CHAPTER 5

The Morama Bean (*Tylosema esculentum*): A Potential Crop for Southern Africa

Jose C. Jackson,[*,1] **Kwaku G. Duodu,**[†] **Mette Holse,**[‡] **Margarida D. Lima de Faria,**[§] **Danie Jordaan,**[‖] **Walter Chingwaru,**[¶] **Aase Hansen,**[‡] **Avrelija Cencic,**[¶] **Martha Kandawa-Schultz,**[#] **Selalelo M. Mpotokwane,**[**] **Percy Chimwamurombe,**[#] **Henrietta L. de Kock,**[†] and **Amanda Minnaar**[†]

Contents

[*] Centre for Scientific Research, Indigenous Knowledge and Innovation (CESRIKI), University of Botswana, Botswana
[†] Department of Food Science, University of Pretoria, Pretoria, South Africa
[‡] Department of Food Science, Quality and Technology Section, University of Copenhagen, Frederiksberg C, Denmark
[§] Department of Human Sciences, Programme for Global Development, Tropical Research Institute–IICT, Rua da Junqueira, Lisbon, Portugal
[‖] Market Matters Inc., South Africa, Ithaca, New York, USA
[¶] Department of Microbiology, Biochemistry, Molecular Biology and Biotechnology, University of Maribor, Hoče, Slovenia
[#] Department of Biochemistry and Chemistry, and Department of Biological Sciences, University of Namibia, Windhoek, Namibia
[**] National Food Technology Research Centre, Kanye, Botswana
[1] Corresponding author: Jose C. Jackson, *E-mail address:* jcjakson@yahoo.com

Advances in Food and Nutrition Research, Volume 61
ISSN 1043-4526, DOI: 10.1016/S1043-4526(10)61005-4

Abstract The morama bean is an underutilized leguminous oilseed native to the Kalahari Desert and neighboring sandy regions of Botswana, Namibia, and South Africa (Limpopo, North-West, Gauteng, and Northern Cape provinces), and forms part of the diet of the indigenous population in these countries. It is also known as gemsbok bean, moramaboontjie, elandboontjie, braaiboonjie, marama, marumana, tsi, tsin, gami, and ombanui. It is reported as an excellent source of good quality protein (29–39%); its oil (24–48%) is rich in mono- and di-unsaturated fatty acids and contains no cholesterol. Morama is a good source of micronutrients such as calcium, iron, zinc, phosphate, magnesium, and B vitamins including folate. It is also reported to be a potential source of phytonutrients including phenolic compounds (e.g., tannins), trypsin inhibitors, phytates, and oligosaccharides, components which have been shown in other foods to contribute to health in particular, prevention of noncommunicable diseases such as cardiovascular diseases, diabetes, and some cancers. From a nutritional and health perspective, the morama bean has potential commercial value as a cash crop and value-added products, particularly in the communities where it is found.

I. INTRODUCTION

The morama bean is an underutilized crop native to the arid and semiarid regions of Botswana, Namibia, and South Africa and forms part of the diet of indigenous populations. Botanically, morama beans belong to the family Fabaceae (Leguminosae), subfamily Ceasalpinoidae, and genus *Tylosema* (Dubois *et al*., 1995; Hartley *et al*., 2002). The morama bean is also known as gemsbok bean (English); *moramaboontjie*, *elandboontjie*, *braaiboonjie* (Afrikaans); *marama*, *morama* (Tswana); *marumana* (Thonga); *tsi*, *tsin* (!Kung San); *gami* (Khoi); *ombanui* (Herero). In Botswana, it is referred to as morama, whereas in Namibia and South Africa, it is referred to as marama. For the purposes of this review, the term ''morama'' will be used.

The economic importance of the genus *Tylosema* has been known for a very long time. Burchell (1824) emphasized the importance and use of morama seeds and the underground tuber by the indigenous population, especially of the Kalahari Desert. The composition of the edible seeds has been reported by different authors as an excellent source of good quality protein (29–39%) and oil contents ranging from 24% to 48% (Amarteifio and Moholo, 1998; Bower *et al*., 1988; Dubois *et al*., 1995; Francis and Campbell, 2003; Holse *et al*, 2010; Ketshajwang *et al*., 1998; Mitei *et al*., 2008). It is also a good source of micronutrients such as calcium, iron, zinc, phosphate, potassium, magnesium, and B vitamins (Wehmeyer *et al*., 1969).

There has been very little research conducted on the morama bean, largely because it is found in the wild and only consumed by a small percentage of the population in the countries where found. However, in these areas, it is used by indigenous communities as a source of food, feed, shelter, and medicine, thus contributing to improve the quality of life in traditional agricultural and forest systems in various ways. The morama has enormous potential value that needs to be exploited for the further benefit of the communities. This review presents a summary of the available literature on its agronomic characteristics, chemistry, nutritional, and functional properties, processing applications, socioeconomic issues in the communities where it is found, consumer demand, and potential strategies for marketing value-added morama bean products.

II. AGRONOMIC CHARACTERISTICS

A. Current distribution and description of morama bean

Coetzer and Ross (1977) recognized four species in the genus *Tylosema*: (i) *Tylosema esculentum* (Burchell) A. Schreiber, (ii) *Tylosema fassoglense* (Kotschy) Torre & Hillc, (iii) *Tylosema argentea* (Chiov) Brenan, and (iv) *Tylosema humifusa* (Pichi-Serm & Roti-Michael) Brena. They are found throughout Africa with the exception of *T. esculentum* (Burchell) A. Schreiber, which is specific only to the semiarid regions of Southern Africa (Fig. 5.1).

The morama bean is presently known only in the wild state. It tolerates the scorching heat and long drought periods of the Kalahari Desert of Botswana and Namibia (Fig. 5.2), where it is an important component of

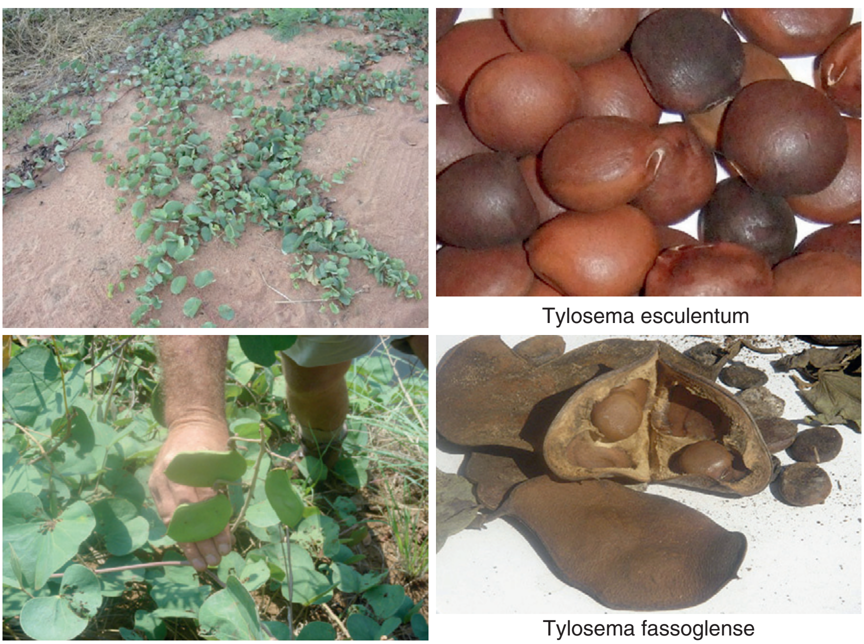

FIGURE 5.1 Morama bean plants and seeds from Southern Africa (*T. esculentum* and *T. fassoglense*) (adapted from Maruatona, 2008 and Kayitesi, 2009).

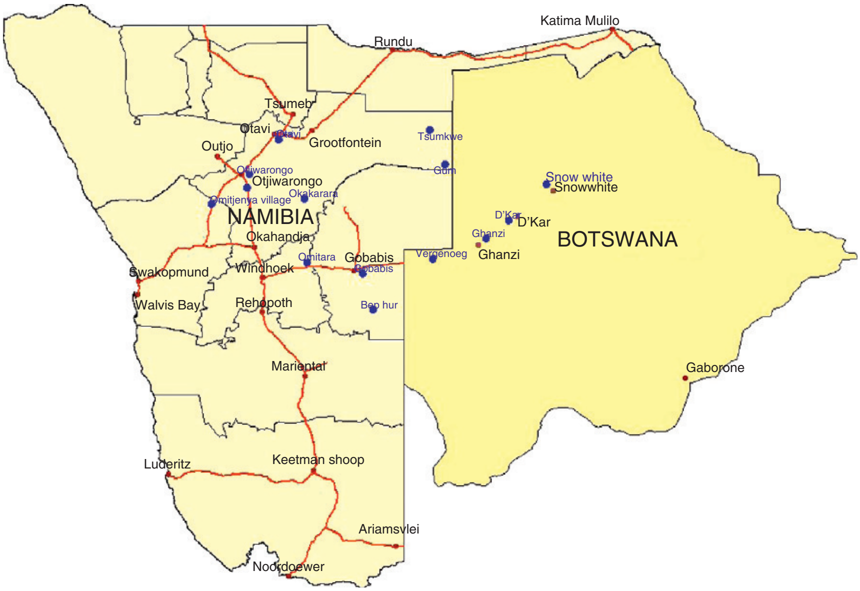

FIGURE 5.2 Current geographic distribution of morama bean in Namibia and Botswana (Agricultural Laboratory; Ministry of Agriculture, Water, and Forestry, 2004 as cited by Müuseler and Schönfeldt, 2006).

the diet of the Khoisan and nomadic Bushmen. It is native to the Kalahari Desert and the neighboring sandy regions of Namibia, Botswana, and South Africa (Northern Cape Province, North-West Province, Limpopo Province, and Gauteng Province), mostly in undulating grassveld or savannas (Bower *et al.*, 1988; National Academy of Sciences, 1979). The word ''*esculentum*'' means edible and was given to the plant because not only does it produce seeds and tubers that are eaten but browsing stock and game also consume the tuberous stems.

The typical habitat is an undulating grassveld (savanna) with morama sprouting among the native grass and acacia-thorn scrub on sandy vlies (wilderness). A mature morama bean plant (Fig. 5.1) has prostrate vines with numerous herbaceous stems which can be up to 6 m or longer (Vietmeyer, 1986). Morama bean is commonly found creeping over the soil surface with vines carrying double-lobed leaves that are soft and reddish brown when young, but later turn leathery and greyish-green with age (National Academy of Sciences, 1979). Golden yellow flowers develop in midsummer and the fruits ripen in late autumn (National Academy of Sciences, 1979).

The vines die in winter, but the plant is maintained by a perennial tuber (Hartley *et al.*, 2002). Storage roots or tubers can attain a weight of up to 12 kg in a few years (Bousquet, 1982) and can contain up to 90%

water, which serves as an important emergency source of water for Kalahari foragers (Keith and Renew, 1975). Powell (1987) attributes the success of the morama bean as an energy-efficient arid land crop to the survivability of tubers during winter dormancy. Typically, the pods can contain one to two seeds and are encased by a hard, water tight coat. Yellow flowers of about 4 cm across, are produced in clusters of three to nine, mostly on the distal two-thirds of the stem.

For every 100 plants from the morama bean population, 77 of them were able to outcross, indicating that the morama bean is predominantly an outcrossing species (Monaghan, 1995). Chromosome counts made from the root tips of morama bean seedlings ranged from 42 to 50 showing a relatively high number of chromosomes, which is consistent with chromosomes count of 52 from its closely related species, *T. fassoglense* (Monaghan, 1995).

B. Seed morphology, seedling development, growing stages, diseases, and pests

Morama bean is a wild tuber producing nonnodulating legume. Generally, the plant is low yielding, producing one or two seeds per pod and in total, a few seeds per plant. The seeds develop in a typical legume pod, which is large and squat in shape. In most cases, there are one to three seeds per pod. Rarely, it is possible to find up to 10 seeds in a single pod (personal observation). In terms of cultivation, there are only a few isolated cultivation efforts ongoing in the countries of interest in Southern Africa. The reason for that is the serious lack of important information on the biology of the plant. However, due to the advent of modern crop development tools, the knowledge gap is closing and the cultivation of morama bean is beginning to gain momentum.

The seed's hard shell means that scarification is necessary in order to increase germination rates. A pH of about 7 is preferred for growth and the plant typically grows in sandy loamy soils where waterlogging will not be a problem. There are only very few places in the world that are propagating morama bean, namely, USA, Australia, Namibia, and Botswana. One of the major hindrances to plant improvement through breeding is the heterostylic property of the flowers. A bee (on its own) has been observed and implicated to be the pollinator for morama. The taxonomic identity of the bee is still being investigated.

In terms of diseases, not much has been recorded, except a recent report (unpublished data) on two fungi coinfecting the pods of morama. The two fungi associated with the necrotic lesions were revealed to be *Alternaria tenuissima* and *Phoma* spp. using DNA-based and morphological characterization. Insects pest have been observed on the wild stand of morama causing seed damage. However, the identity of the insects is yet to be ascertained.

C. Classification and variety identification

There are no varieties of morama bean that have been developed so far. However, there are advanced crop improvement experiments that are designed to produce a variety of cultivars, namely, early maturing cultivars, using morama that matures after about 18–24 months. Microsatellite markers (Weising *et al*., 1998) have been developed and used previously. Current microsatellite markers for morama beans have been developed using a modified procedure by Zane *et al*. (2002). These markers will be used in marker-assisted selection (MAS) for the morama bean.

D. Characteristics of soils from morama bean- and nonmorama bean-growing areas

Thomas (2004) reported on the characteristics of morama bean- and nonmorama bean soils collected from different sites in both Namibia (Sandveld Site 1, 2, 3, 4 and Buitepos) and Botswana (Charleshill, Chobokwane, Ghanzi, Groote Laagte Site 1, Makgobokgobo Site 1, Xhoga, and Xanagas). In general, the soils were fine aeolian (waterlogged) sands characterized by the presence of dolomite or limestone concretions in the soil profile (Table 5.1). Morama bean soils from Sandveld Site 1 were brown and sandy with limestone/dolomite concretions (compact, often rounded accumulations of mineral matter that form in the soil) on the surface and subsurface layer, while soils from Sandveld Site 2 and Buitepos had no limestone or dolomite concretions either on the surface or within the soil profile. The soil from Sandveld Site 3 was virtually white sand with carbonate concretions in the profile but not on the surface.

The soils from the morama bean-growing sites in Botswana were characterized by brown sand with no dolomite or limestone concretions on the surface or in the soil profile. Of all the sites in Botswana, only Ghanzi was characterized by white sand with dolomite or limestone concretions in the soil profile. Nonmorama soils from Namibia (Sandveld Site 4) were very fine white sands that appeared wet, waterlogged, and clayish, while those from Botswana soils (Groote Laagte Site 2 and Makgobokgobo Site 2) were generally brown sands with no limestone or dolomite concretions in the profile.

1. Soil pH

The pH of the morama bean soils (0–120 cm) collected from Namibia ranged from 5.08 ± 0.08 to 6.90 ± 0.26. A significant difference was found between morama bean soils from Sandveld Sites 1 and 2, and Buitepos, and nonmorama bean soils from Sandveld Site 4. The soils from Botswana showed mean pH values of 5.04 ± 0.21 to 7.40 ± 0.25 for morama bean-growing areas and 4.04 ± 0.03 to 4.89 ± 0.16 for

TABLE 5.1 Description of morama and nonmorama bean soils collected from Namibia and Botswana

Site	Soil description
Namibia	
Morama bean soils	
Sandveld Site 1	Brown fine aeolian sand with limestone/dolomite concretions on top and subsurface layers
Sandveld Site 2	Brown fine aeolian sand with no limestone/dolomite concretions
Sandveld Site 3	White fine aeolian sand with limestone/dolomite concretions in soil profile but not on surface
Buitepos	Brown fine aeolian sand with no limestone/dolomite concretions
Nonmorama bean soil	
Sandveld Site 4	White water-logged very fine sand with limestone/ dolomite concretions in profile but not on surface layer. Appeared a bit clayish
Botswana	
Morama bean soil	
Charleshill	Brown fine aeolian sand with no limestone/dolomite concretions
Chobokwane	Brown fine aeolian sand with no limestone/dolomite concretions
Ghanzi	White fine aeolian sand with limestone/dolomite concretions in soil profile
Groote Laagte Site 1	Brown fine aeolian sand with no limestone/dolomite concretions
Makgobokgobo Site 1	Brown fine aeolian sand with no limestone/dolomite concretions
Xanagas	Brown fine aeolian sand with no limestone/dolomite concretions
Xhoga	Brown fine aeolian sand with no limestone/dolomite concretions
Nonmorama bean soil	
Makgobokgobo Site 2	Brown fine aeolian sand with no limestone/dolomite concretions
Groote Laagte Site 2	Brown fine aeolian sand with no limestone/dolomite concretions

nonmorama bean soils. The pH values of morama bean soils from Ghanzi, Groote Laagte Site 1, Xanagas, and Xhoga were significantly higher than those obtained for control soils from Groote Laagte Site 2 and

Makgobokgobo Site 2 (i.e., soils where morama beans do not grow). Morama bean soils collected from Ghanzi showed the highest pH value of 7.40 ± 0.25. The pH of morama bean soils from Groote Laagte Site 1 was significantly different from that of Groote Laagte Site 2, the control from the same location. No significant differences were found between morama and nonmorama bean soils collected from Makgobokgobo. For both Namibia and Botswana, acidity values below pH 5 were recorded for only nonmorama bean soils. Soil pH values did not change significantly with depth within sites.

2. Soil organic matter

The organic matter content of soils collected from Namibia was generally low. The mean organic matter content of morama bean soils (0–120 cm) differed significantly for the four Namibian sites ($p < 0.05$). Buitepos showed the lowest organic matter content of 0.30 ± 0.02%, followed by Sandveld Sites 1 and 2 (0.38 ± 0.01%) and the highest (0.44 ± 0.02%) at Sandveld Site 3. However, these values were significantly lower than those obtained for nonmorama bean soils from Sandveld Site 4 (0.59 ± 0.03%). The soil organic matter content obtained for morama bean soils from Makgobokgobo Site 1 in Botswana was significantly higher than that of nonmorama bean soils from near the same site. As with pH, the organic matter content also did not change with soil depth within each site.

The data showed that soils supporting the growth of morama bean are very poor in nutrients, especially N, which is less than 0.06%, and organic matter below 0.45%. As a result, supplying N and P significantly increased plant growth and tuber yield under both field and glasshouse conditions. This indicates that, despite the species adaptation to low-nutrient conditions, the application of mineral fertilizers to morama bean in an agricultural setting is likely to promote and increase tuber yield. Walvoord *et al.* (2003) reported that there is a large nitrate pool located deep (>1 m) beneath desert soils. However, this was not reflected in the results from Thomas (2004). It should be acknowledged, however, that desert subsoil nitrate inventories are spatially highly variable, thereby requiring substantial measurement efforts to reduce uncertainty in global extrapolations.

III. CHEMISTRY, NUTRITIONAL, AND HEALTH POTENTIAL

A. Overall chemical composition

Morama beans may be eaten when they are still immature green beans, but most of them are eaten as mature beans when the seeds are surrounded by hard woody seed coats, reddish to brownish in color. Therefore, the morama beans need to be decorticated before use.

A number of studies have been carried out, describing the main chemical composition of the edible part of the decorticated morama bean (*T. esculentum*) and few samples of *T. fassoglense* have also been included. A literature survey of the performed proximate analysis is summarized in Table 5.2.

B. Moisture

The moisture content of the morama bean is very low as the dry matter (dm) content ranges from 93.4% to 98.7% (Bower *et al*., 1988; Holse *et al*., 2010; Wehmeyer *et al*., 1969). Variations may arise from external factors such as soil composition, climate, harvest time, and maturation state of the beans.

C. Ash

The ash content is a measure of the total mineral content in the beans, and this seems to be high as the ash content of the beans varies between 2.5% and 3.7% dm (Amarteifio and Moholo, 1998; Bower *et al*., 1988; Holse *et al*., 2010; Wehmeyer *et al*., 1969). Beans from South Africa have significantly higher ash content than beans from both Namibia and Botswana, which do not differ significantly (Holse *et al*., 2010). This might be due to a soil richer in minerals in South Africa. The content of the different minerals is discussed further below.

D. Lipids

The seed oil is golden yellow, with a nutty odor and a pleasant, although slightly bitter flavor, and has been described as similar to almond oil in consistency and taste (van der Maesen, 2006).

The content of lipids in the morama bean has been reported in several studies and large variations were reported. Ranges between 24% and 42% were reported by (Amarteifio and Moholo, 1998; Bower *et al*., 1988; Dubois *et al*., 1995; Francis and Campbell, 2003; Holse *et al*., 2010; Mitei *et al*., 2008; Wehmeyer *et al*., 1969). Ketshajwang *et al*. (1998) reported a lipid content of 48% w/w which is substantially higher than other reported results. The high content of lipids is a great advantage of the beans, especially in regard to producing healthy products that may improve the nutritional status of undernourished people in Southern Africa.

The high amount of lipids in morama beans is comparable to the content found in seeds used for production of commercial vegetable oils such as sunflower seed (22–36%) and rapeseed (22–49%) and closely approaches that of peanuts (45–55%) (Belitz *et al*., 2004; Salunkhe and Kadam, 1989). The amount of lipids is twice that of soybeans

TABLE 5.2 Proximate composition (g/100 g) of the morama bean reported as mean ± SD or range

	Literatur e reviewed							
	Wehmeyer *et al.* (1969)	Bower *et al.* (1988)	Dubois *et al.* (1995)	Ketshajwang *et al.* (1998)	Amarteifio and Moholo (1998)	Francis and Campbell (2003)	Mitei *et al.* (2008)	Holse *et al.* (2010)[a]
	One batch of samples harvested in Botswana	One batch of samples harvested in Botswana during 1978–1980	Two batches of *T. fassoglense* from sites in Zaire and Burundi, respectively	One batch harvested in Botswana	One batch harvested in Botswana	X	1 kg harvested in Botswana	14 batches of *T. esculentum* and two of *T. fassoglense* harvested in Namibia, Botswana, and South Africa during 1990 and 2005–2008
Moisture	5.2	3.9 ± 1.0	–	–	–	–	–	1.3–6.6
Lipid	36.1	42.2 ± 1.6	24–30	48.2	33.5 ± 0.04	41.7	38.4	32.0–41.9
Protein	31.6	31.8 ± 1.1	–	–	34.1 ± 0.12	38.4	–	28.8–38.4
Carbohydrate[b]	23.2	18.9 ± 2.2	–	–	24.1 ± 0.02	–	–	–
Crude fiber	1.0	–	–	–	4.4 ± 0.13	–	–	–
Dietary fiber	–	–	–	–	–	–	–	18.7–26.8
Ash	2.9	3.2 ± 0.1	–	–	3.7 ± 0.14	–	–	2.5–3.7

[a] Note that these results are on dry matter basis, while the results from the other studies are as is.
[b] Obtained by difference.

(17–20% dm) (Belitz *et al.*, 2004; Street and Öpik, 1975), which is the legume that compares best with the high protein content of the morama beans. Most investigations are based on one or two samples, but Holse *et al*. (2010) compared the chemical composition of 16 samples, 14 samples of morama beans, and two samples of *T. fassoglense*.

Mitei *et al*. (2008) determined the percentage composition of lipid classes in morama oil and found that the oil is predominantly composed of neutral lipids, with triacylglycerols (TAGs) and fatty acids (82.8%) being the dominant lipid components. However, the oil appeared to contain fair amounts of polar lipids like diacylglycerols (3.4%) and monoacylglycerols (5.9%), which would suggest the occurrence of lipase-catalyzed hydrolysis in the oil. Indeed, the acid value of 2.96 mg KOH/g tends to support this observation (Mitei *et al*. (2008). In addition, the morama oil contained hydrocarbons (1.4%), sterol esters (1.8%), free sterols (1.9%), glycolipids (1.6%), and phospholipids (1.3%).

1. Triacylglycerols

The principal components of oils and fats on which all the physical and chemical properties depend are the TAG molecules. The TAGs are in turn made up of a variety of fatty acids esterified to the hydroxyl groups on glycerol molecules. TAG profiles of morama bean oil has been carried out by Mitei *et al*. (2008) who found seven major TAG classes, with the dominating classes being C54:4, C54:3, and C52:3. Occupancy of the sn-1 and sn-3 positions is 45.0% saturated, 38.4% oleoyl, and 16.6% linoleoyl. The sn-2 position is occupied by oleoyl (56.4%) and linoleoyl (43.6%).

2. Fatty acids

The lipid of morama beans is mainly (~75%) unsaturated fatty acids, with the principal fatty acid being oleic acid (43%). The beans furthermore contain linoleic (22%) and palmitic acid (13%) as well as stearic, arachidic, linolenic, arachidonic, erucic, behenic, myristic, palmitoleic, and gadoleic acid in lower concentrations (Bousquet, 1982; Bower *et al*., 1988; Engelter and Wehmeyer, 1970; Francis and Campbell, 2003; Ketshajwang *et al*., 1998; Mitei *et al*., 2008). The fatty acid composition resembles that of olive oil (Mitei *et al*., 2008). A literature review of the fatty acid composition of morama beans is given in Table 5.3. Less than 5% of the fatty acids are present as free acids (Bower *et al*., 1988; Dubois *et al*., 1995), which means that the activity of lipases is negligible in dry morama beans.

3. Phytosterols

Mitei *et al*. (2009) determined the relative percentage composition of phytosterols in morama bean oil and found 4-desmethylsterols to be the most abundant phytosterols in the oil (77% or 149.15 μg/g). The content of 4-desmethylsterols is comparable to the phytosterols content of olive oil

TABLE 5.3 Fatty acid composition (% of total fatty acids) of the morama bean reported as mean ± SD

		Literature reviewed						
		Engelter and Wehmeyer (1970)	Bousquet (1982)	Bower *et al.* (1988)	Ketshajwang *et al.* (1998)	Francis and Campbell (2003)	Mitei *et al.* (2008)	
		One batch	x	One mixed batch of samples harvested in Botswana during 1978–1980	One batch harvested in Botswana	x	1 kg harvested in Botswana	Average
Myristic	(14:0)	Trace	–	1.3 ± 0.3	0.13	–	–	1.7
Palmitic	**(16:0)**	**14.1 ± 1.3**	**16.9**	**13.8 ± 5.0**	**12.09**	**12.8**	**12.93 ± 0.06**	**13**
Margaric	(17:0)				0.09			0.1
Stearic	(18:0)	6.5 ± 0.3	10.0	9.7 ± 7.0	6.75	7.3	8.82 ± 0.12	7.7
Arachidic	(20:0)	3.3 ± 0.4	3.4	2.8 ± 1.3	2.76		3.31 ± 0.03	2.9
Behenic acid	(22:0)						1.03 ± 0.02	1.0
Palmitoleic	(16:1)	0.7 ± 0.1	1.8	1.7 ± 0.3	0.38			1.1
Oleic	**(18:1)**	**47.9 ± 0.9**	**34.8**	**48.5 ± 8.0**	**47.61 (n − 9) + 1.67 (n − 7)**	**49.0**	**47.27 ± 0.43**	**43**
Gadoleic	(20:1)	1.0 ± 0.2			0.57		0.61 ± 0.00	0.7

(continued)

TABLE 5.3 (*continued*)

		Literature reviewed						
		Engelter and Wehmeyer (1970)	Bousquet (1982)	Bower *et al.* (1988)	Ketshajwang *et al.* (1998)	Francis and Campbell (2003)	Mitei *et al.* (2008)	
		One batch	x	One mixed batch of samples harvested in Botswana during 1978–1980	One batch harvested in Botswana	x	1 kg harvested in Botswana	Average
Erucic	(22:1)	1.8 ± 0.2					2.63 ± 0.01	2.1
Linoleic	**(18:2)**	**24.6 ± 0.4**	**26.3**	**19.2 ± 9.5**	**26.43**	**23.5**	**23.40 ± 0.42**	**22**
(no common name)	(16:2)	Trace						
α- and γ-linolenic	(18:3)		2.3	2.0 ± 1.5		2.7		2.2
Arachidonic	(20:4)		2.1					2.0
Others	–			1.2 ± 1.0	1.54			1.3

The major fatty acids in the morama bean are in bold. The last column gives the average fatty acid composition (normalized to 100%).

(100 μg/g). The morama seed oil 4-desmethylsterols consisted of b-sitosterol (84.50 μg/g), stigmasterol (32.07 μg/g), campesterol (21.92 μg/g), 22-dihydrospinasterol (5.26 μg/g), Δ5-avenasterol (4.45 μg/g), and Δ7-avenasterol (1.58 μg/g). Morama oil also contained significant amounts of 4,4-dimethylsterols and 4-monomethylsterols (16% in total) as well as unidentified sterols (7%).

E. Protein

Keegan and Van Staden (1981), Bower *et al*. (1988), Amarteifio and Moholo (1998), and Holse *et al*. (2010) have all investigated the protein content of morama beans and it ranges from 29% to 39% on a dry matter basis. The protein content is comparable to or higher than most other legume seeds such as dry peas, chick peas, lentils, kidney beans, cowpea, and lupin with contents between 20% and 40% dm (Gueguen, 1983; Nassar *et al*., 2008) and equals that of soybeans (33–46% dm) (Belitz *et al*., 2004; Gueguen, 1983; Hymowitz *et al*., 1972). The high content of protein in morama beans gives the beans a great potential both as a nutritive food itself and as a protein-rich food ingredient for supplementation in other food products.

A significantly higher amount of protein is found in beans from South Africa compared to beans from Botswana. The amount of protein in beans from Namibia is between the contents from the two other countries (Holse *et al*., 2010). The variation in protein content might be due to different concentration of nitrogen in the soils. Bower *et al*. (1988) found that globulins are the most abundant (53%) protein constituents in morama beans. The beans furthermore consist of albumins (23.3%), prolamins (15.5%), alkali soluble glutelins (7.7%), and acid-soluble glutelins (0.5%).

1. Amino acids

The amino acid composition of proteins in morama beans is largely dominated by glutamic and aspartic acid as well as tyrosine (Bousquet, 1982; Bower *et al*., 1988; Dubois *et al*., 1995; Maruatona *et al*., 2010). All the essential amino acids are present in the beans. However, the sulfur-containing amino acids, methionine and cysteine, are present in quite low amounts. In general, morama bean protein appears to be comparable to soybean in content of essential amino acid, with methionine as the limiting amino acid (Bower *et al*., 1988). Morama protein quality is generally superior to most common legume crops and comparable to that of casein or milk protein (Powell, 1987). A literature review of the amino acid composition of morama bean proteins is given in Table 5.4.

TABLE 5.4 Amino acid composition (% of total amino acids, normalized to 100%) of the morama bean

Amino acid	Bower *et al.* (1988)	Dubois *et al.* (1995)[a]	Maruatona *et al.* (2010)
Essential			
Arginine	6.3	7.8	7.3
Cysteine	0.8	1.0	0.1
Histidine	2.4	2.8	2.8
Isoleucine	4.0	3.3	4.5
Leucine	5.9	5.8	6.6
Lysine	5.5	5.5	5.7
Methionine	0.8	0.3	0.8
Phenylalanine	4.8	4.2	4.8
Threonine	3.0	3.3	3.1
Tyrosine	**11.6**	**11.9**	**11.2**
Tryptophan	1.7	ND	ND
Valine	4.4	3.9	4.9
Nonessential			
Alanine	3.1	3.1	3.6
Aspartic acid	**10.8**	**10.5**	**9.3**
Glutamic acid	**15.6**	**17.7**	**15.5**
Glycine	5.7	6.0	6.3
Proline	6.9	7.6	7.8
Serine	5.3	5.4	5.6
Ammonia	1.3	ND	ND

Amino acids present in the highest amounts in morama beans are highlighted in bold.
[a] *T. fassoglense*.

F. Carbohydrate/dietary fiber

Wehmeyer *et al*. (1969), Bower *et al*. (1988), and Amarteifio and Moholo (1998) reported the content of carbohydrate to be 23%, 24%, and 19%, respectively. These values have been obtained indirectly as the difference between 100% and the content of proteins, lipids, and minerals. Holse *et al*. (2010) found that the content of carbohydrate was dominated by total dietary fiber as it varied between 18.7% and 26.8% dm (Table 5.2). The majority of the dietary fiber is insoluble as only about 4% of the dietary fibers are soluble. Comparing the content of total dietary fiber of morama bean with the content of peanut (9% dm) and soybean (10% dm) (U.S. Department of Agriculture, 2007), it appears that the morama bean has a considerably higher level of indigestible carbohydrates. Holse *et al*. (2010) also reported a very low starch content, which is in contrast to other legumes, in which starch is usually the most abundant carbohydrate

(22–45%) (Hoover and Sosulski, 1991). Hence, the morama bean is quite unique due to its high content of dietary fiber and low content of starch.

G. Minor chemical components

1. Vitamins

Wehmeyer *et al*. (1969) published results on the content of B vitamins (thiamine, riboflavin, and nicotinic acid), vitamin C, and β-carotene and found that the morama bean is a good source of both B vitamins and vitamin C, but a poor source of β-carotene. Holse *et al*. (2010) investigated the content of the eight vitamin E isomers and found that the vitamin E composition in morama beans is dominated by γ-tocopherol with 59–234 μg/g, followed by α- and β-tocopherols with 14–48 μg/g and 1.1–3.3 μg/g, respectively. Furthermore, traces of δ-tocopherol as well as β- and γ-tocotrienols were present in some samples. The remaining two tocotrienols (α- and δ-) were not present in the beans. The presence of α-, β-, and γ-tocopherols in the morama bean was also found by Mitei *et al*. (2009) who examined morama oil and by Dubois *et al*. (1995) who examined two samples of *T. fassoglense*.

The vitamin E components have numerous health benefits. The high content of γ-tocopherol is of particular biological relevance as it has shown potential anticarcinogenic and anti-inflammatory activities (Brigelius-Flohé, 2006; Saldeen and Saldeen, 2005).

2. Minerals

Morama is a good source of macroelements such as potassium, phosphate, magnesium, and calcium as well as the trace elements zinc, iron, and copper (Amarteifio and Moholo, 1998; Holse *et al*., 2010; Wehmeyer *et al*., 1969), as summarized in Table 5.5.

The relatively high level of minerals in the morama bean is quite surprising when taking into account the poor soils in which they grow. The beans actually have a level of macroelements (K, P, Mg, and Ca) similar to that of peanuts and approaching that of soybeans (U.S. Department of Agriculture, 2007) and furthermore contain several trace minerals (Zn, Fe, Cu, and Mn) in amounts that match the content of soybeans and peanuts. Especially the high contents of zinc and iron are important, since large percentages of the population in Africa are deficient or at risk of inadequate intake of zinc and iron (Hotz and Brown, 2004; UNICEF and Micronutrient Initiative, 2004).

3. Phytoestrogens

Phytoestrogens are naturally occurring plant-derived phytochemicals, which are precursors of hormone-like compounds found in mammalian systems. They possess a wide range of health promoting effects in

TABLE 5.5 Concentrations of minerals in the morama bean (mg/100 g) given as mean ± SD or range

	Amarteifio and Moholo (1998)	Holse *et al.* (2010)
K	776 ± 12.8	757–1316
P	397 ± 19.7	334–554
Mg		248–374
S		191–236
Ca	152 ± 4.7	119–133
Al		0.5–8.2
Zn		3.3–3.8
Fe	4.9 ± 0.17	1.3–3.7
Na	4.1 ± 0.29	0.2–2.9
Mn		1.5–2.6
B		1.8–2.9
Cu		0.6–1.6

humans, including potential anticarcinogenic activity (Branca and Lorenzetti, 2005; Kwiatkowska, 2007).

The morama bean is an excellent source of lignans (Holse *et al.*, 2010). The content of secoisolariciresinol in morama beans (305–406 µg/100 g) is higher than that of soybean (13–273 µg/100 g) and peanut (333 µg/100 g) (Mazur *et al.*, 1998). Likewise, the level of lariciresinol in morama beans (614–825 µg/100 g) is higher than that of soybeans (287 µg/100 g), while the level of pinoresinol in morama beans (21–23 µg/100 g) is lower than the level in soybeans (446 µg/100 g) (Penalvo *et al.*, 2004). These lignans can be converted by intestinal bacteria into enterolignans, which possess biological activities such as (anti) estrogenic and antioxidant action. Therefore, they may reduce the risk of certain types of cancers as well as cardiovascular diseases (Adlercreutz, 2007).

Contrary to soybeans which are rich in isoflavones (Mazur *et al.*, 1998), no isoflavones were found in the morama bean samples. The level of secoisolariciresinol and lariciresinol is retained during roasting, which is an important characteristic since the beans usually are eaten roasted (Holse *et al.*, 2010).

H. Antinutritional factors/toxic constituents

1. Trypsin inhibitor

A relatively strong trypsin inhibitor is found in raw morama beans (Bower *et al.*, 1988; Elfant *et al.*, 1985; Maruatona *et al.*, 2010; Powell, 1987). Bower *et al.* (1988) reported that trypsin inhibitor was about 20%

of the total morama seed protein and that the trypsin inhibitor activity can be destroyed by heat. Baking the defatted meal at 140 °C for 30 min decreased the activity by 70%.

2. Cyanogenic glycosides

Morama bean samples have been investigated for their potential cyanogenesis, which is the ability of some plants, including grain legumes and nuts, to release cyanide during degradation of cyanogenic glycosides. Upon tissue disruption, the cyanogenic glycosides may be enzymatically hydrolyzed to the respiratory poison hydrogen cyanide (Breiteneder and Radauer, 2004; Poulton, 1990).

The analyses have shown that morama beans seem to contain neither cyanogenic glycosides nor the enzymes that break these down to hydrogen cyanide (Holse *et al*., 2010). The fact that morama beans (*T. esculentum*) do not seem to be cyanogenic is in accordance with results from Dubois *et al*. (1995) who found that *T. fassoglense* seeds did not contain any detectable amounts of cyanogenic glycosides.

3. Allergens

Lupin and peanut are potent allergens and especially, peanut is one of the most prevalent allergenic foods in the Western World. Humans suffering from allergic reactions to these legumes may also get an allergic reaction to other legumes with proteins that are able to cross-react with proteins of lupin or peanut. Consequently, the IgE antibodies that have been used to test morama beans are antibodies that react with the major allergens in lupin and peanut. The analyses revealed no presence of proteins cross-reacting with the allergenic proteins from lupin and peanut. Hence, there is no reason to suspect that people suffering from lupin or peanut allergy will suffer from allergic reactions when consuming products containing morama beans (Holse *et al*., 2010).

I. Phenolic compounds

Various excellent reviews are available on phenolic compounds, their chemistry and analysis, content in foods and nutritional significance (Bravo, 1998; Dykes and Rooney, 2006; Manach *et al*., 2004; Naczk and Shahidi, 2006; Robbins, 2003). From a nutritional perspective, phenolic compounds (especially tannins) are regarded as antinutritional factors due to their ability to form complexes with dietary proteins and minerals and digestive enzymes (Bravo, 1998). However, lately there has been increasing focus on the positive aspects of phenolics due to their ability to act as antioxidants which may offer potential health benefits such as prevention of diseases such as cancer and cardiovascular disease.

TABLE 5.6 Total phenolic content and antioxidant activity of morama bean seed coat and cotyledon

Sample	Total phenolics (mg CE[a]/100 mg)	Antioxidant activity (μM Trolox equivalents/100 mg)
Morama bean		
Seed coat	24.6 (0.5)[b]	409 (5)
Cotyledon	2.8 (0.1)	8 (1)

Source: van Zyl, 2007.
[a] CE—catechin equivalents.
[b] Standard deviation in parentheses.

Table 5.6 shows the total phenolic content (determined using the Folin–Ciocalteu assay) and antioxidant activity (ABTS radical scavenging capacity) of extracts from morama bean seed coat and cotyledon prepared with acidified methanol. It is clear that morama bean seed coat and cotyledon have appreciable levels of total phenolics and antioxidant activity. These phenolics are concentrated in the seed coat. It has been reported that the morama bean cotyledon contains high levels of the amino acid tyrosine (Maruatona *et al.*, 2010) which is phenolic in nature and can therefore contribute to the total phenolic content of the cotyledon as determined with the Folin–Ciocalteu assay.

Reversed-phase high performance liquid chromatography has been used to determine the types and levels of phenolic acids and flavonoids in morama bean seed coat and cotyledon (Table 5.7). The seed coat has a higher concentration of total phenolic acids and total flavonoids than the cotyledon. On the whole, flavonoids constitute the major class of phenolics in the morama bean. For the phenolic acids, protocatechuic acid and sinapic acid are present in highest concentrations in the cotyledon and seed coat, respectively. For the flavonoids, fisetin and myricetin are present in highest concentrations in the cotyledon and seed coat, respectively. The high levels of myricetin observed may have important contributions to antioxidant activity of the seed coat and may offer potential health benefits. Myricetin, a flavonol, contains structural features that are important for high antioxidant activity of flavonoids. These are an *ortho*-dihydroxy group on the B ring, a 2,3-double bond on the C ring, and a C4 keto group on the C ring.

J. Potential health benefits and negative effects associated with components of morama beans

Tables 5.8 and 5.9 below summarize the potential health benefits and negative effects, respectively, associated with the components of morama beans.

TABLE 5.7 Types and levels (mg/100 g sample) of phenolic acids and flavonoids in acidified methanol extracts of morama bean seed coat and cotyledon determined using reversed-phase HPLC[a] (adapted from van Zyl (2007))

Phenolic compound	Seed coat	Cotyledon
Hydroxybenzoates		
Gallic acid	192 (3)[b]	23 (1)
Protocatechuic acid	69 (2)	153 (9)
p-Hydroxybenzoic acid	157 (7)	ND
Vanillic acid	388 (53)	21 (1)
Syringic acid	ND[c]	13 (0)
Hydroxycinnamates		
Caffeic acid	293 (45)	39 (0)
p-Coumaric acid	119 (17)	ND
Sinapic acid	543 (80)	59 (19)
Ferulic acid	277 (37)	9 (1)
Total phenolic acids	*2038*	*317*
Flavonoids		
Catechin	ND	12 (1)
Rutin	602 (73)	26 (1)
Naringin	492 (120)	10 (0)
Hesperidin	434 (51)	9 (1)
Fisetin	481 (101)	39 (0)
Myricetin	10582 (1067)	19 (2)
Quercetin	331 (21)	24 (0)
Naringenin	18 (1)	ND
Kaempferol	98 (9)	20 (0)
Total flavonoids	*13,038*	*159*
Total	*15,076*	*476*

Column: YMC-Pack ODS AM-303 (250 mm × 4.6 mm, 5 μm) (Waters, MA, USA).
Solvents: A—0.1% acetic acid in water; B—0.1% acetic acid in acetonitrile.
Detector: UV–Vis at 280 nm.
Flow rate: 0.8 ml/min.
Injection volume: 20 μl.
[a] HPLC conditions.
[b] Standard deviation in parentheses.
[c] ND—not detected.

K. Conclusions

While an analysis of individual components in morama beans (above) can give a good lead to their possible beneficial and negative effects, it is the sum total, antagonistic or synergistic effects of the various component combinations which determine their overall effect on health. It is the high content of amino acids, and some fatty acids, complemented with minor

TABLE 5.8 Potential health benefits associated with the components of *Tylosema esculentum* (morama beans)

Component	Effect	Reference
Fatty acids		
Alpha-linoleic acid	Inhibits the growth of breast cancer cells	Kim *et al.* (2009)
	Reduces platelet stickiness and protects against coronary heart disease	Rastogi *et al.* (2004)
	Deficiency can lead to lower levels of docosahexaenoic acid, leading to abnormal brain and eye function	Neuringer *et al.* (1986)
Linoleic acid	Optimizes nutrition, growth, and feeding efficiency of children suffering from cystic fibrosis	van Egmond *et al.* (1996)
	Attenuates diabetic complications	
Myristic acid	Deficiency can lead to cancer and immune system dysfunction	Wright *et al.* (2010)
	Stabilizes proteins used in the immune system	Wright *et al.* (2010)
	Promotes membrane binding that is essential for proper protein localization or biological function	Lakshmikuttyamma *et al.* (2008)
Oleic acid	May hinder progression of adrenoleukodystrophy	Rizzo *et al.* (1986)
Stearic acid	Reduces low-density lipoprotein in the blood	Hunter *et al.* (2009)
Erucic acid	Reduces platelet stickiness and protects against coronary heart disease	Rastogi *et al.* (2004)
Palmitoleic acid	Possibly a signaling molecule which can help fight weight gain; utilized by the key enzymes that control fat oxidation, at extraordinarily high rates	Power *et al.* (1997), Zelkowitz (2008)
Arachidonic acid	Component of phospholipids of membranes of the body's cells, and is abundant in the brain and muscles	
	Necessary for the repair and growth of skeletal muscle tissue	Wang *et* al. (2006)

	Important for neurological health and protection of the brain from oxidative stress	Darios and Davletov (2006)
	Important for growth and repair of neurons. Its disturbed metabolism is associated with neurological disorders such as Alzheimer's disease and Bipolar Disorder	Rapoport (2008)
Amino acids		
Cysteine	Reduces risk of breast cancer	
	Precursor to glutathione, a powerful antioxidant and also used to cleanse the body of toxins	AACR (2003), Agarwal *et al*. (2004), Lin *et al*. (2010), Sun *et al*. (2010)
	N-acetyl-cysteine, a synthetic precursor of cysteine, is commonly used as an antidote to paracetamol-induced liver damage	Kortsalioudaki *et al*. (2008)
	N-acetyl-cysteine suppresses induction of autophagy by bacterial endotoxin lipopolysaccharide, hydrogen peroxide, and nitric oxide	Yuan *et al*. (2009)
Histidine	Metabolic by-products, for example, histamines are involved in regulation of breast cancer growth and progression	Medina *et al*. (2008)
	Mediates clearance of necrotic material	Poon *et al*. (2010)
	Inhibits formation of insoluble immune complexes and enhances their ability to activate complement, resulting in faster clearance	Manderson *et al*. (2009)
	Assists in growth and repair of body tissues, and to maintain myelin sheaths that protect nerve cells	Blank and Shoenfeld (2008)
	Modulates physiological processes such as cell adhesion and migration, fibrinolysis, and coagulation	Blank and Shoenfeld (2008)
Aspartic acid	Induces apoptosis in colon cancer cells	Dadachova (2010), Dia and Mejia (2010)

(*continued*)

TABLE 5.8 (*continued*)

Component	Effect	Reference
	Needed for stamina, brain, and neural health	Ariyannur *et al*. (2010)
	Assists the liver by removing excess ammonia and other toxins from the bloodstream	
Threonine	Promotes thymus growth and activity	Vitamins and Health Supplements Guide (2005)
	Assists in growth and repair of body tissues and maintenance of myelin sheaths protecting nerve cells	Blank and Shoenfeld (2008)
	Necessary for formation of tooth enamel and elastin and collagen	Vitamins and Health Supplements Guide (2005)
	Has a mild glucose-sparing effect and is useful in the stabilization of blood sugar because it can be converted into glucose in the liver by the process of gluconeogenesis	
Arginine	Inhibits herpes virus	Maggs *et al*. (2000)
	Plays an important role in the synthesis of various protein molecules (e.g., creatine and insulin)	Garcia-Miranda *et al*. (2010), Brixel *et al*. (2010)
	Important in maintaining erection and treatment of sterility in men	Gur *et al*. (2007), Mathers *et al*. (2009)
	Important in reduction of alcohol toxicity effects and wound healing	Debats *et al*. (2009)
	Reduces accumulation of compounds such as ammonia, lactate, and other by-products of physical exercise	Liu *et al*. (2009)
	Inhibits platelet aggregation and can also decrease blood pressure	Marfella *et al*. (1996)
	Has antioxidant properties	Kizhakekuttu and Widlansky (2010)
Lysine	Inhibits herpes virus	Thorne Research (2007)
	Lowers cholesterol at a certain ratio with arginine	Sanchez *et al*. (1988), Spielmann *et al*. (2008)

Methionine	Useful in the treatment of Parkinson's disease	Leong *et al*. (2009)
	Has significant positive effects on sufferers of chronic fatigue, muscle, and joint pains	Rutjes *et al*. (2009)
	Helps in breaking down fatty acids and prevents buildup of fat on the artery walls; also involved in the normal detoxification of liver	Caballero *et al*. (2010)
	Functions as an antioxidant by supplying sulfur for inactivating free radicals	Kim *et al*. (2010)
Phenylalanine	Decreases pain and inflammation in the treatment of rheumatoid arthritis and osteoarthritis	Choi *et al*. (2008)
	Improves speech and rigidity in the treatment of Parkinson's disease	Skibo *et al*. (2010)
	Useful in the treatment of vitiligo, a skin pigment disorder	Szczurko and Boon (2008)
Tyrosine	Improves cognitive function; helps reduce the effects of stress and fatigue on tasks requiring concentration and mental sharpness	Govoni *et al*. (2010)
Tryptophan	May enhance relaxation and sleep, causes arterial vessel relaxation, and controls blood pressure	Wang *et al*. (2010), Sayegh *et al*. (1995)
	Relieves minor premenstrual symptoms	Freeman (2004)
	Soothes nerves and anxiety	Wang *et al*. (2010)
	Reduces carbohydrate cravings	Ashley *et al*. (1985)
Other components		
Vitamins	Anticancer effects (B vitamins)	Buhr and Bales (2010), Huang *et al*. (2006)
	Important for immune status	Maggini *et al*. (2007)
	Vitamins B12 and B6 have preventive effects against age-related chronic diseases, including cardiovascular disease (CVD), stroke, and cognitive decline	Buhr and Bales (2010), Huang *et al*. (2006)

(*continued*)

TABLE 5.8 (*continued*)

Component	Effect	Reference
Dietary fiber	Can slow absorption of refined carbohydrates and lower glycemic index of foods, resulting in reduced effects of diabetes due to lower availability of glucose	Preuss (2009)
Phytoestrogens	Anticarcinogenic activity	Branca and Lorenzetti (2005), Kwiatkowska (2007)
	Cholesterol lowering effect	Jenkins *et al*. (2003), Rosell *et al*. (2004)
Lignans	Anticancer effects	Adolphe *et al*. (2010), Torres-Sanchez *et al*. (2008), Fini *et al*. (2008)
Gallic acid	Inhibits herpes virus Anticancer effects	Kratz *et al*. (2008)

TABLE 5.9 Potential negative effects associated with the components of morama beans

Component	Effect	Reference
Fatty acids		
Erucic acid	Can cause thrombocytopenia (the presence of relatively few platelets in the blood)	Crowther *et al.* (1995); FSA (2004)
Palmitic acid	Increases the risk of developing cardiovascular diseases	WHO (2003); Li and Renier (2008)
Amino acids		
Glutamic acid	Causes numbness at the back of the neck, gradually radiating to both arms and the back, general weakness, and palpitations (Chinese restaurant syndrome)	Pulce *et al.* (1992)
Other components		
Protease inhibitors (e.g., Kunitz-type elastase inhibitor)	Potent allergens. Fortunately, these inhibitors can be destroyed by heat, which tends to reverse their antinutrient effects	Yamanishi *et al.* (2003); Shimakura *et al.* (2004)

components as vitamin E, important minerals, lignans, and the absence of allergens and cyanogenic glycosides as potential health risks, which make morama beans an excellent food source with potential health benefits. The relatively high content of amino acids in morama beans [tyrosine ($\approx$ 11%), aspartic acid (9–10.5%), and glutamic acid (15–17%)] and fatty acids, such as oleic acid (55–80% of fatty acid content), linoleic acid (22–26% of fatty acid content), and palmitic acid (12–17% of fatty acid content), also makes these components significant in human health. More studies are urged on the specific effects of the components of morama beans.

IV. FOOD-PROCESSING APPLICATIONS AND UTILIZATION

The morama bean produces edible seeds and tubers that traditionally are eaten boiled or roasted. The tuber (2 years or younger) can be eaten raw, boiled, or baked, while older tubers are used as a source of water, since it

TABLE 5.10 Potential uses of the morama bean Source: Jackson (2010)

Food	Description	Uses
Morama oil	Solvent extracted/ mechanically pressed of whole morama beans	Cooking oil, salads, cosmetic oil
Morama butter	Milling and grinding of whole morama beans to a paste	Confectionery
Morama flour	Milling of morama beans to fine particles; may include defatting first to produce a high protein flour	Supplement to staple cereal flours
Morama texturized foods	Milled flour extruded into various shapes	Snacks, breakfast cereals, meat analogues
Morama nuts	Whole morama dry roasted	Roasted nuts, whole or chopped
Morama biscuits, cookies, muffins, bread, cake	Morama and wheat flour and other ingredients baked into snack foods	Baked snack foods
Morama roast	Morama flour and other spices baked as a meat-like loaf	Meat analogue
Morama ice-cream	Morama powder added to mix for ice-cream	Frozen snack food
Canned morama beans in tomato sauce	Whole morama beans thermally processed in a sauce	Savory cooked beans

contains up to about 90% of water by weight. The roasted bean has a delicious nutty flavor and is cooked with cornmeal to prepare porridge or is ground into a powder that is boiled in water to produce a cocoa-like beverage. More recent research has shown that the bean can be utilized as flour, butter, oil, milk, and meat analogue products as well as a range of snack foods (Table 5.10).

A. Morama milk

Morama milk is a creamy white water extract of morama beans that closely resembles dairy milk or soymilk in appearance and composition. The first report of the processing of morama beans into milk has been described by researchers in Botswana (Mpotokwane *et al.*, 2007).

Although not available commercially, morama milk can be consumed as a refreshing and nutritious beverage similar to dairy milk or soymilk. It can be used as an infant supplement providing additional protein, energy, and other nutrients to vulnerable populations where the supply of dairy milk is inadequate. It can also be an intermediate material for other applications such as yoghurt.

The chemical composition of morama milk is indicated in Table 5.11 and it is compared with soymilk and dairy milk (Mpotokwane *et al*., 2007). Morama milk has 6% total solids compared with 10% for soymilk and 12% for dairy milk. The morama milk solids include protein, which is about 1.5%, fat is 3.1%, carbohydrates is 1.1%, and ash is 0.2%. It has high levels of sodium (47.9 mg/100 g) and iron (3.7 mg/100 g) compared with the other two milks but much lower calcium (6.8 mg/1000 g). The proportion of unsaturated fatty acid in morama milk is significantly higher than in soymilk and dairy milk (Jackson *et al*., 2009).

As with other legumes, the sulfur amino acids, methionine, and cysteine, were limiting in morama milk, which contains 0.28 g/100 g methionine and 0.02 g/100 g cysteine (Table 5.12). Tryptophan was not detected. Of the other essential and semiessential amino acids, leucine, tyrosine, arginine, and lysine were the major amino acids in morama bean milk. Others that were also found in high levels include glutamic acid, aspartic acid, and proline. These findings are consistent with the literature on the amino acid composition of morama bean, which is similar to other legumes like the soybean (Bower *et al*., 1988; Mmonatau, 2005; Ripperger-Suhler and Longenecker, 1982). Morama milk therefore replicates the amino acid composition of the bean.

TABLE 5.11 Composition of morama milk, soymilk, and dairy milk Source: Data adapted from Mpotokwane *et al*. (2007), Jackson *et al*. (2009), and Liu (1997)

Component (/100 g)	Morama milk	Soymilk	Dairy milk
Calorie (kcal)	37.9	44.0	59.0
Protein (g)	1.5	3.6	2.9
Ash (g)	0.2	0.5	0.7
Minerals (mg)			
Calcium	6.8	15	100
Sodium	47.9	2	36
Iron	3.7	1.2	0.1
Moisture (g)	94.1	90.8	88.6
Carbohydrate (g)	1.1	2.9	4.5
Fat (g)	3.1	2.0	3.3
Saturated fatty acid (%)	31.5	40–48	60–70
Unsaturated fatty acid (%)	68.5	52–60	30–40

TABLE 5.12 Amino acid composition (g/100 g milk dry matter basis) of morama bean milk compared with a commercial soybean milk Source: Data adapted from Jackson *et al.* (2009) and Liu (1997)

Amino acid	Morama bean	Morama milk	Soy milk
Aspartic	10.3	2.6 ± 0.7	11.8
Glutamic	14.9	3.9 ± 0.6	19.0
Histidine	2.3	0.8 ± 0.2	2.6
Arginine	6.0	2.0 ± 0.6	7.8
Lysine	5.2	1.6 ± 0.3	6.3
Serine	5.1	1.6 ± 0.1	5.3
Threonine	2.9	1.0 ± 0.03	3.9
Tyrosine	11.1	2.8 ± 0.4	4.0
Cysteine	0.8	0.02 ± 0.0	4.9
Alanine	3.0	1.0 ± 0.2	4.4
Proline	6.6	2.1 ± 0.5	5.0
Valine	4.2	1.4 ± 0.1	4.9
Methionine	0.76–1.32	0.3 ± 0.2	1.4
Isoleucine	3.8	1.3 ± 0.1	5.1
Phenylalanine	4.6	1.1 ± 0.3	5.1
Glycine	5.4	1.7 ± 0.3	4.3
Leucine	5.6	2.3 ± 0.6	8.3

The processing of morama milk generally involves a thermal treatment such as blanching and roasting of the beans, cracking, milling, suspending in water, boiling, and filtration to obtain a milk-like phase. Blanching and roasting techniques are believed to improve the flavor by removing the bitter flavor components and aiding in the development of desirable nutty flavor components (Iwuoha and Umunnakwe, 1997). A small-scale method for processing morama beans into milk is outlined in Fig. 5.3. Morama beans were cracked, preprocessed by blanching in a bicarbonate of soda solution, drained, rinsed, and then ground with hot water to form a slurry. The slurry was heat-processed and then filtered successively. The residue, known as morama pulp, was separated and the resultant liquid extract was heated, homogenized, bottled, and pasteurized before serving.

Other preprocessing treatments, including (i) soaking then water blanching, (ii) soaking only, (iii) water blanching, (iv) roasting shelled, (v) roasting unshelled, (vi) salt water blanching, and (vii) defatted shelled, were also assessed to process morama milk. However, these were not considered acceptable as the milks produced were too watery, too dark, too bitter, or were not creamy enough (Mpotokwane *et al.*, 2007). While

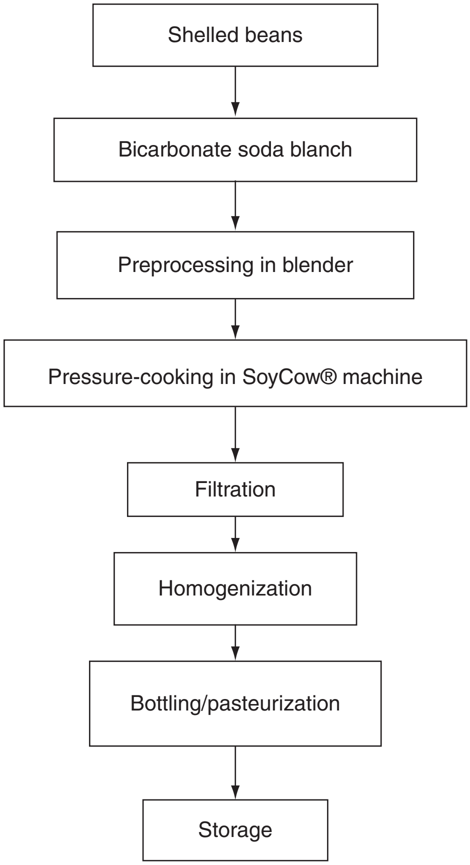

FIGURE 5.3 Flow diagram of processing of morama milk (adapted from Mpotokwane *et al.*, 2007).

the bicarbonate soda blanch pretreatment method was suitable for small-scale processing of morama milk, it does produce milk with a characteristic aftertaste. For consumers who are not accustomed to the flavor and taste, it could be described as an undesirable "bitter" taste. Consequently, unless such flavor and taste are reduced or masked, morama milk may not be readily accepted by some consumers in the population. It can be flavored and colored with natural and artificial flavorants and colors such as strawberry to produce a more acceptable taste that consumers are used to.

Fermented morama milk products such as morama yoghurt have been reported by Phuthego *et al.* (2009). Morama milk yoghurt like soymilk yoghurt, provide economic and nutritional benefits, because they are likely to have higher protein levels at comparable or lower cost than regular fermented milk products (Karleskind *et al.*, 1991). This is because legume milks are relatively easy to prepare and serve as a low-cost protein beverage in countries where commercial dairies are not adequate. Morama milk yoghurt is processed similar to the production of yoghurt from soybeans by fermenting morama milk with lactic acid bacteria (Kumar and Mishra, 2004; Phuthego *et al*., 2009; Yazici *et al*., 1997).

B. Morama oil

Morama oil has been described as resembling almond oil, and being suitable for domestic purposes, having a pleasant nutty flavor, albeit with a slightly bitter taste (FAO, 2010). Chemically, its composition is reported to be similar to that of olive oil, with the exception of the long chain fatty acids (Ketshajwang *et al*., 1998; Mitei *et al*., 2008; Yeboah and Moshoeshoe, 2008). It also contains other important compounds, including 4-desmethylsterols (75%) and significant amounts of 4,4-dimethylsterols and 4-monomethylsterols (15.72% total), which may potentially impact its antioxidant potential favorably (Mitei *et al*., 2009).

The oil potentially has both food and nonfood uses, with the latter primarily being in the processing of cosmetics. Extraction can be done using an oil press, or an organic solvent such as hexane as with other oil seeds. A higher yield of oil is obtained with solvent extraction compared to pressing, but there are inherent health risks with solvent extraction; if not, all the solvent is ultimately evaporated off. Ketshajwang *et al*. (1998) reported extraction rates as high as 48.2% using hexane extraction, while Yeboah and Moshoeshoe (2008) using a 30 kg/cm^2 hydraulic press reported yields of 20%. Therefore, oil pressing may provide a safer and more feasible option particularly for small-scale processors. Oil pressing involves either cold-pressing or warm-pressing; cold-pressing does not involve the use of heat on the seeds that are being pressed, while warm-pressing uses heat application (Fig. 5.4). More residual oil in the press cake is thus obtained from cold-pressing; warm-pressing gives more yield, but compromises oil quality.

Tlhong *et al*. (2009) described the sensory attributes of morama oil as fresh, thick, creamy, and smooth with a grassy and earthy aroma and raw nutty flavor and aftertaste. Compared to both sunflower and olive oils, potato chips fried in morama oil were rated as more acceptable by consumers (Tlhong *et al*., 2009). Therefore, as a cooking oil, morama oil has great potential in terms of consumer acceptability. However, its acceptability as a salad oil remains unexplored.

C. Protein-rich morama flours

The preparation of protein-rich morama flours follows a number of simple unit operations. These include heating, dehulling, defatting (in some cases), and milling (Fig. 5.5). These operations may impact either

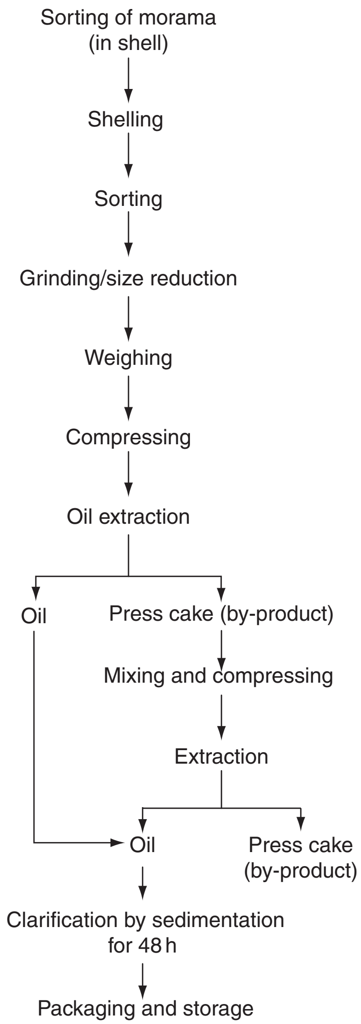

FIGURE 5.4 Process flow diagram for morama oil processing (adapted from Yeboah and Moshoeshoe, 2008).

positively or negatively on nutritional, functional, sensory, and phytochemical quality of resultant flours.

The proximate composition of full fat and partially defatted morama flours prepared from heated and unheated morama beans is provided in Table 5.13. Full fat morama flours had similar protein and fat contents to those reported by Amarteifio and Moholo (1998) and Mmonatau (2005). Defatting is required when protein-rich, stable flours are required. Although full fat flours are deemed to be more energy dense than fully

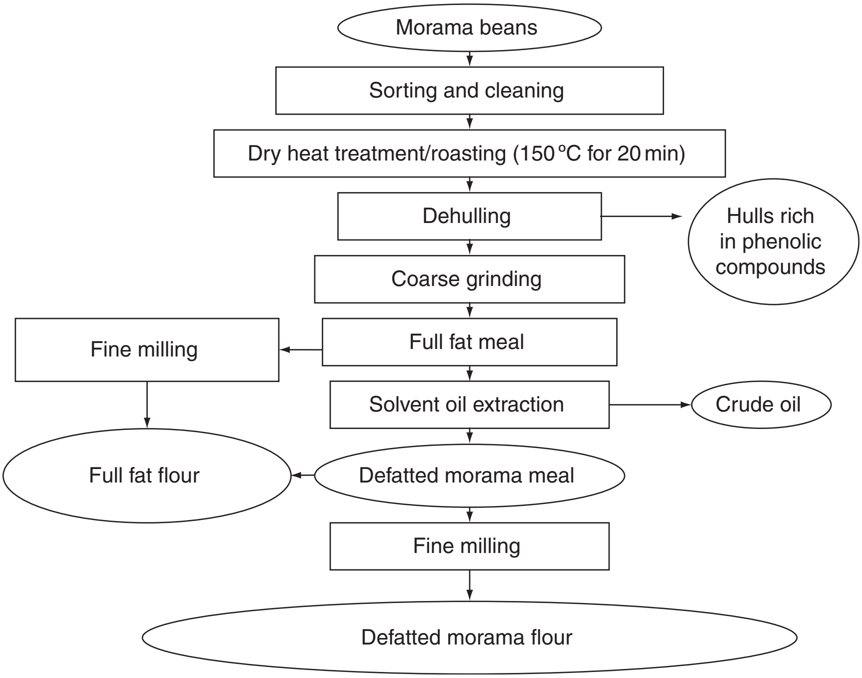

FIGURE 5.5 Schematic of processing procedure for morama flour (adapted from Maruatona, 2008).

TABLE 5.13 Proximate composition of morama flour (g/100 g) dry basis (adapted from Kayitesi, 2009)

Flour	Protein	Fat	Ash	Carbohydrates
Full fat flour from unheated beans (FUH)	34.3[a] (0.5)	38.1[c] (0.0)	2.7[a] (0.0)	24.8[b] (0.1)
Full fat flour from heated beans (FH)	34.6[a] (0.7)	39.1[d] (0.0)	2.9[a] (0.0)	23.3[a] (0.0)
Partially defatted flour from unheated beans (PDUH)	50.0[b] (0.5)	15.3[b] (0.1)	4.2[b](0.1)	30.5[c] (0.0)
Partially defatted flour from heated morama beans (PDH)	53.2[c] (1.5)	11.2[a] (0.0)	4.7[c] (0.1)	31.2[d] (0.0)

[a, b, c, d, e] Mean values within a column with different letters differ significantly ($p < 0.05$). Standard deviations are given in parentheses.

or partially defatted flours, they have lower protein contents and are prone to hydrolytic and oxidative rancidity. Defatting significantly increases the protein contents of resulting flours. Dry heating also results in slightly higher protein contents. Similar findings were reported by Maruatona *et al.* (2010) for defatted morama flour. This is possibly explained by the disruption of lipid bodies of the morama beans upon heating, allowing the oil to be more readily expelled during the defatting step.

Dry heating or roasting is able to effectively inactivate heat labile trypsin inhibitors. Maruatona *et al.* (2010) reported that dry heating of morama beans at 150 °C for 20 min reduced the trypsin inhibitor activity in its defatted flour from 251 TUI/ml extract to 3 TUI/ml extract. Although *in vitro* digestibility was improved by 2.7%, the lysine content was reduced by 11.9% (Maruatona *et al.*, 2010). Slight reductions in lysine upon roasting or dry heating of morama beans have also been reported by Mmonatau (2005) and Kayitesi (2009) (Table 5.14). This may be attributed to the Maillard reaction.

TABLE 5.14 Amino acid composition of morama flours g/100 g flour (dry matter basis) (adapted from Kayitesi (2009)

Amino acid	Partially defatted flour from unheated morama beans (PDUH)	Partially defatted flour from heated morama beans (PDH)
Essential amino acids		
Histidine	1.3[a]	1.4[a]
Isoleucine	2.2[a]	2.9[a]
Leucine	3.0[a]	3.3[a]
Lysine	2.8[b]	2.7[a]
Methionine	0.4[a]	0.4[a]
Phenylalanine	2.1[a]	2.3[a]
Threonine	1.5[a]	1.6[a]
Valine	2.2[a]	2.4[b]
Nonessential amino acids		
Alanine	1.6[a]	1.7[a]
Arginine	3.3[a]	3.5[b]
Aspartic acid	4.0[a]	4.4[b]
Cysteine	0.1[a]	0.1[a]
Glutamic acid	7.7[a]	8.3[b]
Glycine	3.0[a]	3.2[b]
Proline	3.6[a]	4.0[b]
Serine	2.6[a]	2.9[b]
Tyrosine	6.0[a]	6.6[b]

[a, b] Mean values within a row with different letters differ significantly ($p < 0.05$), PDUH = partially defatted morama flour from unheated beans, PDH = partially defatted flour from heated beans (150 °C for 20 min.

Sulfur amino acids, methionine and cysteine, are limiting in partially defatted flours prepared from heated and unheated morama beans, containing 0.4 g methionine/100 g flours and 0.1 g cysteine/100 g flours. The major amino acids in morama flours are glutamic acid, aspartic acid, as well as tyrosine. This is in agreement with amino acid composition of morama beans reported by various researchers (Bousquet, 1982; Bower *et al*., 1988; Dubois *et al*., 1995; Maruatona *et al*., 2010). Morama bean flours seem to be comparable in terms of essential amino acids composition to commercial soybean flours (Maruatona *et al*., 2010).

The use of dry heating processes in the preparation of morama flours can also affect their functional and sensory properties. Heating of morama beans prior to decortication reduced protein solubility and emulsifying capacity of resulting defatted morama bean flours (protein contents: 53% and 56% for unheated and heated samples; fat contents: 7% and 1.9% for unheated and heated samples) but improved water absorption capacity significantly (Maruatona *et al*., 2010). Jideani *et al*. (2009) also found that roasting increased the water absorption capacity of full-fat morama flour (protein content: 32–33%; fat content: 36–39%) but reported increased protein solubility and emulsifying activity upon heating. Differences in results can probably be attributed to the fact that Maruatona *et al*. (2010) worked with defatted flours, whereas Jideani *et al*. (2009) worked with full fat flours. Functional properties of morama flours and its potential application in food systems are summarized in Fig. 5.6.

Kayitesi (2009) studied the potential use of morama flours to improve the nutritional quality of sorghum porridge, a staple food to millions in Africa. Compositing sorghum porridge with morama bean flours significantly increased protein and fat contents in porridges. Lysine content of the composite porridges was 3–4 times higher than that of sorghum porridge alone. The total phenolic content and antioxidant activity of composite porridges were also significantly higher than that of sorghum porridge. Porridge composited with full fat morama flour from heated beans was found to be as acceptable as sorghum porridge, but more acceptable than that of composites using defatted flour. A bitter taste and aftertaste were perceived in composite porridges from defatted flours, whereas composite porridges from full fat morama flours were described as buttery/creamy.

Existing literature demonstrates several possible morama bean-processing applications, including nutritious milk beverage and yoghurt, high value oil, and protein-rich flours. The physico-chemical and sensory properties suggest the high quality and acceptability of the products. However, research on the market potential of these products is also required to determine their commercial feasibility for small-scale processors in Africa.

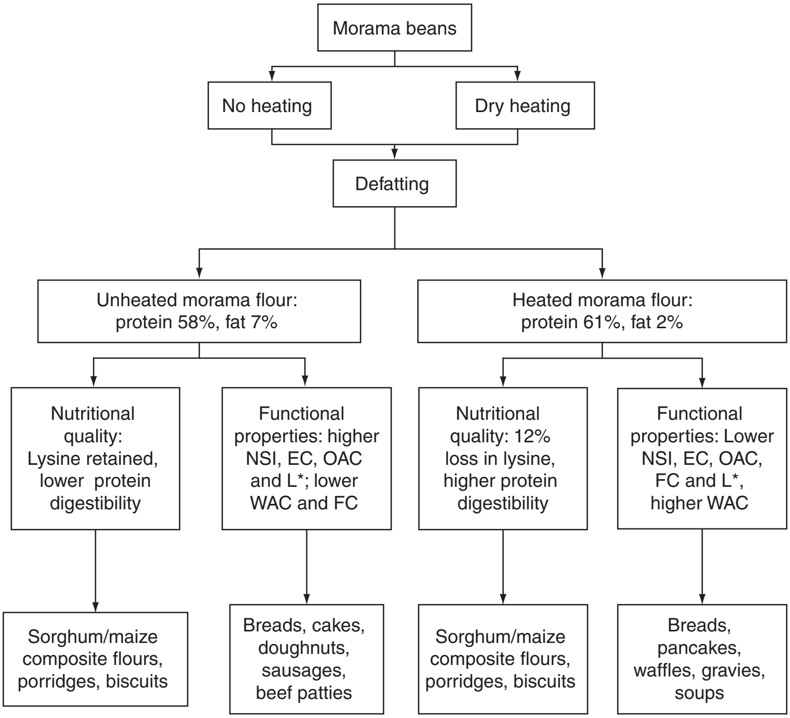

FIGURE 5.6 Physico-chemical and protein-related functional properties of defatted morama bean flours and their potential applications in food systems (adapted from Maruatona, 2008).

V. POTENTIAL MARKETING STRATEGIES FOR MORAMA-PROCESSED PRODUCTS

A large number of indigenous Southern African plants have, over the ages, been used for nutrition and medicine (Ham *et al.*, 2008). Traditionally, some of these plants have been collected from the wild or obtained in crude form from traditional healers for home consumption and as a result have not been commercialized. Commercialization and value addition of indigenous plants have been mooted as a possible solution to the alleviation of poverty in resource poor communities (Jordaan *et al.*, 2008). Such initiatives would provide income-generating opportunities for these communities as well as serve as an incentive to value and conserve natural resources more.

The first steps toward the commercialization of the morama bean were taken with the European Union-funded project (MARAMA II), which was aimed at developing innovative and healthful morama bean products targeting niche markets. The products are targeted at niche markets, initially in Southern Africa (Botswana, Namibia, and South Africa) and then potentially also global niche markets.

A range of prototype morama bean products were developed. These included morama milk, a dairy substitute; full fat and defatted morama flours aimed to enhance the nutritional value of cereal staples for example sorghum porridge; morama oil for use in salads, cooking and cosmetics; and roasted morama for use as a snack product. The process used for these products was based on existing technology to manufacture products from similar raw materials, for example, soybeans and peanuts. The market characteristics of and demand for these products were assessed during a pilot study to determine the scope for commercializing these products. Consumers' perceptions of these products were also tested to identify possible marketing strategies for each of the prototype products.

A. Market overview

1. Market size and characteristics

The market for products derived from morama in Botswana, Namibia, and South Africa is potentially significant, with the three countries serving as home to around 50 million people, most of which are concentrated in South Africa (Central Intelligence Agency, 2007; Planet Retail, 2007). However, a very large proportion of this population is relatively poor, with a large section of the wealth within these countries concentrated among a very small section of the population (UNDP, 2009). Consumers in these countries are also quite diverse, with a large number of ethnic groups, religions, and languages making the region a very diverse social and cultural region (Central Intelligence Agency, 2007). Urbanization is also a growing phenomenon (Central Intelligence Agency, 2007; Institute of Security Studies, 2007; Statistics South Africa, 2006), and some of the major health issues include a very high incidence of HIV/AIDS, micronutrient deficiencies, and noncommunicable chronic diseases (NCDs) such as diabetes, high blood pressure, cancer, and cardiovascular diseases (Central Intelligence Agency, 2007). With growing disposable incomes, urbanization, increasingly formalized markets, and growing consumer awareness in terms of health, sustainability, and social responsibility issues in these countries, the market for niche or speciality products has been growing and presents opportunities for new and innovative products. This creates opportunities for the commercialization of new products based on morama.

2. Retail environment

The retail environment in Botswana, Namibia, and South Africa is dominated by a number of large retail groups that account for a significant proportion of the retail sales in these countries. It is of note that five major retailers account for 86% of the market share in South Africa, 80.5% in Botswana, and 72.6% in Namibia based on the banner sales of the respective retailers (Planet Retail, 2007). This is indicative of high levels of retail concentration in all these three countries, with a small number of companies controlling very large proportions of the retail sales in the respective countries (Planet Retail, 2007).

In terms of the size of the retail sectors in Botswana, Namibia, and South Africa, it is evident that the size of the South African retail sector is significantly larger than both Botswana and Namibia's retail sectors. The value of the South African retail sector is estimated at US$6285 Million for 2007 while that of Botswana is estimated at US$674 Million and that of Namibia at US$237 Million. These differences are attributable to the differences in the sizes of the economies and population (Planet Retail, 2007).

Based on the size, differentiation, and value of the South African retail sector, it would appear that it is the most attractive of the three countries for retail of value-added morama products. The South African market hosts a diversity of retail outlets that range from low-cost commodity retailers who offer basic products at relatively low cost to exclusive niche product retailers who offer niche products at higher prices (Planet Retail, 2007). It also receives significantly larger numbers of tourists. However, based on interviews held with consumers, knowledge about morama was higher in Botswana and Namibia which could influence their purchase decision (Tlhong *et al*., 2009). This would need to be taken into consideration in terms of recommending niche markets to target.

3. Competition

An analysis of competing products and potential substitutes revealed that morama products will potentially compete with a number of other, well-established products and brands that are already commercialized. These include soy-based products such as soy milk, soybean oil, and high protein soy flour. The direct implication of this is that for morama bean products to compete on price directly with the competing products, it will need to do so based on the health benefits or other novelty value identified by the current Marama II FP-6 project consortium. Without these, it may prove to be very challenging to the feasibility of these products.

B. Consumer analysis

Table 5.15 provided the purchasing characteristics of consumers who participated in the market testing through structured questionnaires and in-depth interviews. It indicated that consumers in the three markets were aware of the competitive products, bought them almost on a monthly basis, and spent on an average between US$4–16 monthly.

TABLE 5.15 Consumer purchasing characteristics and willingness to pay for morama bean-processed products in Botswana, South Africa and Namibia (adapted from Jordaan *et al.* (2009))

Morama product	Market	Consumer responses
Morama milk	Botswana	• Familiar with predominantly long life dairy milk but not really soy milk. • Buy long-life milk products on a weekly or monthly basis. • Spend on average US$15.94 per month on long-life milk products and not really aware of the health benefits of soy products. Consumers who were aware of the health benefits were identified as being high in protein and low in cholesterol as the primary benefits. • 80% willing to pay the same price or less compared to similar know products. • Price, ingredients, and health benefit play a significant role in decision-making.
Morama–sorghum composite porridge	South Africa	• Familiar with a variety of nutritionally enhanced porridges, for example, vitamin- and iron-fortified maize, especially maize and oats. • Buy such porridge products on a monthly basis. • Spend on average US$10 per month on porridge products and are not too aware of the health benefits of these products. Consumers who were aware of the health benefits were identified as being high in energy and fiber as the primary benefits. • 73% willing to pay the same price or more compared to similar know products.

TABLE 5.15 (*continued*)

Morama product	Market	Consumer responses
		• Price, ingredients, and health benefit play a significant role in decision-making.
Morama roasted nuts	Namibia	• Familiar with a variety of snack products, especially peanuts as well as a variety of luxury nuts such as cashews, almonds, although they rarely bought snack products. • Buy snack products on a monthly or 6 monthly basis. • Spend on average US$4 per month on snack products. The individuals were quite aware of the health benefits of roasted nut products, including high levels of protein and unsaturated fats. • 90% willing to pay the same price or less compared to similar known products. • Price, ingredients, and health benefit play a significant role in decision-making.

Consumers in South Africa and Namibia were more aware of the health benefits of the competitive products; almost all of the health benefits they identified were related to the nutritional value. None of them indicated any phytochemical properties or any specific disease that they could prevent.

Consumers' willingness to pay for the morama products in comparison to similar products, for example, soy milk, cereal–protein composite porridges, and roasted peanuts in the same market segment, is also shown in Table 5.15. The reasons for the specific levels of willingness to pay varied between products and consumers. Some consumers experienced morama products as having an unpleasant bitter taste. Due to the relative newness of the products, they also indicated that if the morama products were more expensive than other products, then they would be unwilling to buy them; they suggested that it was better for morama to establish itself first through low prices. They also added that if morama products had the same benefits as other products, then they would want to pay the same price. Some consumers however were willing to support indigenous or natural value-added products even if they were a little more expensive. A small number of consumers commented that in their experience more expensive products tended to be always the healthiest in similar commodities but that they would still need to balance this carefully against the limitations of their disposable income.

1. Conjoint analysis

Jordaan *et al*. (2009) reported on the key product attributes that would trigger consumers' buying decisions of the morama-processed products. For morama milk, they found that consumers would achieve the greatest utility from similar products that were already known in the market and which offered many benefits at a low price. Conversely, unknown products with no additional benefits at a relatively high price are expected to offer the least utility to consumers. This observation is significant in the light of the commercialization of morama milk. Therefore, they concluded that commercialization would be impeded by marketing messages that offered no significant benefits and products that were relatively expensive (Jordaan *et al*., 2009). Their research also showed that with long-life milk products, consumers' purchasing choices was primarily driven by the health benefits of the product and not the price (Jordaan *et al*., 2009). This is usually indicative of the types of products that are considered by consumers to be ''luxury'' such that there is focus on the attributes of the product rather than of the price (Jordaan *et al*., 2009).

For the morama–sorghum composite porridge product, consumers highlighted that a good tasting product at a low price will be preferable than a high-priced product with an average taste (Jordaan *et al*., 2009). As with the results reported previously on morama milk, the commercialization potential of the porridge will be impeded by a conventional tasting cereal product at a high price. It is noteworthy that consumers' choices with regard to their purchasing decisions for composite porridges are primarily driven by the price of the product and not the taste of the product. This preference is usually indicative of a staple, necessity-type product where consumers are focused on the price of the product rather than the other product attributes (Jordaan *et al*., 2009). This is expected since sorghum porridges are considered to be staple foods in the Southern African diet.

From the utility estimates for the roasted morama product, consumers indicated that a more expensive product will generate greater utility than a less expensive version (Jordaan *et al*., 2009). This behavior is typical of ''Veblen'' goods, which are characterized by an increasing preference for the product as the price of the product increases rather than decreases according to the law of demand (Leibenstein, 1950; Wood, 1993). This may be applicable to luxury nut products such as cashew nuts where part of the allure of the product is derived from the price rather than the attributes. It is noteworthy that consumers' choices with regard to their purchasing decisions for luxury nuts are driven by the type of luxury nut, in all likelihood due to strong individual preferences, not only the taste or the price. When roasted morama was considered as a luxury nut, there was a negative correlation between it and consumer utility. This was likely due in part to consumers' unfamiliarity with morama (Jordaan *et al*., 2009).

C. Commercialization strategies

Based on the analysis of the morama market and the potential consumers as reported by Jordaan *et al*. (2009), a number of strategies for commercializing morama products in South Africa, Botswana, and Namibia were possible. Firstly, morama bean products needed to have at least similar product performance to competing products in terms of consumer acceptability. Besides the product performance, the differentiating benefits of morama products needed to be clearly conveyed to consumers. This was especially important since most consumers were currently not even aware of the benefits of consuming soy and some, particularly in South Africa, were unfamiliar with morama. This would require further product research, advertisement, packaging, and promotions.

Consumers were also very aware of the balance between the value and the price for products; therefore, morama products would need to reflect their intrinsic and perceived value (Jordaan *et al*., 2009). Since consumers of morama products appeared to be price-sensitive, the pricing of morama products would likely need to be similar or less than competing products such as soy milk or soy–sorghum composite porridge products to convince consumers to consider morama products.

Jordaan *et al*. (2009) reported on the marketing strategy for several morama products. They suggested that morama milk could be placed in the market as a nondairy milk supplement with health benefits similar to soy milk. This product could be sold through the various formal and informal retail networks in the respective countries at a pricing level equal to or less expensive than competing products. The promotion of the product should be undertaken through a variety of marketing channels aimed at reaching target consumers and should focus on the unique benefits and characteristics of the product.

The sorghum–morama composite porridge is aimed at the fortified sorghum porridge market. Given the high nutritional properties reported by Maruatona *et al*. (2010), morama flour could be positioned either as a commercial fortified product or as a fortified complimentary food product in feeding programs aimed at improving the nutritional status of vulnerable populations including infants, young children, pregnant and lactating women, as well as HIV/AIDS patients. The pricing level should be equal to or cheaper than competing products.

If morama–sorghum composite flour was used in a feeding scheme, it should be made available either as a ''recipe'' to communities that have direct access to morama beans as a method to improve the nutritional value of their traditional sorghum porridges or as a feeding program product available to vulnerable people at very little or no cost. The promotion of the product should be undertaken through a variety of marketing channels aimed at reaching target consumers and should focus on its unique benefits and characteristics, for example, as a healthier, more nutritious porridge which is made from local ingredients and which has an improved, unique taste.

D. Conclusions

Notwithstanding the market opportunities available for morama products, the ecological and economic feasibility of these products still need further research. Depending on which products are considered commercially viable, it is recommended that existing commercial manufacturers of products similar to the envisaged morama products in Botswana, Namibia, or South Africa be considered as partners in the commercialization. Such a partnership could involve existing business enterprises and the rural communities from where the raw material is either collected or grown. These businesses should typically already have commercial interests in similar products to the prototype morama products.

VI. SOCIO-ECONOMIC ANALYSIS OF COMMUNITIES WHERE MORAMA IS FOUND

A socio-economic study of communities where morama is found was conducted by Lima de Faria *et al*. (2008) in six rural areas in Botswana, South Africa, and Namibia. The aim was to assess the current uses and benefits of the morama bean and the viability of cultivating and adding value to it. Also, the extent to which adding value could help to improve the well-being of the populations living in the regions in which morama beans are endemic was also evaluated. In Botswana, the areas included the regions of Jwaneng (Sese and Naledi villages) and Ghanzi (East Hanahai, West Hanahai, Grootlaagte Qabo, and Kagakae villages). In South Africa, the areas were Lephalale district (Marapong settlement) and in the Steenbokpan region (Leseding settlement). In Namibia, it was the Gobabis region (Sandveld, Epukiro Post 3, and RC Mission villages) and in the Okakarara region (Okatuuo, Okatjau, Ohamueke villages). In all villages, at least one focus group (n = 15–20) was held. In-depth interviews were also conducted with key informants (e.g., village headmen, village development leaders, doctors, nurses, traditional healers, school teachers, street vendors, and local administrators).

A. The value of morama as perceived by the communities

Local knowledge of wild edible plants and plant gathering is normally linked to people living in remote or isolated areas, in which local communities display a high cultural homogeneity (Saka *et al*., 2008). Such was not the case in the areas targeted by the fieldwork, in the three countries, in which multiethnic communities displayed different approaches both to this natural product and to the way they envisaged its uses.

In Botswana, the gathering of wild plants and fruits still form an integral part of the traditions of people living in the Kalahari region. Apparently, besides enhancing food security, autonomy, and freedom, gathering wild fruit gives these populations a particular sense of identity. Morama is part of the populations' collective memory and continues to be a topic they are eager to discuss with outsiders. It still plays an important role in (San people) rituals such as the initiation of girls. However, gathering expeditions are becoming increasingly rare, which is mostly due to the long distances that separate the settlements from the areas where morama grows (Lima de Faria *et al*., 2008).

In South Africa, gathering and eating (roasted) morama is considered to be a longstanding tradition for both the black people (living on farms or in squatter camps) as well as for the white farmers. Both groups expressed how much they appreciated morama. They also shared memories of growing up with morama, gathering them from the wild, thereby in similar ways showing a sense of local belonging (Lima de Faria *et al*., 2008). However, in South Africa, current gathering of these beans is mostly confined to the plants that grow spontaneously along the roadside. Only the few people who still live and work on farms can freely gather them there. For people living in periurban townships (such as Marapong in the Lephalale district), gathering morama is a risky activity since they are not allowed to enter the perimeters of privately held farms. This explains why the information collected about knowledge and usage of morama was scarce in South Africa. According to this survey, morama does not seem to be associated with specific livelihoods of a single cultural/ethnic group or community in South Africa (Lima de Faria *et al*., 2008). The groups that were surveyed lived in either (i) black ''townships'' related to new industrial periurban areas (such as Marapong in Lephalale), that is, new residential areas of black people coming from different origins, culturally heterogeneous, seeking work in the new industrial enterprises and on its surrounding economic and urban structures, (ii) (rural) squatter camps occupied by families that were previously integrated in the farming system, and are now expected to restart their lives outside of it (such as Leseding in Steenbokpan) (Sadiki and Ramutsindela, 2002), or (iii) groups of people gathered to participate in the focus group discussion coming from diversified geographic and cultural origins, having in common the fact that they work and live in the same area (Lima de Faria *et al*., 2008).

In Namibia, morama beans are also perceived to be part of local communities' traditions and food habits. The San in the Namibian Kalahari area, who still gather morama in group expeditions, have inscribed the relation with these natural products in their holistic and spiritual world view—''It was planted by God, so one cannot replant'' (Lima de Faria *et al*., 2008). When asked if they needed permission to gather the morama, they replied: ''God gave us this food, why should we ask for permission?'' (Lima de Faria *et al*., 2008). The Herero communities in the Okakarara region, who were originally nomadic pastoralists and therefore used to collecting wild plants while on the move, retain a strong relationship with the beans. This relationship linking people and this natural resource was apparent when a Herero informant, when asked about the possibility of cultivating morama, replied that he considered it to be unfeasible as the tuber ''had always been there!'' (Lima de Faria *et al*., 2008).

B. Morama availability

In the regions surveyed, there was a general agreement that in the past morama was more widespread and abundant. The reduction in availability of morama was mostly ascribed to pervasive drought conditions and important shifts in government land policies. In addition, the changes in the cultural habits of new generations, reinforced by better roads and improved transportation networks, have facilitated access to local food markets. This in turn reduced the practice of gathering food products, a practice left to the elderly and the poorer sections of the population (Lima de Faria *et al*., 2008).

Land redistribution policies have affected the availability of morama. In Botswana, the villages surveyed were built in the late 1980s under the National Program of Resettlement, forming complex interethnic communities with limited access to the ''morama areas''. Morama beans grow in areas that became inaccessible for local populations since the land in question has mostly been allocated to diamond mining, tourism, and cattle industries.

In South Africa, the end of agricultural farming and post-Apartheid, moved ''black'' people to periurban settlements (Lyne and Darroch, 2003). The latter is also as a result of urbanization. This situation limits access to arable land as they are living far away from the areas where morama beans grow. Also, many of the morama-growing areas are now privately owned, fenced-in properties, targeted at tourist (safari and game) activities (Lima de Faria *et al.*, 2008).

Only in the Namibian rural areas surveyed, a closer relationship between the human units and the morama beans was recorded. Herero chiefdoms, traditionally acting as land owners and cattle-herders, kept their own lands and have free access to the communal areas where they still freely pursue traditional gathering practices (Lima de Faria *et al.*, 2008). These communities sustain a certain hierarchy combined with political autonomy within the Namibian state that gives them power to organize their economies and share the benefits, while maintaining a measure of economic and social sustainability (Lima de Faria *et al.*, 2008).

C. Morama uses in diets in Botswana, Namibia, and South Africa

As a food product, morama beans are mostly recognized for their good taste and high nutrient levels. The most popular way of eating morama is by roasting the dry seeds in hot sand (either in a pot or directly on hot soil by an open fire) (Lima de Faria *et al.*, 2008). Once roasted, they are eaten as a snack (in a similar way as roasted peanuts). No salt is added.

Like peanuts, they are valued for being high in calories and for satisfying immediate nutritional needs. They can also be eaten boiled like any other types of beans, when they are fresh. In both Botswana and Namibia, the morama had a variety of alternative applications even though some of the recipes (e.g., those made with the morama tuber) are no longer in use. Oil is extracted from the boiled green beans and used for cooking as well as a body lotion. Morama was generally added to maize porridges (which form part of the daily diet). The tuber was also consumed while young, after being roasted on hot ashes.

In Namibia and Botswana, morama is seen as an important and complementary food supplement (which is often compared to meat). However, in South Africa, the uses of morama are limited to the gathering of the dry beans, if and when available, which are usually roasted or very seldom, boiled when fresh. In South Africa, there was no evidence of people using other parts other than the beans of the plant in their diets. No other forms of processing or alternative uses have been found in the areas studied.

D. Morama health benefits as perceived by the local people

It was broadly recognized in the communities interviewed that the nutritional qualities of the morama beans had obvious benefits by boosting people's immune systems thereby protecting them from illness. They are used as a supplement for babies and infants, as well as in women's diets during pregnancy. Morama is seen as an energizer and a sexual booster. Owing to its oily composition, morama is also used for skin care (as an oil, lotion, or scrub) and may be used for the treatment of skin-related problems such as eczema (Lima de Faria *et al.*, 2008). In one of the settlements surveyed in Namibia (Epukiro Post 3 in the Sandveld area), the San referred to the use of mashed morama beans for the treatment of eye infections. In South Africa, no medical uses of morama plants were identified, although people repeatedly stated that ''before, when there were more morama, people had fewer diseases''. An old farm worker from Steenbokpan said: ''In the past we used to eat morama regularly and we did not get sick of anything''. People stated that, after eating morama beans, they felt stronger and more energetic. For this reason, morama beans are also given to breastfeeding women and to old people.

E. Morama: A staple food for very poor populations

The possibility of the beans being stored for long periods of time adds to the value of morama. It is regarded as a kind of ''life saver'' in times of crisis, when other foods are not readily available. Morama beans may even replace an entire meal in emergency situations in which people have little income, are unemployed, and are living in periurban townships (without access to arable land). The beans may also be used as a means of diversifying poor people's diet, as Hitchcock (2002) puts it: ''There are relatively few San, if any, in Southern Africa today who derive their subsistence and income from hunting and gathering, although a number of communities do depend on foraging as a buffering strategy and as a means of diversifying their diets''. Thus, there is an obvious link between situations of social stress, defined by high rates of unemployment and associated poverty, and the importance given to these beans.

The great value attributed to morama and their increasing scarcity is confirmed by people describing the collection of morama from mice holes. Also in the isolated and very dry regions of the Kalahari in Botswana, morama beans are reutilized by villagers after being digested by animals such as goats and hens. This important link between the cultural value attributed to morama and social and economic deprivation was also supported by local farmers' testimonies. In Steenbokpan in South Africa, one farmer explained that black people are not gathering as much morama as in the old times because their standards of living have improved, while they have increased their access to more diversified foods richer in proteins (Lima de Faria *et al.*, 2008).

F. Morama domestication: Problems related to cultivating morama as a crop

In the three countries surveyed, there was no evidence of any successful experience regarding morama cultivation. In Botswana, cultivation had only been experimented with on a very small scale in the 1990s in two villages of the Ghanzi region with the help of an NGO called KURU. Morama was also cultivated on a research farm in the Namibian Sandveld region (Sandveld Research Station), but without any tangible results. According to key informants of both countries, the cultivated plots were not properly fenced and supervised (mostly in Botswana), while local people did not understand the reasons for the implementation of these projects and therefore failed to perceive their value (both in Botswana and Namibia). In South Africa, in the regions surveyed, so far no trials of morama cultivation have been carried out and locally, morama is only known as a wild plant. Most informants were quite surprized when asked about this possibility (Lima de Faria *et al.*, 2008).

The main problems underlined by rural populations regarding the cultivation of morama as a crop were the (i) soil quality; (ii) labor inputs (man power); (iii) availability of water; availability of land; (iv) slow growth cycle/low yields; and (v) prevalent instant cash/economic culture. In some villages, the soil was considered inadequate for being too sandy. Morama cultivation was also considered to be very labor-intensive since it required continuous weeding. The availability of water was also considered to be a major problem. According to key informants, the establishment of irrigation infrastructure for morama beans needs to be associated with other cultivated crops or plantation projects, such as vegetable gardens. Mostly in Botswana and Namibia, the availability of land was also said to be an important issue owing to the large size of the tuber. Moreover, continuous relocation processes have reduced its availability in the villages' surrounding areas, increasing the competition for arable land which is used primarily for products with higher yields such as sorghum and maize.

The slow growth cycle of the plant and its low yields were also mentioned as a constraint for morama domestication, given that one is dealing with food crops and communities that are generally anxious to see immediate results. Economic reasons were also identified as a constraint to domestication. According to a key informant in Botswana, domestication of morama means that people would be obliged to wait longer to generate income compared with other cash crops. The current prevalence of casual employment replacing long-term work has created a culture in which people expect immediate payment upon the completion of the task at hand. For this reason, morama that grows spontaneously and provides instant cash may be considered more favorably in comparison to its domesticated version. Domestication may also cause people to steal morama for quick cash (Lima de Faria *et al.*, 2008).

G. Morama market

In the past, similar to other wild berries or fruits, morama was not marketed and only used for individual or household consumption by hunter–gatherer populations. Morama commercialization, within an informal and local market, is therefore a result of the impact of the monetary economy. Together with other food products it became a source of instant cash. The market for morama beans is characterized by (i) the shortage of raw materials due to poor yields; (ii) low prices, poor information on growing; (iii) limited market access; and (iv) limited involvement of retailers (Lima de Faria *et al.*, 2008). Only small quantities of morama are sold in the villages, mostly to neighbors, or in nearby towns by villagers who temporarily act as street vendors. On account of the small quantities gathered, morama is generally channelled into household consumption and food sustainability (as they are easy to store and can be kept for long periods).

People only sell morama when there is a surplus. In areas where it is easy to gather, vendors do not make much profit from selling the beans, as most people already have access to them. Although morama is sold in the local market throughout the year, supply significantly increases in the month of April when the gathering season starts. In most cases, there is a direct relationship between gathering and selling morama, without any retailers being involved in the marketing of the beans (Lima de Faria *et al.*, 2008). Only in the Okakarara area of Namibia were there reports of morama gatherers (very poor San people) being paid by morama sellers (Herero farmers) to collect them in large quantities, which were later on sold in nearby markets. The beans are rarely sold fresh. Instead, they are normally sold uncooked in their shells or roasted either with the shell or unshelled (Lima de Faria *et al.*, 2008).

Prices vary somewhat between villages as they are determined by the seller, in accordance with their weight (measured in kilograms or by using approximate measures such as a cup or another container). In Botswana and Namibia, prices also depend upon morama being (un) shelled, fresh, raw, or roasted. The price may increase a little if the beans are sold in nearby towns. Small-scale and medium-scale farmers also sell morama to local people (to villagers or to farm workers). In the Okakarara area in Namibia, relations between commercial food stores and the ''kapanas,'' the traditional street vendors, seem to be good and they appear to act in a complementary fashion. Nomadic vendors sell morama in conjunction with other products such as vegetables or meat. Yet, this type of vending implies considerable costs as a result of poor public transportation; thus most vendors rely upon private transport, that is, by hitching a ride. In South Africa, the local (informal) market for morama beans is very weak compared to those observed in the regions surveyed in Botswana and Namibia (in which there were certain linkages between rural and urban areas, given that morama is brought by street vendors from rural villages to the nearest town or even to the capital cities). Thus, only a few cases were recorded of people selling them in South Africa. Apparently, morama beans are not being sold along the main roads. Shop vendors in Steenbokpan in South Africa said that there was no need to sell them since morama beans were plentiful and everyone had access to them (Lima de Faria *et al*., 2008).

H. Conclusions and recommendations

Most communities surveyed showed their readiness to engage in an experimental project regarding morama processing and marketing at the local level. They were quite positive about the prospects of generating profits from such a project. It was nevertheless in Namibia that the correlation between developing small processing industries and an increase in the populations' well-being appeared to have some measure of sustainability. In terms of looking for local partners to start an experimental project, the Gobabis area and the Sandveld Research Station looked like the most appropriate site for morama cultivation trials involving the local dwellers. They had already cultivated morama and it worked (Lima de Faria *et al*., 2008). In this region, the village RC Mission would also be a good place for such experiences because of its strong engagement in several organizational activities with the local population. To support this idea, it is important to note that in this village, there is a strong interest to integrate the San into the community, in spite of their nomadic lifestyle and a certain self-image of exclusion.

In the Okakarara area, the domination of the Herero is quite apparent. Being cattle herders, they have always had a reliable source of income. Having built a strong traditional leadership structure, they have developed an efficient system of community self-help. These characteristics suggest that they would also be a suitable group to work with in terms of creating a common project that would empower these communities and help build sustainable and fair market chains for morama value-added products.

There is a risk that if wild morama seeds are to be commercialized, they could end up being removed from the local communities who instead of collecting the beans in accordance with their own needs while rationally exploring their use, would be forced to buy them in the market at higher prices. This situation should be taken into account once proposals are presented to these communities (Lima de Faria *et al*., 2008).

Morama domestication on a certain scale seems to be the sole solution if a market for these means is supposed to reach broader boundaries (such as the national and the international level). Communal land would be best suited for morama domestication, by involving mostly poor populations within their already existent representative and cooperative structures. Processing industries should be developed at the local level and inscribed within existing local infrastructures in order to benefit and employ the poorer sections of the population.

VII. CHALLENGES AND FUTURE RESEARCH

The major challenge with the morama bean achieving its potential as a crop for Southern Africa is having a sustainable supply for commercial activities. Morama has not been domesticated and is still only available in the wild. The issue of sustainable supply is always a challenge with wild products, which generally have very intricate requirements for optimal production conditions, rendering them very difficult to propagate and hence hindering domestication efforts. However, its excellent properties and potential value commercially suggests that for the short term, a balance should be established that would allow for sustainable harvesting from the wild while long-term efforts be targeted toward breeding and domestication.

The morama bean is one of the many plants native to Africa with great agricultural potential, but which still needs to be developed through plant breeding to improve growth and yield. As reported by Chimwamurombe (2008) and Nepolo *et al*. (2009), the plant needs to be converted into a crop by developing desirable cultivars that are high yielding and early maturing. With the increasing human population, improvements in drought-tolerant crops such as morama bean could be of great benefit to indigenous populations. If not sustainably harvested, the legume will face the problem of overexploitation from local people through overharvesting of seeds as well as defoliation by game and livestock.

The morama bean, like other wild underutilized crops, is currently highly underresearched. There have been only two major funded research projects conducted on the morama bean; both of these were funded by the European Union. One focused on production issues and the other on postproduction. While a significant amount of new knowledge about the chemistry, processing applications, and health benefits of morama has been obtained through these projects, particularly using new techniques, there still remains a lot that is unknown. In order to achieve its potential, research is needed to understand the chemistry of the oil, protein, and carbohydrate components on varietal selection and breeding of these leguminous grains to enhance productivity and end-use quality as well as the nutritional and health-promoting components and antinutrients of the morama. Emphasis needs to be placed on the development of suitable processing technologies for the morama, for example, dehulling and milling operations to process into value-added products such as infant foods. Finally, appropriate markets need to be identified and developed for these grains as cash crops or value-added products.

REFERENCES

AACR (2003). Common antioxidant may decrease risk of breast cancer. http://www.eurekalert.org/pub_releases/2003-07/aafc-cam071403.php.

Adlercreutz, H. (2007). Lignans and human health. *Crit. Rev. Clin. Lab. Sci.* **44**, 483–525.

Adolphe, J. L., Whiting, S. J., Juurlink, B. H., Thorpe, L. U., and Alcorn, J. (2010). Health effects with consumption of the flax lignan secoisolariciresinol diglucoside. *Br. J. Nutr.* **103**, 929–938.

Agarwal, A., Munoz-Najar, U., Klueh, U., Shih, S. C., and Claffey, K. P. (2004). *N*-Acetylcysteine promotes angiostatin production and vascular collapse in an orthotopic model of breast cancer. *Am. J. Pathol.* **164**, 1683–1696.

Amarteifio, J. and Moholo, D. (1998). The chemical composition of four legumes consumed in Botswana. *J. Food Compos. Anal.* **11**, 329–332.

Ariyannur, P. S., Moffett, J. R., Manickam, P., Pattabiraman, N., Arun, P., Nitta, A., Nabeshima, T., Madhavarao, C. N., and Namboodiri, A. M. (2010). Methamphetamine-induced neuronal protein NAT8L is the NAA biosynthetic enzyme: Implications for specialized acetyl coenzyme A metabolism in the CNS. *Brain Res.* doi: 10.1016/j.brainres.2010.04.008.

Ashley, D. V., Fleury, M. O., Golay, A., Maeder, E., and Leathwood, P. D. (1985). Evidence for diminished brain 5-hydroxytryptamine biosynthesis in obese diabetic and non-diabetic humans. *Am. J. Clin. Nutr.* **42**, 1240–1245.

Belitz, H. D., Grosch, W., and Schieberle, P. (2004). Food Chemistry. 3rd edn. Springer, New York.

Blank, M. and Shoenfeld, Y. (2008). Histidine-rich glycoprotein modulation of immune/autoimmune, vascular, and coagulation systems. *Clin. Rev. Allergy Immunol.* **34**, 307–312.

Bousquet, J. (1982). The morama bean of the Kalahari Desert as a potential food crop, with a summary of current research in Texas. *Desert Plants* **3**, 213–215.

Bower, N., Hertel, K., Oh, J., and Storey, R. (1988). Nutritional evaluation of marama bean (*Tylosema esculentum*, Fabaceae): Analysis of the seed. *Econ. Bot.* **42**, 533–540.

Branca, F. and Lorenzetti, S. (2005). Health effects of phytoestrogens. *Diet Divers. Health Promot.* **57**, 100–111.

Bravo, L. (1998). Polyphenols: Chemistry, dietary sources, metabolism and nutritional significance. *Nutr. Rev.* **56**, 317–333.

Breiteneder, H. and Radauer, C. (2004). A classification of plant food allergens. *J. Allergy Clin. Immunol.* **113**, 821–830.

Brigelius-Flohé, R. (2006). Bioactivity of vitamin E. *Nutr. Res. Rev.* **19**, 174–186.

Brixel, L. R., Monteilh-Zoller, M. K., Ingenbrandt, C. S., Fleig, A., Penner, R., Enklaar, T., Zabel, B. U., and Prawitt, D. (2010). TRPM5 regulates glucose-stimulated insulin secretion. *Pflugers Arch.* doi: 10.1007/s00424-010-0835-z.

Buhr, G. and Bales, C. W. (2010). Nutritional supplements for older adults: Review and recommendations–Part II. *J. Nutr. Elder.* **29**(1), 42–71.

Burchell, W. J. (1824). Travels in the Interior of Southern Africa. Longman, London Vol. 2, p. 589.

Caballero, F., Fernandez, A., Matias, N., Martinez, L., Fucho, R., Elena, M., Caballeria, J., Morales, A., Fernandez-Checa, J. C., and Garcia-Ruiz, C. (2010). Specific contribution of methionine and choline in nutritional nonalcoholic steatohepatitis: Impact on mitochondrial *s*-adenosyl-l-methionine and GSH. *J. Biol. Chem.* doi: 10.1074/jbc.M109.099333.

Central Intelligence Agency (2007). Country report factbook—South Africa, Botswana and Namibia. https://www.cia.gov/.

Chimwamurombe, P. (2008). ABS and creation of an enabling environment for innovation, is it an issue for SADC countries? Marama bean domestication: An ABS case. *Build. Bridg.* **3**, 5–7.

Choi, J., Ha, K. H., Byun, M. S., Min, S. Y., Park, M. J., Park, H. S., Oh, H. J., Ju, J. H., Kim, H. Y., and Jue, D. M. (2008). Treatment with *N*-tosyl-L-phenylalanine chloromethyl ketone after the onset of collagen-induced arthritis reduces joint erosion and NF-kappaB activation. *Eur. J. Pharmacol.* **595**(1–3), 108–113.

Coetzer, L. A. and Ross, J..H. (1977). Tylosema. *In* ''Flora of Southern Africa, Vol. 16'', (J. H. Ross, Ed.), pp. 61–64. Botanical Research Institute, Pretoria, Number 2.

Crowther, M. A., Barr, R. D., Kelton, J., Whelan, D., and Greenwald, M. (1995). Profound thrombocytopenia complicating dietary erucic acid therapy for adrenoleukodystrophy. *Am. J. Hematol.* **48**(2), 132–133.

Dadachova, E. (2010). Cancer therapy with alpha-emitters labelled peptides. *Semin. Nucl. Med.* **40**, 204–208.

Darios, F. and Davletov, B. (2006). Omega-3 and omega-6 fatty acids stimulate cell membrane expansion by acting on syntaxin 3. *Nature* **440**, 813–817.

Lima de Faria, M., Saraiva, M. C., and Mosime, S. (2008). Consumer focus groups and socio-cultural studies conducted in three areas where Morama beans are found. Annual Report Marama II Project, Copenhagen, Denmark.

Debats, I. B., Wolfs, T. G., Gotoh, T., Cleutjens, J. P., Peutz-Kootstra, C. J., and van der Hulst, R. R. (2009). Role of arginine in superficial wound healing in man. *Nitric Oxide* **21**(3–4), 175–183.

Dia, V. P. and Mejia, E. G. (2010). Lunasin promotes apoptosis in human colon cancer cells by mitochondrial pathway activation and induction of nuclear clusterin expression. *Cancer Lett.* doi: 10.1016/j.canlet.2010.02.010.

Dubois, M., Lognay, G., Baudart, E., Marlier, M., Severin, M., Dardenne, G., and Malaisse, F. (1995). Chemical characterization of *Tylosema fassoglensis* (Kotschy) Torre & Hillc Oilseed. *J. Sci. Food Agric.* **67**, 163–167.

Dykes, L. and Rooney, L. W. (2006). Sorghum and millet phenols and antioxidants. *J. Cer. Sci.* **44**, 236–251.

Elfant, M., Bryant, L., and Starcher, B. (1985). Isolation and characterization of a proteinase inhibitor from marama beans. *Proc. Soc. Exp. Biol. Med.* **180**, 329–333.

Engelter, C. and Wehmeyer, A. S. (1970). Fatty acid composition of oils of some edible seeds of wild plants. *J. Agric. Food Chem.* **18**, 25–26.

FAO (2010). *Tylosema esculentum* (Burch.) Schreiber. http://www.fao.org/ag/AGP/AGPC/doc/GBASE/Safricadata/tylesc.htm.

Fini, L., Hotchkiss, E., Fogliano, V., Graziani, G., Romano, M., De Vol, E. B., Qin, H., Selgrad, M., Boland, C. R., and Ricciardiello, L. (2008). Chemopreventive properties of pinoresinol-rich olive oil involve a selective activation of the ATM-p53 cascade in colon cancer cell lines. *Carcinogenesis* **29**(1), 139–146.

Food Standards Agency (FSA) (2004). Agency issues warning on erucic acid. http://www.food.gov.uk/news/newsarchive/2004/sep/erucic (Accessed on 22nd April, 2010).

Francis, C. M. and Campbell, M. C. (2003). New high quality oil seed crops for temperate and tropical Australia. Rural Industries Research and Development Corporation, Barton, Australia. http://www.rirdc.gov.au/reports/NPP/03-045sum.html.

Freeman, E. W. (2004). Luteal phase administration of agents for the treatment of premenstrual dysphoric disorder. *CNS Drugs* **18**, 453–468.

Garcia-Miranda, P., Peral, M. J., and Ilundain, A. A. (2010). Effect of antidiuresis on renal creatine metabolism. *J. Physiol. Pharmacol.* **61**(1), 83–88.

Govoni, S., Amadio, M., Battaini, F., and Pascale, A. (2010). Senescence of the brain: Focus on cognitive kinases. *Curr. Pharm. Des.* **16**, 660–671.

Gueguen, J. (1983). Legume seed protein extraction, processing, and end product characteristics. *Qual. Plant Plant Foods Hum. Nutr.* **32**(3–4), 267–303.

Gur, S., Kadowitz, P. J., Trost, L., and Hellstrom, W. J. (2007). Optimizing nitric oxide production by time dependent L-arginine administration in isolated human corpus cavernosum. *J. Urol.* **178**(4 Pt 1), 1543–1548.

Ham, C., Akinnifesi, F. K., Franzel, S., Jordaan, D., Hansman, C., Ajayi, O. C., and de Kock, C. (2008). Opportunities for commercialization and enterprise development of indigenous fruit in Southern Africa. *In* ''Indigenous Fruit Trees in the Tropics: Domestication, Utilization and Commercialization'', (F. K. Akinnifesi, R. R. B. Leakey, O. C. Ajayi, G. Sileshi, Z. Tchoundjeu, P. Matakala, and F. R. Kwesiga, Eds). CAB International Publishing, UK.

Hartley, M. L., Tshamekang, E., and Thomas, S. M. (2002). Functional heterostyly in *Tylosema esculentum* (Caesalpinioideae). *Ann. Bot.* **89**, 67–76.

Hitchcock, R. (2002). We are the first people: Land, natural resources and identity in the central Kalahari Botswana. *J. South Afr. Stud.* **28**, 4.

Holse, M., Husted, S., and Hansen, Å. (2010). Chemical composition of marama bean (*Tylosema esculentum*)—A wild African bean with unexploited potential. *J. Food Comp. Anal.* **23**, 648–657.

Hoover, R. and Sosulski, F. W. (1991). Composition, structure, functionality, and chemical modification of legume starches—A review. *Can. J. Physiol. Pharmacol.* **69**, 79–92.

Hotz, C. and Brown, K. (2004). International Zinc Nutrition Consultative Group (IZiNCG) technical document #1. Assessment of the risk of zinc deficiency in populations and options for its control. *Food Nutr. Bull.* **25**(1, Suppl 2), S94–S203.

Huang, H. Y., Caballero, B., Chang, S., Alberg, A., Semba, R., Schneyer, C., Wilson, R. F., Cheng, T. Y., Prokopowicz, G., Barnes, G. J., 2nd, Vassy, J., and Bass, E. B. (2006). Multivitamin/mineral supplements and prevention of chronic disease. *Evid. Rep. Technol. Assess. (Full Rep.)* **May**(139), 1–117.

Hunter, J. E., Zhang, J., and Kris-Etherton, P. M. (2009). Cardiovascular disease risk of dietary stearic acid compared with trans, other saturated, and unsaturated fatty acids: A systematic review. *Am. J. Clin. Nutr.* **91**(1), 46–63.

Hymowitz, T., Collins, F. I., Walker, W. M., and Panczner, J. (1972). Relationship between content of oil, protein, and sugar in soybean seed. *Agron. J.* **64**, 613–616.

Institute of Security Studies (2007). Country file: Botswana. http://www.issafrica.org.

Iwuoha, C. I. and Umunnakwe, K. E. (1997). Chemical, physical and sensory characteristics of soymilk as affected by processing method, temperature and duration of storage. *Food Chem.* **59**, 373–379.

Jackson, J. C. (2010). Food applications of the morama bean. Presented at the workshop on the Morama Bean: Food Processing and Marketing Opportunities for Small and Medium Enterprises, Ghanzi.

Jackson, J. C., Mpotokwane, S., Tlhong, T., and Mthombeni, M. (2009). Nutritional characterisation of morama bean milk. Annual Report Marama II Project, Copenhagen, Denmark.

Jenkins, D. J., Kendall, C. W., D'Costa, M. A., Jackson, C. J., Vidgen, E., Singer, W., Silverman, J. A., Koumbridis, G., Honey, J., Rao, A. V., Fleshner, N., and Klotz, L. (2003). Soy consumption and phytoestrogens: Effect on serum prostate specific antigen when blood lipids and oxidized low-density lipoprotein are reduced in hyperlipidemic men. *J. Urol.* **169**, 507–511.

Jideani, V. A., Van Wyk, J., and Cruywagen, M. H. (2009). Physical properties of *Tylosema esculentum* and the effect of roasting on the functional properties of flour. *Afr. J. Agric. Res.* **4**, 1208–1219.

Jordaan, D., Akinnifesi, F. K., Ham, C., and Ajayi, O. C. (2008). The feasibility of small-scale indigenous fruit processing enterprises in Southern Africa. *In* ''Indigenous fruit trees in the tropics: Domestication, utilization and commercialization'', (F. K. Akinnifesi, R. R. B. Leakey, O. C. Ajayi, G. Sileshi, Z. Tchoundjeu, P. Matakala, and F. R. Kwesiga, Eds). CAB International Publishing, Wallingford, UK.

Jordaan, D., Christy, R. D., and Mabaya, E. (2009). Marketing Strategies for Morama Bean Products. Annual Report Marama II Project, Copenhagen, Denmark.

Karleskind, D., Laye, I., Halpin, E., and Morr, C. V. (1991). Improving acid production in soy based yogurt by adding cheese whey proteins and mineral salts. *J. Food Sci.* **56**, 999–1001.

Kayitesi, E. (2009). Sensory and nutritional quality of marama–sorghum composite flours and porridges. MSc (Agric) Food Science and Technology dissertation. University of Pretoria, Pretoria, South Africa.

Keegan, A. B. and Van Staden, J. (1981). Marama bean, *Tylosema esculentum*, a plant worthy of cultivation. *S. Afr. J. Sci.* **77**, 387.

Keith, M. E. and Renew, A. (1975). Notes on some edible wild plants found in the Kalahari. *Koedoe* **18**, 1–12.

Ketshajwang, K. K., Holmback, J., and Yeboah, S. O. (1998). Quality and compositional studies of some edible leguminosae seed oils in Botswana. *J. Am. Oil Chem. Soc.* **75**, 741–743.

Kim, J. Y., Park, H. D., Park, E., Chon, J. W., and Park, Y. K. (2009). Growth-inhibitory and proapoptotic effects of alpha-linolenic acid on estrogen-positive breast cancer cells. *Ann. NY Acad. Sci.* **1171**, 190–195.

Kim, G., Cole, N. B., Lim, J. C., Zhao, H., and Levine, R. L. (2010). Dual sites of protein initiation control the localization and myristoylation of methionine sulfoxide reductase A. *J. Biol. Chem.* doi: 10.1074/jbc.M110.119701.

Kizhakekuttu, T. J. and Widlansky, M. E. (2010). Natural antioxidants and hypertension: Promise and challenges. *Cardiovasc. Ther.* doi: 10.1111/j.1755-5922.2010.00137.x.

Kortsalioudaki, C., Taylor, R. M., Cheeseman, P., Bansal, S., Mieli-Vergani, G., and Dhawan, A. (2008). Safety and efficacy of *N*-acetylcysteine in children with non-acetaminophen-induced acute liver failure. *Liver Transpl.* **14**(1), 25–30.

Kratz, J. M., Andrighetti-Frohner, C. R., Leal, P. C., Nunes, R. J., Yunes, R. A., Trybala, E., Bergstrom, T., Barardi, C. R., and Simoes, C. M. (2008). Evaluation of anti-HSV-2 activity of gallic acid and pentyl gallate. *Biol. Pharm. Bull.* **31**, 903–907.

Kumar, K. and Mishra, H. N. (2004). Mango soy fortified set yoghurt: Effect of stabilizer addition on physicochemical, sensory and textural properties. *Food Chem.* **87**, 501–507.

Kwiatkowska, E. (2007). Phytoestrogens in osteoporosis prevention. *Przegl. Menopauzalny* **6**, 306–309.

Lakshmikuttyamma, A., Selvakumar, P., Tuchek, J., and Sharma, R. K. (2008). Myristoyltransferase and calcineurin: Novel molecular therapeutic target for epilepsy. *Prog. Neurobiol.* **84**, 77–84.

Leibenstein, H. (1950). Bandwagon, snob, and Veblen effects in the theory of consumers demand. *Q. J. Econ.* **64**, 183–207.

Leong, S. L., Pham, C. L., Galatis, D., Fodero-Tavoletti, M. T., Perez, K., Hill, A. F., Masters, C. L., Ali, F. E., Barnham, K. J., and Cappai, R. (2009). Formation of dopamine-mediated alpha-synuclein-soluble oligomers requires methionine oxidation. *Free Radic. Biol. Med.* **46**, 1328–1337.

Li, L. and Renier, G. (2008). Palmitic acid-induced endothelial nitric acid inhibition is mediated by C-reactive protein. Poster Sessions, Abstracts 77th Congress of the European Atherosclerosis Society. *Atheroscler. Suppl.* **9**(1), 66.

Lin, J., Lee, I. M., Song, Y., Cook, N. R., Selhub, J., Manson, J. E., Buring, J. E., and Zhang, S. M. (2010). Plasma homocysteine and cysteine and risk of breast cancer in women. *Cancer Res.* **70**, 2397–2405.

Liu, K. (1997). Soybeans: Chemistry, Technology and Utilization. Chapman and Hall, New York pp. 137–164.

Liu, T. H., Wu, C. L., Chiang, C. W., Lo, Y. W., Tseng, H. F., and Chang, C. K. (2009). No effect of short-term arginine supplementation on nitric oxide production, metabolism and performance in intermittent exercise in athletes. *J. Nutr. Biochem.* **20**, 462–468.

Lyne, M. C. and Darroch, M. A. G. (2003). Land redistribution in South Africa: Past performance and future policy. *In* ''The challenge of change: Agriculture, land and the South African economy'', (W. L. Nieuwoudt and J. Groenewald, Eds). University of Natal Press, Durban.

Maggini, S., Wintergerst, E. S., Beveridge, S., and Hornig, D. H. (2007). Selected vitamins and trace elements support immune function by strengthening epithelial barriers and cellular and humoral immune responses. *Br. J. Nutr.* **98**(Suppl 1), S29–S35.

Maggs, D. J., Collins, B. K., Thorne, J. G., and Nasisse, M. P. (2000). Effects of L-lysine and L-arginine on *in vitro* replication of feline herpesvirus type-1. *Am. J. Vet. Res.* **61**, 1474–1478.

Manach, C., Scalbert, A., Morand, C., Rémésy, C., and Jimenez, L. (2004). Polyphenols: Food sources and bioavailability. *Am. J. Clin. Nutr.* **79**, 727–747.

Manderson, G. A., Martin, M., Onnerfjord, P., Saxne, T., Schmidtchen, A., Mollnes, T. E., Heinegard, D., and Blom, A. M. (2009). Interactions of histidine-rich glycoprotein with immunoglobulins and proteins of the complement system. *Mol. Immunol.* **46**, 3388–3398.

Marfella, R., Acampora, R., Verrazzo, G., Ziccardi, P., De Rosa, N., Giunta, R., and Giugliano, D. (1996). Metformin improves hemodynamic and rheological responses to L-arginine in NIDDM patients. *Diabetes Care* **19**, 934–939.

Maruatona, G. N. (2008). Physicochemical, nutritional and functional properties of defatted marama bean flour. MSc Food Science dissertation. University of Pretoria, Pretoria, South Africa.

Maruatona, G. N., Duodu, K. G., and Minnaar, A. (2010). Physicochemical, nutritional and functional properties of marama bean flour. *Food Chem.* **121**, 400–405.

Mathers, M. J., Brandt, A. S., Rundstedt, F., Roth, S., Sommer, F., and Klotz, T. (2009). Metabolism of nitric oxide (NO) and arginine: Significance for male health. *Aktuelle Urol.* **40**(4), 235–241 (Abstract only, Article in German).

Mazur, W. M., Duke, J. A., Wahala, K., Rasku, S., and Adlercreutz, H. (1998). Isoflavonoids and lignans in legumes: Nutritional and health aspects in humans. *J. Nutr. Biochem.* **9**, 193–200.

Medina, V., Croci, M., Crescenti, E., Mohamad, N., Sanchez-Jiménez, F., Massari, N., Nuñez, M., Cricco, G., Martin, G., Bergoc, R., and Rivera, E. (2008). The role of histamine in human mammary carcinogenesis: H3 and H4 receptors as potential therapeutic targets for breast cancer treatment. *Cancer Biol. Ther.* **7**(1), 28–35.

Mitei, Y. C., Ngila, J. C., Yeboah, S. O., Wessjohann, L., and Schmidt, J. (2008). NMR, GC–MS and ESI–FTICR–MS profiling of fatty acids and triacylglycerols in some Botswana seed oils. *J. Am. Oil Chem. Soc.* **85**, 1021–1032.

Mitei, Y. C., Ngila, J. C., Yeboah, S. O., Wessjohann, L., and Schmidt, J. (2009). Profiling of phytosterols, tocopherols and tocotrienols in selected seed oils from Botswana by GC–MS and HPLC. *J. Am. Oil Chem. Soc.* **86**, 617–625.

Mmonatau, Y. (2005). Flour from the morama bean: Composition and sensory properties in a Botswana perspective. Stellenbosch University, Stellenbosch, South Africa, Masters Degree Thesis.

Monaghan, B. G. (1995). Genetic variation in the marama bean (*Tylosema esculentum*). Master of Agricultural Science, University of Melbourne, Melbourne.

Mpotokwane, S., Mmonatau, Y., Mthombeni, F., Mahgoub, S., Sopejame, M., and Jackson, J. C. (2007). Quality evaluation of morama milk. In: Proceedings of the Annual meeting of the South African Association of Food Science and Technology (SAAFoST), Durban, South Africa.

Mūseler, D. L. and Schönfeldt, H. C. (2006). The nutrient content of the marama bean (*Tylosema esculentum*), an underutilised legume from Southern Africa. *Agricola* **16**, 7–13.

Naczk, M. and Shahidi, F. (2006). Phenolics in cereals, fruits and vegetables: Occurrence, extraction and analysis. *J. Pharma. Biomed. Anal.* **41**, 1523–1542.

Nassar, A. G., Mubarak, A. E., and El-Beltagy, A. E. (2008). Nutritional potential and functional properties of tempe produced from mixture of different legumes. 1: Chemical composition and nitrogenous constituent. *Int. J. Food Sci. Technol.* **43**, 1754–1758.

National Academy of Sciences (1979). Tropical legumes: Resources for the future. National Research Council, Washington, DC.

Nepolo, E., Takundwa, M., Chimwamurombe, P., Cullis, C. A., and Kunert, K. (2009). A review of the geographical distribution of marama bean [*Tylosema esculentum* (Burchell) Schreiber] and genetic diversity in the Namibian germplasm. *Afr. J. Biotechnol.* **8**, 2088–2093.

Neuringer, M., Connor, W. E., Lin, D. S., Barstad, L., and Luck, S. (1986). Biochemical and functional effects of prenatal and postnatal omega-3 fatty acid deficiency on retina and brain in rhesus monkeys. *Proc. Natl. Acad. Sci. USA* **83**, 4021–4025.

Penalvo, J. L., Heinonen, S. M., Nurmi, T., Deyama, T., Nishibe, S., and Adlercreutz, H. (2004). Plant lignans in soy-based health supplements. *J. Agric. Food Chem.* **52**, 4133–4138.

Phuthego, L., Mpotokwane, S., Tlhong, T., Mthombeni, F., and Jackson, J. C. (2009). Processing and quality evaluation of morama yoghurt. Annual Report Marama II Project, Copenhagen, Denmark.

Planet Retail (2007). Country analysis—Botswana, Namibia and South Africa. http://www.planetretail.net.

Poon, I. K., Hulett, M. D., and Parish, C. R. (2010). Histidine-rich glycoprotein is a novel plasma pattern recognition molecule that recruits IgG to facilitate necrotic cell clearance via FcgammaRI on phagocytes. *Blood* **115**, 2473–2482.

Poulton, J. E. (1990). Cyanogenesis in plants. *Plant Physiol.* **94**, 401–405.

Powell, A. M. (1987). Marama bean (*Tylosema esculentum*, Fabaceae): Seed crop in Texas. *Econ. Bot.* **41**, 216–220.

Power, G. W., Cake, M. H., and Newsholme, E. A. (1997). The influence of diet on the activity of carnitine palmitoyltransferase 1 toward a range of acyl CoA esters. *Lipids* **32**, 31–37.

Preuss, H. G. (2009). Bean amylase inhibitor and other carbohydrate absorption blockers: Effects on diabesity and general health. *J. Am. Coll. Nutr.* **28**, 266–276.

Pulce, C., Vial, T., Verdier, F., Testud, F., Nicolas, B., and Descotes, J. (1992). The Chinese restaurant syndrome: A reappraisal of monosodium glutamate's causative role. *Adverse Drug React. Toxicol. Rev.* **11**(1), 19–39.

Rapoport, S. I. (2008). Arachidonic acid and the brain. *J. Nutr.* **138**, 2515–2520.

Rastogi, T., Rastogi, T., Reddy, K. S., Vaz, M., Spiegelman, D., Prabhakaran, D., Willett, W. C., Stampfer, M. J., and Ascherio, A. (2004). Diet and risk of ischemic heart disease in India. *Am. J. Clin. Nutr.* **79**, 582–592.

Ripperger-Suhler, J. A. and Longenecker, J. B. (1982). Assessment of the nutritional value of Morama Bean. Division of Graduate Nutrition, University of Texas, Austin Report to the Center for the Study of Human Adaptation.

Rizzo, W. B., Watkins, P. A., Phillips, M. W., Cranin, D., Campbell, B., and Avigan, J. (1986). Adrenoleukodystrophy: Oleic acid lowers fibroblast saturated C22–26 fatty acids. *Neurology* **36**, 357–361.

Robbins, R. J. (2003). Phenolic acids in foods: An overview of analytical methodology. *J. Agric. Food Chem.* **51**, 2866–2887.

Rosell, M. S., Appleby, P. N., Spencer, E. A., and Key, T. J. (2004). Soy intake and blood cholesterol concentrations: A cross-sectional study of 1033 pre- and postmenopausal women in the Oxford arm of the European prospective investigation into cancer and nutrition. *Am. J. Clin. Nutr.* **80**, 1391–1396.

Rutjes, A. W., Nuesch, E., Reichenbach, S., and Juni, P. (2009). *S*-Adenosylmethionine for osteoarthritis of the knee or hip. *Cochrane Database Syst. Rev.* (4), CD007321.

Sadiki, P. and Ramutsindela, M. (2002). Peri-urban transformation in South Africa: Experiences from Limpopo province. *GeoJournal* **57**, 75–81.

Saka, J. D. K., Kadzere, I., Ndabikunze, B. K., Akinnifesi, F. K., and Tiisekwa, B. P. M. (2008). Product development: Nutritional value, processing and utilization of indigenous fruits from the miombo ecosystem. *In* ''Indigenous fruit trees in the tropics: Domestication utilization and commercialization'', (F. K. Akinnifesi, R. R. B. Leakey, O. C. Ajayi, G. Sileshi, Z. Tchoundjeu, P. Matakala, and F. R. Kwesiga, Eds). CAB International Publishing, Wallingford, UK.

Saldeen, K. and Saldeen, T. (2005). Importance of tocopherols beyond [alpha]-tocopherol: Evidence from animal and human studies. *Nutr. Res.* **25**, 877–889.

Salunkhe, D. K. and Kadam, S. S. (1989). CRC handbook of world food legumes: Nutritional chemistry, processing, technology and utilization. CRC Press, Boca Raton, FL, USA.

Sanchez, A., Rubano, D. A., Shavlik, G. W., Hubbard, R., and Horning, M. C. (1988). Cholesterolemic effects of the lysine/arginine ratio in rabbits after initial early growth. *Arch. Latinoam. Nutr.* **38**, 229–238.

Sayegh, R., Schiff, I., Wurtman, J., Spiers, P., McDermott, J., and Wurtman, R. (1995). The effect of a carbohydrate-rich beverage on mood, appetite, and cognitive function in women with premenstrual syndrome. *Obstet. Gynecol.* **86**(4 Pt 1), 520–528.

Shimakura, K., Miura, H., Ikeda, K., Ishizaki, S., Nagashima, Y., Shirai, T., Kasuya, S., and Shiomi, K. (2004). Purification and molecular cloning of a major allergen from Anisakis simplex. *Mol. Biochem. Parasitol.* **135**(1), 69–75.

Skibo, E. B., Jamil, A., Austin, B., Hansen, D., and Ghodousi, A. (2010). Triple molecular target approach to selective melanoma cytotoxicity. *Org. Biomol. Chem.* **8**, 1577–1587.

Spielmann, J., Noatsch, A., Brandsch, C., Stangl, G. I., and Eder, K. (2008). Effects of various dietary arginine and lysine concentrations on plasma and liver cholesterol concentrations in rats. *Ann. Nutr. Metab.* **53**(3–4), 223–233.

Statistics South Africa (2006). Urban/Rural population of South Africa. Unpublished Report.

Street, H. E. and Öpik, H. (1975). The Physiology of Flowering Plants. Elsevier, New York, USA.

Sun, C. A., Wu, M. H., Chu, C. H., Chou, Y. C., Hsu, G. C., Yang, T., Chou, W. Y., Yu, C. P., and Yu, J. C. (2010). Adipocytokine resistin and breast cancer risk. *Breast Cancer Res. Treat.* doi: 10.1007/s10549-010-0792-4.

Szczurko, O. and Boon, H. S. (2008). A systematic review of natural health product treatment for vitiligo. *BMC Dermatol.* **8**, 2. doi: 10.1186/1471-5945-8-2.

Thomas, T. (2004). Marama bean (*Tylosema esculentum*), a non-nodulating high protein legume indigenous to the Kalahari sands: Studies of its N nutrition. University of Cape Town, South Africa, M.Sc. dissertation.

Thorne Research (2007). L-Lysine. Monograph. *Altern. Med. Rev.* **12**(2), 169–172.

Tlhong, T., Sopejame, M., Mthombeni, F., Mpotokwane, S., and Jackson, J. C. (2009). Sensory attributes of morama oil. Annual Report Marama II Project, Copenhagen, Denmark.

Torres-Sanchez, L., Galvan-Portillo, M., Wolff, M. S., and Lopez-Carrillo, L. (2008). Dietary consumption of phytochemicals and breast cancer risk in Mexican women. *Public Health Nutr.* **12**, 825–831.

UNDP (2009). Human Development Report. United Nations Development Programme (UNDP), Washington, DC. http://hdr.undp.org/en/reports/global/hdr2009/ (Accessed on September 6, 2010).

U.S. Department of Agriculture, A.R.S (2007). USDA National Nutrient Database for Standard Reference, Release 21. http://www.ars.usda.gov/nutrientdata.

UNICEF (2004). Micronutrient Initiative; Vitamin and Mineral Deficiency, A Global Progress Report. *In* ''Micronutrient Initiative''. UNICEF (The United Nations Children's Fund.

Van der Maesen, L. J. G. (2006). *Tylosema esculentum* (Burch.) A.Schreib. *In* ''PROTA 1: Cereals and pulses/Céréales et légumes secs'', (M. Brink and G. Belay, Eds). PROTA, Wageningen, Netherlands.

van Egmond, A. W., Kosorok, M. R., Koscik, R., Laxova, A., and Farrell, P. M. (1996). Effect of linoleic acid intake on growth of infants with cystic fibrosis. *Am. J. Clin. Nutr.* **63**, 746–752.

Van Zyl, J. (2007). Marama bean cotyledon and seed coats: Phenolic composition and antioxidant activity. Univerity of Pretoria, Pretoria, South Africa B.Sc. Honours Project Report.

Vietmeyer, N. D. (1986). Lesser-known plants of potential use in agriculture and forestry. *Science* **232**, 1379–1384.

Vitamins and Health Supplements Guide (2005). http://www.vitamins-supplements.org/amino-acids/threonine.php Threonine.

Walvoord, M. A., Plumer, M. A., Sonestrom, D. A., Evans, R. D., Hartsough, P. C., Newman, B. D., and Striegl, R. G. (2003). A reservoir of nitrate beneath desert soils. *Science* **30**, 1021–1024.

Wang, Z. J., Liang, C. L., Li, G. M., Yu, C. Y., and Yin, M. (2006). Neuroprotective effects of arachidonic acid against oxidative stress on rat hippocampal slices. *Chem. Biol. Interact.* **163**, 207–217.

Wang, Y., Liu, H., McKenzie, G., Witting, P. K., Stasch, J. P., Hahn, M., Changsirivathanathamrong, D., Wu, B. J., Ball, H. J., Thomas, S. R., Kapoor, V., Celermajer, D. S., *et al*. (2010). Kynurenine is an endothelium-derived relaxing factor produced during inflammation. *Nat. Med.* **16**, 279–285.

Wehmeyer, A. S., Lee, R. B., and Whiting, M. (1969). The nutrient composition and dietary importance of some vegetable foods eaten by the !Kung Bushmen. *S. Afr. Med. J.* **43**, 1529–1530.

Weising, K., Winter, P., Huttel, B., and Kahl, G. (1998). Microsatellite markers for molecular breeding. *J. Crop Prod.* **1**, 113–143.

Wood, J. C. (1993). Thorstein Veblen: Critical assessments, 352. Routledge, London0-415-07487-8.

World Health Organization (WHO) (2003). Diet, Nutrition and the Prevention of Chronic Diseases. World Health Organization, Geneva Technical Report Series 916, Report of a Joint WHO/FAO Expert Consultation, p. 88.

Wright, M. H., Heal, W. P., Mann, D. J., and Tate, E. W. (2010). Protein myristoylation in health and disease. *J. Chem. Biol.* **3**, 19–35.

Yamanishi, R., Yusa, I., Miyamoto, A., Sato, I., Bando, N., and Terao, J. (2003). Alum augments the experimental allergenicity of Kunitz-type soybean trypsin inhibitor independent of the antigen-adsorption. *J. Nutr. Sci. Vitaminol. (Tokyo)* **49**, 409–413.

Yazici, F., Alvarez, V. B., and Hansen, P. M. T. (1997). Fermentation and properties of calcium-fortified soy milk yogurt. *J. Food Sci.* **62**, 457–461.

Yeboah, S. O. and Moshoeshoe, E. (2008). Oil extraction and characterization of the oil from the morama seed, *Tylosema esculentum*. Annual Report Marama II Project, Copenhagen, Denmark.

Yuan, H., Perry, C. N., Huang, C., Iwai-Kanai, E., Carreira, R. S., Glembotski, C. C., and Gottlieb, R. A. (2009). LPS-induced autophagy is mediated by oxidative signaling in cardiomyocytes and is associated with cytoprotection. *Am. J. Physiol. Heart Circ. Physiol.* **296**(2), H470–H479.

Zane, L., Bargelloni, L., and Pattarnello, T. (2002). Strategies for microsatellite isolation: A review. *Mol. Ecol.* **11**, 1–16.

Zelkowitz, R. (2008). Fat molecule fights weight gain. *Science.* http://news.sciencemag.org/sciencenow/2008/09/19-03.html.