The Use of Baobab Leaves (*Adansonia digitata* L.) for Food in Africa: A Review

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The Use of Baobab Leaves (*Adansonia digitata*) for Food in Africa: A Review. The massive long-lived African baobab (*Adansonia digitata* L.) is a celebrated member of a small pantropical group of trees in the Malvaceae family. Its much-loved fruit is generally considered the tree's most important food offering, and the baobab is more widely known as a fruit and fiber tree than a vegetable tree. Recent studies indicate that baobab leaves are eaten throughout its range, most notably in West Africa, and there is now ample documentation of the tree being valued in some places chiefly for its edible leaves. This paper presents a review of the use of baobab leaves for food in Africa. It identifies the species as one of Africa's important leafy vegetables and highlights issues related to baobab management strategies for leaf production, the distinguishing characteristics of palatable leaves, and the seasonal dimension of leaf consumption. The culinary uses of baobab leaves and their nutritiousness are discussed, as well as current efforts to cultivate young baobabs for their leaves. The use of baobab leaves for food outside of Africa is also noted, and several suggestions are offered for future studies of baobab leaf consumption in Africa.

L'utilisation des feuilles de baobab en tant que nourriture en Afrique: Un compte- rendu. Le Baobab africain énorme et d'une grande longévité (*Adansonia digitata* L.) est un membre glorieux d'un petit groupe d'arbres tropicaux des deux émisphères dans la famille des Malvaceae. Son fruit bien aimé est considéré comme étant l'offrande la plus importante et le baobab est plus connu comme un arbre à fruit et à fibres qu'un arbre potager. Des études récentes indiquent que les feuilles du baobab sont mangées d'un bout à l'autre de son étendue, plus particulièrement en Afrique de l'Ouest, et l'on trouve maintenant une multitude de documents sur cet arbre étant estimé dans certains endroits principalement pour ses feuilles comestibles. Cet article présente un compte-rendu de l'utilisation des feuilles de baobab comme nourriture en Afrique. Il identifie les espèces comme un des légumes à feuilles importants en Afrique et souligne les problèmes liés aux stratégies de gestion du baobab, les caractéristiques des feuilles savoureuses et l'étendue saisonnière de la consommation de feuilles. Les utilisations culinaires des feuilles de baobab et leur valeur nutritionnelle sont étudiées ainsi que les efforts en cours de cultiver de jeunes baobab pour leurs feuilles. L'utilisation des feuilles de baobab en tant que nourriture en dehors de l'Afrique est également mentionnée et plusieurs suggestions sont proposées quant à des études futures sur la consommation de la feuille de baobab en Afrique.

Key Words: Baobab uses, food, morphotypes, subspecific variation, ethnobotany, pollarded baobabs.

Introduction

The massive long-lived African baobab (*Adansonia digitata* L.) is a celebrated member of a small pantropical group of trees in the Malvaceae family (Adanson 1771). In addition to the African baobab, there are six species endemic to Madagascar, the center of the genus' diversity, and one to Australia (Baum 1995a, b; Baum et al. 1998; Wickens and Lowe 2008). The baobab's extraordinary adaptation to the dry conditions of the African savanna—an adaptation that makes it the biggest tree of the continent—is evident in its wide-spreading shallow roots, moisture-laden wood, photosynthesizing bark, water-conserving leaves, deciduous habit, and well-protected seeds. The tree produces large glossy white flowers through the annual rains, especially in summer. They are suspended upside down at the end of long flexible stalks and are night

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blooming, odiferous, and bat pollinated. From these flowers develop large indehiscent fruits with a thick shell and fuzzy exterior whose variable shape can be broadly categorized as rounded, oblong, oval, and elongated (Gurashi and Kordofani 2014; De Smedt et al. 2011; Sanchez 2011). Within the fruit is a white acidic pulp in which many hard kidney-shaped seeds are embedded, and through the pulp and forming the chambers of the fruit are tough, stringy red fibers. A healthy baobab produces hundreds of fruits that ripen in the dry period from mid-autumn to early spring, with most fruits falling from the tree in the winter dry season.

The baobab is justly famous for its diverse resources both with respect to the tree as a whole and its various parts. These resources include the baobab as a place marker, shade tree, and gathering place; delicious leaves, fruit pulp, and seeds widely used as staples; bark fiber valued for such things as cordage, baskets, and mats; a hollow trunk that stores water and provides a nesting site for bees, the latter accounting for the baobab's reputation as one of Africa's most important honey trees; and a durable fruit pod used for such things as containers, fishnet floats, and musical instruments. The baobab's impressive size, striking shape, and numerous uses have made it an icon of the African savanna and a familiar symbol of the continent and its diverse cultures. This review of baobab leaf consumption in Africa begins with a description of the leaf emphasizing its morphological variability and a characterization of the species as one of Africa's important leaf vegetable trees. The review focuses on outstanding issues in the literature related to baobab leaf production management strategies, the distinguishing characteristics of desirable baobab leaves, and the seasonal dimension of baobab leaf preservation, consumption, and sale. The culinary uses and nutritional value of baobab leaves are also discussed, as well as the cultivation of young baobabs for their leaves and baobab leaf consumption outside of Africa. Several suggestions are offered for future studies of baobab leaves as a food source in Africa.

Methods

This review is based on recent journal articles and graduate theses. These works were identified using bibliographic citations, Google Scholar, and databases such as the Web of Science, JSTOR, and Science Digest. A number of search terms were used including "baobab leaf," "baobab foods," "baobab morphotypes," and "baobab pollarding." Because the literature on baobab leaf consumption in Africa is limited, it was not necessary to filter out information from credible sources such as technical reports, field manuals, and important baobab websites. The review also incorporates a familiarity with the baobab in East and West Africa and an ongoing research project on the introduction, history, and cultural importance of the species in the Americas.

Leaf Description

Baobab leaves are highly variable. They may be simple or digitate with a glossy or dull appearance that is light or dark green in color. Palmately compound leaves alternately arranged at the end of branches typically have five leaflets and are up to 20 cm in diameter. Leaves with seven leaflets are not uncommon; leaves with nine leaflets have also been reported. Seedlings have simple leaves, and seedlings, saplings, and the short spurs that develop on the trunk of mature trees often have simple leaves and compound leaves with two to four leaflets. Similar kinds of leaves are also seen when new leaves first appear in the early spring. The sessile or petiolate leaflets are 5–15 cm × 2–7 cm in size and variable in shape, including lanceolate, ovate, obovate, and oblong. Lateral leaflets are smaller than the medial leaflet, and leaflet margin may be entire or toothed and their apex acute, apiculate, or occasionally obtuse. The leaf base may be cuneate or decurrent and lamina glabrous or tomentose. When hairs are present, they can be simple or clumped (Baum 1995a, b; Baum et al. 1998; Sanchez 2011; Wickens and Lowe 2008; Zhigila et al. 2015).

The Baobab as a Fruit, Fiber, and Vegetable Tree

The baobab is more widely known for its fruit and bark fiber than for its edible leaves. For example, in listing the important plants of the six major regions of the world, Harlan's (1992, pp. 71–72) included the baobab among the "fruit and nuts" and "fiber plants" of Africa but not among Africa's "vegetables and spices." But according to Irvine (1952, p. 33), "Dried leaves are widely used [in Africa] as condiments and flavourings" and the "best known of these is the baobab (*Adansonia*)." Recent accounts, such as those of Yazzie et al. (1994), Gebauer et al. (2002), and Rahula et al. (2015), indicate that baobab leaves are eaten throughout its range, most notably in West Africa, and there is now ample documentation of the tree being valued in some places chiefly for its edible leaves. Maundu et al. (2009, p. 75) report that the use of the baobab as "a fruit and vegetable is widespread." In their market survey of the useful savanna trees of the Cinzana Municipality of Mali, Gustad et al. (2004, p. 580) found that baobab leaf and fruit products were "particularly important for local households" and that baobab leaves are sold year-round in markets. In their study of Dogon management strategies for baobab and tamarind trees "in the midst of conflict and change," Leach et al. (2011, p. 602) also reported that "Not every household in the village participates in the dry season baobab fruit harvest because trees that are intensively managed for leaf production do not always fruit …. All respondents stated that, while fruit is a welcome supplement to the diet, it is secondary to leaf production, and management practices are geared towards maximizing leaf production even if it diminishes fruit production."

Sidibé and Williams (2002, p. 47) indicate the relative food value of baobab leaves and fruit in the following comment on research done in Mali:

> There is a marked seasonality in use of leaves. Nordeide et al. (1996) surveyed two villages and a town neighbourhood to compare rural and urban use of wild foods in southern Mali. Out of over 100 rural households, 26% used baobab leaves in the rainy season, and 56% in the dry season; and out of over 150 urban households, 6% used baobab leaves in the rainy season and 13% in the dry season. Use of fruits was much lower and ranged from 0.5% of households, with roughly a two-fold increased use in the dry season.

Even when the baobab is recognized as a fruit and vegetable tree, the tendency is to give preeminence to its value as a fruit tree. For example, Schumann et al. (2010) present an ambiguous view in their study of the use, management, and population status of the baobab in eastern Burkina Faso. At the beginning of their article, they reported "Interviews reveal that the baobab is harvested by local people for 25 use-types," and they noted that "The fruits are the most important plant part and baobab products are of special importance for nutritional uses." However, further on in the article, they note that the 25 "different types of uses" were divided into four categories of which 17 were medicinal, 7 were food, and 1 was construction (2012, p. 268). Of the food uses, they write "Overall, the principal types of food uses were the utilization of the leaves to prepare sauce followed by the use of the fruit pulp for making beverages and porridge and the seeds as spice in sauces and as a food additive." In their discussion of the locally recognized varieties of baobab in Mali, Sidibé and Williams (2002, p. 62) wrote "In general, trees are selected based on leaves. For this reason wild trees are chosen with a desired quality and seedlings (wildlings), occasionally cuttings, are transplanted to fields near homes where they can receive 'protection.'" The baobab is a naturally occurring tree of the African savanna where it is also incidentally favored by human use and by intentional human assistance. Intentional human assistance is the precise definition of cultivation, and it is likely the baobab is one of Africa's oldest cultivated fruit, fiber, and vegetable trees (Chevalier 1906; Hugot 1968; Rindos 1987; Ambrose-Oji 2009).

Baobab Management Strategies

Pruning is one of the most important ways in which people directly control the growth of baobab trees. The naturally formed baobab has a spreading crown. When subjected to "severe pruning" (Sanchez 2010, p. 36), however—what Schumann et al. (2012, pp. 270–271) identify as "destructive harvesting" and Dhillion and Gustad (2004, p. 89) and Sanchez (2010, p. 108) as "mutilation"—the tree is often little more than a thick trunk with a few stubby primary and secondary branches. In their study of the impact of land use types and leaf and bark harvesting on baobab population structure and fruit production in Burkina Faso, Schumann et al. (2010, p. 2035) found that "Nearly all baobabs were pruned and debarked in villages, croplands and fallows while half of the individuals were harvested in the park." They also noted that "Most of the trees were pruned and debarked moderately." In popular thought, the pollarding of trees is particularly associated with esthetic enjoyment and tree space management, especially in landscaped areas such as waysides, parks, and gardens. Historically, however, pollarding has long been an expression of the sustainable use of trees for obtaining important resources. These include leaves for food and fodder, branches for basketry, and wood for various uses, especially construction and cooking, warming, and lighting fuel.

The familiar sight of pollarded baobab trees in Africa is both an incidental effect of leaf harvesting and intentional management strategies, and the aim of the latter is to increase the efficiency of leaf production. It is often noted that pruning limits the production of fruits (Dhillion and Gustad 2004; Niang 2003), but the baobab field manual (SCUC 2006, p. 14) describes pollarding as a production technique. Among other things, "Regular pruning by shortening branches at the end of the rainy season … prevents the development of fruits in order to improve the food quality of leaves" (see also Sanchez et al. 2010 and Wickens and Lowe 2008, p. 68). The literature cited in this review identifies three basic reasons for pruning baobab trees. The first is to stimulate the growth of an abundance of leaf-bearing branches with tasty young leaves by maintaining trees in a state of continuous releafing through the period of the annual rains. The second is to increase the efficiency of leaf gathering by spatial management that facilitates tree climbing and canopy movement and that also benefits understory crops. The third is tree care.

Having found that the Dogon manage baobab trees for leaves at the expense of fruit, Leach et al. (2011, p. 602) speculate that "It may be only very large old trees that are too tall to harvest, or trees with particularly bitter leaves that are infrequently harvested that produce fruit." They also thought that "With enough trees to provide an adequate supply of leaves for the year, villagers might leave the top section of the tree uncut so that it will produce fruit." The common perspective of leaves versus fruit assumes trees with tasty leaves are always trees with sweet fruits, and this underplays the significance of locally recognized morphotypes with respect to leaves, fruit, and tree fertility. But, leaf production is not an inevitable sacrifice of fruit if the idea of Africans cultivating different varieties of baobabs for different uses is taken seriously.

In light of the research of Assogbadjo et al. (2008, 2009) and the reference of Leach et al. (2011, p. 602) to "trees with particularly bitter leaves," we could theorize that only the morphotype with sweet fruits and tasty leaves would involve the sacrifice of fruit for leaves and this variety would likely remain unpruned. The three morphotypes with bitter leaves—the bitter-leaf male trees, bitter-leaf trees with acidic fruit, and bitter-leaf trees with sweet fruit—would also remain unpruned. Of these, the most likely to be unpruned would be the variety with bitter leaves and sweet fruits. This variety would be spared for its tasty fruit even more so than the variety with sweet fruits and tasty leaves since there would be no need to sacrifice fruits for leaves. By contrast, male trees with tasty leaves would be the most likely trees to be pollarded since this does not involve sacrificing the harvest of fruits. It is likely, however, that unpruned trees are present in an environment of pruned trees, not only for their delicious fruits or because they have grown too tall to harvest as Leach et al. (2011, p. 602) suggest, or even because they have unpalatably bitter or tasteless leaves, but also because they are valued in their natural form for such things as shade, landmark, kinship marker, political emblem, and inspiration, the latter especially in relationship to oral traditions and religion.

There are other examples of productive pruning in the literature that also contribute to the presence of pruned and unpruned trees in the same location. The harvesting of baobab leaves for fodder must be taken into account because it has a long history in the agro-pastoral and pastoral way of life that has developed on the African savanna. For example, Tukur and Rabi'u (2013, p. 491) write "Because of its high economic values, the baobab tree has not been used as animal feed unless on occasions, where a tree is identified with low quality and taste of its leaves or fruit pulp, then the leaves will be used to feed livestock." This means even baobab varieties with unpalatable leaves are subject to pruning. Consequently, baobab pollarding for food and fodder must be considered together in any effort to account for the presence of pruned and unpruned baobabs in the same environment.

Baobabs are also pollarded to protect them. Wickens (1982, p. 192) notes that in the Sudan, productive "pollarding is also carried out on hollow trees used for water storage in order to prevent them becoming top-heavy and falling over." Others report it is also done to protect the trunk from splitting (Shepstone 1919, p. 260, 272).

Variability in the Palatability of Baobab Leaves

The documented variability of the baobab is evident in its size, shape, bark, leaf, flower, fruit shape, fruit pulp, seed, and genetic makeup. This variability is no doubt related to the fact that the baobab is a widespread sexually reproducing species that has long been subject to the selective pressures of its mosaic savanna environment, especially the varied influence of human incidental and intentional activities. Baobab variability is especially evident in the palatability and nutritional value of its leaves, fruit pulp, and seeds, which are among its most valuable products (De Smedt et al. 2011; Gurashi and Kordofani 2014, 2017; Kyndt et al. 2009, Ibrahim et al. 2014; Sanchez 2011; Sanchez et al. 2010; Sanogo et al. 2013; Wickens 1982, pp. 188–189; Wiehle et al. 2014; and Zhigila et al. 2015). But, this variability is not reflected in botanical or commercial nomenclature. There are no taxonomically ranked varieties or formally named cultivars. Nevertheless, recent studies show that farming communities throughout its range do recognize local varieties and the distinguishing attributes of these varieties are based on the most important uses of the tree, including its edible fruits and leaves and its high-quality bark fiber.

It is a reasonable assumption that all baobab leaves are edible since there has never been a report of poisonous baobab leaves. But, it is also clear that not all baobab leaves are equally desirable. Variation in leaf palatability has been associated with the age and texture of leaves, with leaves from young rather than old trees, with leaves from trees with a particular bark color, with the leaf taste which ranges from tasteless to bitter, and with leaves from what are locally identified as male and female trees. It has also been associated with the degree of sliminess in the texture of leaves.

A Preference for Young Leaves

A number of accounts of baobab leaf eating mention a preference for young leaves (e.g., Booth and Wickens 1988, p. 13; Davidson 1999, p. 57; Wickens and Lowe 2008, p. 68). But, there is an ambiguity in the "young leaf" perspective since it is not clear whether it is the young leaves of all variety of baobabs that are preferred or just the young leaves from trees with tasty leaves.

Chapter 4 of Sanchez's (2010) dissertation focused on "variation in baobab leaf morphology and its relation to drought tolerance." The study was intended to aid in the identification of the most suitable planting material to meet the challenges of climate change and the rapid intensification in the commercialization of the species. Sanchez (2010, p. 108) included pruned trees in her research, and she found that pruning had a strong effect on leaf morphology. "It seems," she wrote, "that pruned branches produce young leaves which are smaller in size, less hairy, lighter green, and tastier (compared with leaves from non-pruned branches, A. Assogbadjo 2008, pers. comm.)." In a publication of the contents of this chapter that was first made available online in June 2009, Sanchez et al. (2010, p. 23) gave the following account of the sites they studied in Benin:

> Foliage age due to pruning might account for the variation in leaf size, thickness and SLW [Specific Leaf Weight]. In Karimama, Comé and Sèhouè trees were not as pruned as in other sites. In the south (Comé and Sèhouè), locals do not use daily baobab leaves for food as they do in the north (Dansi et al. 2008). Trees are not pruned in Karimama, where baobab density is high and baobab fruits are highly economically valued and exported to Niger (Assogbadjo et al. 2005a, b). Leaves from Karimama, Come and Sèhouè, apart from being bigger, were found to be always hairy, another characteristic of old foliage. Old leaves have more secondary compounds and tend to be thicker.

From the perspective of Sanchez and colleagues, we can conclude that unpruned baobabs have old leaves that are larger, thicker, darker, hairier, and less tasty. But, this view of the tastiness of baobab leaves is only related to the developmental stages of all baobab leaves, not to foliar morphotypes. With respect to the latter, it must be taken into account that tastiness is not always correlated with young leaves. Leaf age is indeed an important criterion of leaf palatability that points to a preference for leaves that are tender and smooth rather than thick and hairy. But, leaf age by itself is not sufficient to account for what makes baobab leaves desirable. If it was, all small baobab trees would be equally eligible to be harvested for their young leaves and this has not been shown to be the case.

A Preference for Smooth Leaves

The baobab's leaf surface has not received the attention it deserves, given the importance of the smooth/hairy distinction in determining the palatability of young and old leaves and in distinguishing foliar morphotypes. This distinction is recognized by West Africans, and the link between smoothness and palatability has been stressed in the literature (Morton 1990, p. 247). For Wickens and Lowe (2008, p. 68), young/old and glabrous/tomentose (as smooth/hairy) are the two sets of qualities involved in determining the palatability of baobab leaves. They write "Glabrous leaves are preferred, while tomentose leaves are generally considered unsuitable." They also note that "depending on the indumentum [defined as a covering of hairs], crude fibre and mineral content, and taste, the desirability of the leaves is reported to differ from tree to tree and that the leaves from some trees are not eaten." The view of Wickens and Lowe is ambiguous as to whether it is the smoothness of the leaves at the early stage of their development that is important or a particular kind of baobab with tasty hairless young leaves.

Surveys of different ethnic groups in Benin, Burkina Faso, Ghana, and Senegal conducted by Assogbadjo and colleagues shed light on this ambiguity of age-based palatability versus morphologically based palatability. In the earlier of two studies (2008, p. 79), they found that people in rural areas were well aware of the links between different baobab traits, some of which were related to the whole tree and others to its various uses.

> The survey revealed that local people are able to recognize eight morphotypes, a morphotype being defined as a group of baobabs sharing some linked traits identified by the ethnic groups. The persons most familiar with the traditionally recognized morphotypes became our key people in each district and were asked to participate in the selection of baobab individuals to sample for DNA fingerprinting. In total, 18 key people provided us their help, their number varying between 2 and 3 per ethnic group.

The survey found that West Africans used 21 criteria to categorize baobab trees in their traditional agroforestry systems, including 11 for fruit (52.4%), 6 for leaves (28.6%), 2 for bark (9.5%), and 2 for the whole tree (9.5%). These criteria provided the framework for the matrix of linked traits in relationship to which eight locally recognized morphotypes were identified (Assogbadjo et al. 2009, p. 159). The six distinguishing foliar characteristics were taste, color, smoothness, phenology, and resistance to insect attack. It is noteworthy that the smooth/hairy difference as a morphotyping criterion was only identified by 72.4% of the 98 interviewees from Benin and 3.1% of the 128 from Senegal, but it was not identified by the 92 interviewees from Burkina Faso and from Ghana. Neither was this criterion explicitly incorporated into the matrix that identified the eight West African morphotypes (Assogbadjo et al. 2009, p. 159). It should also be mentioned here that the practical manual on cultivating the baobab aimed at "extension workers and farmers" produced by the Southampton Centre for Underutilised Crops (ICUC 2006) did not emphasize a difference in palatability between smooth and hairy leaves. The sources cited above suggest the smooth/hairy distinction might be more local rather than general as assumed earlier. It is probably also the case that smoothness and hairiness are not prominent morphotyping criteria because they are considered qualities of leaf age and are therefore commonly subsumed under the widely recognized preference for young leaves rather than old leaves.

A Preference for Leaves from Young Trees

Johansson (1999, p. 14) reported a preference for the leaves of young baobab trees in her study of the baobab in the Kondoa Irangi Hills of Tanzania. As part of the study, she compiled the results of interviews with "five elders in five villages" into a single statement. We learn that in response to her question about the absence of young baobab trees, the elders told her "The young ones are taken by animals, man and cattle and they are affected by fire during the dry season." They also noted that "The young baobabs' leaves are preferred as green vegetable." To suggest that people preferentially select leaves from young baobab trees because they are tastier than leaves from mature baobab trees is problematic. It is more likely that palatable leaves are selected from both young and mature trees, but the leaves of young trees are preferentially selected because they are easier to harvest. It is well known that climbing baobab trees is difficult and dangerous and climbers have also to deal with encounters with aggressive bees, snakes, and other dangerous wildlife (Dhillion and Gustad 2004, p. 91; Sweeney 1969, pp. 79–97, 1974, pp. 51–74; Wickens and Lowe 2008, pp. 2003–2226).

Bark Color as a Marker for Desirable Fruit, Leaves, and Bark Fiber

Of the 21 locally recognized criteria identified by Assogbadjo et al. (2008, p. 74) that were used to differentiate "individual baobab trees growing in traditional agroforestry systems," we learn that "ease of bark harvest" and "bark color and texture" are the only two that were bark related. The four variants of "bark color and texture" were "pink and smooth," "black," "rough and gray," and "smooth and gray." But, only in Burkina Faso did 41.3% of the 92 interviewees mention "pink and smooth" bark as a significant varietal marker. None of the 318 interviewees of Benin, Ghana, or Senegal recognized bark color in morphotyping. However, in a 2008 grant report, Assogbadjo (2008, p. 76) mentioned the use of bark color and texture as a morphotyping trait in Benin. Bark color differences have also been reported for Eastern (Gebauer et al. 2016, pp. 386–387) and Southern Africa (Watson 2007, p. 23). Sidibé and Williams (2002, pp. 61–62) report rural people in Mali use bark color to distinguish baobab varieties with good-tasting leaves and fruit and high-quality bark fiber. The black variety was associated with "mild-tasting" leaves and fruit, the red with "delicious" fruits, and the gray/white with good bark fiber (see also SCUC 2006, pp. 2b and 12b). While bark color variation is clearly evident in baobab populations and has been shown to be a criterion of classification for some Africans, current studies suggest it is of limited value in local morphotyping compared to the palatability of leaves and fruit.

Taste Determines the Palatability of Baobab Leaves

The surveys of Assogbadjo et al. (2008, 2009) did not support the idea that young or smooth leaves only, or the leaves of a specific bark color variety of baobab, were salient morphological criteria in baobab leaf consumption in West Africa. Instead, Assogbadjo et al. (2008, pp. 76–77) reported 100% agreement among the 410 interviewees representing various ethnic groups in Benin, Burkina Faso, Ghana, and Senegal that the most important trait for distinguishing baobab varieties in West Africa was leaf taste. They found that "two types of baobab can be distinguished" based on leaf trait and they were "baobab with bitter leaves and baobab with delicious leaves." The matrix Assogbadjo et al. (2009, p. 159) presented to distinguish eight locally recognized morphotypes in West Africa included "leaf characteristics" as tasty or bitter; "pulp characteristics" as sweet, slimy, or acidic; and "fertility of tree" as unfertile or fertile.

Compared to other foliar traits, we can appreciate just how significant the unanimous agreement on leaf taste really was when we consider that only in Burkina Faso did 1.79% of the 92 interviewees identify leaf color as a morphotyping trait. It is the same with leaf phenology. Senegal was the only country that recognized the precociousness leafing out as a criterion, and this was a mere 1% of the 128 interviewees. Senegal was also the only other country besides Benin where the timing of leaf defoliation was used as a varietal marker. But in Senegal, unlike Benin, defoliation timing was significant for only 6.4% of interviewees compared to 53.1% of the 98 interviewees in Benin. Only 3.1% of the 98 interviewees in Benin and 1.2% of those in Senegal identified leaf resistance to insect attack. What stands out here is not only that all interviewees in West Africa identified leaf taste as the most important criterion in foliar morphotyping but also that none of the other 21 criteria, not even pulp taste or capsule shape, came close to this level of agreement.

Leaf Taste and "Male" and "Female" Baobab Trees

A widely recognized morphotyping trait in West Africa is the difference between productive baobabs which develop mature fruits and are identified as female trees and unproductive baobabs which do not develop mature fruits and are identified as male trees. Because the baobab produces perfect flowers, it is difficult to explain why baobab populations should have the so-called male and female trees (Rashford 2015, pp. 220–223; Swanapoel 1993; Venter et al. 2017, p. 263). Assogbadjo et al. (2008, p. 77) found that tree fertility was one of the 21 traits West Africans used to differentiate baobab morphotypes. The female/male variable was noted by 59.2% of the 98 interviewees from Benin, 19% of the 92 from Burkina Faso, 26.8% of the 92 from Ghana, and 16.2% of the 128 from Senegal. We also learn from this study that "According to local people, hairy baobab leaves are … tasteless" and that "male baobabs always produce tasteless and sometimes bitter leaves." But, the result of a later study of Assogbadjo et al. (2009) contradicts this local view. Two of the eight locally recognized morphotypes identified in the 2009 study were male trees and one produced "bitter" leaves and the other produced "tasty" leaves. In light of these morphotypes, it cannot simply be said then that "male baobabs always produce tasteless and sometimes bitter leaves."

Unlike smooth/hairy and tasty/bitter, the tasty/tasteless distinction which shows up in reports has received little attention in the literature and no attempt has been made to systematically relate the tasty/bitter and the tasty/tasteless distinctions. The most informative way to combine them is to recognize that baobab leaves are either tasty because they are mild-flavored (SCUC 2006, p. 12b) or they are unpalatable because they represent the extremes of being tasteless or bitter.

Slimy Leaves and the Distinction Between Tasty and Unpalatable Baobab Leaves

It should be clear at this point that a number of criteria have been used to distinguish palatable from unpalatable baobab leaves but they have not been systematically related in the literature. To do so, we must start by recognizing that tasty young baobab leaves are preferred in Africa. But, this characterization leaves out one widely recognized criterion which is the mucilaginous nature of baobab leaves (Morton 1990; Woolfe et al. 1977). All baobab leaves are slimy although some are slimier than others, and this trait was included in Chadare's (2010, pp. 82–83) discussion of folk morphotyping in Benin but not in the accounts of Assogbadjo et al. (2008, 2009), which also included Benin. While the key criteria that mark the palatability of baobab leaves are taste and age, sliminess is a variable quality that does not seem to influence in a pronounced way the desirability of leaves. Taste ranging from tasteless to bitter is a function of morphological variation, while young leaves as tender and smooth is a function of leaf age. Undesirable leaves are therefore unpalatably tasteless or bitter, or they are old leaves that are thick and hairy. We can conclude then that it is tasty young baobab leaves which may be more or less mucilaginous that are the preferred kind of leaves for consumption in Africa.

The Seasonal Dimension of Baobab Leaf Consumption

The Baobab as a Hunger-Time Food Tree

The seasonality of baobab leaf consumption in Africa merits attention because of its practical and theoretical importance (Speth 1987), particularly with respect to seasonal food scarcity. Hunger has long been associated with seasonal changes as well as such things as drought, natural disasters, ruinous economic circumstances, social unrest, and warfare. The baobab's value as a hunger-time food source is especially appreciated during the annually recurring period of food scarcity which, depending on latitude, local ecology, and mode of subsistence, most often occurs at some point from the end of winter in March through the beginning of summer in June. More broadly, however, the baobab provides hunger relief in many parts of Africa because it is a multisource food tree whose edible parts are available year round or for several months and whose leaves and fruit, in particular, can be preserved and stored for use throughout the year. The tree produces leaves in association with the return of the annual rains in the spring, sheds them at the beginning of the dry time in autumn, and is leafless in the winter dry season. The ripe fruits are naturally dry, and leaf storage involves collecting and cleaning the leaves and drying them whole or in small pieces; after drying, they are pounded or ground and then sieved to make a powder (Raji and Adeyemi 2018).

Given its well-known reputation as a food source in times of hunger, it is not surprising that Freedman (2018) included the baobab in his list of famine foods. According to Awori (1989), the baobab "has often been used as a life sustaining plant during famines" and he noted that it "is often the only thriving food plant during … famines especially when they are accompanied by prolonged drought." As Wright and Kerfoot (1966, p. 52) point out, "Much of the tree can be eaten in one form or another" and in "times of scarcity it becomes a staple." Similarly, Sidibé and Williams (2002, p. 37) identified baobab leaves, fruit pulp, and seeds as "wild-gathered foods," noting that "Such foods play a significant role in the preparation of traditional dishes and as sources of food during times of scarcity and famine (Sai 1969)." In his study of Nigerian household food strategies in response to seasonality and famine, Longhurst (1986, p. 27) emphasized the importance of secondary crops. He divided these into gathered crops, crops mixed into fields of staples, cultivated vegetables in home gardens near the compound, and non-staple root crops grown as a contingency reserve, and gathered crops included wild vegetables occasionally cultivated, such as species of *Cassia* and *Loranthus*, "[and] leaves of the baobab (*Adansonia digitata*)." It is also significant that the field manual on baobab cultivation produced for farmers and extension workers by the Southampton Centre for Underutilised Crops (SCUC 2006, p. 2) reports that "The processing and sale of baobab products, especially in urban areas, offers a secondary means of income … especially in times of drought and famine."

There is, however, an ambiguity in the sources cited above since hunger foods can be either hunger-time or hunger-only foods. Hunger-time foods are staples that are available in times of hunger. Hunger-only foods are eaten only in times of hunger. The accounts of Awori (1989) and Sidibé and Williams (2002) suggest the baobab is a hunger-time food tree, especially in West Africa and Sudan where baobab leaves are more widely eaten than in East or Southern Africa. In Gambia, for example, Annegers (1973, p. 254) found that in the spring hunger season, "boiled leaves and baobab seed were commonly the only ingredients in meals." Mertz et al. (2001, p. 285) provide insight into significance of the spring harvest of baobab leaves in their study focused on the consumption and marketing of wild and cultivated vegetable in Burkina Faso. They found that "*Adansonia digitata* and *Annona senegalensis* follow the same pattern as Corchorus spp.," and of Corchorus, they wrote "The peak season is clearly in May-June, the early part of the rainy season, when the desirable fresh new leaves are most abundant and cultivated vegetables are in short supply." But, we also know from the literature that baobab's leaves, fruit pulp, and seeds are hunger-only foods for some Africans, as suggested by Riley and Brokensha (1988, p. 197). In the writing of the Mbeere of the plains south of Mount Kenya, they report that "young leaves in times of famine are used as vegetable relish when they appear at the start of the rainy season." This suggests that there are some groups for whom the new leaves of spring can be considered a seasonal hunger-only food.

If the baobab leaves were indeed highly significant as a seasonal hunger-time or hunger-only food, we should expect West Africans to be aware of trees that leaf out early as an aspect of taking advantage of the new leaves as soon as they become available in the early spring. But of the four West African countries surveyed by Assogbadjo et al. (2008, p. 77), only interviewees from Senegal identified precocious foliation as a morphotyping criterion, and this was a mere 1% of the 128 interviewees. But if the important thing was the preserving and storing of baobab leaves for household use and sale in the dry time when other leafy vegetables were unavailable, scarce, or expensive, paying attention to early defoliating trees makes sense. These trees would be harvested before trees that retained their leaves for a longer period, and it would also be more efficient to skip these trees at the peak harvesting of leaves in September. But, only 53.1% of the 98 interviewees from Benin and 6.4% of the 128 from Senegal paid attention to precocious defoliation as a morphological marker, while none of the 92 interviewees from Ghana and from Burkina Faso did.

Leaf Harvesting for the Spring Hunger Season, the Annual Rains, and the Dry Time of the Year

An issue evident in studies that touch on the seasonality of baobab leaf consumption is whether the preservation of leaves is done primarily to take advantage of the spring and summer surplus or to produce a resource for use and sale in the dry time of the year when fresh leaves are unavailable. Most researchers have focused on the autumn harvest rather than the spring hunger-season harvest and harvesting through the rains. For example, the baobab manual (SCUC 2006, p. 16) reports leaves can be harvested from trees of any age and throughout the annual rains but "Mass leaf harvesting is usually carried out from September to November in West Africa." Dhillion and Gustad (2004, p. 90) attributed the peak harvest of September to the end of the main work in the fields. Leach et al. (2011, p. 601) associated it with the period "after the rains have ended in late August or early September and the fields have dried." No doubt baobab leaf senescence in October and leaf fall starting in November would also play a part in the September timing of the communal peak harvest.

Kalinganire et al. (2007, p. 188) also emphasized the fact that the baobab was "one of the main sources of income, food and nutritional security during the dry season in the Sahel" and that "leaves are typically harvested during the rainy season, then dried and stored for further use during the long dry season" (see also Gebauer et al. 2002, p. 158; Gustad et al. 2004, p. 582; NRC 2006, p. 82; Rahula et al. 2015, p. 82; Sidibé and Williams 2002). Kalinganire et al. (2007) did not mention "food and nutritional security" in association with the spring hunger season, thus overlooking groups like the Mbeere of Kenya that were discussed earlier. But, Dhillion and Gustad (2004, p. 90) showed that the people of Cinzana, Mali, clearly recognize a spring harvest. They write "As soon as the leaves have developed in May to June the women start harvesting fresh leaves for daily consumption …. When the main work in the fields ends in September to October, the men climb up in the trees to do the large harvest for stocking through the dry season." They found that 40 of 41 respondents identified May–November as the harvest period, with "at least 50%" of the respondents associating peak leaf harvesting with May and September.

The ideal seasonal scenario for baobab leaf eaters, then, would be to harvest leaves for household use in the spring hunger season and through the annual rains and to preserve and store them for use and sale in the dry time from mid-autumn to the beginning of spring. The Dogon of Mali appear not to be able to achieve the ideal, and their tradition of baobab leaf eating seems to be an example of leaf preservation primarily to manage the abundance of leaves during the annual rains (Leach et al. 2011, p. 601):

> Unlike tamarind fruit, there are not enough baobab leaves to sell in large enough quantities to generate substantial income, and informants from all hamlets need to buy leaves to supplement their diet. Only one person (n = 36) said that his family was able to sell baobab leaves in a neighboring market town last year. Everyone else either purchased leaves or relied on their own trees.

The Baobab as a Hunger-Time Source of Fodder

The hunger-time value of the baobab is not only in the foods it provides for human beings but also for livestock. The *Lost Crops of Africa* (NRC 2006, p. 82) indicates that "Baobab leaves are among the livestock owner's favorite forages. They become vitally important at the beginning of the rainy season, a time of year when the old pasture has been eaten out and the new has yet to regrow. The tree's roots, when tapping into underground moisture, help generate an early flush of foliage that can make the difference in bridging this feed gap."

Are There Evergreen Baobabs?

The baobab is usually identified in the literature as a deciduous tree that produces leaves in early spring and sheds them in autumn in anticipation of the winter dry season. But, Gebauer and Luedeling (2013, p. 1590) reported encountering morphotypes that retained their leaves in the dry time. They did not, however, make a convincing case for recognizing what could be called evergreen baobabs. Granted, their fieldwork was done over a period of 11 years. They also provided a photograph with three leafless trees and one tree in full leaf. The problem is they do not provide an adequate conception of the seasonal year and baobab leaf phenology, nor do they indicate the precise time of the year when the photograph was taken.

For example, baobab leaf fall can occur from the mid-autumn of November to the beginning of spring in March. Normal leaf fall would be the early part of the dry time from November to the start of winter in December. Late leaf fall would be the early and mid-winter months of January and February. Very late leaf fall would be in March as the transition from the end of winter to the beginning of spring. At the height of the dry time from the end of winter to the early spring, all baobabs should have dropped their leaves except the very late defoliators of March. Wicken's experience in Eastern Africa did not support the evergreen thesis and is in keeping with the view presented here. He observed that trees "in Sudan show that some baobabs in favoured sites may produce leaves through most of the year apart from the height of the dry season" (Wickens and Lowe 2008, p. 164). It could be that the three leafless trees in the photograph were normal leaf shedders that dropped their leaves between November and December, while the fourth tree was a late or very late leaf shedder that dropped its leaves in January–February or in March. When all the necessary phases of baobab foliar seasonality are carefully considered, particularly changes in the dry time involving leaf senescence and fall, it is easy to understand why fully leaved and leafless baobabs would be found growing in the same locality without having to posit the existence of evergreen varieties of baobab.

What has also been reported in the literature, however, is that baobabs growing in uncharacteristically humid environments or under the favorable conditions of cultivation are late or very late defoliators (see Sidibé and Williams 2002; Wickens and Lowe 2008). Identifying evergreen baobabs would certainly be an advantage in selecting trees for leaf production. If the photograph Gebauer and Luedeling (2013, p. 1592) present was taken at the February–March height of the dry time, it would be much more likely that there are truly evergreen baobabs. However, this would have to involve either pre-rain leaf replacement in the early spring of April or the year-round production and shedding of leaves.

Culinary Uses of Baobab Leaves

As earlier noted, there are few reports of baobab leaf consumption in East and Southern Africa compared to West Africa and Sudan (Weinberger and Swai 2006; Maundu et al 1999). In West Africa, freshly harvested leaves are eaten as a cooked vegetable. Fresh and dried leaves are also used as a thickener, flavoring, and nutritive addition to everyday dishes categorized in the literature as condiments, relishes, sauces, soups, and stews (Chadare et al 2010). The appetizing use of baobab leaves complement the staple starches of the African diet. These include root crops such as yam and cassava and cereals such as millet, sorghum, maize, and rice. Wickens and Lowe (2008, p. 69) note that powdered leaves are known throughout much of West Africa as *lalo*, and they write:

> In The Gambia *soupa lalo* is prepared from fresh ground baobab leaves, chopped meat, smoked fish, onions, okra (*Abelmoschus esculentus*), fruit pulp of tulingo (*Parkia biglobosa*), hot peppers (*Capsicum annuum*) and palm oil (*Elaeis guineensis*). The meat and vegetables are boiled for 2h, then the baobab leaves and fish are added and the mixture is boiled with the palm oil until the liquid has completely evaporated. More fish and oil are added and the food is stewed for another hour. The dish is then eaten with *futo* (porridge made from millet, *Pennisetum glaucum*) or maize flour season with *lalo*, millet or rice.

Based on interviews with 253 informants in Benin, Chadare et al. (2008, p. 345) reported that baobab 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)." They also indicate that "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* is described as a sauce of dried baobab leaves plus *afitin*, "a traditional fermented condiment from African locust bean (*Parkia biglobosa* [Jac.] G. Don)." Baobab leaves are the main ingredient of a popular traditional dish of Northern Nigeria known as *Miyar Kuka* that is especially loved by the Hausa.

Baobab leaves are "rarely used" for food in East Africa according to Gebauer et al. (2016, p. 384) in their review of current information on the ecology, diversity, and utilization of the baobab in the region. Citing Muthoni and Nyamongo (2010), they note that "In Kenya, leaves are … reported to be used as vegetable in certain parts of the country … and are prepared like spinach or mixed and cooked with coarser vegetables like cassava leaves (Maundu et al. 2009)." Contrary to Muthoni and Nyamongo, however, Gebauer and colleagues found that "during the interviews of 64 farmers along a transect from Kibwezi to the coast, only two farmers mentioned a potential use of the leaves as vegetable." The perspective of Gebauer et al. might more accurately reflect the use of baobab leaves used as a hunger-only food in East Africa as discussed earlier for the Mbeere of Kenya (Riley and Brokensha 1988, p. 197). Gebauer et al. (2016, p. 384) also report that "baobab trees are also heavily pruned for fresh green leaves in Sudan" and that "In many parts of western Sudan in contrast [to East Africa], young tender leaves are mixed with peanuts and used as salad (Bella et al. 2002)." In Southern Africa, Sidibé and Williams (2002, p. 47) note that in Malawi, baobab leaves "are boiled with potash (Williamson 1975)" and that in "Zimbabwe, they provide fresh vegetables that are substituted for the commercially grown leafy vegetables such as cabbages and lettuce (Dovie forthcoming)."

Nutritiousness of Baobab Leaves

A number of studies identify baobab leaves as a good source of essential nutrients (e.g., Chadare et al. 2009; Nordeide et al. 1994). They are rich in vitamins, especially vitamins A and C; they contain protein; they contribute a wide spectrum of essential amino acids, including lysine, often limited in the starchy diet of people who consume little meat; and they are an excellent source of minerals, most notably iron and calcium (see Appendix). According to Sidibé and Williams (2002, p. 39), who cite Glew et al. (1997), "baobabs' leaves have a high content of iron compared to numerous other wild-gathered foods, and are a rich source of calcium." They go on to point out that "Iron is of especial importance because of the prevalence of iron-deficiency anaemia in savannah areas." The high concentration of vitamin A is identified as beneficial to pregnant women and children because it helps to prevent blindness and birth defects which can result from a deficiency of vitamin A. The highest levels of pro-vitamin A were found in young leaves (Sidibe et al. 1996). Current researchers have documented the considerable variation in the nutrient composition of baobab leaves. The Appendix provides a table showing the composition of baobab leaves with respect to the average, minimum, and maximum values for macronutrients, minerals, amino acids, and fatty acids. The table is adapted from Chadare (2010, pp. 27 and 32). Her complete table also includes similar information for baobab "pulp," "whole seeds," and "kernels."

Intensive Production of Baobab Leaves

The baobab is Africa's premier multipurpose tree whose uses include the increasing commercial value of its various parts. The tree is now highlighted in the literature for its potential to provide significant benefits to the people of the African savanna, including improved nutrition and food security, more sustainable agricultural practices, and rural development (Buchmann et al. 2010; Kalinganire et al. 2007; Schreckenberg et al. 2006). For example, the International Centre for Research in Agroforestry and its partners in West Africa have developed a procedure for growing young baobabs as a market garden crop valued for their leaves. Citing Niang (2003), Wickens and Lowe (2008, p. 240) write:

> In Mali, farmers who raise baobab seedlings for their leaves, sow the seeds in small, 16-m^2 plots. The plots receive animal manure, are watered morning and evening, and weeded when necessary. After 4 weeks the tender leaves are ready for harvesting, a process that can be repeated every 2 weeks throughout the year, with yields of up to 3 kg per picking.

Ibrahim et al. (2014, p. 301) collected and germinated seeds from 36 populations of baobabs in the northeast and west of Nigeria, and seedling leaves were assessed at 16 weeks after sowing for the "nutritional traits such as carbohydrate, crude protein, fat, moisture content, fiber and ash." They report "Highly significant differences were observed in all the traits assessed showing that high variability exists among the populations." They found that their results were "in conformity with the works of Sidibe et al. (1996) who noted that variability of vitamin C content exist in the pulp of *A. digitata* fruits among the trees assessed in Mali." Their results were also in conformity with the work of Sidibe et al. (1998) who "recorded difference in vitamin A content and other minerals in the leaves of different trees of baobab."

Given the documented variability of the species and the palatable baobab leaves being more associated with different locally recognized foliar morphotypes, baobab propagation by cutting, grafting, budding, tissue culture, and micropropagation will no doubt be the most important means of growing suitable saplings and small trees as a vegetable crop (Assogbadjo et al. 2008; Gebauer et al. 2016, p. 393; Maranz et al. 2008). In the face of human reproductive success in Africa, as elsewhere in the rest of the world, this kind of market garden cultivation is yet another step in the ongoing intensification of the human use of the baobab.

The Consumption of Baobab Leaves Outside of Africa

A survey of baobabs in Florida, the Caribbean, and Brazil has not recorded a single instance of baobab leaves being eaten in the Americas. According to Sidibé and Williams (2002, p. 47), baobab leaves are not eaten in India. But, Wickens and Lowe (2008, p. 70), who cite Watt (1885), reported that "the fishermen of Gujarat eat baobab leaves with their food and consider them 'cooling'."

Considerations for Future Research

Future research will, no doubt, shed light on the baobab's status as one of Africa's important leafy vegetable trees with deep connections to our evolutionary past as hominins of the African savanna. For example, baobab management strategies associated with the use of the leaves for both food and fodder deserve more attention, especially in accounting for the presence of pollarded and unpollarded baobabs in the same environment. The same is true of the influence of seasonal hunger on the eating of baobab leaves in the spring. There is still much we do not know about cases where the baobab leaves are a hunger-only food. The kinds of dishes in which baobab leaves are the main ingredient or a contributing ingredient certainly deserve further consideration. However, given what is already known about the food value of the leaves, the cultivation of young baobabs as a vegetable crop is an important initiative. In the interest of a more comprehensive view, baobab leaf eating in India and elsewhere deserves greater attention. Finally, it is curious that tree shape is not among the 21 criteria of folk morphotyping. One wonders if it is actually the case that tree shape is not used as a criterion or if the significance of tree shape as a criterion has not been captured in the research that has been done so far. In the context of this paper, the most important question would be, of course, if there is a correlation between tree shape and the preferred qualities of baobab leaves, fruit, and bark. Even if tree shape should prove not to be significant for local morphotyping, it is a relevant criterion for documenting baobab variation and is worthy of consideration (see Gebauer et al. 2016, pp. 386–387, and Wickens 1982).

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APPENDIX. Composition of baobab leaves

	Average	Min	Max	References
Macronutrients				
Water (%)	7.3	6.4	8.2	(Lockett and Grivetti 2000; Nordeide et al. 1996)
Energy (kJ/100 g dw)	1380	1180	1581	(Becker 1983; Nordeide et al. 1996)
Carbohydrates (g/100 g dw)	56.4	40.2	69.0	(Becker 1983; Lockett and Grivetti 2000; Nordeide et al. 1996)
Crude protein (g/100 g dw)	12.8	10.1	15.0	(Becker 1983; Lockett and Grivetti 2000; Nordeide et al. 1996)
Crude lipids (g/100 g dw)	4.9	4.0	6.3	(Becker 1983; Lockett and Grivetti 2000; Nordeide et al. 1996)
Fiber (g/100 g dw)	19.2	11.0	27.5	(Becker 1983; Lockett and Grivetti 2000)
Ash (g/100 g dw)	13.7	11.5	15.9	(Lockett and Grivetti 2000; Nordeide et al. 1996)
Minerals (mg/100 g dw)				
Ca	1582	307	2640	(Barminas et al. 1998; Boukari et al. 2001; Glew et al. 1997; Lockett and Grivetti 2000; Nordeide et al. 1996; Oomen and Grubben 1978; Prentice et al. 1993; Sena et al. 1998; Yazzie et al. 1994)
Cu	0.8	0.3	1.6	(Barminas et al. 1998; Glew et al. 1997; Lockett and Grivetti 2000; Smith et al. 1996)
Fe	65.3	1.2	254	(Barminas et al. 1998; Glew et al. 1997; Lockett and Grivetti 2000; Nordeide et al. 1996; Sena et al. 1998; Smith et al. 1996; Yazzie et al. 1994)
K	531	140	1080	(Sena et al. 1998; Yazzie et al. 1994)

(Continued)

	Average	Min	Max	References
Mg	339	93.6	549	(Barminas et al. 1998; Glew et al. 1997; Lockett and Grivetti 2000; Sena et al. 1998; Smith et al. 1996; Yazzie et al. 1994)
Mn	6.0	1.9	9.8	(Glew et al. 1997; Lockett and Grivetti 2000; Sena et al. 1998; Smith et al. 1996; Yazzie et al. 1994)
Na	83.4	3.8	163	(Glew et al. 1997; Sena et al. 1998)
P	274	115	875	(Barminas et al. 1998; Glew et al. 1997; Lockett and Grivetti 2000; Prentice et al. 1993; Sena et al. 1998; Yazzie et al. 1994)
Zn	4.1	0.7	22.4	(Barminas et al. 1998; Glew et al. 1997; Lockett and Grivetti 2000; Nordeide et al. 1996; Sena et al. 1998; Smith et al. 1996; Yazzie et al. 1994)
Amino acids (g/100 g proteins)				
Alanine	6.4	5.8	7.5	(Glew et al. 1997; Sena et al. 1998; Yazzie et al. 1994)
Arginine	7.7	6.4	11.1	(Glew et al. 1997; Sena et al. 1998; Yazzie et al. 1994)
Aspartic acid	10.6	8.1	12.5	(Glew et al. 1997; Sena et al. 1998; Yazzie et al. 1994)
Cysteic acid	2.3	1.5	3.9	(Glew et al. 1997; Sena et al. 1998; Yazzie et al. 1994)
Glutamic acid	10.5	7.4	12.9	(Glew et al. 1997; Sena et al. 1998; Yazzie et al. 1994)
Glycine	5.5	4.8	6.7	(Glew et al. 1997; Sena et al. 1998; Yazzie et al. 1994)
Histidine	2.1	1.7	2.6	(Glew et al. 1997; Nordeide et al. 1996; Sena et al. 1998; Yazzie et al. 1994)
Isoleucine	5.7	4.7	7.5	(Yazzie et al. 1994; Nordeide et al. 1996; Glew et al. 1997; Sena et al. 1998)
Leucine	8.3	7.2	9.7	(Glew et al. 1997; Nordeide et al. 1996; Sena et al. 1998; Yazzie et al. 1994)
Lysine	5.6	4.7	6.7	(Yazzie et al. 1994; Nordeide et al. 1996; Glew et al. 1997; Sena et al. 1998)
Methionine	1.7	0.9	2.6	(Yazzie et al. 1994; Nordeide et al. 1996; Glew et al. 1997; Sena et al. 1998)
Phenylalanine	5.5	4.8	6.5	(Glew et al. 1997; Nordeide et al. 1996; Sena et al. 1998; Yazzie et al. 1994)
Proline	5.6	4.9	6.6	(Glew et al. 1997; Sena et al. 1998; Yazzie et al. 1994)
Serine	4.3	3.6	5.6	(Glew et al. 1997; Sena et al. 1998; Yazzie et al. 1994)
Threonine	3.9	3.4	4.8	(Glew et al. 1997; Nordeide et al. 1996; Sena et al. 1998; Yazzie et al. 1994)
Tryptophan	1.9	1.0	3.0	(Glew et al. 1997; Nordeide et al. 1996; Sena et al. 1998; Yazzie et al. 1994)
Tyrosine	4.0	3.4	5.1	(Glew et al. 1997; Nordeide et al. 1996; Sena et al. 1998; Yazzie et al. 1994)
Valine	6.0	5.2	7.0	(Glew et al. 1997; Nordeide et al. 1996; Sena et al. 1998; Yazzie et al. 1994)
Fatty acids (mg/g dw)				
C:8 (caprylic)	0.01	0.01	0.01	(Sena et al. 1998)
C:12 (lauric)	0.09	0.09	0.09	(Sena et al. 1998)
C14:0 (myristic)	0.37	0.37	0.37	(Sena et al. 1998)
C16:0 (palmitic)	1.72	0.24	3.2	(Glew et al. 1997; Sena et al. 1998)
C16:1 (palmitoleic)	0.11	0.01	0.21	(Glew et al. 1997; Sena et al. 1998)
C18:1 (oleic)	0.22	0.06	0.39	(Glew et al. 1997; Sena et al. 1998)
C18:2 (linoleic)	0.55	0.1	1	(Glew et al. 1997; Sena et al. 1998)
C20:0 (arachidic)	0.15	0.15	0.15	(Sena et al. 1998)
C20:1 (gadoleic)	–	–	–	

Adapted with permission from a table by Chadare (2010, pp. 27–32) in which comparable data is also presented for the fruit pulp, whole seeds, and kernels