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INDIGENOUS KNOWLEDGE AND PROCESSING OF *ADANSONIA DIGITATA* L. FOOD PRODUCTS IN BENIN

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Indigenous knowledge related to baobab food products was investigated in Benin among 253 food processors from 15 ethnic groups. Descriptive statistics and correspondence analysis (CA) were used for data analysis. The following food categories were identified: dough, gruel, drinks (from pulp); sauces (from leaves, seeds and kernels), and flavouring agents (from kernels). CA showed that the food use of baobab parts varies among ethnic groups. Most ethnic groups have similar opinions about the difficulty of certain processing operations, in particular seed decortication, grinding and sieving operations

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for product recovery. Storage and preservation problems were mentioned for kernels and pulp.

KEYWORDS baobab, food uses, processing, storage, ethnic groups, Benin

INTRODUCTION

Among the numerous forest food resources available in the wild, the baobab tree (*Adansonia digitata* L.) is of key economic importance, being used daily by local populations in Africa (Wickens, 1982, Baum, 1995, Sidibe and Williams, 2002, Diop et al., 2005, Assogbadjo et al., 2006). It is characterized by its massive size, reaching to a height of 18–25 m, with a rounded crown and showing a stiff branching habit. Fruits are dehiscent, containing kidney-shaped seeds and powdery fruit pulp (Baum, 1995). A number of bilateral agencies promoted the species in the past, e.g., NORAD (Norway) in Kenya and SIDA (Sweden) in Tanzania. The World Agroforestry Centre (ICRAF) and the International Centre for Underutilized Crops (ICUC, UK) accorded high priority to research and development of baobab and continue to promote its use as a multipurpose species. Biodiversity International classifies the species amongst the most important edible forest trees to be conserved, domesticated and valorized in Benin (Eyog Matig et al., 2002). National research efforts, especially in Benin, Nigeria, Burkina Faso, Mali and Senegal, have provided relatively recent data on agronomy, ethno-botanical knowledge, ecology and genetic diversity of baobab (Codjia et al., 2001, Assogbadjo et al., 2005a, 2005b, 2006, Diop et al., 2005). In Benin, studies on baobab are quite recent and relate to its general importance (Codjia et al., 2001, 2003) and ecological and genetic diversity (Assogbadjo et al., 2005a, 2005b, 2006). However, the ethno-food knowledge and economic potential of baobab for local populations are poorly documented whereas local populations have outstanding knowledge on the processing of several forest trees with edible parts such as shea tree (*Vitellaria paradoxa*) and the African locust tree (*Parkia biglobosa*) (Teklehaimanot, 2004).

There is a recent awakening of interest and concern about the lack of documentation about traditional and indigenous food cultures which are important not only for their own sake, but for the legacy of food knowledge which they can confer on future generations, provided that they are not lost; hence, the value of special focus on African food cultures (Wahlqvist, 2007). Effective valorization through improvement of traditional techniques and

products, and production of added value products (i.e., with functional properties) for a larger market will increase income of rural, poor populations. Unfortunately, there is no sustained research capitalizing on endogenous processing and food knowledge. Such research, however, is a prerequisite for any valorization and promotion of the products (Sidibe and Williams, 2002), and to better orient and prioritize further research. The present study aims at filling this gap.

MATERIALS AND METHODS

Sampling of Informants

First, a random check was performed on 198 processors offering their foods for sale on local markets to determine the proportion of processors of baobab food products. This proportion was used to compute the sample size N_i of baobab processors to be interviewed, using the following formula: $N_i = \frac{4pi(1-p_i)}{d^2}$, (Dagnelli, 1998) where N_i is the total number of processors to be surveyed for the study; p_i is the proportion of baobab processors among the 198 randomly checked persons; d is the expected error margin in the conclusion, which is fixed at 0.05 (Dagnelli, 1998). Next, the number of processors to be interviewed in each municipality was calculated on the basis of its population size. If T is the proportion of the population of a community among the total number of people living in the study area, N, according to $T_j = \frac{n_j}{N}$ where n_j is the number of people in community j, then N_{ij} is the number of processors to be surveyed in community j, according to $N_{ij} = N_i \times T_j$.

Field Data Collection

Field data were collected from December 2006 to January 2007 to establish ethno-food knowledge related to baobab among different communities in Benin where baobab foods are commonly used. Questionnaires were used which were tested with local inhabitants prior to the formal survey, and adjusted if needed. Discussions were conducted in the villages of the selected localities, based on the adjusted questionnaires. Interviews were conducted in the language/dialect that was best understood by the

Table 1. Study localities and ethnic groups

Localities	Municipality	Ethnic groups
Badjoude	Waké	Lokpa
Dassa-zoume	Dassa-zoume	Datcha, Mahi, Fon
Dassari	Materi	Berba, Yom
Birni-Lafia	Karimama	Dendi
Kandi	Kandi	Bariba, Dendi, Peulh*
Karimama	Karimama	Dendi
Korontiere	Boukoumbe	Otamari, Comcombè*, Tchokossi*, Peulh*
Kouaba	Natitingou	Otamari
Koussoucoingou	Boukoumbe	Otamari
Natitingou	Natitingou	Otamari
Tanguieta	Tanguieta	Brouba, Wama
Tantega	Materi	Berba
Tayakou	Cobli	Gourmantche, Nateri

*Not native of that area.

informants with translation when necessary. In total, 253 processors of baobab food products were interviewed. Informants, from different ethnic groups and localities (Table 1, Figure 1) of both genders (223 women and 30 men) and various ages (young, adults, elderly) were randomly selected and interrogated on baobab food uses, traditional processing technologies, specific problems related to baobab traditional processing, and preservation and storage problems of products.

Data Processing and Analyses

The collected data were recorded in a database. Statistical analyses were performed using SAS.v8 software (SAS Institute Inc.). The importance of processed food products from baobab parts was evaluated by asking the population to rank the derived products from the most (ranked 1) to the least important (ranked 5) considering each baobab part. Descriptive statistics and correspondence analysis (CA) were used as mathematical tools. CA is similar to principal component analysis (PCA) but has more flexibility, since it inherently includes weights on both rows and columns of tables (Greenacre, 1993). This method was used to link socio-cultural groups according to local perception of various parameters. For CA, correlations and partial contributions of the modality under consideration allowed to obtain the best represented modalities on each axis. Projections

Figure 1. Map of Benin showing the municipalities included in the study.

of modalities on axes allowed us to describe linkages between choices and perceptions of indigenous knowledge related to baobab food products by different ethnic groups.

Table 1 presents the ethnic groups encountered in each study locality, as shown in Figure 1. The interpretation of CA graphs and tables was according to this table. In total, 15 ethnic groups were interviewed during the survey on baobab food processing.

RESULTS

Food Uses of Baobab: Importance and Processing Techniques

Table 2 presents an overview of the utilization, perceived importance, and unit operations involved in the processing of a wide variety of baobab-derived products. According to local respondents, foods from baobab are mainly derived from the following baobab parts: leaves (27.5% of informants), pulp (27.2%), fruits (23.4%), seeds (14%), kernels (7.6%), and roots (0.3%). Each baobab part is

Table 2. Proportion and importance of baobab food products for baobab parts

Baobab parts	Processing products	Frequency of informants ranking the product according to their relative importance (%)	Importance of product (median rank)[1]	Other ingredients added	Main unit process operations
Leaves	Fresh leaves sauce	36.9	1	Flavouring agents	Grinding/milling, cooking
	Dry leaf powder	29.3	2	-	Drying, grinding, sieving
	Dry leaf sauce	3.4	2	Flavouring agents	Cooking
	Dry leaf	14.4	3	-	Drying
	Dry leaf powder sauce	3.9	3	Flavouring agents	Drying, cooking
	Yatirankounti sauce (whole fresh leaves + dehulled beans)	1.5	3	Whole beans (*Vigna unguiculata*)	Beans dehulling, cooking
	Touwoundou sauce (ground dry or fresh leaves + dehulled beans)	8.7	3	Dehulled beans (*Vigna unguiculata*)	Beans dehulling, leaves grinding, cooking
	Kouimkoundi sauce (leaves sauce or touwoundou + afitin)	2.0	4	"Afitin"	Cooking
Pulp	Gruel	29.9	1	Maize or millet flour	Cooking
	Sour dough or *Mutchayan*[2]	9.1	2	Maize or millet flour	Dough cooking, fermentation
	Nanganfirou	8.8	2	Millet flour	Millet milling
	Yewowi beverage	10.6	2	Broken millet	Millet breaking/grinding
	Solani	0.2	2	Sugar	Cooking (facultative), freezing
	Pulp beverage	15.0	2	-	Pulp extraction
	Tcho beverage	10.0	2	Maize or millet dough	Dough cooking
	Iced pulp beverage	13.7	3	Sugar	Freezing
	Norendoorou	0.7	4	Locust bean pulp	Pulp extraction
	Baobab pulp syrup	0.7	4	Sugar	Cooking
	Moukou-moukou	1.4	5	Sugar	Pulp extraction

(*Continued*)

Table 2. (*Continued*)

Baobab parts	Processing products	Frequency of informants ranking the product according to their relative importance (%)	Importance of product (median rank)[1]	Other ingredients added	Main unit process operations
Fruit	Pulp	40.7	1	-	Grinding, sieving
	Seeds	41.1	2	-	Grinding
	Potash	18.3	3	-	Incineration, filtration
Seeds	Kernels	42.1	1	-	Decortication
	Moutokpei sauce	25.3	2	Common sauce ingredients[3]	Roasting, grinding, cooking
	Matofaman sauce[2]	18.1	2	Common sauce ingredients[3]	Breaking, fermentation, sieving, cooking
	Mougoundoro	0.3	2	Salt, sugar	Roasting
	Batokoue sauce	10.9	2.5	Common sauce ingredients[3]	Grinding, sieving, cooking
	Powder from roasted seed	1.3	3	-	Roasting, grinding, sieving
	Dikouanyouri sauce[2]	0.7	3	Common sauce ingredients[3]	Cooking, soaking, grinding, fermentation, drying, milling
	Mougou-Mougou	1.3	4	Sugar	Roasting, grinding
Kernels	Kernels sauce	71.1	1	Common sauce ingredients[3]	Roasting, grinding, cooking
	Sarai sauce (kernels + dehulled beans)	16.3	2	Dehulled beans, cowpea leaves	Bean dehulling, kernels grinding, cooking
	Tayohounta type 2[2]	3.6	2	Locust beans	Locust beans decortication, cooking, fermentation
	Tayohounta type 1[2]	6.6	2	-	Cooking, fermentation
	Roasted Kernels	2.4	2.5	-	Roasting
Root	Potash	100.0	2	-	Incineration, filtration

[1]1 = most; 5 = least important; [2]Fermented food; [3]Tomato, spices, animal proteins.

used to prepare several types of foods with different importance for local people.

Food Derived from Baobab Leaves. Leaves are used mainly for fresh leaf sauce, classified as the most important product from leaves (37% of informants), for dry leaf powder, classified as the second most important product from leaves (29%) and for dry leaves (14% of informants) (Table 2). Dry leaf powder and dry leaves are also used to prepare sauce. Ranking scores confirmed that sauce from fresh leaves is understood to be the most important leaf product and is ranked 1 while "*Kouimkoundi*" is the least important one, ranked 4. *Kouimkoundi* sauce is dry leaves sauce+"*Afitin",* a traditional fermented condiment from African locust bean (*Parkia biglobosa* (Jacq.) G.Don).

There are two main types of fresh leaves sauce (with or without added potash). In general, the fresh leaves are washed, ground (using mortar and pestle, or millstone). The ground product is added to boiling water and cooked for approximately 5 min.; during cooking, spices and animal protein (meat, fish) are added. In some cases, potash may be added as an ingredient.

To obtain dry leaf powder, fresh leaves are dried under shade, ground and sieved. The powder thus obtained is stored and used to make dry leaf powder sauce. However, fresh leaves are also dried without any grinding to obtain dry leaves that can be ground later when needed or used to make dry leaf sauce.

Yatirankounti sauce and *Touwoundou* sauce are quite similar. The difference is that *Yatirankounti* is made with whole baobab fresh leaves while *Kouimkoundi* is made with ground fresh or dry baobab leaves. In both cases, beans (*Vigna unguiculata*) are wet cleaned, dehulled and cooked. Whole fresh leaves (for *Yatirankounti*) or ground fresh or dry leaf (in the case of *Touwoundou*) are added and the mixture is cooked further. Flavouring agents such as spices and oil are then added to obtain the final product.

Foods Derived from the Fruit. The pulp is the most important product from the fruit and is ranked 1, followed by the seed ranked 2 and potash ranked 3 (Table 2). The pulp is a powdery product. Its extraction is achieved by dry or wet manual operations. After breaking the fruit, the whole content of the fruit (consisting of pulp, fibers, and seeds) is crushed using mortar and pestle; the crushed product is sieved to separate the pulp from seeds and fiber. Wet pulp extraction is easier for the

local population. Water is added to the whole content of the fruit, thereby dissolving the pulp in the water. A sieving process allows separation of the seeds and fiber. The liquid extract is used immediately.

The fabrication of potash requires incineration of baobab parts. Water is added to the obtained ash and the mixture is filtered through several layers of filtering material (e.g., wood, charcoal). The potash solution can be used as such for food purposes, or is concentrated and dehydrated to obtain solid potash.

Foods Derived from Baobab Pulp. According to the interviewees, the most important food from baobab pulp is gruel, which is ranked 1, followed by sour dough, and most beverages (*Nanganfirou, Yewowi*, pulp beverage, and *Tcho*) and *Solani*, which are ranked 2. The least important product is *Moukou-Moukou* (mixture of pulp and sugar), ranked 5 (Table 2).

Gruel is made from cereal (i.e., maize or millet) flour and baobab pulp. There are two techniques. In the first case, water is boiled and cereal flour is mixed with cold water. This mixture is subsequently added to the boiling water to make cereal gruel. This gruel is removed from the fire and diluted baobab pulp is added, and mixed to obtain baobab gruel. For the second method, baobab pulp is diluted in water and boiled, and diluted cereal flour is added to the boiling baobab juice to obtain the pulp gruel. The first method seems to be more convenient and may retain more nutrients in the gruel, since many nutrients are heat sensitive and may be destroyed while boiling the baobab juice.

To make sour dough, a fermented paste from baobab pulp, diluted baobab pulp is required. This can be obtained by soaking the content of baobab fruits in water or by diluting baobab pulp in water. The second important ingredient for sour dough is cereal (i.e., maize, millet or sorghum) dough (prepared with cereal flour and water). The cereal dough (locally named *Mutchayan*) is mixed with diluted baobab pulp, or alternatively the diluted pulp is boiled and used to make dough with cereal flour. The mixture is put in a jar, covered and fermented for at least 24 h. This dough keeps on fermenting up to 7 days without any deterioration. After 5–7 days, part of this dough can be used as starter in the preparation of another sour dough. In this case, the starter will be mixed with the freshly prepared cereal dough and will be left again for 1 to 7 days to ferment like the previous one. This "back-slopping" technique is used mainly during periods of pulp shortage.

To prepare *Solani,* pulp is mixed with water, and heated with crystalline sugar until it turns brown. Sugar can also be added without heating and then there will be no brown colour. Sometimes, aroma (e.g., vanilla aroma bought from town) is added and the mixture is put in a top-freezer refrigerator (the generator of which is heated by kerosene) before consumption. One *tohoungolo* (i.e., 450 g) of pulp, 1 kg of sugar, 6 L of water and aroma are required for making this product.

Pulp beverage is obtained either by soaking the whole contents of the fruit in water to extract the drink from it, or by diluting baobab pulp in water. The consistency is adjusted according to consumer preference.

Various beverages can be prepared with a cereal to which baobab is added. *Nanganfirou* is a beverage made from millet flour and baobab pulp. Millet flour is added to diluted baobab extract and mixed. *Yewowi* beverage is made from broken/ground (using mortar and pestle) millet seeds and baobab pulp. The two ingredients are mixed and water is added. *Tcho* beverage is obtained by mixing cereal dough with water to which baobab pulp is added.

Iced pulp beverage is prepared by diluting baobab pulp in water, adding sugar and freezing the mixture. One volume of pulp for 5 volumes of water, and 1 kg of sugar are required.

Norendoorou is a beverage made from a mixture of baobab pulp, locust bean pulp and water.

Baobab pulp syrup is prepared by adding sugar and water to the pulp and boiling the mixture for 1 to 2 h to concentrate the syrup.

Moukou-Moukou is a dry mixture of baobab pulp and sugar.

Foods from the Whole Seeds. The most important products from the seeds are kernels ranked 1, followed by *Moutokpei* and *Matofaman* sauces ranked 2. *Batokoue* is ranked 2.5, *Dikouanyouri* sauce ranked 3, while the least important product is *Mougou-Mougou,* ranked 4 (Table 2).

Kernels are obtained by decortication of the seed. Seed decortication is a tedious process comprising the following steps: cooking (for 4–6 h), soaking (in cooking water) and finally manual coat removal. An overcooking or undercooking may render the decortication nearly impossible. Seed coats need to be removed from individual seeds to obtain the kernels. This fastidious operation requires time and experience. If seeds are difficult to decorticate, a mild roasting and boiling process before seed coat removal may follow the soaking process.

For *Moutokpei* sauce, whole seeds are roasted, ground and added to boiling common sauce (i.e., tomato or spiced sauce). The mixture is further boiled for a few minutes to obtain *Moutokpei* sauce.

Matofaman sauce is a sauce from fermented baobab seeds. The seeds are broken using mortar and pestle and water is added to the broken seeds. The mixture is exposed to the sun for 24 to 72 h and then sieved. The liquid thus obtained is used as the basis to prepare *Matofaman* sauce. Usually some of the fermented liquid is kept and used later as starter for the fermentation of newly broken seeds. This will shorten the fermentation time to a maximum of 12 h.

To make *Batokoue* sauce, seeds are roasted, ground, sieved, and the powder obtained is added to common sauce (tomato or spiced sauce), further cooked for 5 min to obtain *Batokoue* sauce. *Dikouanyouri* sauce is usually made from seeds that cannot be decorticated. When after cooking and soaking the seeds, decortication turns out to be impossible, the cooked seeds are ground (using mortar and pestle), put in a pot, mixed with potash and fermented for 72 h. The fermented paste is then dried and preserved as such. To make sauce, the powder is both used directly in common sauce (tomato or spiced sauce), or ground further (on a millstone), mixed with water and sieved. The liquid obtained is used to make *Dikouanyouri* sauce.

To obtain *Mougoundoro*, baobab seeds are roasted, ground, sieved, and salt and sugar are added to the obtained flour. This mixture is used as a snack. *Mougou-Mougou* is made of a mixture of powder from roasted seeds and sugar. It is quite similar to *Mougoudoro* (*Mougoudoro* = *Mougou-mougou* + salt).

Foods from the Kernels. Baobab kernels are used for kernel sauce, the most important product from kernels (71% of informants), with a median rank of 1. Other foods from kernels are: *Sarai* sauce, *Tayohounta* type 2 (from locust bean + baobab kernels) and *Tayohounta* type 1 (from baobab kernels only) ranked 2, and finally the least important kernel product is roasted kernels with a median rank of 2.5.

Kernel sauce is prepared by optional roasting of the kernels, followed by grinding; the resulting product is used as protein concentrate in tomato or spiced sauce (Table 2). *Sarai* sauce is made from dehulled locust beans, cowpea (*Vigna unguiculata* (L.) Walp.) leaves and roasted baobab kernels. The locust beans are wet cleaned, dehulled, and cooked; baobab kernels are roasted and ground; cowpea leaves are added to the ground baobab

kernels and cooked dehulled locust beans. The mixture is cooked further with addition of spices and potash to obtain the *Sarai* sauce.

Tayohounta type 1 is a fermented product made from baobab kernels only. The kernels are roasted and further cooked for approximately 30 min., drained off and packed in a container covered with plant leaves. They are left for 72 h of fermentation and further sun dried. The obtained product is shaped and used as flavouring agent in sauce. *Tayohounta* type 2 is made from a mixture of baobab kernels and locust bean kernels. Locust beans are cooked, decorticated and mixed with baobab kernels. Both are boiled for 45–60 min., drained off, spread out over a clean surface and covered. Next, the mixture is left to ferment for 48 h and then sun dried, ground and shaped. The shaped *Tayohounta* type 2 may also be sun dried to increase its shelf life. *Tayohounta* is a pungent, nutritious spice or condiment used in sauces and stews.

Foods from Baobab Roots. Potash is the only food ingredient made from baobab roots and is thus the most important one, ranked 1. Potash solution is made with the ash from incineration of the roots, as was described in the section "Foods derived from the fruit".

Relationship Between Final Food Uses and Socio-Cultural Groups

Some ethnic groups have similar uses of parts of the baobab tree, while others differ. The result of the correspondence analysis (CA) (Table 3, Figures 2a and 2b) performed on the final food uses and socio-cultural groups showed that the first three axes explained 55.2% of the observed variation. Partial correlations and contribution of each of the considered modalities allow identification of the socio-cultural groups and the end uses that are the best represented on each axis. The projection of the different modalities in the axes system shows that the food uses of baobab parts are specific for the ethnic groups.

Considering axis 1 (Table 3, Figure 2a), Berba, Wama, and Yom ethnic groups use baobab pulp to make *Yewowi* (P36 = product n°36), *Tcho* (P35) and *Nanganfirou* (P10) beverages. These ethnic groups, especially the women, process leaves in dry leaf (P5), dry leaf sauce (P22), and *Touwoundou* sauce (P28). Kernels are mainly used for *Sarai* sauce (P27). By contrast, Otamari and Tchocossi ethnic groups, especially adult and elderly people, use baobab pulp for making sour dough (P12), pulp drink (P3) and baobab syrup (P30). In these ethnic groups, seeds are used for

Table 3. Correspondence Analysis to reveal linkages between end uses and socio-cultural groups

Axis 1		Axis 2		Axis 3	
Products	Groups	Products	Groups	Products	Groups
P3	Berba	P1	Bariba	P4	Berba
P5	Otamari	P2	Berba	P6	Brouba
P7	Tchocossi	P9	Comcombè	P10	Dendi
P8	Wama	P12	Datcha	P11	Gourmantché
P10	Old	P13	Dendi	P15	Nateri
P12	Yom	P14	Lokpa	P18	Peulh
P17		P16	Mahi	P21	Wama
P19		P17	Otamari	P23	
P20		P19	Tchocossi	P24	
P22		P21	Wama	P27	
P27		P26	Women		
P28		P29	Men		
P30		P31	Young		
P34		P32	Adult		
P35		P33			
P36		P35			
		P36			

Legend: P = Product; P1 = Kernels; P2 = Roasted kernels; P3 = Pulp drink; P4 = Gruel; P5 = Dry leaf; P6 = Seeds; P7 = Mougou-Mougou; P8 = Mougoundoro; P9 = Moukou-Moukou; P10 = Nanganfirou; P11 = Norendoorou; P12 = Sour dough; P13 = Potash; P14 = Dry leaf powder; P15 = Powder from roasted seeds; P16 = Pulp; P17 = *Matofaman* sauce; P18 = Kernels sauce; P19 = *Batokoue* sauce; P20 = *Dikouanyouri* sauce; P21 = Fresh leaves sauce; P22 = Dry leaf sauce; P23 = *Kouimkoundi* sauce; P24 = *Moutokpei* sauce; P26 = Leaf powder sauce; P27 = *Sarai* sauce; P28 = *Touwoundou* sauce; P29 = *Yatirankounti* sauce; P30 = Baobab syrup; P31 = Solani; P32 = Iced pulp beverage; P33 = *Tayohounta* type 1; P34 = *Tayohounta* type 2; P35 = Tcho; P36 =Yewowi.

Explanation If an ethnic group is present on more than one axis, it means that this ethnic group is compatible with the criteria that were explained by those axes. In our case, Berba, Otamari, Tchocossi and Wama are characterized by the products listed in axis 1 (Table 3) for their uses of baobab food products. However, we can see in the graph which axis that ethnic group is more compatible with. Some ethnic groups may be grouped together on the graph if they have similar uses and opposed otherwise. In this case, looking at the graph (Figure 2a), Berba, Wama and Yom are opposed to Otamari and Tchocossi for axis1. This does not exclude the fact that the same ethnic groups have other uses that could be in axis 2 or 3.

Each figure has two axes. Parallel lines represent the same axis. On Figure 2.a axis1 (dim1) is horizontal and axis 2 (dim2) is vertical. On Figure 2b, axis 1 is the same, i.e., horizontal, whereas axis 3 is vertical.

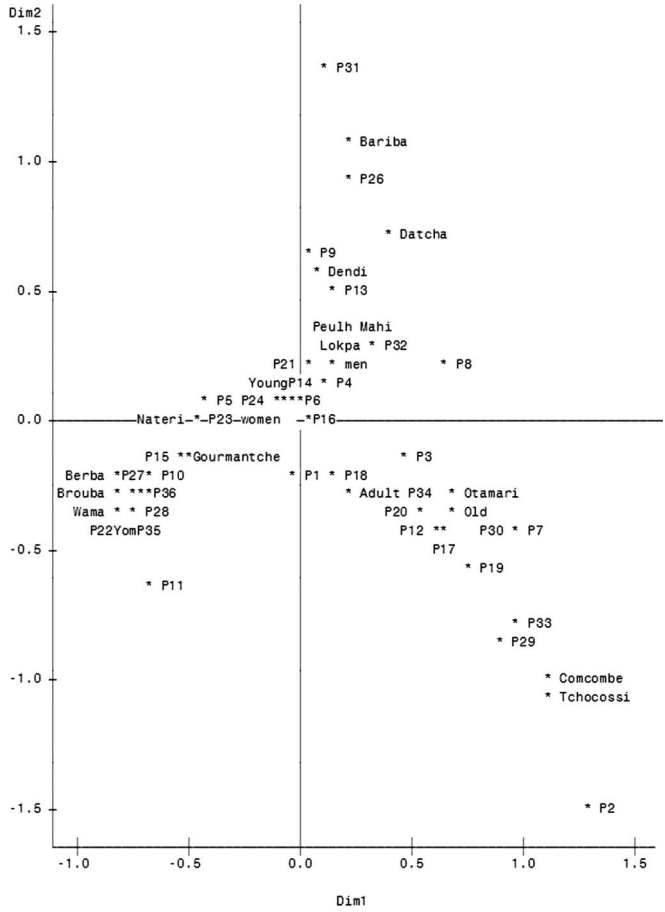

Figure 2a. Correspondence Analysis to reveal linkages between Baobab uses and socio-cultural groups on axes 1 and 2. The figure shows the linkages between the baobab food uses by different ethnic groups best represented on axes 1 and 2 of Correspondence Analysis. Ethnic groups with similar uses are grouped together and with the uses with respect to the two axes. Groups with different uses are opposed.

Legend: P = Product; P1 = Kernels; P2 = Roasted kernels; P3 = Pulp drink; P4 = Gruel; P5 = Dry leaf; P6 = Seeds; P7 = Mougou-Mougou; P8 = Mougoundoro; P9 = Moukou-Moukou; P10 = Nanganfirou; P11 = Norendoorou; P12 = Sour dough; P13 = Potash; P14 = Dry leaf powder; P15 = Powder from roasted seeds; P16 = Pulp; P17 = *Matofaman* sauce; P18 = Kernels sauce; P19 = *Batokoue* sauce; P20 = *Dikouanyouri* sauce; P21 = Fresh leaves sauce; P22 = Dry leaf sauce; P23 = *Kouimkoundi* sauce; P24 = *Moutokpei* sauce; P26 = Leaf powder sauce; P27 = *Sarai* sauce; P28 = *Touwoundou* sauce; P29 = *Yatirankounti* sauce; P30 = Baobab syrup; P31 = Solani; P32 = Iced pulp beverage; P33 = *Tayohounta* type 1; P34 = *Tayohounta* type 2; P35 = Tcho; P36 = Yewowi.

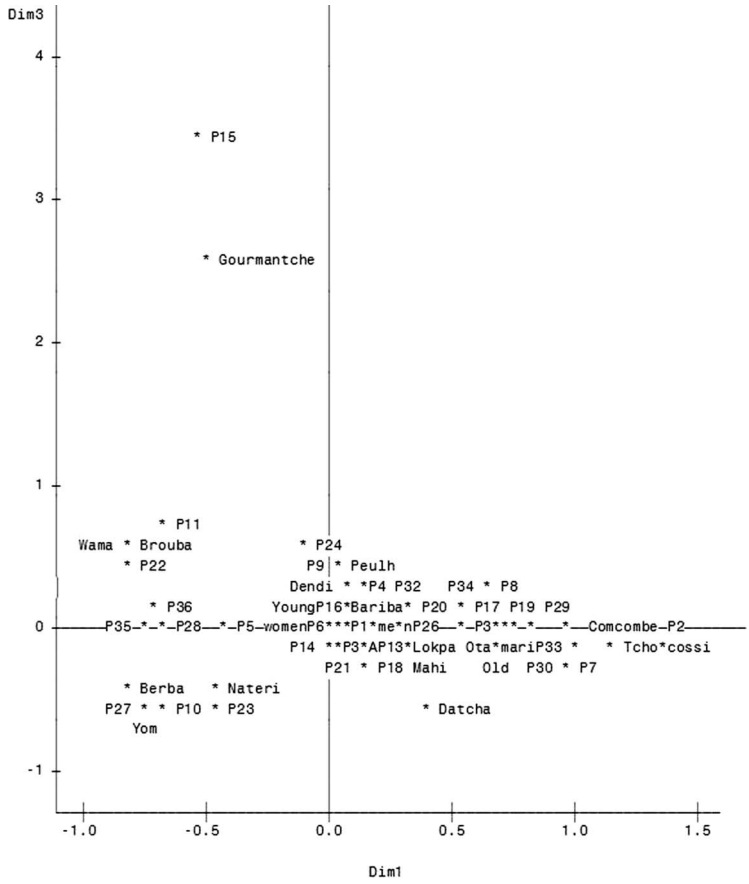

Figure 2b. Correspondence Analysis to reveal linkages between Baobab uses and socio-cultural groups on axis 3. The figure shows the relationships between the baobab food uses by different ethnic groups best represented on axis 3 of the CA. The information on axis 3 is used to complete the ones on axes 1 and 2 in Figure 2a. Ethnic groups with similar uses are grouped together and with the uses with respect to axis 3. Groups with different uses are opposed.

Legend: P = Product; P1 = Kernels; P2 = Roasted kernels; P3 = Pulp drink; P4 = Gruel; P5 = Dry leaf; P6 = Seeds; P7 = Mougou-Mougou; P8 = Mougoundoro; P9 = Moukou-Moukou; P10 = Nanganfirou; P11 = Norendoorou; P12 = Sour dough; P13 = Potash; P14 = Dry leaf powder; P15 = Powder from roasted seeds; P16 = Pulp; P17 = *Matofaman* sauce; P18 = Kernels sauce; P19 = *Batokoue* sauce; P20 = *Dikouanyouri* sauce; P21 = Fresh leaves sauce; P22 = Dry leaf sauce; P23 = *Kouimkoundi* sauce; P24 = *Moutokpei* sauce; P26 = Leaf powder sauce; P27 = *Sarai* sauce; P28 = *Touwoundou* sauce; P29 = *Yatirankounti* sauce; P30 = Baobab syrup; P31 = Solani; P32 = Iced pulp beverage; P33 = *Tayohounta* type 1; P34 = *Tayohounta* type 2; P35 = Tcho; P36 =Yewowi.

making *Matofaman* (P17), *Batokoue* sauce (P19), and *Dikouanyouri* (P20) especially from the seeds that cannot be decorticated. Specifically, the Otamari people use baobab kernels mixed with locust beans for making *Tayohounta* type 2 (P34) and *Mougoun-Mougoun* (P7).

With respect to axis 2 (Table 3, Figure 2a), the following ethnic groups: Datcha, Mahi (locality of Dassa), Otamari, Tchocossi, Comcombè, Dendi, and Lokpa have quite similar uses of some baobab parts; they use baobab fruits for making potash (P13). Apart from Datcha and Mahi, who use the whole fruit to make potash, all other ethnic groups use the empty fruit shell as raw material to make potash. In addition, the other ethnic groups (except Datcha and Mahi) produce baobab pulp (P16) from the fruits; they use pulp for making iced pulp beverage (P32) and they use leaves to produce and prepare dry leaf powder (P14), fresh leaves sauce (P21), and dry leaf powder sauce (P26). Specifically, Bariba use the pulp for *Solani* (P31) production; young people from the Dendi ethnic group produce *Moukou-Moukou* (P9) from pulp; the Dendi from Karimama locality produce *Mougoundoro* (P8) from whole seeds; Otamari, Tchocossi and Comcombè ethnic groups use seeds for making kernels (P1), kernels for making *Tayohounta* type 1 (P33) and roasted kernels (P2), and leaves to make *Yatirankounti* sauce (P29).

Regarding axis 3 (Table 3, Figure 2b), it can be observed that the Gourmantche ethnic group produces roasted seed powder (P15); and the Nateri use leaves for *Kouimkoundi* sauce (P23); the Wama ethnic group uses pulp to make *Norendoorou* beverage (P11). Most ethnic groups (Berba, Brouba, Gourmantche, Dendi, Peulh, Otamari and Wama) produce seeds (P6) from the fruits, *Moutopkei* sauce (P24) from the seeds, gruel from the pulp and, with the exception of the Dendi, produce kernel sauce (P18) from the kernels.

Constraints in Processing Operations According to Socio-Cultural Groups

CA of cumbersome processing operations and socio-cultural groups (Table 4, Figure 3), shows that with the first two axes, 71.1% of the collected information was explained. Correlations and partial contributions of each modality allowed identifying the socio-cultural groups that are best represented on each axis. The projection of the different modalities in the axes system and their interpretation showed that most ethnic groups find similar operations difficult.

Table 4. Correspondence Analysis to reveal linkages between cumbersome processing operations and socio-cultural groups

Axis1		Axis 2	
Operation	Groups	Operation	Groups
Op1	young	Op1	Bariba
Op2	Adult	Op2	Dendi
Op4	Old	Op3	Gourmantche
Op5	Women	Op6	Otamari
Op7	Men	Op8	Peulh
	Bariba	Op9	Wama
	Berba		
	Brouba		
	Dendi		
	Lokpa		
	Natéri		
	Tchokossi		
	Yom		

Legend: Op = Operation; Op1 = Fruit breaking; Op2 = Leaves harvesting; Op3 = Fruits harvesting; Op4 = Seeds decortication; Op5 = Leaves grinding; Op6 = Seeds grinding; Op7 = Grinding of the fruit content; Op8 = Pulp sieving; Op9 = Sieving of dry leaf powder.

Considering axis 1 (Figure 3), all classes of populations from Brouba, Berba, Lokpa, Yom, Tchokossi, and Nateri ethnic groups perceive seed decortication (Op4 = Operation n° 4) as a very cumbersome processing operation; these ethnic groups produce kernels from the seeds. In fact, individual seeds are decorticated manually after a long cooking process, followed by soaking. In contrast, the Gourmantche perceive the grinding of the fruit content (Op7) – to separate pulp, seed and fiber before sieving - as a difficult operation, while the Bariba mentioned leaf harvesting (Op2) as a hard operation. Indeed, the baobab tree is very big and high, and climbing sometimes causes accidents. In addition, the Dendi and Peulh consider dry leaf grinding (Op5) a difficult operation.

Considering axis 2 (Figure 3), Otamari and Wama also consider fruit breaking (Op1), seed grinding (Op6) and pulp sieving (Op8) - for removal of fibers and seeds - as difficult processing operations. In fact, the shell of the fruit is very hard and requires some strength to break, but the most difficult is that the fruit is covered with short hairs and, during breaking, these get into contact with the human skin and cause itching. During grinding and sieving of seeds and pulp, a substantial amount of

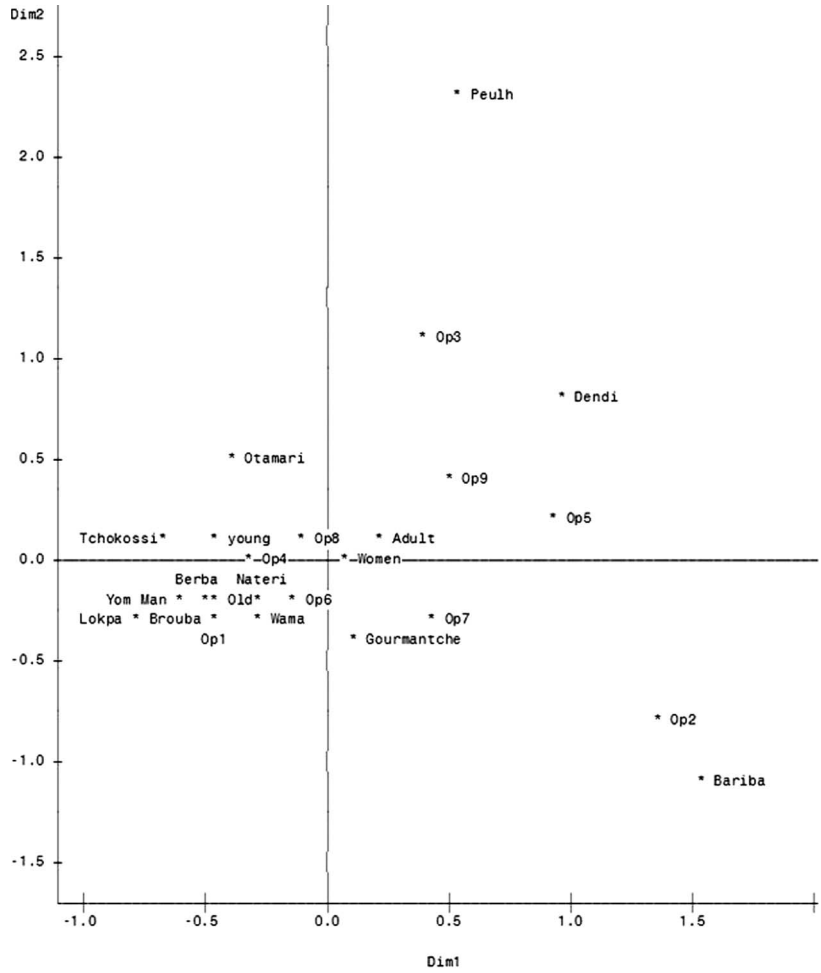

Figure 3. Correspondence Analysis to reveal linkages between difficulty of processing operations and socio-cultural groups on the axes 1 and 2. The figure shows correlations between ethnic groups and fastidious processing operations. Ethnic groups that found specific processing operations difficult, are grouped together and with the operations.
Legend: Op = Operation; Op1 = Fruit breaking; Op2 = Leaves harvesting; Op3 = Fruits harvesting; Op4 = Seeds decortication; Op5 = Leaves grinding; Op6 = Seeds grinding; Op7 = Grinding of the fruit content; Op8 = Pulp sieving; Op9 = Sieving of dry leaf powder.

product is lost due to air currents. Dendi and Peulh ethnic groups also mentioned fruit harvesting (Op3), and sieving of dry leaf powder (Op9) as problematic operations.

Storage Problems According to Socio-Cultural Groups

CA of storage and preservation problems and socio-cultural groups (Table 5, Figure 4) showed that 79.2 % of the collected information was explained with the first two axes. Correlations and partial contributions of each modality allowed identifying the socio-cultural groups and the problems that are best represented on each axis. The projection of the different modalities in the axes system and its interpretation showed that the recorded storage time varies from one ethnic group to another depending on the storage circumstances (e.g., packaging, humidity, drying frequency).

Considering axis 1 (Figure 4), Lokpa, Gourmantche, and Peulh ethnicities, especially young persons, found that after 6 months, insect larvae invade the pulp if it is exposed to humidity (Prob 10 = Problem n°10). Similarly, the Comcombè mention the development of insect larvae in the kernels after 6 months, if they are exposed to humidity and not regularly dried (Prob 9). In contrast, the Berba mentioned that particularly roasted kernels are usually attacked by mice (Prob 1) and that insects

Table 5. Correspondence Analysis to reveal linkages between baobab food storage problems and socio-cultural groups

Axis1		Axis2	
Problems	Groups	Problems	Groups
Prob1	Young	Prob1	Adult
Prob9	Women	Prob2	Old
Prob10	Men	Prob3	Berba
Prob11	Berba	Prob5	Otamari
	Comcombè	Prob6	Tchokossi
	Gourmantché	Prob7	Wama
	Lokpa	Prob8	
	Peulh		

Legend: Prob = Problem; Prob1 = Mice attack kernels; Prob 2 = Pulp changes colour after 1 year protected against humidity; Prob 3 = Pulp changes colour after 6 months if exposed to humidity; Prob 5 = Appearance of insect larvae in kernels after 1 year if protected against humidity; Prob 6 = Appearance of insect larvae in the kernels after 1 month if exposed to humidity; Prob 7 = Appearance of insect larvae in the pulp after 3 months if exposed to humidity; Prob 8 = Appearance of insect larvae in the kernels after 3 months if exposed to humidity; Prob 9 = Appearance of insect larvae in the kernels after 6 months if exposed to humidity; Prob 10 = Appearance of insect larvae if the pulp after 6 months if not regularly dried Prob 11 = Insects attack pulp rendering it sticky.

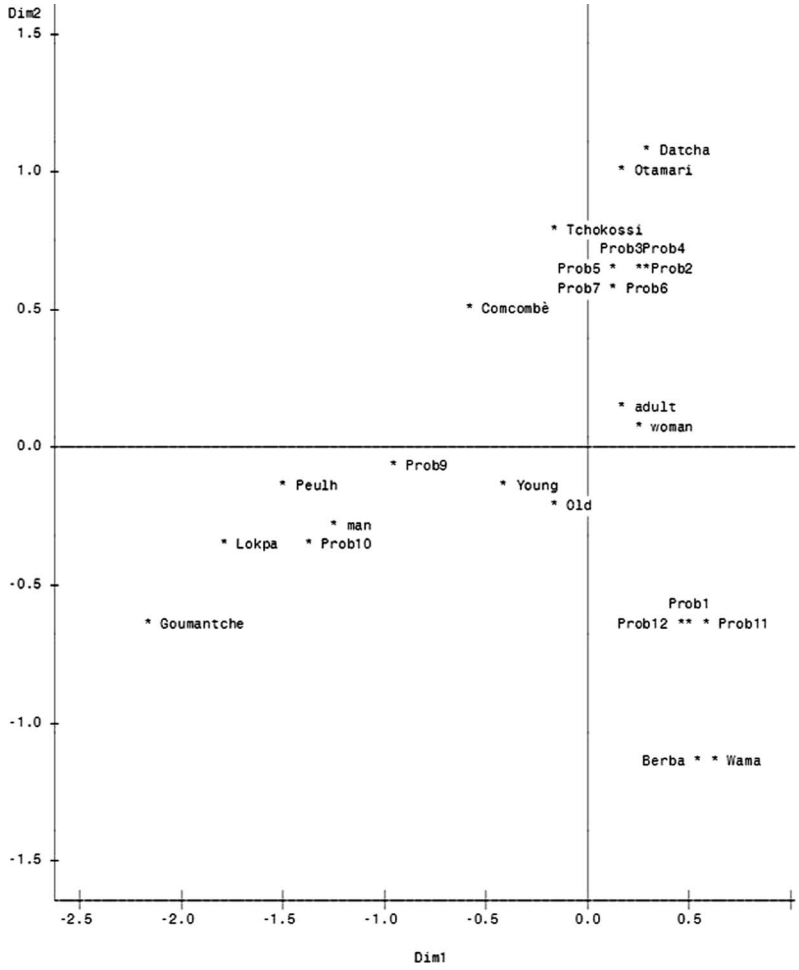

Figure 4. Correspondence Analysis to reveal linkages between storage problems and socio-cultural groups represented on each axis. The figure shows that socio-cultural groups that encountered similar storage problems are grouped together and with the problems.
Legend: Prob = Problem; Prob1 = Mice attack kernels; Prob 2 = Pulp changes colour after 1 year protected against humidity; Prob 3 = Pulp changes colour after 6 months if exposed to humidity; Prob 5 = Appearance of insect larvae in kernels after 1 year if protected against humidity; Prob 6 = Appearance of insect larvae in the kernels after 1 month if exposed to humidity; Prob 7 = Appearance of insect larvae in the pulp after 3 months if exposed to humidity; Prob 8 = Appearance of insect larvae in the kernels after 3 months if exposed to humidity; Prob 9 = Appearance of insect larvae in the kernels after 6 months if exposed to humidity; Prob 10 = Appearance of insect larvae if the pulp after 6 months if not regularly dried; Prob 11 = Insects attack pulp rendering it sticky.

invading the pulp render it sticky (Prob 11) and unacceptable for consumption.

Considering axis 2 (Figure 4), Otamari and Tchokossi, especially adult women, mentioned insect larvae invading the pulp after 3 months if exposed to humidity (Prob 7), discoloration of pulp after 6 months if exposed to humidity, or after 1 year if kept dry. They also mentioned that insect larvae invade kernels after 1 month if not regularly dried or if exposed to humidity (Prob 6) or after 1 year if protected against humidity (Prob 5). In addition, mice attack of kernels (Prob1) was mentioned by the Wama.

DISCUSSION AND CONCLUSION

Preferred End Uses of Baobab Food Products

The end uses of baobab parts are quite specific for the ethnic groups interviewed and we observed differences in the processing techniques for similar products among these ethnic groups. Over time, socio-cultural groups have accumulated a rich knowledge on the use of baobab. Over the centuries, various peoples have been using baobab for a variety of purposes and have gained rich experience and knowledge in processing techniques, but mostly with reference to their locality of origin. Moreover, ethnic groups are located in specific localities; the combination of an ethnic group and its locality may be determinant for their food uses since food practices are usually cultural. These findings agree with those by Nguyen (2003) who compared knowledge on 10 traditional Vietnamese fruits and vegetables between urban Vietnamese living in Vietnam and Hawaii; he found that Vietnamese immigrants in Hawaii listed more food uses than those in Vietnam due to adoption of multi ethnic foods found in Honolulu. According to Wahlqvist (2007), food culture is influenced most by the locality of its origin, which will have been one of food acquisition and processing by various means. Rivera et al. (2007), using hierarchical cluster analysis on gathered food plants in the mountains of Castilla-La Mancha in Spain, found that clusters of food plants species form culture-specific logical entities, which allow people to structure and manage their environment.

Processing, Preservation and Storage Problems

Seed decortication appears to be one of the most difficult processing operations. In fact, it is done manually for individual seeds, after a long

cooking process followed by soaking. It is a tedious operation and is mainly handled by women in several communities. Because many seeds are very hard to decorticate, a large amount of seeds are thrown away. Some seeds cannot even be decorticated, whatever the cooking and soaking time. It is difficult to visually distinguish seeds that can be decorticated from those which are not decorticable. A mechanical seed decortication method would significantly contribute to the use of seeds as a source of food. The baobab seed coat is waxy, making it slightly elastic (Danthu et al., 1995) and therefore difficult to break compared to other common seeds.

Thus, a sustainable solution is required for seed decortication for improving the livelihood of local populations. Finding a solution for such an operation through research activities resulting in a semi-mechanization of this processing operation, as wished by local populations, will save time for women involved in that activity. The saved time is likely to be spent on other remunerative activities resulting in a higher income that can e.g., be spent on education of children supporting their development.

An advantage of the cooking and soaking process (in hot water) before decortication might be the inactivation of antinutritional factors in baobab whole seeds (e.g., Trypsin Inhibitor Activity of 5.7 TIU/mg sample, 73 mg/100g of phytic acid and 23% catechin equivalent of tannin) (Osman, 2004). As indicated by Igboeli et al. (1997) cold water, hot water, hot alkali and acid treatments reduced the tannic acid concentration in baobab whole seeds significantly, and the activity of amylase inhibitors in whole seeds was reduced significantly by dehulling (from 35 to 10 μg/100g) and cold water treatments. The aspect of antinutritional factors merits further investigation.

The preparation of food ingredients such as pulp and leaf powder also faces problems. It requires grinding (with mortar and pestle), generally followed by a sieving process for removal of fiber/seed. These two operations are made difficult by air currents that take away part of the product. For pulp extraction, Baobab Fruit Company (http://www.baobabfruitco.com) claims to have developed a mechanical process. Extension of this mechanical process may be beneficial, if adequate to local realities; otherwise, it would be interesting to investigate how this operation can best be facilitated for rural local populations.

Apart from separation processes, some storage and preservation problems were recorded, mainly for the kernels and the pulp. Infestation with insect larvae during storage (according to some ethnic groups) is the main problem for kernel preservation, in addition to attack by mice. For

the pulp, the two main storage problems are insect larvae infestation and changes in colour. Most of these problems are related to exposure to humidity and consequently depend on the quality of packaging material and the packaging techniques (Ros-Chumillasa et al., 2006). Moreover, apart from humidity, exposure to light and oxygen may affect storage properties. Packaging techniques are indeed very poor and need to be studied and improved to increase the shelf life of the products. Increasing the shelf life of the pulp and the kernels, the two most important commercialized products, will surely add value to these products. Hence it will increase their marketability and improve the income of poor rural populations involved in the production and trade of baobab food products. Moreover, while improving the quality of the products in general and their packaging in particular, attention should be paid to their normalization to increase their chance to be exported and sold on more remunerative markets. Local processing centers need to be established for production of standardized products.

In fact, some baobab products (kernels, leaf powder, pulp) are important on the local market (Benin), as well as at regional and international markets. Many baobab food products can be considered as functional foods because they are claimed to have a therapeutic effect on health in addition to their food properties (Sidibe and Williams, 2002, Diop et al., 2005, Gruenwald and Galizia, 2005, Assogbadjo et al., 2006). In recent years in Europe, a market has developed for food and beverage products that provide a specific positive impact on health. On average, each European spends 15 Euro annually to buy such health-supporting foods (Gruenwald and Galizia, 2005). Baobab foods (based on pulp, leaves) may match this new generation of functional foods. Consequently, any research on valorization and standardization of baobab products will be beneficial for rural people involved in selling these products. Effective valorization through improvement of traditional techniques/products and production of value added products (with functional properties) for a larger market would increase the income of rural, poor populations. For instance, at retail level in Europe, baobab fruit pulp cost 200 Euro per kg, while the supplier in Africa sells it at $ US 3 to 5 (i.e., 2.2 to 3.7 Euro) Freight on Board (Gruenwald and Galizia, 2005). It is necessary to perform research on cumbersome processing operations and preservation to solve problems that limit a wider distribution and commercialization of the products for the benefit of local populations.

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