Tamarind (*Tamarindus indica* L.) in the traditional West African diet: not just a famine food

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Received 21 May 2010
Accepted 9 August 2010

Fruits, 2011, vol. 66, p. 171–185

DOI: 10.1051/fruits/2011025
www.fruits-journal.org

***RESUMEN ESPAÑOL**, p. 185*

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Abstract -- **Introduction**. Tamarind (*Tamarindus indica* L.) is a multipurpose, tropical fruit tree originating in Africa. Although the main commercial production of tamarind fruits takes place in Asia and America, tamarind plays an essential subsistence role in rural West Africa. This study highlights the importance of tamarind in traditional diets of rural communities in Benin, Mali and Senegal. **Methods**. Ethnobotanical field data was gathered through structured individual interviews, semi-structured group discussions, agricultural calendars and participatory mapping with 220 informants of eleven ethnic groups across four agroecological zones. Data was processed by quantitative and qualitative analytical methods. **Results**. Tamarind adds vitamins and minerals, as well as the traditionally appreciated sour taste, to drinks and meals. It is consumed daily and year-round by many rural West Africans. Ethnic similarities and differences in food use patterns of tamarind highlight the importance of tamarind in West African subsistence. The results include detailed descriptions of tamarind processing and traditional meal preparations of tamarind fruits, seeds, flowers and leaves. **Conclusions**. Documentation of local knowledge on tamarind processing and uses is needed to assist local and regional promotion and domestication efforts of tamarind to prevent a further decline in tamarind tree populations. High local use and demand for tamarind fruits and leaves in subsistence should stimulate the development of sustainable production as well as conservation efforts, in order to secure a continued harvest and satisfy local demand for this important traditional food in the future.

Benin / Mali / Senegal / *Tamarindus indica* / human feeding / subsistence farming / processed foods / indigenous knowledge

Le tamarinier (*Tamarindus indica* L.) dans le régime alimentaire traditionnel de l'Afrique de l'Ouest : pas seulement un aliment de subsistance.

Résumé - **Introduction**. Le tamarinier (*Tamarindus indica* L.) est un arbre fruitier tropical multifonction, originaire d'Afrique. Bien que la production commerciale des fruits de tamarinier ait principalement lieu en Asie et en Amérique, l'arbre joue un rôle de subsistance essentiel dans les régions rurales de l'Afrique de l'Ouest. Cette étude souligne l'importance du tamarin dans l'alimentation traditionnelle des communautés rurales au Bénin, au Mali et au Sénégal. **Méthodes**. Des données de terrain ethnobotaniques ont été recueillies par des questionnaires individuels structurés, des discussions de groupe semi-structurées, des calendriers agricoles et de la cartographie participative auprès de 220 informateurs appartenant à onze groupes ethniques répartis au travers de quatre zones agro-écologiques. Les données ont été traitées par des méthodes d'analyses quantitatives et qualitatives. **Résultats**. Le tamarin apporte des vitamines et des minéraux, ainsi qu'une saveur acide traditionnellement appréciée, aux boissons et aux plats. Il est consommé quotidiennement et tout au long de l'année par de nombreux Africains des zones rurales. Les similitudes et différences ethniques dans les habitudes de consommation du tamarin soulignent l'importance de ce fruit comme aliment de subsistance de l'Afrique de l'Ouest. Les résultats incluent la description détaillée du traitement du tamarin et de la préparation des plats traditionnels à partir de ses fruits, graines, fleurs et feuilles. **Conclusions**. Des connaissances locales sur le traitement du tamarin et son utilisation sont nécessaires pour aider sa promotion locale et régionale et appuyer les efforts de domestication afin d'empêcher une nouvelle baisse des populations de *T. indica*. L'importance des utilisations locales et les fortes demandes comme aliment de subsistance pour les fruits et feuilles de tamarin devraient stimuler le développement de sa production durable, ainsi que les efforts de conservation, afin d'assurer, dans l'avenir, une récolte continue et satisfaire la grande demande locale de cet aliment traditionnel.

Bénin / Mali / Sénégal / *Tamarindus indica* / alimentation humaine / agriculture de subsistance / aliment transformé / connaissance indigène

1. Introduction

Tamarind (*Tamarindus indica* L., Caesalpiniaceae[1], also placed in Fabaceae[2]) is a multifunctional drought-tolerant fruit tree providing food, medicine and other services to many rural African communities. Tamarind is thought to originate in Africa [1], either in the drier savannahs in the central Sudanian region of Mali, Burkina Faso and Niger [2][3]; or in oriental Africa, in the Nile valley, where it was known and cultivated in Egypt as early as 400 B.C. [3–5]. Tamarind has been dispersed by men worldwide and is nowadays cultivated in all tropical countries [2, 3, 6]. Major production areas of tamarind are found in Asia (India, Bangladesh, Sri Lanka, Thailand, Vietnam and Indonesia) and America (Mexico, Belize, Costa Rica and Brazil) [7–9]. In Senegal, The Gambia, Kenya, Tanzania and Zambia, tamarind is only produced commercially on a minor scale [7]: this fact may lead to the assumption that the African tamarind is not valued or used frequently. Quite the opposite: tamarind proves to be an essential part of African subsistence, as shown in this article with the case study of three West African countries (Benin, Mali and Senegal) and a literature review on the traditional food use of tamarind covering all Africa.

With this documentation of traditional processing and use of tamarind by eleven different ethnic groups across Benin, Mali and Senegal, we aim to show similarities and differences among the ethnic groups and hypothesise that ethnic groups which are in close contact geographically will share the most similarities of knowledge. While reasons for sharing or denying sharing of traditional knowledge among ethnic groups may vary, differences should be taken into account when designing local domestication programmes. Programmes that take into account local knowledge are more likely to be successful and sustainable in the future.

Tamarind adds valuable vitamins and minerals to the otherwise staple crop-based and (micro-) nutrient-poor diet of many rural West Africans. Tamarind fruit pulp contains up to 98% of tartaric acid and soluble sugar [10, 11]. It is rich in pectin, organic acids [10], vitamin B and minerals, and contains carotene and vitamin C [7]. Tamarind leaves are rich in minerals, such as potassium, phosphorus, calcium and magnesium, and a source of vitamin C and ß-carotene [12]. Tamarind seeds are rich in protein and minerals, such as calcium, phosphorus, magnesium and potassium [12]. Although tamarind food uses have been mentioned in the literature, the variety of preparation methods and detailed traditional processing techniques based on different tamarind plant parts have not been documented so far. Our study aims to fill this gap.

Such documentation of local knowledge on tamarind processing and uses is needed to assist local and regional promotion and domestication efforts of tamarind trees to prevent a further decline in already threatened tamarind populations [13]. Wild tamarind populations are vulnerable and are especially under threat in habitats of higher human pressure and drought stress, as has been recently documented in Benin [13, 14]. It is most likely that tamarind populations in other West African countries are in a similar state. This situation demands new strategies, such as the selection of preferred tamarind varieties and their domestication, in order to retain tamarind as an essential part of daily rural subsistence in West Africa.

[1] The International Plant Names Index [Online Database]. The Royal Botanic Gardens Kew, UK; The Harvard University Herbaria, USA; Australian National Herbarium, Australia, http://www.ipni.org [accessed 2 September 2010], 2008.

[2] Germplasm Resources Information Network - (GRIN) [Online Database]. USDA (United States Department of Agriculture), ARS (Agricultural Research Services), National Genetic Resources Program, National Germplasm Resources Laboratory, Beltsville, Maryland. http://www.ars-grin.gov [accessed 2 September 2010], 2010.

[3] ICRAF Agroforestry Tree Database [Online Database]. World Agroforestry Centre. http://www.worldagroforestrycentre.org [accessed 31.03.2007], without year.

Table I.
Research sites and ethnic groups with local vernacular names of tamarind in three countries surveyed in West Africa.

Country	Agroecological zone	Village	Ethnic group	Local name of tamarind
Benin	Sudanian	Mamassy Peulh	Peulh (Fulbe)	Djatani
		Birni Lafia	Dendi	Bobosséi
		Mamassy Gourma	Gourmantché	Bupugubu
	Sudano-Guinean	Manigri	Nagot (Yoruba)	Caíma
	Sudano-Guinean	Kpakpa Igbo	Idatcha	Ariran
Mali	Sahelian	Bendjely	Dogon	Somé
	Sudanian (North)	Njaanaanjali	Peulh (Fulbe)	N'djapí
	Sudanian (South)	Bakaribougou	Sénoufo	N'tomi (Bambara)
		Tabarako		Jimmé
Senegal	Sahelian	Niakhoul	Wolof	Dahar
		N'Dande		Dakhar
		Sackal		Dakhar
		Coki		Dakhar
	Sudano-Sahelian	M'bassis	Serer	Somb
		Mt Rolland		Karat
		Foua 1		Somb
	Sudanian	Ibel	Peulh (Fulbe)	Diabbéhi (singular), Diabbé (plural)
		Velingara		Diabbé

2. Methods

Our research was conducted within the "Domestication and Development of Baobab and Tamarind" (DADOBAT[4]) project. An intensive literature review was undertaken in March 2007 – August 2008. Field research was prepared and tested during an exploratory field trip in August-September 2007. Field data collection was undertaken from November 2007 to March 2008. In Benin, Mali and Senegal, research sites were chosen in four agroecological zones [15] (*table I*). Within those agroecological zones, research sites (*figure 1*) were selected for their abundance of tamarind tree populations, according to former tree surveys by our local partner institutes. Eleven ethnic groups were investigated (*table I*). The Peulh, also called Fulani or Fulbe, took part in the research in all three countries. Since migration and subsequent adaptation to different local ecosystems is expected to result in different knowledge systems, these three Peulh groups are therefore regarded as three different ethnic groups in our ethnobotanical research and are thus counted three times.

[4] DADOBAT is financed by the EU INCO-DEV, 6th framework programme.
Project Partners: 1 - Laboratory of Tropical and Subtropical Agronomy and Ethnobotany, Department of Plant Production, Faculty of Bio-Engineering Sciences, University of Ghent, Belgium. 2 - Centre for Underutilised Crops (CUC), University of Southampton, UK. 3 - Institute for Organic Farming, Department for Sustainable Agricultural Systems, University of Natural Resources and Applied Life Sciences, Vienna, Austria. 4 - Laboratoire d'Écologie Appliquée - Département d'Aménagement et Gestion de l'Environnement - Faculté des Sciences Agronomiques - Université d'Abomey-Calavi, Benin. 5 - Institute of Rural Economy, Mali. 6 - Centre d'Etude Régional pour l'Amélioration de l'Adaptation (Ceraas), Senegal.

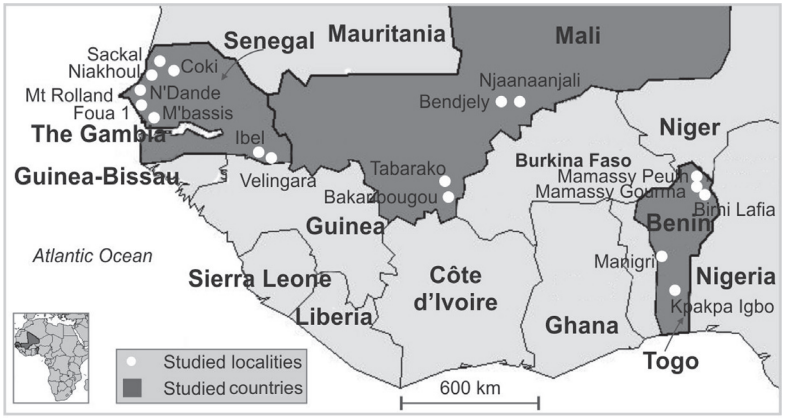

Figure 1.
Map indicating countries and field sites chosen for studies regarding the use of *Tamarindus indica* in the traditional West African diet.

A stratified purposeful sample [16] was used with the strata 'ethnic group' and 'sex', *i.e.*, resulting in 110 interviews with women and 110 with men. The informants were aged between 10 years and 108 years (mean: 41 years). Informants (n = 220) perform work as farmers (43%), in the household (25%), as pupils/students (11%), in commerce (7%), in handcraft (4%), as traditional healers (3%), as herders (1%) and in other occupations (6%). Twenty-six per cent of informants attended school to primary level, 17% of informants attended school to secondary level and only 1% continued with higher education. Among the informants, 79% are Muslims, 15% are Christians and 6% stated they were animists, although most informants continue to practice animism alongside other religions. Local informants participated and provided information on a voluntary basis after educated prior informed consent. Where applicable, the ISE ethics [17] were respected.

In total 220 individual interviews were conducted. The structured questionnaire [16] used in the individual interviews yielded the main body of ethnobotanical data on uses, preferences, processing and storage of tamarind plant parts, as well as a ranking of useful trees. Semi-structured interviews based on agricultural calendars and participatory resource mapping were used in 11 discussion groups (between 5 and 15 informants per group) on resource access and local tree tenure systems. Notes on participant and non-participant observation were collected in a field diary, and subsequently coded and analysed. This information served to triangulate data and provide additional qualitative data about the informants' life and plant-related actions. No plant voucher specimens were collected as the main emphasis of this study is on one plant species, *Tamarindus indica* L., easily identifiable by all researchers. Data were analysed using SPSS 16 (SPSS Inc. 2007) software.

Multidimensional scaling provides a visual representation of the pattern of similarities or distances among a set of objects. Here, the similarities among the ethnic groups based on food uses of all tamarind plant parts were plotted by Multidimensional Scaling (MDS) using SPSS. The Kruskal-Wallis and Mann-Whitney tests were applied to test significant differences among use categories.

3. Results

3.1. Uses: overview

In total, we recorded 250 different uses of tamarind during the field research and subsequently we categorised them into use categories: medicinal, nutritional, spiritual, ethnoveterinary and other uses. The differentiation among the mentioned 250 uses is based on variations in preparation (*e.g.*, cold extraction, boiling, fermentation), application (*e.g.*, external, internal) and product form (liquid, paste, powder). The medicine-use category contains the greatest variety, with 184 different uses[5]. In comparison with the great variety of medicinal uses, the 22 documented nutritional uses seem few.

Tamarind was ranked as the second most important tree in comparison with other useful trees found in the local ecosystems (stated by 41 informants, n = 220). The baobab (*Adansonia digitata* L., 71 informants) ranked highest. Following tamarind (41 informants), other useful trees that were most frequently stated are shea tree (*Vitellaria*

[5] Medicinal data will be published separately, as they are out of the scope of this paper.

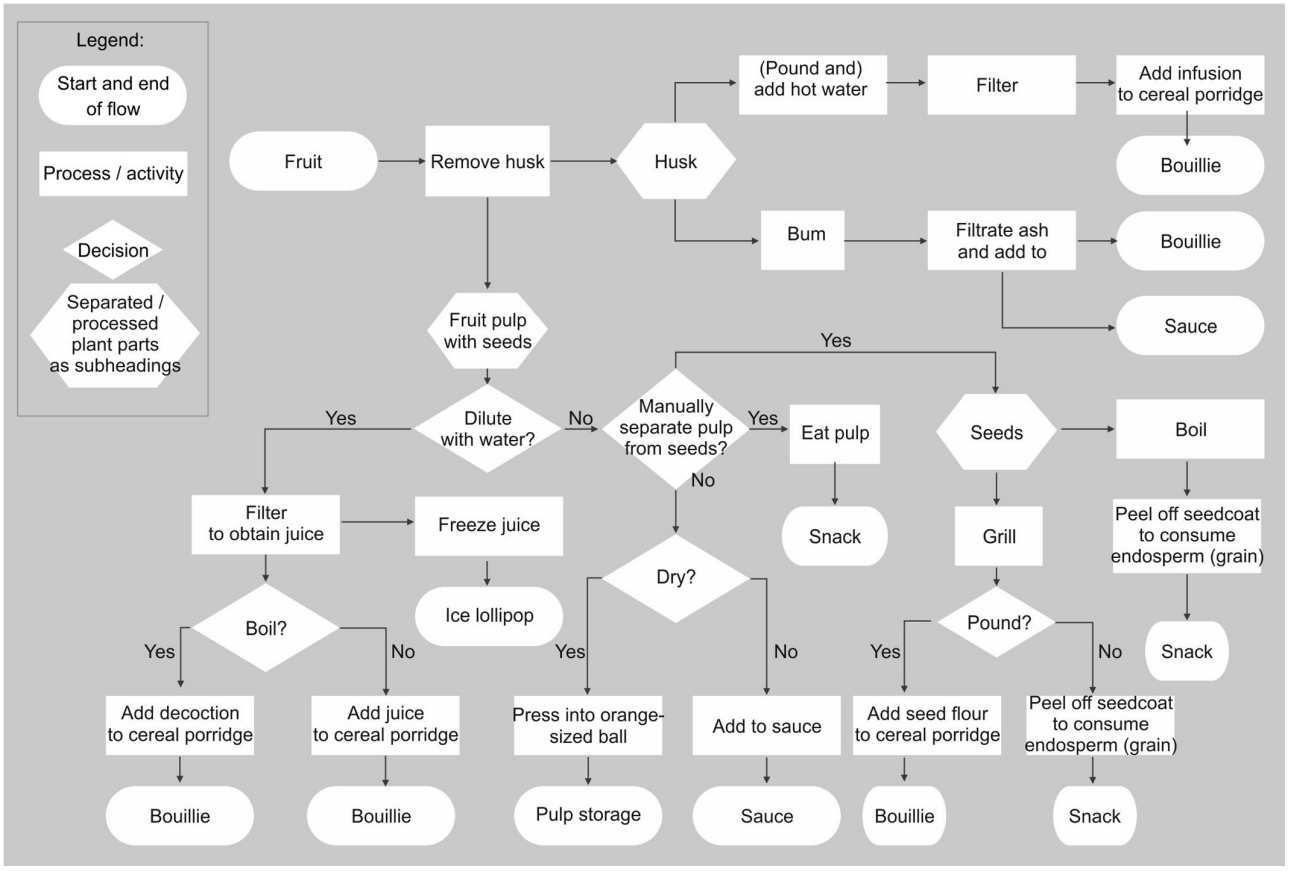

Figure 2.
Traditional food preparations using tamarind fruit, fruit husk and seeds in West Africa.

paradoxa C.F. Gaertn., 38 informants), mango (*Mangifera indica* L., 26 informants), néré (*Parkia biglobosa* Benth., 21 informants) and cashew (*Anacardium occidentale* L., 13 informants). This prominent position of the tamarind, ranking even higher than other valuable food and even cash crops, is mostly grounded in the local appreciation of the nutritional use of tamarind (144 informants) and its use in traditional healing (70 informants). 'Commerce', *e.g.*, selling tamarind fruits and leaves on local and regional markets, ranked as the third reason for local importance of tamarind (30 informants). The use of wood in construction (7 informants) and the use of tamarind in rituals and ceremonies (6 informants) were also stated reasons for the local importance of tamarind. The Kruskal-Wallis test indicates significant differences among the use categories ($p < 0.001$). Mann-Whitney tests show that the use as nutrition is cited most often, followed by the use as medicine and the use in commerce ($p < 0.001$ for each). There is no difference between the number of uses in construction and tradition.

Every part of the tamarind is used. The numerous uses of leaves (59 uses), fruit pulp (50 uses), bark (44 uses), roots (23 uses), *Tapinanthus* ssp. Danser (31 uses), pods (13 uses), wood (9 uses), flowers (7 uses), seeds (7 uses) and gum (6 uses) provide proof of the 'holistic' use of the tamarind in rural West Africa. The inclusion of *Tapinanthus* species in this calculation is grounded in the fact that the informants consider this (semi-) parasitic plant as part of the tree.

3.2. Food uses

The use of fruit pulp in *bouillie* (porridge in the French language), or as juice or a snack is widely known and results show that 100%

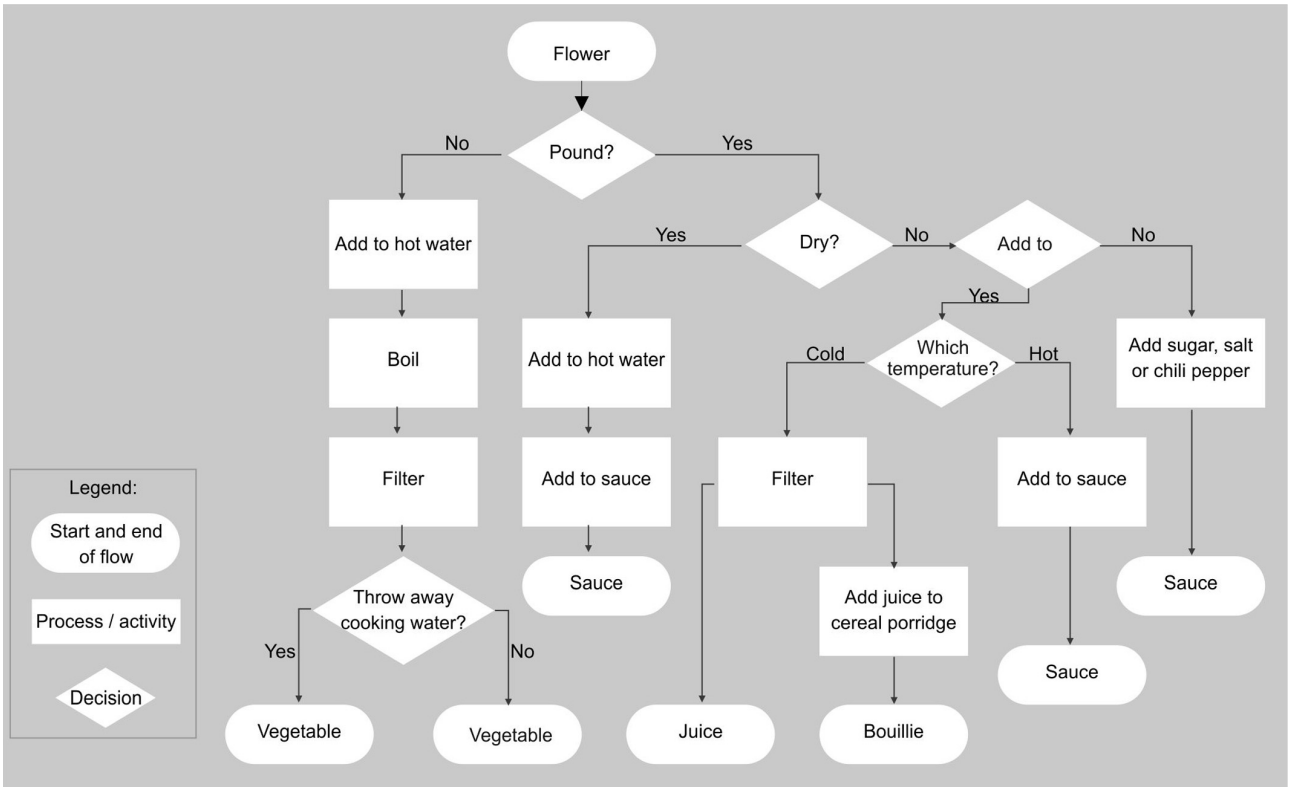

Figure 3.
Traditional food preparations using tamarind flowers in West Africa.

of informants stated fruit pulp use in their diet. Food processing using tamarind fruits, seeds, leaves and flowers includes complex processes as well as various processing methods (*figures 2–4*). For the preparation of *bouillie*, a porridge is prepared with flour of maize (*Zea mays* L.), millet (*Pennisetum glaucum* R.Br.), rice (*Oryza sativa* L.), fonio (*Digitaria exilis* Stapf) or sorghum [*Sorghum bicolour* (L.) Moench] and tamarind fruit pulp, pod, seeds or leaves. The *bouillie* is based on many different preparation methods using various tamarind plant parts (*figures 2–4*). In Mali the *bouillie* may also be called *crème*. However, the definitions of *bouillie* and *crème* vary and sometimes the preparation of crème even includes butter and milk. The fruit pulp is used to prepare tamarind juice, which is widely consumed as a refreshing drink, but also commonly added to *bouillie* (*figure 2*). Peulh and Nagot informants in Benin reported adding 'piment' (chilli pepper) to the juice before drinking. Tamarind juice is the preferred juice for breaking the fast in Islamic Ramadan celebrations (*i.e.*, drunk at sunset at the end of each fasting day to 'prepare the stomach' for the evening meal).

In Senegal, tamarind is added to the sauce of the national dish, *Thiebo Dienne* (rice with fish), as either juice or as whole fruit (without husk). Some Wolof prepare a separate dish, the *Mathiate*. In this case, tamarind is not added to the sauce, but it will be served after the *Thiebo Dienne*, together with a sauce of lemon [*Citrus limon* (L.) Burm f.], bissap (*Hibiscus sabdariffa* L.), pepper (*Piper nigrum* L.), manioc (*Manihot esculenta* Crantz), chilli pepper (*Capsicum annuum* L.), tomatoes (*Lycopersicon esculentum* Mill.) and pieces of fish. The Peulh in Senegal use the tamarind husk as a replacement for the fruit. If there is no fruit available, the pounded husk is mixed into the *bouillie* to add taste (*figure 2*). The seeds are consumed as a snack food or are grilled, pounded and added to the *bouillie* (*figure 2*) by the Dendi and Peulh ethnic groups in Benin but not by any other ethnic group within our sample. If fruits are not available, flowers can be used to prepare the *bouillie* (*figure 3*), a use most frequently

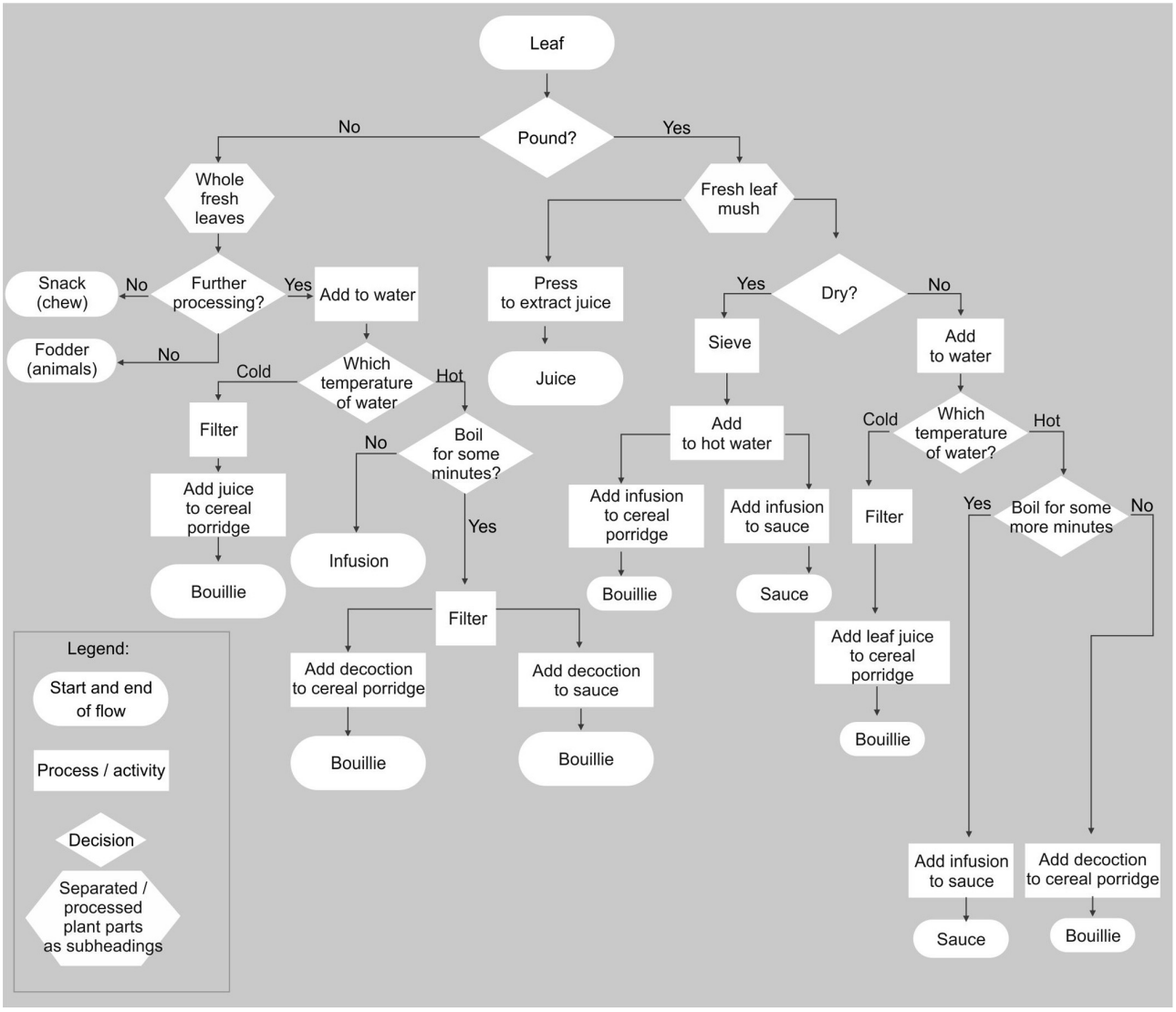

Figure 4.
Traditional food preparations using fresh tamarind leaves in West Africa.

documented with Serer and Wolof informants (15 Serer, 10 Wolof, $n = 20$ for each ethnic group). In addition, the Serer use the flowers as an ingredient for sauces. Tamarind flowers may also be used to prepare juice. This use was reported by the Peulh in Benin as a 'use from the past', which is no longer applied there. The Wolof mention eating the flowers mixed with sugar, salt or chilli in between meals. The Gourmantché in Benin sometimes add the flowers to pre-boiled beans; the mixture is then boiled together before consumption. If tamarind fruits are not available for the *bouillie*, tamarind leaves are widely used as a substitute. There are many different possibilities for the preparation of tamarind leaves to be used in the *bouillie* (*figure 4*). We illustrate the preparation using fresh leaves, as this is most common, and due to the tree's semi-evergreen habit fresh leaves are available year-round. However, dried leaves are also used in the preparation of *bouillie* and can be stored or bought on the local market. Dried leaves are stored by only 10% of informants ($n = 220$). They either store sun-dried whole leaves or the dried leaves are further processed (pounded and sieved) into powder, which is stored in plastic bags, old plastic bottles or pots. No pests are

reported when storing tamarind leaves. Tamarind fruits are stored by 43% informants ($n = 220$). The whole fruits (with the husk) can be stored in sacks. The fruit pulp, including seeds, is stored in pots or formed into orange-sized balls and dried. Some pests were reported that may affect the stored tamarind fruits, but informants said that there will be no pest infestation if the pulp is well dried and stored in sealed pots or in the granary.

In all three countries studied and across all four agroecological zones considered, tamarind fruits are harvested in the dry season months of January and February. Due to seasonal and microclimatic variations, an early harvest may begin in November-December (in Senegal: Coki, Ibel, Mt Rolland and Niakhoul) and a late harvest may last until April (in Senegal: M'bassis; in Benin: Birni Lafia, Manigri, Mamassy Gourma and Mamassy Peulh; in Mali: Tabarako).

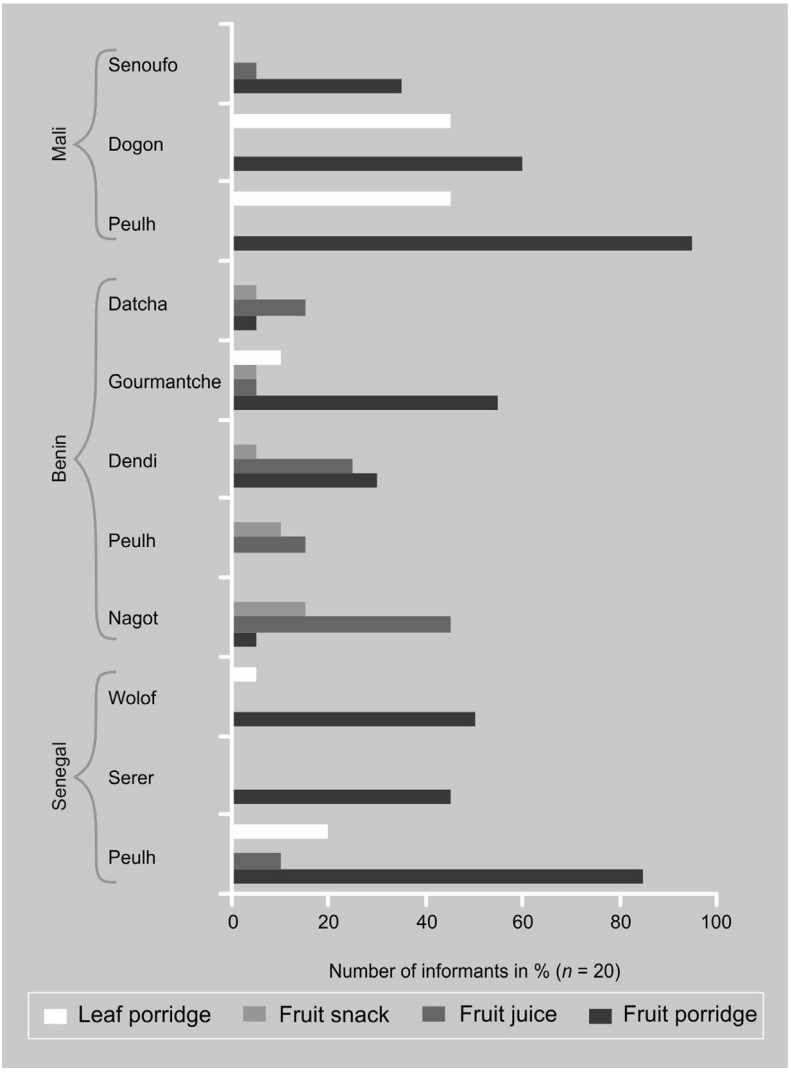

Figure 5.
Frequencies of year-round tamarind leaf and fruit consumption (≥ 1 portion/day) in 11 ethnic groups in Benin, Mali and Senegal (100% = 20 informants per ethnic group).

3.3. Nutritional importance of tamarind

Tamarind fruits are consumed by almost all informants (99%, $n = 220$), whereas the leaves are consumed by 64% of informants. Tamarind offers a source of vitamins and is often added as a sour component to food. Fruit porridge and/or fruit juice is consumed daily by each ethnic group (*figure 5*). Eight ethnic groups prefer the preparation of tamarind fruit porridge (*bouillie*). The high proportion of informants stating consumption of tamarind leaf porridge is due to personal taste preferences as well as access to fruiting trees. Informants who do not own tamarind trees may be allowed to harvest tamarind leaves but not fruits from privately owned trees.

We indicated the daily consumption of at least one portion of tamarind per day (*figure 5*). However, additional consumption during harvest periods, when there are plenty of tamarind products available, and also the frequency of regular consumption per day, can be much higher. In Benin, the fruit porridge is consumed twice daily by 30% of Dendi informants ($n = 20$) and 5% of Datcha informants ($n = 20$) and, also in Benin, the Nagot (45%, $n = 20$), Peulh (15%, $n = 20$), Dendi (25%, $n = 20$) and Gourmantché (5%, $n = 20$) ethnic groups all consume the fruit juice twice daily. Some Gourmantché (10%, $n = 20$) in Benin prepare porridge with leaves twice a day.

Differences and similarities among the ethnic groups based on their food uses of all tamarind plant parts were plotted with multidimensional scaling (*figure 6*). The largest cluster represents all five ethnic groups interviewed in Benin plus the Senoufo ethnic group of Mali. The other two ethnic groups from Mali (Dogon and Peulh) form another cluster, based on their comparably

high use of leaves and fruit pulp. The largest difference is found among the Senegalese ethnic groups, with the Wolof and Serer in one cluster at a great distance to the Peulh. The Peulh in Senegal stand out with the highest percentage of year-round use of tamarind fruit, as well as a very high use of the tamarind fruit husk and pulp. The Wolof and Serer informants report a high use of fruit pulp and flowers, but appreciate the tamarind products in different recipes, such as in the preparation of Senegal's national dish: *Thiebo Dienne*. The Dendi in Benin stand out for their very high use of fruit pulp.

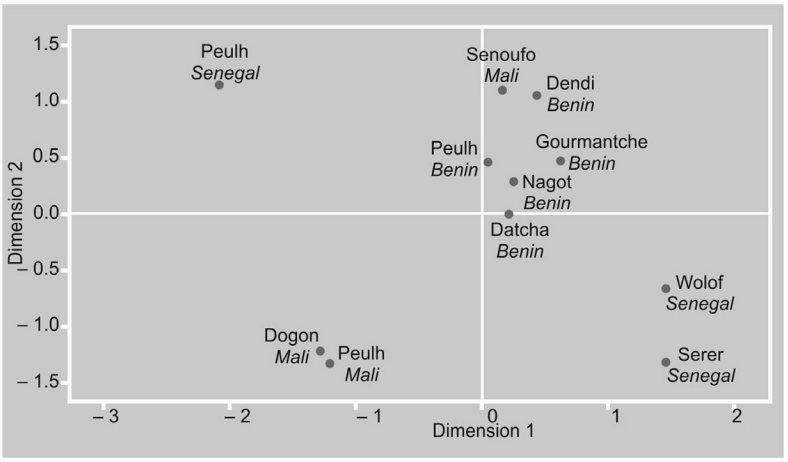

Figure 6.
Multidimensional Scaling (MDS) plot: differences and similarities among 11 ethnic groups in Benin, Mali and Senegal (total of respondents = 220, *n* = 20 per ethnic group) based on the number of food uses of all tamarind plant parts.

3.4. Preferred characteristics of tamarind fruit and leaves

Eighteen per cent of informants prefer large fruits ($n = 220$). The preference for sweet fruit taste (27%) is slightly higher than for sour taste (22%). Eight per cent of informants stated that they like the fact that tamarind is sweet and sour at the same time and said they wouldn't like a tamarind fruit to be 'just' tasting sweet. Sour taste of the leaves is stated as a preferred characteristic by 4% of informants. This is probably due to the fact that with acidic leaves, fewer are needed to prepare the *bouillie* to obtain the acquired taste. Multiple answers were possible (*e.g.*, to state size and taste of fruits), but many informants did not state any preferences.

3.5. Fodder

Apart from informants from the Peulh ethnic group in north-eastern Benin, no other ethnic group within our sample stated the use of tamarind leaves as fodder.

4. Discussion

The field research results show that tamarind is a highly appreciated and locally preferred tree species which is used for a variety of food preparations. The importance of tamarind in the daily diet of rural people in Benin, Mali and Senegal was stated by the informants in group discussions and individual interviews, but is also revealed through the diversity of preparation methods (*figures 2–4*) and frequency of consumption (*figure 5*). In addition, tamarind was ranked as the second most important useful tree after the baobab [see also 18]. These two species, along with *Balanites aegyptiaca* L., have been documented in the literature as wild fruit trees that are most appreciated by the Sahelian-Sudano populations [11]. The fact that tamarind leaves, and not sour fruits from other plant species (*e.g.*, lemon) are used in case of unavailability of tamarind fruits indicates a high local appreciation for the 'typical' sweet-sour taste of tamarind. Although there are regional, local and individual variations and preferences (*figure 6*), tamarind food use is high and traditionally appreciated among the eleven ethnic groups investigated, across all age groups and regardless of gender, education, religion or occupation. With some exceptions, food uses are similar among all ethnic groups in each country studied. The similarities and differences in tamarind food uses (*figure 6*) could be grounded in the sharing of knowledge and general interaction between ethnic groups that live close together (*e.g.*, the Dogon and the nearby Peulh in Mali) and/or who are connected through trade (*e.g.*, all ethnic groups in Benin). In Senegal, the Serer and the Wolof consider themselves to be similar to each other, but both distance themselves from the "more traditional" (semi-) nomadic Peulh, thus reducing the possibility of sharing

knowledge. The high dependency on natural resources due to transhumance, leading to a more thorough use of all tamarind plant parts, may explain why the Peulh in Senegal hold such a different and varied knowledge on tamarind food uses.

Whereas local tamarind preferences have been documented regarding the whole tree, *e.g.*, different types of tamarind [19, 20], we focused on fruit size and taste, with large and sweet fruits stated as the most preferred ones. Fandohan *et al.* [20] describe criteria that several ethnic groups in Benin use to differentiate tamarind trees, including fruit size and shape, pulp taste and colour, seed size and colour and the bark surface. Kalinganire *et al.* [19] identified ideotypes for tamarind based on participatory research with farmers in Senegal, Mali, Burkina Faso, Niger and Kenya. They report the following preferred characteristics for tamarind: vigour, early fruit set, sweetness of the fruits, resistance to pests and diseases, long and straight pods, a large and round canopy with many branches for greater fruit production, a large number of seeds, high pod production, and exocarp and fibres easily removable from the fruit pulp.

A high appreciation of tamarind fruit consumption has been documented in the literature for Burkina Faso [21–23], north-east Nigeria [24] and Mali [25, 26]. The use of tamarind in *bouillie* has been recorded in Burkina Faso [23], Mali [26], Nigeria [24] and The Gambia [27]. The reasons given for adding tamarind fruits to the food range from improving the taste [28–30], and improving digestibility [31, 32] to keeping food free from bacteria [33]. In Nigeria, tamarind fruit pulp is used in weaning food [34]. Fruits are consumed as a snack in Nigeria [35], The Gambia [27] and Tanzania [36]. Tamarind fruit pulp is used in local cuisine as a digestive and as a cold infusion [2, 3, 6, 37]. Tamarind juice and soft drinks are produced and consumed in several African countries: in Benin, Mali [see also 38], Senegal [39], Nigeria [35] and Côte d'Ivoire [40]. In Guinea, the fruit juice is mixed with ginger, and served frozen as ice-cream [28]. Our study confirms food uses of tamarind fruits as documented in the literature, *i.e.*, fruits are consumed as a snack, used to prepare juice, and added to *bouillie* and to daily meals. Tamarind fruit pulp is used as a beverage or food additive during the Islamic Ramadan celebration, a use which has also been recorded in Sudan [9, 41] and Burkina Faso [23]. Our study also proves that tamarind not only provides an important source of food during dry seasons and times of famine [2, 27, 42], but is also a component of daily diets [see also 7, 43, 44]. The results of our field study (*figures 2–5*) indicate the importance of *bouillie* in daily consumption. Tamarind fruit use for the preparation of *bouillie* is preferred to that of tamarind leaves by all ethnic groups investigated. However, in case of the unavailability of fruits, tamarind leaves will be added to *bouillie*.

Tamarind leaves can also be used as a substitute in sauces or as tea [45], in soups or as a salad [5, 10]. In the Sine Saloum region, Senegal, the leaves of tamarind were stated among the five most appreciated ingredients for vegetable sauce [46]. In Benin [13] and The Gambia [27], tamarind leaves are used to prepare a sauce, usually served with a thick cereal porridge (*e.g.*, prepared with millet, sorghum or maize). The leaves are an ingredient for soup by the Nankani of Northern Ghana (Lynn in [47]) and by the Hausa of Northern Nigeria [32]. Tamarind leaves are also prepared as vegetables, *e.g.*, by Nigerian Hausa communities [32] and in Senegal [5, 39].

Tamarind flowers are used in the preparation of juice or infusions to be mixed into *bouillie*, but may also be prepared as vegetables. It seems that flowers are consumed only occasionally or that their use may be restricted to certain regions or ethnic groups, such as the Serer and Wolof in our sample. Flowers can be added to a sauce [2, 37] or even be eaten fresh in a salad, as documented in Northern Nigeria [32, 47] and in Senegal [39]. In an extensive study by Fandohan [13], ethnic groups in Northern Benin (Peulh, Gourmantché and Dendi) did not report tamarind flower consumption.

Tamarind seeds are consumed roasted, cooked and mixed into dishes in the form of flour [47]. Seed consumption has been documented in several African countries, such as in Benin [13], Nigeria [32] and Ethiopia [48].

In The Gambia, the seeds may be eaten in times of famine [27]. None of the references on seed consumption [12, 13, 27, 32, 47, 48] report if tamarind seeds are consumed as a snack food, as documented in our study with the Dendi and Peulh ethnic groups in Benin. However, tamarind seeds are gradually gaining importance as a cheap and alternative protein source to alleviate protein malnutrition among traditional people living in developing countries (Siddhuraju in [7]).

Tamarind has been documented as a source for fodder, *e.g.*, in Nigeria [49], Burkina Faso [50] and Senegal [39], as leaves are appreciated by cattle [6]. In north-eastern Benin, the use of the leaves is specified for feeding sheep and goats [13]. In our study, informants belonging to the seminomadic Peulh ethnic group in north-eastern Benin were the only ones mentioning the use of tamarind leaves as fodder. Thus, tamarind does not seem to rank high as a preferred source for animal fodder.

Tamarind not only serves for subsistence but as a source of income. Its products are traded throughout the dry regions of Africa [9, 25, 28, 30, 36, 41, 46, 47, 51–58]. Due to the good storage capacity of the dry pulp [11], that is rarely infested by pests, transportation and trade, and thus year-round consumption is facilitated.

Considering the local and regional importance of tamarind, one may assume that tamarind trees are cultivated and protected *in situ*. However, our study [see also 59], as well as recent literature [13, 14] suggests that West African tamarind populations are threatened and planting efforts by the rural communities are minimal. Therefore, there is a need to include tamarind as a key indigenous tree species in local and regional management policies and development initiatives on tree domestication, conservation and agroforestry.

5. Conclusion

The results presented in our ethnobotanical study and further information drawn from the literature indicate that tamarind is not just a famine food, but forms a consistent part of West African subsistence. Tamarind is well adapted to arid and semi-arid zones, making it a valuable tree species in regions where few other food plants survive. The fruit pulp is the most valued part of the tree, for consumption as well as in local trade. The overall high number of different uses and methods of food preparation of tamarind plant parts that are applied today indicate the continuous appreciation of this traditional food plant. Knowledge on tamarind food uses held by different ethnic groups in each country studied proves to be similar, notably among those groups that live close together or are connected through trade. However, use differences among ethnic groups of countries should be acknowledged, especially when planning regional development and domestication programmes for tamarind. Local knowledge and preferences need to feed into development programmes to stimulate the domestication and incorporation of tamarind into local agroforestry systems to secure a continuous and sustainable harvest of those valuable trees for future generations.

Acknowledgements

We are grateful for the support of all African informants who participated in the survey. We wish to thank all partners of the Domestication and Development of Baobab and Tamarind (DADOBAT) project for greatly facilitating field research. We would like to thank Reinout Havinga for his support in the literature review and evaluation, Beatrix Gasienica-Wawrytko for help with graphics, Christoph Schunko and Henning Vogt for support in statistical analyses, and Heather Leach for revising earlier drafts. Ongoing research is financed by the European Union (DADOBAT project).

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El tamarindo (*Tamarindus indica* L.) en el régimen alimentario tradicional del África Occidental: no solo un alimento de subsistencia.

Resumen - Introducción. El tamarindo (*Tamarindus indica* L.) es un árbol frutal tropical multifunción, originario de África. A pesar de que la producción comercial de los frutos de tamarindo tenga lugar principalmente en Asia y en América, el árbol desempeña un papel esencial de subsistencia en las regiones rurales del África Occidental. Este estudio subraya la importancia del tamarindo en la alimentación tradicional de las comunidades rurales en Benín, Mali y Senegal. **Métodos**. Se colectaron datos de terreno etnobotánicos mediante cuestionarios individuales estructurados, debates de grupo semi-estructurados, calendarios agrícolas y cartografía participativa de aproximadamente 220 informadores, pertenecientes a once grupos étnicos, repartidos a través de catorce zonas agroecológicas. Los datos se trataron mediante métodos de análisis cuantitativos y cualitativos. **Resultados**. El tamarindo aporta vitaminas y minerales, así como un sabor ácido tradicionalmente apreciado tanto en las bebidas como en los platos. Se consume cotidianamente y a lo largo del año por muchos africanos de las zonas rurales. Las similitudes y las diferencias étnicas en las costumbres de consumo del tamarindo subrayan la importancia de este fruto como alimento de subsistencia del África Occidental. Los resultados incluyen la descripción detallada del tratamiento del tamarindo y la preparación de platos tradicionales a partir de sus frutos, semillas, flores y hojas. **Conclusiones**. Los conocimientos locales del tratamiento del tamarindo y de su uso son necesarios para estimular su promoción local y regional, y apoyar los esfuerzos de domesticación, con el fin de impedir una nueva bajada de las poblaciones de *T. indica*. La importancia de los usos locales y las fuertes solicitudes como alimento de subsistencia de los frutos de tamarindo deberían estimular el desarrollo de su producción sostenible, así como los esfuerzos de conservación, de modo a garantizar, en el futuro, una cosecha continua y a satisfacer la gran demanda local de este alimento tradicional.

Benin / Malí / Senegal / *Tamarindus indica* / alimentación humana / agricultura de subsistencia / alimentos procesados / conocimiento indígena