra	[22]	Hankey, 2009
Genealogy	2023	Elephant bush, *Portulacaria afra*	Website	https://hort.extension.wisc.edu/articles/elephant-bush-portulacaria-afra/	[23]	Mahr, 2023
	2021	*Portulacaria afra* plants guide: how to grow & care for "elephant bush"	Website	https://gardenbeast.com/portulacaria-afra-guide/	[24]	Secuianu, 2021
	2014	Phylogenetic relationships in the Didiereaceae with special reference to subfamily Portulacarioideae	Journal article	Taxon, Vol. 63 No. 5, p1053–1064. https://doi.org/10.12705/635.36	[25]	Bruyns et al., 2014
Varieties, types	2020	*Portulacaria afra*-elephant bush care, types and propagation	Website	https://succulentplantcare.com/portulacaria-afra-elephant-bush-care-types-and-propagation/	[26]	Slim, 2020
	2021	*Portulacaria* monograph, the elephant's food or spekboom	Website	https://magiminiland.org/Portulacaria.html	[20]	Baran, 2021
Carbon sequestering	2009	*Portulacaria afra*	Website	http://pza.sanbi.org/portulacaria-afra	[22]	Hankey, 2009
	2021	*Portulacaria* monograph, the elephant's food or spekboom. Part 3	Website	https://magiminiland.org/Portulacaria.html	[20]	Baran, 2021
	2021	Greenhouse gas sources and mitigation strategies from a geoscience's perspective	Journal article	Advances in Geo-Energy Research, Vol. 5, No. 3	[27]	Soeder, 2021
	2012	Distribution and stability of soil carbon in spekboom thicket, Eastern Cape, South Africa	Thesis	Stellenbosch University, https://scholar.sun.ac.za/handle/10019.1/20031	[28]	Mchunu, 2012
Photosynthetic pathways	2017	Crassulacean acid metabolism as a continuous trait: variability in the contribution of crassulacean acid metabolism (CAM) in populations of *Portulacaria afra*	Journal article	Heliyon, January, e00293, http://dx.doi.org/10.1016/j.heliyon.2017.e00293	[29]	Guralnick and Gladsky, 2017

Table 1. *Cont.*

Descriptor	Date	Title	Type of Source	Link or Journal Details	No	Citation
	2014	Temperature response of photosynthesis in C3, C4, and CAM plants: temperature acclimation and temperature adaptation	Journal article	Photosynthesis Research Vol 19	[30]	Yamori et al., 2014
	2023	Elephant bush, *Portulacaria afra*	Website	https://hort.extension.wisc.edu/articles/elephant-bush-portulacaria-afra/	[23]	Mahr, 2023
General plant growth	2021	Portulacaria monograph, the elephant's food or spekboom	Website	https://magiminiland.org/Portulacaria.html	[20]	Baran, 2021
	2019	*Portulacaria afra*	Website	https://treesa.org/portulacaria-afra/	[21]	Becking, 2019
	2017	Survivorship of spekboom (*Portulacaria afra*) planted within the subtropical thicket restoration programme	Journal commentary	South African Journal of Science Vol. 113 No. 1	[31]	Mills et al., 2017
	2021	*Portulacaria afra* plants guide: how to grow & care for "elephant bush."	Website	https://gardenbeast.com/portulacaria-afra-guide/	[24]	Secuianu, 2021
	2020	*Portulacaria afra*—elephant bush care, types and propagation	Website	https://succulentplantcare.com/portulacaria-afra-elephant-bush-care-types-and-propagation/	[26]	Slim, 2020
Trunk	2021	*Portulacaria* monograph, the elephant's food or spekboom	Website	https://magiminiland.org/Portulacaria.html	[20]	Baran, 2021
	2019	*Portulacaria afra*	Website	https://treesa.org/portulacaria-afra/	[21]	Becking, 2019
	1972	*Trees of Southern Africa: covering all known indigenous species in the Republic of South Africa, South-West Africa, Botswana, Lesotho & Swaziland*	Book	Volumes 1; 2.	[32]	Palmer and Pitman 1972
	2019	Spekboom: 5 things you didn't know	Website	https://www.samara.co.za/blog/five-things-didnt-know-spekboom/	[33]	Samara, 2019
	2023	Elephant bush, *Portulacaria afra*	Website	https://hort.extension.wisc.edu/articles/elephant-bush-portulacaria-afra/	[23]	Mahr, 2023

Table 1. *Cont.*

Descriptor	Date	Title	Type of Source	Link or Journal Details	No	Citation
Leaves	2021	*Portulacaria* monograph, the elephant's food or spekboom	Website	https://magiminiland.org/Portulacaria.html	[20]	Baran, 2021
	2019	*Portulacaria afra*	Website	https://treesa.org/portulacaria-afra/	[21]	Becking, 2019
Flowers and fruit	2021	*Portulacaria* monograph, the elephant's food or spekboom	Website	https://magiminiland.org/Portulacaria.html	[20]	Baran, 2021
	2019	*Portulacaria afra*	Website	https://treesa.org/portulacaria-afra/	[21]	Becking, 2019
	2014	Phylogenetic relationships in the Didiereaceae with special reference to subfamily Portulacarioideae	Journal article	Taxon, Vol. 63 No. 5 p1053–1064 https://doi.org/10.12705/635.36	[25]	Bruyns et al., 2014
Roots	2021	*Portulacaria* monograph, the elephant's food or spekboom	Website	https://magiminiland.org/Portulacaria.html	[20]	Baran, 2021
	2023	Is the spekboom flower edible?	Website	https://www.onsecrethunt.com/is-the-spekboom-flower-edible/	[34]	On secret hunt, 2023
Propagation	2021	*Portulacaria* monograph, the elephant's food or spekboom	Website	https://magiminiland.org/Portulacaria.html	[20]	Baran, 2021
	2003	Acocks' valley bushveld 50 years on: new perspectives on the delimitation, characterization and origin of subtropical thicket vegetation	Journal article	South African Journal of Botany Vol. 69 No. 1	[35]	Vlok et al., 2003
	2006	Albany thicket biome	Journal article	Strelitzia, Vol 19	[36]	Hoare et al., 2006
	2016	To the root of the problem with spekboom rehabilitation	Blog	http://pottsresearch.blogspot.com/2016/04/to-root-of-problem-of-spekboom.html	[37]	Potts, 2016
	2017	Respect the spekboom!	Blog	https://babylonstoren.com/blog/post/respect-the-spekboom	[38]	Babylons-toren, 2017

Table 1. *Cont.*

Descriptor	Date	Title	Type of Source	Link or Journal Details	No	Citation
	2021	A biome-wide experiment to assess the effects of propagule size and treatment on the survival of *Portulacaria afra* (spekboom) truncheons planted to restore degraded subtropical thicket of South Africa	Journal article	PLOS ONE e0250256 Vol. 16 No. 4	[39]	Van der Vyver et al., 2021
	2020	*Portulacaria afra*—elephant bush care, types and propagation	Website	https://succulentplantcare.com/portulacaria-afra-elephant-bush-care-types-and-propagation/	[26]	Slim, 2020
	2021	*Portulacaria afra* plants guide: how to grow & care for "elephant bush"	Website	https://gardenbeast.com/portulacaria-afra-guide/	[24]	Secuianu, 2021
	2009	*Portulacaria afra*	Website	http://pza.sanbi.org/portulacaria-afra	[22]	Hankey, 2009
Frost	2020	*Portulacaria afra*—elephant bush care, types and propagation	Website	https://succulentplantcare.com/portulacaria-afra-elephant-bush-care-types-and-propagation/	[26]	Slim, 2020
	2020	Frost, *Portulacaria afra* Jacq., and the boundary between the Albany Subtropical Thicket and Nama-Karoo biomes	Journal article	South African Journal of Botany Vol. 101	[40]	Duker et al., 2020
	2017	Respect the spekboom!	Blog	https://babylonstoren.com/blog/post/respect-the-spekboom	[38]	Babylonstoren, 2017
	2006	Albany thicket biome	Journal article	Strelitzia, Vol. 19	[36]	Hoare et al., 2006
	1972	*Trees of Southern Africa: covering all known indigenous species in the Republic of South Africa, South-West Africa, Botswana, Lesotho & Swaziland*	Book	Volumes 1; 2.	[32]	Palmer and Pittman (1972)
Distribution	2014	Phylogenetic relationships in the Didiereaceae with special reference to subfamily Portulacarioideae	Journal article	Taxon,63(5),1053–1064. https://doi.org/10.12705/635.36	[25]	Bruyns et al., 2014
	2021	Portulacaria monograph, the elephant's food or spekboom	Website	https://magiminiland.org/Portulacaria.html	[20]	Baran, 2021

Table 1. *Cont.*

Descriptor	Date	Title	Type of Source	Link or Journal Details	No	Citation
	2009	*Portulacaria afra*	Website	http://pza.sanbi.org/portulacaria-afra	[22]	Hankey, 2009
	2006	Albany thicket biome	Journal article	Strelitzia, Vol 19	[36]	Hoare et al., 2006
	2023	Elephant bush, *Portulacaria afra*	Website	https://hort.extension.wisc.edu/articles/elephant-bush-portulacaria-afra/	[23]	Mahr, 2023
	2019	*Portulacaria afra*	Website	https://treesa.org/portulacaria-afra/	[21]	Becking, 2019
	2020	Spekboom–climate change superhero	Website	https://www.thegreendirectory.net/blog/spekboom-climate-change-super-hero	[41]	Ambreen, 2020
Recipes	2020	Spekboom–climate change superhero	Website	https://www.thegreendirectory.net/blog/spekboom-climate-change-super-hero	[41]	Ambreen, 2020
	2020	Spekboom, chickpea and tomato salad	Website	https://taste.co.za/recipes/spekboom-chickpea-and-tomato-salad/	[42]	Erasmus, J
	2019	Spekboom recipes for the soul	Website	https://www.getaway.co.za/travel-news/spekboom-recipes-for-the-soul/	[43]	Searra, 2019
	2009	Pork belly with gooseberry and spekboom pickle	Website	https://showme.co.za/paarl/lifestyle/winelands-kitchen/recipes-winelands-kitchen/pork-belly-with-gooseberry-and-spekboom-pickle/	[44]	Showme.co.za
	2016	Exploring our hunter-gatherer past & palates in Paternoster	Website	https://stayinpaternoster.co.za/2016/09/exploring-our-hunter-gatherer-past-palates-in-paternoster/	[45]	Hepburn, 2016
Food for animals	2021	*Portulacaria afra* plants guide: how to grow & care for "elephant bush"	Website	https://gardenbeast.com/portulacaria-afra-guide/	[24]	Secuianu, 2021
	2021	*Portulacaria* monograph, the elephant's food or spekboom	Website	https://magiminiland.org/Portulacaria.html	[20]	Baran, 2021

Table 1. *Cont.*

Descriptor	Date	Title	Type of Source	Link or Journal Details	No	Citation
	2019	Spekboom–5 amazing facts about this wonder plant- Shamwari	Website	https://www.shamwari.com/5-amazing-facts-about-spekboom/	[46]	Shamwari, 2019
Honey production	2019	*Portulacaria afra*	Website	https://treesa.org/portulacaria-afra/	[21]	Becking, 2019
On the spekboom being edible	2023	The physicochemical and nutritional value of fresh and processed *Portulacaria afra* (Spekboom) leaves	Journal article	Agronomy Volume 13, No 3.	[19]	Mahlanza et al., 2023
	2021	Portulacaria monograph, the elephant's food or spekboom	Website	https://magiminiland.org/Portulacaria.html	[20]	Baran, 2021
	2019	Spekboom–5 amazing facts about this wonder plant- Shamwari	Website	https://www.shamwari.com/5-amazing-facts-about-spekboom/	[46]	Shamwari, 2019
	2023	Elephant bush, *Portulacaria afra*	Website	https://hort.extension.wisc.edu/articles/elephant-bush-portulacaria-afra/	[23]	Mahr, 2023
	2021	*Portulacaria afra* Plants Guide: How to Grow & Care for "Elephant Bush"	Website	https://gardenbeast.com/portulacaria-afra-guide/	[24]	Secuianu, 2021
Nutritional content	2023	The physicochemical and nutritional value of fresh and processed *Portulacaria afra* (Spekboom) leaves	Journal article	Agronomy Volume 13, No 3.	[19]	Mahlanza et al., 2023
	2021	Using the wonderplant for a wonderful initiative	Online content (pdf) on website	http://www.tembele.co.za/wp-content/uploads/2021/02/Carbon-Footprint-offset-Spekboom-33.pdf	[47]	Grosel, 2021
	2019	Spekboom trees for all!	Website	https://zingelaulwazi.org.za/spekboom-trees-for-all/	[48]	Harmon, 2019
		11-year-old plants 750 spekbooms during holidays	Magazine article	https://www.getaway.co.za/travel/nature-and-conservation/11-year-old-plants-750-spekboom-during-holiday/	[49]	Kirsten, 2020

Table 1. *Cont.*

Descriptor	Date	Title	Type of Source	Link or Journal Details	No	Citation
	2009	Elephant's food (*Portulacaria afra*)	Online	Feedipedia online Encyclopedia of animal feeds https://www.feedipedia.org/node/112	[50]	Feedipedia, n.d.
About the taste	2009	Restoration of degraded subtropical thickets in the Baviaanskloof Megareserve, South Africa: The role of carbon stocks and *Portulacaria afra* survivorship	Dissertation	Dissertation, Rhodes University	[51]	Powell, 2009
	2020	The health benefits of the Spekboom plants	YouTube	https://www.youtube.com/watch?v=eY5XeyGYDdg	[52]	Singels (2020)
	2021	*Portulacaria* monograph, the elephant's food or spekboom	Website	https://magiminiland.org/Portulacaria.html	[20]	Baran, 2021
	2009	*Portulacaria afra*	Website	http://pza.sanbi.org/portulacaria-afra	[22]	Hankey, 2009
Pharmaceutical action	2023	A phytochemical screening, antioxidant and antibacterial activity analysis in the leaves, stems and roots of *Portulacaria afra*	Journal article	Journal of Herbmed Pharmacology Vol. 12 No 1	[53]	Basson et al., 2023
	2022	Screening of phytochemical profile and biological activities in the leaves, stems and roots of South African *Portulacaria afra* using four extraction solvents	Journal article	Biomedical and Pharmacology Journal Vol. 15 No. 3	[54]	Adeleye and Risenga, 2022
	2022	A short communication on the ethnobotany, physiochemistry, pharmacological evidence and ecosystems restoration potential of South African *Portulacaria afra*	Short communication	Journal of Medical Studies Vol. 10 No. 2	[55]	Teffo et al., 2022
	2022	Phytochemical, biological, and *in-silico* characterization of *Portulacaria afra* Jacq.: A possible source of natural products for functional foods and medicine	Journal article	South African Journal of Botany 150	[56]	Tabassum et al., 2022

Table 1. *Cont.*

Descriptor	Date	Title	Type of Source	Link or Journal Details	No	Citation
	2021	In vitro antibacterial, antioxidant, anti-quorum sensing and cytotoxic properties of *Portulacaria afra* leave extract	Journal article	Bioscience Research Vol. 18 No. 1, https://www.isisn.org/BR18(1)2021/455-463-18(1)2021BR20-305.pdf	[57]	Khanyile et al., 2021
	2013	Medicinal plants used for the treatment of various skin disorders by a rural community in northern Maputaland, South Africa	Journal article	Journal of Ethnobiology and Ethnomedicine, Vol. 9 No. 51, https://doi.org/10.1186/1746-4269-9-51	[58]	De Wet et al., 2013
	2017	Phytochemical screening, antioxidant, anti-inflammatory, and glucose utilization activities of three South African plants used traditionally to treat diseases	Journal article	Biology and Medicine, Vol. 9 No. 5	[59]	Olaokun et al., 2017
Treat hydration	2016	Investigating soil microbial interactions of *Portulacaria afra*	Dissertation	Dissertation, Rhodes University	[60]	Fulmaka, 2016
Antibacterial action	2019	Green synthesis of silver nanoparticles using *Portulacaria afra* plant extract: characterization and evaluation of its antibacterial, anticancer activities	Journal article	Novel Research in Microbiology Journal, Vol. 3 No. 1	[61]	Salaheldin, 2019
Anticancer action	2008	An ethnobotanical survey of medicinal plants in the southeastern Karoo, South Africa	Journal article	South African Journal of Botany, Vol. 77, No. 4	[62]	Van Wyk, 2008

5. Search Criteria and Analysis of Literature

The review included a comprehensive search on Google, Google Scholar, and the University of the Free State library guide system on all electronic resources (including 264 databases). The investigation took place between 2019 and 2023. We searched intending to find available information on *P. afra* pertaining to the aim of this study. Websites were included in this review since some of the most informative general information was on the websites of private enthusiasts, nurseries, and nature conservation parks in South Africa. Comprehensive or new information presented in an organized fashion, rather than general information, was included. Keywords included "*Portulacaria afra*",/"Spekboom",/" Elephant's food". The sources had to be published after 1999, except for books.

Of the sources found, eighteen peer-reviewed papers were included in this paper as they were the most relevant to the objectives. Of these, eight were published in the South African Journal of Botany. Four dissertations or theses were found, three from Rhodes University and one from Stellenbosch University. Nineteen websites containing information were found. Four of the sources presented here comprised spekboom recipes; three were blogs with relevant information; one was an outdated encyclopedia on animal feed. There are three excellent websites (online sources) on spekboom [Baran (2021), Hankey (2009) and Becking (2019)]. The online source of Baran (2021), a spekboom bonsai enthusiast, was the best with his website, last edited in October 2020 (see Table 1 showing literature on *Portulacaria afra* organized in categories according to the descriptor). One credible peer-reviewed paper was found on the nutritional content of the leaves [19]. Many websites mentioned nutritional information but needed data, citations, or source information. A summary of the sources was included, categorized into themes, and, with the full referencing details, is found in Table 1.

6. *Portulacaria afra*

P. afra (Figures 1 and 2) was introduced by Nikolaus Joseph von Jacquin, who lived from 1727 to 1817 [20] and is a popular garden plant worldwide [23]. *P. afra* has advantageous characteristics, such as carbon sequestration, mitigating climate change, restoration purposes, and as a food source for animals [22]. *P. afra* falls under the least concern group of the national conservation status as it is widespread over Africa [21].

Figure 1. Closeup of spekboom growing in a flowerpot.

6.1. Synonyms for P. afra Subsection

P. afra owes its scientific name to its resemblance to the fleshy-leafed subshrubs of the Portulaca genus and its African origin, as afra implies, "plant in Africa" [20,21]. Colloquially, the *P. afra* is known as Pork bush\ Elephant's food (English); Spekboom\ Olifantskos (Afrikaans); iNtelezi\ isiDondwane/isAmbilane\ iNdibili\ isiCococo (isiZulu); iGqwanitsha (isiXhosa), Isidondwane (siSwati) and Tshilepwete (Tshiveda) on account of its leaves'

plump, succulent nature [21,22]. Olifantskos/elephant's food was ascribed to *P. afra* as it triggers a feeding frenzy amongst elephants [20].

Figure 2. Spekboom in a flowerpot with other plants.

P. afra belongs to the Didiereaceae succulent plant family inhabiting the arid and semiarid regions of Africa and Madagascar. The Portulacaria genus consists of seven species, of which *P. afra* and *P. namaquensis* are the only species indigenous to South Africa. *P. afra* forms part of the bigger, more populous, and widespread purslane family called Portulacaceae [23]. The phylogenetic relationship studies suggest that Portulacaria should form part of the Didiereaceae family, which is closely related to the Cactaceae family [25].

Baran [20] noted historical references to *P. afra*, already called spekboom, from 1834 to 1922. The plant can live for 200 years and adapts to its surroundings. It can tolerate and thrive in intense sun, severe heat, high and low humidity, and rain [24]. However, the plant cannot withstand frost but can survive moderately cold conditions. The plant plays a critical role, especially in arid areas, as it maintains soil moisture after rainfall [17] and promotes the re-establishment of [63] a carbon-rich microclimate [64] where other plant species could flourish, and dense thickets could be formed [65].

6.2. Varieties of P. afra

Several plant varieties exist and the regular or most common plant is easily found in nurseries. The other varieties listed below are available from specialty nurseries. *P. afra* looks similar to and is often confused with the jade plant, though the leaves are much smaller, and the stem is reddish brown [23]. There is a disagreement in the literature about the varieties, but those that appeared in most sources are listed:

- The regular or most common plant has bright green leaves with red tips. The new stems are initially light green but turn reddish brown. The red branches are indicative of spekboom. Older stems eventually turn brown and develop cork bark [26];
- Variegata (Foliia Variegaris) is also known as variegated elephant bush or rainbow bush. The leaves have cream and green stripes. In addition to the leaves, the plant looks like a regular plant but tends to grow more slowly and laterally. This plant is trendy among gardeners for its attractive leaves [20,23,26];
- The giant or mammoth elephant bush (*P. afra* forma macrophylla) has much bigger leaves, almost twice the size of the regular plant [26];
- Minima (microphylla) or lilliput leaves are twice as small as the regular plant. It is recognized by the shiny leaves and red stems [23,26];
- Manny (medio picta) is very attractive; the leaves have wavy patterns at the edges, and a white shaded line runs through the middle of the leaf [23,26];
- Aurea is a compact form with a reddish stem and small yellow leaves flushed with pink [20,23].

6.3. Distribution and Habitat

P. afra is distributed widely across South Africa and is indigenous to the subtropical Albany Thicket biome though more common in the wetter Eastern parts of Southern Africa [25]. *P. afra* is sister to the Portulacarioideae subfamily and is found in Angola, Southwestern Mozambique, Namibia, South Africa, and Swaziland [20–22]. They flourish in warm areas on rocky slopes in the succulent Karoo scrub thicket, bushveld, and dry river valleys [22]. The Albany district (surrounding Grahamstown) is the centre of this ecoregion (200 to 950 mm annual rainfall), from where it expands into other bioregions of the Eastern Cape and marginally in the Western Cape semiarid Little Karoo and Great Karoo [23,25,36]. *P. afra* is even found throughout the East coast of KwaZulu-Natal and northwards into the Lowveld in Mpumalanga. They grow alongside the Lebombo Mountains in Limpopo and the Sekhukhune district of southern Limpopo [21]. The plants are also found in the arid and semiarid areas of Arizona and California in the USA and Australia [41].

The spekboom favours the arid deep-sided riverbeds across the Albany Thicket and the north-facing rocky outcrops of the inland Cape Fold Mountains, where they are optimally exposed to sunlight (Figures 3 and 4). The spekboom towers above other plants in some of the bioregions' vegetation units. Hence, several researchers refer to the Spekboom-dominated arid river and intermontane valleys as the "Spekboom Thicket" and "Spekboomveld". During periods of drought, the spekboom forms pure stands in mountainous areas, known as the "Arid Spekboomveld" [36,66].

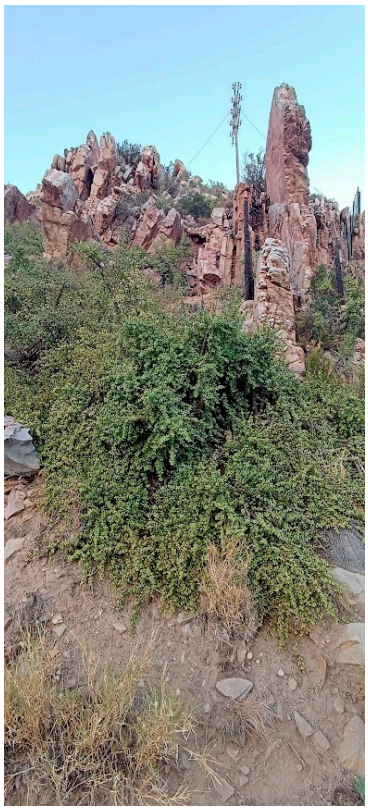

Figure 3. Spekboom growing on a north-facing rocky slope in the arid Karoo.

P. afra thrives in the arid Gamka district, covering the lower Gamka River Valley and Groot Swartberg Mountains and the Groot Thicket near Willowmore. The eastern side of this bioregion adjoins the Gamtoos Thicket. Here spekboom serves as the basis of the thicket clumps in the Gamtoos River Valley [36]. Spekboom is dominant during drought in the Sunday's thicket in Somerset East, Pearston, Jansenville, Kirkwood, and the Addo Elephant National Park. The spekboom canopy is a distinctive feature in the Great Fish River valley, which stems from local dominance in the Cookhouse and Adelaide District.

The spekboom grows on rugged, steep slopes of the Great Escarpment in the Camdeboo District, encompassing Aberdeen and Graaff-Reinet. Two- to three-meter-tall clumps are found on the south-facing slopes of the Camdeboo Escarpment Thicket instead of the northern face with less favourable extreme daily temperatures and moisture content [36]. However, spekboom populations can be eradicated by scavenging goats and wildlife since the leaves are sweet and, thus, more palatable than grassy plants or woody shrubs [20]. The spekboom supports foraging animals in national parks and game farms and, therefore, the tourism industry in the Eastern Cape. Many farmers are transforming their farms into sustainable game farms by protecting *P. afra* from being overgrazed by sheep and goats [67].

Figure 4. A close-up of the same plant's leaves and branches.

6.4. Spekboom and Climate Change

P. afra has been described as a carbon sponge, as it sequesters free carbon from the atmosphere, which is utilized to produce plant tissue [22]. There is currently more carbon in the atmosphere than the ecosystem can absorb, resulting in a carbon deficit that lingers in the atmosphere, trapping heat from the sun instead of radiating it back into space [27]. It is wrongly claimed by social media [68] and online sources [33] that the spekboom's carbon-sequestration ability is as effective as the Amazon Forest [33] and that it is a hundred times more efficient than a pine tree of comparable size. It is also incorrectly stated that *P. afra*-dominated thickets store 200 tons of carbon per hectare [28]. Hence, it is claimed that *P. afra* is one of the foremost climate-change-combating plants [20,33,68]. Wild [69] concluded that these statements are misleading. A short communication published in 2014 [70], proved that *P. afra* has carbon sequestering rates comparable to other CAM plants. In fact, 14 tons of carbon dioxide per hectare per year (14t CO_2 ha^{-1} yr^{-1}) is quite normal for CAM plants and not unusually high compared to other CAM plants such as *Agave salmiana* (77 t CO_2 ha^{-1} yr^{-1}) and *Agave mapisaga* (70 t CO_2 ha^{-1} yr^{-1}) [70].

In altitudes up to 1400 m, *P. afra* can benefit from two photosynthetic pathways [22,29]. In adversely dry periods when other plants cannot flourish, the spekboom can switch from the C_3 pathway to crassulacean acid metabolism (CAM). The plant could thus continue to

grow and use carbon despite experiencing considerable growth variations in the fluctuating day and night temperatures [29,30]. This allows the plant to excel in its native arid or semiarid conditions. The CAM pathway works continuously at low levels, even during C_3 photosynthesis, which explains the plant's water efficiency and ability to sequester carbon at higher rates than some other CAM plant species [29].

7. The Plant: General

P. afra is an upright succulent perennial shrub or tree [20,21,24,31]. The branches are fragile as they are soft wooded. The foliage may be shed briefly in late winter (semievergreen). It could grow 2–5 m in height [21] (Figure 5) and could expand between 1.5 and 2 m [23]. In the wild, the plant can be spread out in a straggling manner. It can thrive in scorching and dry climates or intermontane areas with steep slopes, as seen in Figure 3, and rocky soil [20,21]. *P. afra* thrives on as little as 250–350 mm of rain annually. The plant needs full sun and tolerates heat. The leaves show sunburn when not acclimatized to the sun, but plants growing in the wild tolerate sun and heat [26].

Figure 5. The spekboom grows up to 5 m high in a garden in the hot and arid Karoo.

7.1. Trunk

The spekboom has a glabrous soft-wooded succulent trunk with slightly sunken circumferential rings [20,21]. A mature tree trunk's diameter can range from 30 to 80 mm [32]. A cross section exposes annual rings, demonstrating a life expectancy of over 50 years [20], although the spekboom can live up to 200 years [33].

The plant's bark varies in colour as it matures and grows [21]. A young plant's stems are green, brittle, and break off easily. They change into a glossy red-brown colour with age. The older branches mature to a grey colour, with slightly sunken rings [23]. The trunk and branches have a woody inner tissue, allowing branches to grow into a thicket [21].

7.2. Branches

Young green brittle shoots sprout from perpendicular stems and develop into glossy, pliant red-brown branchlets [21], where phototropic leaves and twigs arise from the nodes at a 45-degree angle [20]. In due course, the branches lignify, turn grey, become more wrinkled and start to feed several secondary branches. New branches and branchlets continually shoot from the trunk and stems, respectively. Thus, a dense *P. afra* shrub forms a network of intertwined branches [20].

7.3. Leaves

The spekboom leaves are single-blade, obovate margined in a decussate leaf arrangement (grow opposite and at right angles to each other). The leaves are smooth with even edges and succulent without prominent leafstalks. The rounded apex has a short, pointed tip and a rounded-to-narrow base with a short or absent leaf stalk (petiole). Leaves have

no stipules and vary between shades of green [21]. Younger leaves occasionally have red outer edges with a centre-pointed or centre-drawn apex [20,21]. The latter feature results in a heart-shaped leaf that cannot revert to obovate (tear shaped) once the red edge fades away. Older leaves are more elliptic, rounded, obovate, or triangular. The terminal half of the leaf is broader than the base [21]. Fully matured spekboom leaves measure 2.2 mm in length and 1.89 mm in width [19] and weigh 0.64 g. Smaller leaves are notable in hot and arid conditions to conserve water [20].

The leaf colour changes from light green to dull green during the life cycle. Leaves can last for several seasons [25]. Yellow and pulpier leaves are a function of old or stressed plants. In this case, the leaves immediately separate from the tree or become blackish and withered, whereafter the tree drops them. After defoliation, new leaf buds will appear if the plant is healthy, and the weather is favourable [20]. The plant is also known for its high leaf-litter production [60].

7.4. Flowers and Fruit

The spekboom blooms during September and March in Southern Africa after sufficient rainfall. Flowering consumes a great deal of energy, so the spekboom will not yield flowers in dry summers to increase its chance of survival [46]. Cultivated plants seldom blossom, but unpruned older plants might bloom following rainfall in arid regions [20].

The plant produces countless tiny star-shaped, pale-pink to purplish flowers [21]. A profusion of pale to rosy, pink, and violet short-stemmed small (2 to 2.5 mm long) star-like flowers are borne in 50 to 75 mm open clusters at the spekboom's upper axils [20]. The flowers have five-pointed connate petals and are actinomorphic as they possess radial symmetry [21]. The symmetric flower is bisexual, having prominent stamens and pistils, and consists of a calyx with two exposed sepals; five joined petals; four to seven purple-anthered stamens fused to the petals; a corolla tube with four or five whitish or pinkish lobs; and a pistol with three-angled superior one-chambered ovary, a short style, and three stigmas [20,21,25].

The flowers are rich in nectar, which lures bees, other insects, and songbirds to pollinate the plant [20,46]. Fascicles of these flowers are borne towards the end of the branches producing nectar that attracts bees [71]. Subsequently, a 5 mm long, light, dry, transparent, thin-walled, indehiscent, one-seeded nut with three wings develops in drooping clusters [20,21]. The nuts have a pinkish hue resembling a second blossoming [20].

7.5. Roots

The roots are thick and scored with a fibrous root system that anchors the plant in well-drained sandy or rocky soil. In nature, the primary roots of the spekboom are white at the core with a grey or ruby-red rhizodermis. A delicate network of white hair-like feeder roots supports the thick, seamed, smooth roots [20]. The spekboom has a noninvasive root system, a positive for urban gardens [34].

7.6. Propagation

Little is known about the spekboom's reproductive nature [35]. Research suggests that it primarily relies on asexual propagation instead of seeds. Foraging herbivores indigenous to the Albany Thicket facilitate vegetative multiplication when they eat and subsequently break the branches. The broken branches on the ground will put out new shoots (coppicing) [36]. Later, the spekboom skirts out laterally via creeping shoots to cover the ground where it takes root [35,36]. Semichewed spekboom branches also strike roots and continue to grow [37].

In the Camdebo District, browsing goat flocks threaten vegetative propagation by defoliating 50% of the plant from the sides. The spekboom takes 18 months to recover or could wither due to wind and water erosion [36]. Hence, circumstantial evidence implies that spekboom utilizes wind-dispersed seeds to procreate in open microsites (away from goats) [35].

Propagation for general gardening and thicket restoration utilizes the same principle as the vegetative natural reproductive system [37]. This straightforward process entails breaking off a 5 to 8 cm spekboom sprig [38] or a truncheon with a 22.5 mm diameter for thicket restoration purposes [39], whereafter it is left to dry for one or two days. The spekboom sprig and truncheon are planted directly in well-drained soil (without rooting hormone) at depths of 3 to 5 cm and 10 to 30 cm, respectively [39]. After four to six weeks, the spekboom will have established roots. However, extensive waterlogging will cause ground pathogens and, thus, root rot, in cuttings [26,37,39].

7.7. Frost

P. afra tolerates mild frost and freezing temperatures, though not for extended periods (Slim, 2020). It thrives in USDA hardiness zones 9–11, the average annual minimum winter temperature. Zones 9–11 range from −1.1 °C to 10 °C [26,72]. Frost leads to ice formations in spekboom leaf tissue. Cellular fluids leak via lesions that destroy the plant's photosynthetic activity. The plant cannot sustain other metabolic activities as it cannot access frozen water. Thus, the succulent leaf's morphology is unsuitable for subzero temperatures [40]. Hoare et al. [36] stated that in the Albany Thicket valleys during July (winter), frost inhibits growth and reproduction and hinders spekbooms' survival. However, Duker et al. [32] and Palmer and Pittman [32] state that dense thicket clumps protect the spekboom population against frost.

8. Food Source, Nutritional Value, and Taste Attributes

8.1. Food Source for Animals

Several wild and domestic animals, such as elephants, chickens, tortoises, ostriches, sheep, cattle, goats, kudus, black rhinos, and other antelope find spekboom leaves exceptionally palatable [20,24,41]. Spekboom sustains high-biomass animals such as the rhinoceros, buffalo, and elephants in the Addo Elephant National Park near Gqeberha (formerly Port Elizabeth) and surrounding private game reserves such as Shamwari [46]. The Addo Elephant National Park is 12.126 hectares (30.315 acres) of gently undulating valley bushveld, dominated by spekboom [66]. The spekboom covers approximately 80% of the area [20]. Elephants eat up to 200 kg of *P. afra* leaves daily, forming 80% of the elephants' diet in the National Park [68]. Spekboom flourishes when grazed moderately [23].

8.2. Food Source for Humans

Research on *P. afra* as a human food source is minimal. Most sources claim the leaves are edible, and Zulus, Xhosas and other traditional food systems have consumed spekboom leaves for centuries [46]. The taste is described as sour or tart [22] and the leaves "have a slight but pleasantly tart flavour" [20] (part III). Becking [21] describes the leaves as a local delicacy.

Mahlanza et al. [19] proved that the leaves could serve as an economical replacement for green leafy vegetables as good quality-preserved marketable products such as preserves, pickles, chutney, and spices were produced from the leaves [19].

8.3. P. afra as An Ingredient in Recipes

Recently, magazines and websites have reported on incorporating spekboom into dishes such as salads, soups, fruit smoothies, and brownies [41,43]. Secuianu [24] considers spekboom a delicacy served in soups, salads, and stews. The plant has been used in salads [42,43], pickles [44], smoothies [43], and stews and has become a trendy ingredient. Spekboom is slowly being introduced to fit our palate with well-known chefs like Kobus Van der Merwe foraging for wild edible plants such as *P. afra*; he describes the plant as unusual, earthy, and more delicate than our palates are used to [45].

8.4. Nutritional Content

A recently published journal article [19] determined the baseline nutritional information of *P. afra* fresh leaves and related processed products. It was found that the fresh

leaves had low protein (0.75 g/100 g), low energy (61.15 KJ/100 g), low crude fibre (1.17 g/100 g neutral detergent fibre and 0.40 g/100 g acid detergent fibre) and low-fat content (0.12 g/100 g). However, it was a good source of water since it had high moisture content (93.18%) and ascorbic acid (35.26 mg/100 g) [19].

Website sources claim that spekboom leaves are rich in vitamin C, manganese, cobalt, magnesium, iodine, and selenium [47–49]. However, the claims are unsubstantiated as the source of information is not given. Baran [20] provides the nutritional content of the leaves in % dry matter as protein 11.8; fibre 14.6; ash 11.8; crude fat 3.9; carbohydrates 57.9; calcium 2.87; and phosphorous 0.35. However, none of the sources Baran [20] listed could be accessed. On Feedipedia, a website with animal feed information, a nutrition table for *P. afra* fresh leaves is available [50]. The reference for the information is indicated as a paper in the *Proceedings of the South African Society of Animal Production* in 1967 by Groenewald, J. W.; Joubert, D. M.; Tölken, H., 1967, The chemical composition of South African fodder plants. Proc. S. Afr. Soc. Anim. Prod., 6: 117–128. The authors could not find this paper. It may seem that the nutrient content, as reported by Baran [20], was according to Feedipedia, where the crude protein, fibre, and ether extract (fat and fatty acids) account for 11.8%, 14.6%, and 3.9% of spekboom dry matter, respectively. Additionally, 11.8% of dry spekboom is proposed to be minerals. A nutritional table indicates 27.8 g/kg calcium and 3.5 g/kg phosphorus is present in a kilogram of dry matter. Calculations show that one kilogram of dry spekboom provides a gross energy value of 17.3 MJ [50]. However, no traceable or recent scientific-based research is available to support these nutritional values. No information could be found to substantiate the high vitamin C claims other than Mahlanza et al. [19].

8.5. Taste

Varying tannin levels in spekboom leaves alter the taste to such an extent that two *P. afra* types are described as sweet and sour. The latter is less palatable due to higher tannin production induced by defoliation. Tannin levels are subjective to the season and the individual spekboom tree [51]. Day-to-night variations in the taste of spekboom leaves are a function of CAM that converts malic acid to malate throughout the day. Singels [52] advised consumers during a television broadcast to harvest spekboom for culinary use in the afternoon rather than in the morning when leaves were sour and unpleasantly bitter. Becking [21] explains that CAM causes the leaves to be sourer when harvested in the morning.

9. Pharmaceutical Advantages

P. afra is considered a medicinal plant traditionally used in South Africa to treat ailments such as skin disease, diabetes, and hypertension [55]. Teffo et al. [55] reviewed the literature for information on the ethnobotanical, phytochemical, pharmacological, and ecosystem restoration potential of *P. afra*. Ethnomedical uses included dermatitis, chronic sores, kidney and urinary tract conditions, oral thrush, toothache, colds, sore throat, pain and inflammation, constipation, and cancer. The authors mention that the red-brown stems of the plants derive their colour from anthocyanin pigments.

A recent study by Basson et al. [53] used a phytochemical colour test and four solvents to determine the presence of ten phytochemicals. They determined the antioxidant capacity of the leaves, roots, and stems of *P. afra*. Results showed that although flavonoids and phlobatannins were absent, saponins, glycosides, phenolics, tannins, terpenoids, steroids, coumarins and volatile oils were present. Coumarins were high in the leaves and stems. Coumarins have antioxidant, antibacterial, anticancer, anti-inflammatory and analgesic properties. Of the three parts of the plant (leaves, branches, and roots), the leaves showed the highest presence of phytochemicals and, thus, the most medicinal properties [53]. The high antioxidant and antibacterial agents proved effective against *E. coli* and *S. aureus* infections. It is concluded that *P. afra* is a medicinal plant with significant potential [53]. Similarly, Adeleye and Risenga [54] determined phytochemical and biological activities in

the leaves, stems, and roots using four different solvents. They found high quinone and total flavonoid contents in root extracts. The plant was recommended for drug production [54].

The studies on phytochemical analysis were those of Basson et al. [53], Adeleye and Risenga [54], Olaokun et al. [59], and De Wet et al. [58] regarding skin disorders. Khaynyile et al. [57] studied the antibacterial and antioxidant content of leaf extract. It was concluded that more research was needed. Extensive phytochemical and pharmacological analyses were recommended since sustainable plants such as *P. afra* may be used to prevent or treat illnesses and diseases [55]. Tabassum et al. [56] highlighted the chemical and biological parameters of extracts from the whole plant and demonstrated substantial phenolic, flavonoid, and antioxidant contents. The n-hexane extract had higher total phenolic (36.07 mg GAE/g) and flavonoid (831.58 QE/g) contents than other tested extracts. It was concluded that further studies were necessary as *P. afra* could have novel bioactive compounds benefiting medicine and functional foods [56].

Medicinal Uses

Silver nanoparticles biosynthesized from *P. afra* leaf extract showed antibacterial activity against Gram-positive and Gram-negative bacteria and exhibited anticancer activity against a breast-cancer cell line (MCF 7) [61]. Van Wyk [62] studied the diverse medicinal plants used in Eastern Karoo. Many of the plants are well-known for their medicinal uses. *P. afra* was one of 86 plants mentioned for inflammation relief using bruised leaves folded in cloth and applied externally [62]. The leaves relieve pain when rubbed on blisters and corns [22]. *P. afra* is used to treat rashes, insect stings, pimples, and sunburn as it soothes and hydrates the skin [61]. Folk medicine practitioners use the leaves to treat skin disorders [58] Lay people interviewed in Northeastern KwaZulu-Natal use both traditional and Western medicine in combination to treat sores, ringworm, boils, burns, wounds, rashes, and inflammation [58].

Olaokun et al. [59] investigated *P. afra* as one of three plants known in folklore for their therapeutic qualities in treating skin disorders. The plant had a total phenolic content of 63.06 mg/g GAE, total flavonoid content of 22.16 mg/QE, antioxidant activity (DPPH) of 32.05 µg/mL and LOX inhibitory activity of 107.26 µm/mL. It was suggested that the plant is a renewable source of compounds to control or treat diseases [59].

P. afra could be used to treat dehydration, as the thick green leaves contain moisture [60]. During times of drought, the plant provides animals with food and moisture. The juice extracted from the plant could be used for dehydration and heat stroke [60]. The leaves and the roots are occasionally eaten as a thirst quencher or snack by the Xhosa [20].

10. Other Advantages

10.1. Prevents Soil Erosion

The plant's roots are excellent at soil binding, preventing soil erosion, and promoting a diversity of plant life. This also contributes to conserving healthy watering holes [46,60,71]. The plant has a symbiotic relationship with mycorrhizal fungi. Its interaction with rhizobacteria may play a role in its growth and establishment [60].

P. afra benefits the environment as it re-establishes other plant species by regenerating degraded landscapes and restoring the soil [28]. This has led to the South African government starting programs where succulents are planted to enhance landscapes in degraded thickets. It acts as a foundation in the ecosystem during drought and produces carbon-rich mulch beneath its dense canopy. Furthermore, research on *P. afra* to survive in different soil types showed that the plant tolerated different soil conditions, including nutrient-rich, nutrient-poor, alkaline shale-derived and acidic sandstone-derived soils [73] which are positive factors for the restoration of sites [74].

10.2. Fences

In modern-day gardening, dense stands of spekboom are informal fences (Figure 6) or pruned into hedges (Figure 7) that serve as ornamental high-growing ground cover [22].

Spekboom hedges date back centuries to when the Xhosa cultivated plants for kraal fences. These live kraal fences enclosed the stock, concurrently allowing them to graze on the spekboom leaves while the outer side of the hedge was left to grow [68]. Spekboom hedges are suitable shelterbelts to shield crop fields and vegetable gardens against the wind [41].

Figure 6. Spekboom used as a fence for a garden.

Figure 7. Spekboom pruned into a hedge.

10.3. Desertification

Spekboom is one of the best plants for quickly establishing vegetation on eroding dry lands. It is being recommended as a plant which could aid in areas experiencing drought, land degradation, and wind erosion [75]. Its remarkable ability to combat desertification is due to its ability to survive in dry areas and the ease with which it is multiplied from rooting cuttings and leaves [75].

11. Projects

In Cape Town, a project was launched that aimed at planting 5 000 spekboom trees, to be distributed for replanting during Climate Change Month in April 2022 by people who claim to be passionate about the battle against climate change [76]. The project aimed to reduce the effects of climate change by mitigating carbon emissions in South Africa. There is also a plan to plant one million *P. afra* plants on a wine farm in the Karoo [77]. A project at Stellenbosch aims to build the most extensive labyrinth in Africa made entirely from spekboom plants [78].

The Subtropical Thicket Restoration Programme (2004), launched by the South African government aimed to restore the subtropical thicket found in the Eastern Cape on a large

scale, planned to plant 21.5 million *P. afra* cuttings over twelve years from 2004–2016 in the Addo Elephant Park, Great Fish River Nature Reserve, and the Baviaanskloof Nature Reserve [65]. However, in 2017 a survivorship study showed that only 28% of the cuttings (6 million plants) survived [31].

Researchers, conservation managers, landowners, rural communities, and other interested parties formed the Thicket Forum in 2004 [79]. Annual meetings are held in June at the Addo Elephant Park. The forum also offers workshops, conservation plans, and guidelines with regard to the restoration of the subtropical thicket, sustainable management of the thicket, and the conservation of natural biomes such as the subtropical thicket. The chairman of the Thicket Forum is Dr Alistair Potts from the Botany Department at Nelson Mandela University. The highly informative website contains lists of theses and journal articles regarding the conservation of the Valley Bushveld and its plants, soil, and elephants [79]. Five of the listed journal publications deal with the *Portulacaria afra* plant. On the website is valuable information on spekboom under the knowledge tab, with links to articles that were in the news or published online [75].

12. Conclusions and Recommendations

Southern Africa has a high risk for food and nutrition insecurity. More food must be cultivated and harvested to alleviate the existing problem and meet future demands. Climate change is one of the biggest challenges the world and Southern Africa face, as it influences food production. Indigenous to South Africa, *P. afra* is a sustainable edible plant that thrives in semiarid areas and can be cultivated by gardeners, smallholder farmers, and commercial farmers. It may not be the excellent carbon sequestration plant that has been reported on social media, but if developed into a crop, *P. afra* could solve more than one threat in Southern Africa. However, more research is necessary to persuade academics and consumers that *P. afra* can be used to alleviate food insecurity. Currently, limited information is available. The available information is often on misleading nonpeer-reviewed websites, while peer-reviewed journal articles are not accessible to nonacademics. Researchers should publish sufficient information for the plant to be used as a crop, for therapeutic use, functional food ingredients, and ingredients in dishes as peer-reviewed resources accessible to interested consumers, journalists, and researchers. Research on the nutritional content, sensory acceptability of leaves, cooking methods, and processed products is encouraged. Agronomy scientists are urged to research the technicalities of harvesting regarding the method and time taken to harvest the leaves. Consumer awareness and acceptance tests must be conducted to change consumers' attitudes toward this new food ingredient.

Author Contributions: Ideation, A.d.T.; literature search and data analysis, A.d.T., R.M., E.S., A.B.Z. and Z.P.M.; revised the work, A.d.T.; Supervision, A.d.T. and M.d.W.; project administration, A.d.T.; funding acquisition, M.d.W. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the University of the Free State Central Research Fund (2020).

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Garrity, D.P.; Akinnifesi, F.K.; Ajayi, O.C.; Weldesemayat, S.G.; Mowo, J.G.; Kalinganire, A.; Larwanou, M.; Bayala, J. Evergreen Agriculture: A Robust Approach to Sustainable Food Security in Africa. *Food Secur.* **2010**, *2*, 197–214. [CrossRef]
2. Food and Agriculture Organization of the United Nations. *FAO Food and Agriculture Key to Achieving the 2030 Agenda for Sustainable Development 2*; FAO: Rome, Italy, 2016.
3. United Nations Food Systems Summit x SDGs | United Nations. 2021. Available online: https://www.un.org/en/food-systems-summit/sdgs (accessed on 3 October 2021).
4. Gil, J.D.B.; Reidsma, P.; Giller, K.; Todman, L.; Whitmore, A.; van Ittersum, M. Sustainable Development Goal 2: Improved Targets and Indicators for Agriculture and Food Security. *Ambio* **2019**, *48*, 685–698. [CrossRef]

5. FAO. *The State of Food Security and Nutrition in the World 2021*; FAO: Rome, Italy; IFAD: Rome, Italy; UNICEF: New York, NY, USA; WFP: Rome, Italy; WHO: Geneva, Switzerland, 2021.
6. Nguyen, H. Sustainable Food Systems—Concept and Framework | Policy Support and Governance | Food and Agriculture Organization of the United Nations. 2018. Available online: https://www.oneplanetnetwork.org/sites/default/files/from-crm/ca2079en.pdf (accessed on 20 January 2022).
7. Masipa, T.S. The Impact of Climate Change on Food Security in South Africa: Current Realities and Challenges Ahead. *JAMBA J. Disaster Risk Stud.* **2017**, *9*, 7. [CrossRef]
8. Oxford, T. The Complex Insecurity of Hunger in South Africa. *The Mail & Guardian*, 26 October 2018.
9. Ngcuka, O. Biggest Threat to Food Security in South Africa Is 'Lack of Subsistence Farming'—Panel Warns. *Daily Maverick*, 6 October 2022.
10. Sunderland, T.C.H. Food Security: Why Is Biodiversity Important? *Int. For. Rev.* **2011**, *13*, 265–274. [CrossRef]
11. Labadarios, D.; Mchiza, Z.J.; Steyn, P.N.; Gericke, G.; Maunder, E.M.W.; Davids, D.Y.; Parker, W. Food Security in South Africa: A Review of National Surveys. *Bull World Health Organ.* **2011**, *89*, 891–899. [CrossRef]
12. de Vynck, J.C.; van Wyk, B.E.; Cowling, R.M. Indigenous Edible Plant Use by Contemporary Khoe-San Descendants of South Africa's Cape South Coast. *S. Afr. J. Bot.* **2016**, *102*, 60–69. [CrossRef]
13. Altman, M.; Hart, T.G.B.; Jacobs, P.T. Household Food Security Status in South Africa. *Agrekon* **2009**, *48*, 345–361. [CrossRef]
14. Van Wyk, B.E. The Potential of South African Plants in the Development of New Food and Beverage Products. *S. Afr. J. Bot.* **2011**, *77*, 857–868. [CrossRef]
15. Freyssa, D.H.; Njoka, J.T.; Asfaw, Z.; Nyangito, M.M. Wild Edible Fruits of Importance for Human Nutrition in Semiarid Parts of East Shewa Zone, Ethiopia: Associated Indigenous Knowledge and Implications to Food Security. *Pak. J. Nutr.* **2011**, *10*, 40–50. [CrossRef]
16. Baldermann, S.; Blagojević, L.; Frede, K.; Klopsch, R.; Neugart, S.; Neumann, A.; Ngwene, B.; Norkeweit, J.; Schröter, D.; Schröter, A.; et al. Are Neglected Plants the Food for the Future? *CRC Crit. Rev. Plant Sci.* **2016**, *35*, 106–119. [CrossRef]
17. Cowling, R.M.; Mills, A.J. A Preliminary Assessment of Rain Throughfall beneath *Portulacaria afra* Canopy in Subtropical Thicket and Its Implications for Soil Carbon Stocks. *S. Afr. J. Bot.* **2011**, *77*, 236–240. [CrossRef]
18. Omotayo, A.O.; Aremu, A.O. Underutilized African Indigenous Fruit Trees and Food–Nutrition Security: Opportunities, Challenges, and Prospects. *Food Energy Secur.* **2020**, *9*, e220. [CrossRef]
19. Mahlanza, Z.P.; De Wit, M.; Hugo, A.; Du Toit, A. The Physicochemical and Nutritional Value of Fresh and Processed *Portulacaria afra* (Spekboom) Leaves. *Agronomy* **2023**, *13*, 709. [CrossRef]
20. Baran, R.J. Portulacaria afra Monograph, the Elephant's Food or Spekboom. Available online: https://www.magiminiland.org/Portulacaria.html (accessed on 13 June 2022).
21. Becking, D. Portulacaria afra. Available online: https://treesa.org/portulacaria-afra/ (accessed on 1 July 2021).
22. Hankey, A. Portulacaria afra. Available online: http://pza.sanbi.org/portulacaria-afra (accessed on 14 January 2023).
23. Mahr, S. Elephant Bush, Portulacaria afra—Wisconsin Horticulture. Available online: https://hort.extension.wisc.edu/articles/elephant-bush-portulacaria-afra/ (accessed on 20 January 2023).
24. Secuianu, M. Portulacaria afra Plants Guide: How to Grow & Care for "Elephant Bush". Available online: https://gardenbeast.com/portulacaria-afra-guide/ (accessed on 23 January 2023).
25. Bruyns, P.V.; Oliveira-Neto, M.; Melo-de-Pinna, G.F.; Klak, C. Phylogenetic Relationships in the Didiereaceae with Special Reference to Subfamily Portulacarioideae. *Taxon* **2014**, *63*, 1053–1064. [CrossRef]
26. Slim, J. Portulacaria afra—Elephant Bush Care, Types and Propagation—Succulent Plant Care. Available online: https://succulentplantcare.com/portulacaria-afra-elephant-bush-care-types-and-propagation/ (accessed on 23 January 2023).
27. Soeder, D.J. Greenhouse Gas Sources and Mitigation Strategies from a Geosciences Perspective. *Adv. Geo-Energy Res.* **2021**, *5*, 274–285. [CrossRef]
28. Mchunu, S.E. *Distribution and Stability of Soil Carbon in Spekboom Thicket, Eastern Cape, South Africa*; University of Stellenbosch: Stellenbosch, South Africa, 2012.
29. Guralnick, L.J.; Gladsky, K. Crassulacean Acid Metabolism as a Continuous Trait: Variability in the Contribution of Crassulacean Acid Metabolism (CAM) in Populations of *Portulacaria afra*. *Heliyon* **2017**, *3*, e00293. [CrossRef]
30. Yamori, W.; Hikosaka, K.; Way, D.A. Temperature Response of Photosynthesis in C3, C4, and CAM Plants: Temperature Acclimation and Temperature Adaptation. *Photosynth. Res.* **2014**, *119*, 101–117. [CrossRef]
31. Mills, A.J.; Robson, A. Survivorship of Spekboom (*Portulacaria afra*) Planted within the Subtropical Thicket Restoration Programme. *S. Afr. J. Sci.* **2017**, *113*, 1–3. [CrossRef]
32. Palmer, E.; Pitman, N. *Trees of Southern Africa: Covering All Known Indigenous Species in the Republic of South Africa, South-West Africa, Botswana, Lesotho & Swaziland. Volumes 1 & 2*; Balkema: Cape Town, South Africa, 1972.
33. Samara Spekboom: 5 Things You Didn't Know. Available online: https://www.samara.co.za/blog/five-things-didnt-know-spekboom/ (accessed on 13 June 2022).
34. On Secret Hunt Is the Spekboom Flower Edible? Available online: https://www.onsecrethunt.com/is-the-spekboom-flower-edible/ (accessed on 21 January 2023).
35. Vlok, J.H.J.; Euston-Brown, D.I.W.; Cowling, R.M. Acocks' Valley Bushveld 50 Years on: New Perspectives on the Delimitation, Characterisation and Origin of Subtropical Thicket Vegetation. *S. Afr. J. Bot.* **2003**, *69*, 27–51. [CrossRef]

36. Hoare, D.B.; Mucina, L.; Rutherford, M.C.; Vlok, J.H.J.; Euston-Brown, D.I.W.; Palmer, A.R.; Powrie, L.W.; Lechmere-Oertel, R.G.; Procheş, Ş.M.; Dold, A.P.; et al. Albany Thicket Biome. *Strelitzia* **2006**, *19*, 541–567.
37. Potts, A.J. Potts Research Group Blog: To the Root of the Problem with Spekboom Rehabilitation. Available online: http://pottsresearch.blogspot.com/2016/04/to-root-of-problem-of-spekboom.html (accessed on 21 January 2023).
38. Babylonstoren Respect the Spekboom! Available online: https://babylonstoren.com/blog/post/respect-the-spekboom (accessed on 21 January 2023).
39. van der Vyver, M.L.; Mills, A.J.; Cowling, R.M. A Biome-Wide Experiment to Assess the Effects of Propagule Size and Treatment on the Survival of *Portulacaria afra* (Spekboom) Truncheons Planted to Restore Degraded Subtropical Thicket of South Africa. *PLoS ONE* **2021**, *16*, e0250256. [CrossRef]
40. Duker, R.; Cowling, R.M.; du Preez, D.R.; Potts, A.J. Frost, *Portulacaria afra* Jacq., and the Boundary between the Albany Subtropical Thicket and Nama-Karoo Biomes. *S. Afr. J. Bot.* **2015**, *101*, 112–119. [CrossRef]
41. Ambreen, A. Spekboom—Climate Change Super Hero—The Green Directory. Available online: https://www.thegreendirectory.net/blog/spekboom-climate-change-super-hero (accessed on 13 June 2022).
42. Erasmus, J. Spekboom, Chickpea and Tomato Salad | Woolworths TASTE. Available online: https://taste.co.za/recipes/spekboom-chickpea-and-tomato-salad/ (accessed on 25 January 2023).
43. Searra, I. Spekboom Recipes for the Soul. Available online: https://www.getaway.co.za/travel-news/spekboom-recipes-for-the-soul/ (accessed on 25 January 2023).
44. showme.co.za Pork Belly with Gooseberry and Spekboom Pickle | Paarl. Available online: https://showme.co.za/paarl/lifestyle/winelands-kitchen/recipes-winelands-kitchen/pork-belly-with-gooseberry-and-spekboom-pickle/ (accessed on 25 January 2023).
45. Hepburn, F. Exploring Our Hunter-Gatherer Past & Palates in Paternoster—Stay in Paternoster. Available online: https://stayinpaternoster.co.za/2016/09/exploring-our-hunter-gatherer-past-palates-in-paternoster/ (accessed on 25 January 2023).
46. Shamwari Spekboom—5 Amazing Facts About This Wonder Plant. Available online: https://www.shamwari.com/5-amazing-facts-about-spekboom/ (accessed on 13 June 2022).
47. Grosel, J. Using the Wonderplant for a Wonderful Initiative. 2021. Available online: http://www.tembele.co.za/wp-content/uploads/2021/02/Carbon-Footprint-offset-Spekboom-33.pdf (accessed on 14 October 2021).
48. Harmon, B. Spekboom Trees for All! Available online: https://zingelaulwazi.org.za/spekboom-trees-for-all/ (accessed on 21 January 2023).
49. Kirsten, E. 11-Year-Old Plants 750 Spekbooms during Holidays. Available online: https://www.getaway.co.za/travel/nature-and-conservation/11-year-old-plants-750-spekboom-during-holiday/ (accessed on 21 January 2023).
50. INRAE; CIRAD; AFZ; FAO. Elephant's Food (Portulacaria afra). Available online: https://www.feedipedia.org/node/112 (accessed on 21 January 2023).
51. Powell, M.J. *Restoration of Degraded Subtropical Thickets in the Baviaanskloof Megareserve, South Africa: The Role of Carbon Stocks and Portulacaria afra Survivorship*; Rhodes University: Grahamstown, South Africa, 2009.
52. Singels, E. The Health Benefits of the Spekboom Plant—YouTube. Available online: https://www.youtube.com/watch?v=eY5XeyGYDdg (accessed on 21 January 2023).
53. Basson, D.C.; Teffo, T.K.; Risenga, I.M. A Phytochemical Screening, Antioxidant and Antibacterial Activity Analysis in the Leaves, Stems and Roots of *Portulacaria afra*. *J. Herbmed Pharmacol.* **2023**, *12*, 109–117. [CrossRef]
54. Adeleye, O.C.; Risenga, I.M. Screening of Phytochemical Profile and Biological Activities in the Leaves, Stems and Roots of South African *Portulacaria afra* Using Four Extraction Solvents. *Biomed. Pharmacol. J.* **2022**, *15*, 1561–1572. [CrossRef]
55. Teffo, T.K.; Ramalepe, P.; Risenga, I. A Short Communication on the Ethnobotany, Phytochemistry, Pharmacological Evidence and Ecosystem Restoration Potential of South African *Portulacaria afra*. *J. Med. Plants Stud.* **2022**, *10*, 112–115.
56. Tabassum, S.; Ahmad, S.; Rehman, K.; Khurshid, U.; Rao, H.; Alamri, A.; Ansari, M.; Ali, B.; Waqas, M.; Saleem, H.; et al. Phytochemical, Biological, and in-Silico Characterization of *Portulacaria afra* Jacq.: A Possible Source of Natural Products for Functional Food and Medicine. *S. Afr. J. Bot.* **2022**, *150*, 139–145. [CrossRef]
57. Khanyile, A.; Maliehe, T.S.; Shandu, J.S.; Khan, R. In Vitro Antibacterial, Antioxidant, Anti-Quorum Sensing and Cytotoxic Properties of *Portulacaria afra* Leave Extract. *Biosci. Res.* **2008**, *18*, 455–463.
58. De Wet, H.; Nciki, S.; Van Vuuren, S.F. Medicinal Plants Used for the Treatment of Various Skin Disorders by a Rural Community in Northern Maputaland, South Africa. *J. Ethnobiol. Ethnomed.* **2013**, *9*, 51. [CrossRef] [PubMed]
59. Olaokun, O.O.; Mkolo, N.M.; Mogale, M.A.; King, P.H. Phytochemical Screening, Antioxidant, Anti-Inflammatory, and Glucose Utilization Activities of Three South African Plants Used Traditionally to Treat Diseases. *Biol. Med.* **2017**, *9*, 5. [CrossRef]
60. Fulmaka, A. *Investigating Soil Microbial Interactions of Portulacaria afra*; Rhodes University: Grahamstown, South Africa, 2016.
61. Salaheldin, T.A.; El-Chaghaby, G.A.; El-Sherbiny, M.A. Green Synthesis of Silver Nanoparticles Using *Portulacaria afra* Plant Extract: Characterization and Evaluation of Its Antibacterial, Anticancer Activities. *Nov. Res. Microbiol. J.* **2019**, *3*, 215–222. [CrossRef]
62. Van Wyk, B.E.; De Wet, H.; Van Heerden, F.R.; Oormeyer, J.; Salmon, A.; Wessels, A.; Williams, E. An Ethnobotanical Survey of Medicinal Plants in the Southeastern Karoo, South Africa. *S. Afr. J. Bot.* **2008**, *74*, 696–704. [CrossRef]
63. Prisa, D. Plant Growth Promoting Rhizobacteria: Increase of Vegetative and Roots Biomass in *Portulacaria afra*. *GSC Adv. Res. Rev.* **2020**, *2*, 1–7. [CrossRef]

64. van der Vyver, M.L.; Cowling, R.M.; Mills, A.J.; Difford, M. Spontaneous Return of Biodiversity in Restored Subtropical Thicket: *Portulacaria afra* as an Ecosystem Engineer. *Restor. Ecol.* **2013**, *21*, 736–744. [CrossRef]
65. Mills, A.J.; Van der Vyver, M.; Gordon, I.J.; Patwardhan, A.; Marais, C.; Blignaut, J.; Sigwela, A.; Kgope, B. Prescribing Innovation within a Large-Scale Restoration Programme in Degraded Subtropical Thicket in South Africa. *Forests* **2015**, *6*, 4328–4348. [CrossRef]
66. Spriggs, A. Albany Thickets. Available online: https://www.worldwildlife.org/ecoregions/at1201 (accessed on 21 January 2023).
67. Frielinghaus, M. Spekboom | The Complete Book. Available online: https://thecompletecookbook.wordpress.com/tag/spekboom/ (accessed on 25 January 2023).
68. Delport, S. About the Spekboom the Wonder Plant of the 21st Century. Available online: https://www.facebook.com/187179314663175/posts/about-the-spekboomthe-wonder-plant-of-the-21st-century-by-stef-delportthe-spekbo/2100007213380366/?_rdc=1&_rdr (accessed on 13 July 2022).
69. Wild, S. No, Spekboom Isn't More Effective than the Amazon Rainforest at 'Sucking Carbon' out of the Atmosphere—Africa Check. Available online: https://africacheck.org/fact-checks/reports/no-spekboom-isnt-more-effective-amazon-rainforest-sucking-carbon-out-atmosphere (accessed on 28 March 2023).
70. Mills, A.J.; Cowling, R.M. How Fast Can Carbon Be Sequestered When Restoring Degraded Subtropical Thicket? *Restor. Ecol.* **2014**, *22*, 571–573. [CrossRef]
71. McCarthy, K. Species Spotlight— *Portulacaria afra* | The Succulent Eclectic. Available online: https://thesucculenteclectic.com/species-spotlight-portulacaria-afra/#%3A~%3Atext%3DPortulacaria%20afra%20Flower%20Portulacaria%20afra%20flowers%20only%20when%2Cand%20wildly%20attractive%20to%20bees%20and%20other%20insects (accessed on 21 January 2023).
72. USDA. Plant Hardiness Zones. Available online: https://www.fs.usda.gov/wildflowers/Native_Plant_Materials/Native_Gardening/hardinesszones.shtml (accessed on 23 January 2023).
73. Mills, A.J.; Cowling, R.M.; Steyn, D.; Spekreijse, J.; Van den Broeck, D.; Weel, S.; Boogerd, C. *Portulacaria afra* Is Constrained under Extreme Soil Conditions in the Fish River Reserve, Eastern Cape, South Africa. *S. Afr. J. Bot.* **2011**, *77*, 782–786. [CrossRef]
74. Sholto-Douglas, C. *Factors Influencing Survivorship of Portularia afra Cutting in Restoration of Degraded Lands*; Rhodes University: Grahamstown, South Africa, 2018.
75. Van Cotthem, W. Use Drought Tolerant *Portulacaria afra* (Spekboom) to Combat Desertification, e.g. for the Great Green Wall—Desertification. Available online: https://desertification.wordpress.com/2017/03/05/use-drought-tolerant-portulacaria-afra-spekboom-to-combat-desertification-e-g-for-the-great-green-wall/?fbclid=IwAR1ygZyNp3FaO2NmTwGoQ1kCHzvb6KYgfNyZfmVsByFhoBm13txeKMRDEfs (accessed on 29 March 2023).
76. Dordley, L. Cape Town to Plant 5000 Spekboom. Available online: https://www.capetownetc.com/cape-town/cape-town-to-plant-5-000-spekboom/ (accessed on 17 April 2023).
77. Pretorius, A. Boplaas to Plant 1 Million Spekboom by 2025 in the Fight for Climate Change—Wineland Media. Available online: https://www.wineland.co.za/boplaas-to-plant-1-million-spekboom-by-2025-in-the-fight-for-climate-change/ (accessed on 17 April 2023).
78. Spekboom. Challenge Aims to Tackle Climate Change. Available online: https://www.capetownetc.com/cape-town/spekboom-challenge-aims-to-tackle-climate-change/ (accessed on 22 January 2023).
79. Lunderstedt, K. Thicket Forum. Available online: https://www.thicketforum.org.za/home (accessed on 3 March 2023).