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Status of production and use of *Artocarpus altilis* and *Artocarpus camansi* in Benin Republic

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Abstract

The fruits of *Artocarpus altilis* and *Artocarpus camans* are non-timber forest products with a great nutritional and medicinal potential but still underused in Benin. This study was initiated to take stock of the production and use of the two species. A survey was carried out among 300 people who owned trees of the species in South Benin. The study was conducted using a cluster sampling technique. At the end of the study, two varieties were distinguished; these are the round shape and the oval/oblong shape for *A. camansi* species whereas *A altilis* presented a round, oval/oblong shape with yellow pulp and round, oval/oblong shape with white pulp. The number of trees or plantation per house varies between 1 to 1000 for *A. altilis* and 1 to 8 for *A camansi*. The median number of fruits/tree peryear is 260 for *A. altilis* and 205 for *A. camansi*. Both fruits are available all year round and abundant in the rainy season. Among the people surveyed, 78.3% are owners of *Artocarpus altilis* trees, 15.0% of *Artocarpus camansi* and 6.7% of both species. The organs of the two trees are used in several fields, namely food, traditional medicine, energy and crafts. However, conservation problems are noted in the study area and the work on fruit valorization of the fruit of the two species can contribute to the food and nutritional security of local populations.

Keywords: Artocarpus; Fruit; valorization; Food security

1. Introduction

Non-timber forest products (NTFP) are useful substances, materials or goods derived from forests that do not require the felling of trees [1]. They contribute to the realization of the right to food security and good health in two ways: through their direct consumption in rural and urban households, adding proteins, fats, minerals and vitamins to basic foods and through their trade which creates income that enable people to buy food and medicine and to have access to health care, clean water and sanitation facilities [2]. Breadfruit (*Artocarpus altilis Fosberg*) and brednut (*Artocarpus camansi Blanco*) are among these non-timber forest products, both species belonging to the Moraceae family. *Artocarpus camansi* originated in New Guinea, the Molusca (Indonesia) and the Philippines around 3000 years ago. The species *A. camansi* is the ancestral form of the species *A. altilis* which was first domesticated in the western Pacific and spread to the tropics by migratory Polynesians [3,4,5]. Both species are available worldwide [3] and in Benin [6,7] and represent important trees for the population due to the nutritional and medicinal virtues of the plant's organs. The fruit of the *Artocarpus altilis* species has a high nutritional value with a complex carbohydrate composition and a low fatty acid content. It is a good source of essential amino acids such as leucine, isoleucine and valine [8]. It constitutes a solution for improving global food security and helps reduce the rate of diabetes. Its flour is gluten-free and has a low

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glycemic index. The skin of the fruit contains an antioxidant better than synthetic antioxidants that can extend the shelf life of food products by preventing the formation of peroxide in the product containing fat and oil [9].

As for the *Artocarpus camansi* species, its seeds contain very beneficial nutrients for body such as omega-3 fatty acid which is able to easily control and maintain healthy and balanced cholesterol levels, strengthen bone construction and promote mental health by reducing the risk of bipolar problems [10]. The plant has pharmacological properties and is widely used in traditional medicine to treat several diseases. In Benin the fruits of both species constitute a food source for populations in the south. However, despite all the benefits these two species offer, they still remain underutilized in Benin Republic. Information relating to the production and processing of *Artocarpus altilis* and *Artocarpus camansi* in Benin is little known. This study was carried out to assess the status of production and use of the fruits of *Artocarpus altilis* and *Artocarpus camansi* in Benin, in order to enhance local resources for the food and nutritional security of the populations.

2. Material and methods

2.1. Study zone

Our study was carried out in five (5) communes of South Benin (Figure 1), notably three (3) communes of the Ouémé department (Adjohoun, Avrankou and Dangbo) and two (2) communes of the Plateau department (Adja-Ouèrè and Pobè). These municipalities were chosen because of the high availability of both species in these areas [7, 11]**.** Figure 1 shows the map of the study area.

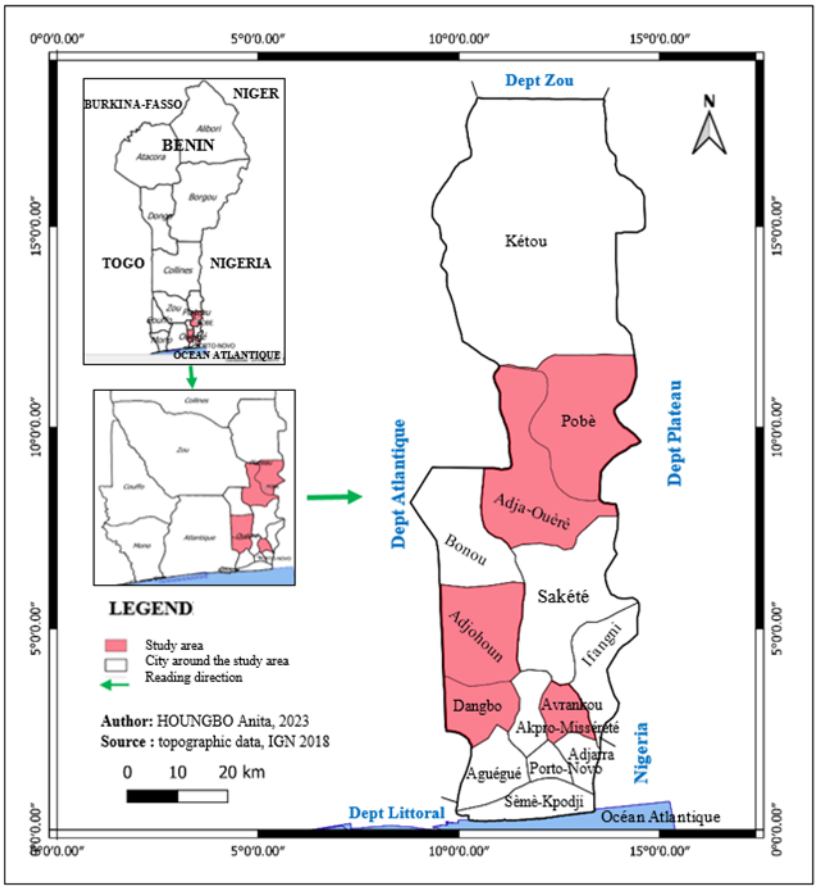

Figure 1 Map of the survey area

2.2. Sampling technique

The study was conducted using the cluster sampling technique, as recommended by the WHO for monitoring risk factors for non-communicable diseases such as consumption of fruits and vegetables [12]**.** The basis of the survey was

constituted by the list of villages and administrative districts of the different communes established with their respective populations.

2.3. Sample size

The sample size was calculated by the Schwartz formula

$$n = \frac{k * Z_{\alpha}^2 * p * q}{i^2}$$

With :

n: sample size;
α : the accepted risk of error α = 0.05;
Z_{α} : the difference reduced to the agreed risk α = 1.96;
p: proportion of informants using NTFPs; p= 0.90 [13] ;
q = 1-p;
k = cluster effect = 2;
i: desired precision for our results i = 0.05

$$\mathbf{n} = \frac{\mathbf{2} * (\mathbf{1.96})^{\mathbf{2}} * \mathbf{0,90}\ (\mathbf{1} - \mathbf{0,90})}{(\mathbf{0.05})^{\mathbf{2}}} \text{ with } n = 277$$

The size of each cluster was then 9.2 (277/30), approximately equal to 10 individuals per cluster. This, redefined the sample size to 300 subjects (30*10) (Table I). The household in each village or district were chosen at random by the turned pen method. The selected concessions had at least one tree of both species.

2.4. Collection of data

Data were collected by interview in face-to-face interviewer-respondent mode using a digital questionnaire on Android devices using Kobocollect software. Data was collected on the age of the respondents, gender, ethnicity, literacy or not, profession, number of trees per house/plantation , number of fruits per tree/year, the varieties, the names of the fruit and the tree in the local language, the propagation mechanisms, the types of treatments, year of production of the first fruits, season of availability, forms of consumption, uses of the organs of the plant and the preservation of the fruit.

2.5. Statistical analysis of data

The data collected during the survey were processed and analyzed with R 3.6.0 software. Qualitative variables are presented as percentages and quantitative variables as mean (with standard deviation) and median (with their interquartile ranges) depending on the normality or not of the distribution. This check of normality was carried out by the Shapiro Wilk test. Multiple correspondence analyzes were performed to evaluate the effect of ethnic group on the form of use of *Artocarpus altilis* and *Artocarpus camansi.*

3. Results and discussion

3.1. Sociodemographic, socio-cultural and professional characteristics

Seven ethnic groups were surveyed. The Wéménou and the Tolinou were represented respectively by 38.0% and 23.7% of the respondents. “Non-literate” and “literate” respondents are represented in a proportion of 48.3% compared to 51.7% who have at least completed primary school. Concerning profession, one in two (50.3%) was a farmer. Respondents married or living as a couple were 65.7%. Of the 300 people surveyed during our study; 65% were male (Table I). The median age was 40 years with an interquartile range of [32-51] years (TableI). The extreme ages varied between 18 and 83 years. The analysis of socio-demographic characteristics (Tables I and II) reveals that there is a high rate of men 65.0%, and a high rate of young people (under 50 years old represented by 72.7%) within the surveyed population who own trees of both species. These results could reflect that men and young people are more involved in agriculture and have knowledge on the cultivation of both trees. Previous studies have mentioned that adult men and old men hold more knowledge about the species *A. altilis* [11]**.** The high rate of young people cultivating the tree of both species recorded during our study could reflect the existence of a transmission of knowledge relating to the species *A. altilis* and *A. camansi* over the generations. Details on professional characteristics (Table II) reveal a diversity of professions with a significant presence of farmers (50.3%), highlighting the importance of agriculture in this study area.

The different ethnic groups identified who practice tree cultivation are similar to the ethnic groups using the fruit of *Artocarpus altilis* cited by the results of previous studies [7].

Table I Sociodemographic characteristics of respondents the study on two species of *Artocarpus altilis* ; South from Benin; 2023; (N=300)

	Number (n)	**Frequency (%)**
Sex		
Male	195	65.0
Female	105	35.0
Age (year)		
<30	51	17.0
[30-40[	89	29.7
[40-50[	78	26.0
[50-60[	34	11.3
[60-70[	27	9.0
≥70	21	7.0
Marital status		
Divorcee)	13	4.3
Widower	17	5.7
Bachelor	73	24.3
Married/Common union	197	65.7

Table 2 Socio-cultural and professional characteristics of the respondents in the study relating to the two species; Southern Benin; 2023 (N=300)

	Number (n)	**Frequency (%)**
Ethnic group		
Idatcha	2	0.7
Fon	17	5.7
Nagot	25	8.3
Goun	34	11.3
Yoruba	37	12.3
Tori	71	23.7
Wéménou	114	38.0
Educational level		
Not literate	112	37.3
Literate	33	11.0
Primary	80	26.7
Secondary	54	18.0

Superior	21	7.0
Occupation		
Trader/reseller	86	28.7
Farmer	151	50.3
Others	63	21.0

3.2. Name of the fruit and the tree according to ethnic groups

The names of the two species (Table III) with their fruits vary depending on the ethnic groups.

Table 3 Different names of the two species with their fruits

Ethnicities	***Artocarpus altilis***		***Artocarpus camansi***	
	Tree name	**Fruit name**	**Tree name**	**Fruit name**
Idatcha, Yoruba and Nago	Igui-béréfutu	Béréfutu; Icthu-éyibo	Igui-èkpa-rubu	Ekpa-rubu
Tori, Wéménou, Goun and Fon	Tevitin, Belefututin	Tévi-agaton, Belefuttu	Azintin	Azin-agaton

3.3. Fruit production of both species

3.3.1. Tree and fruit of Artocarpus altilis and/or Artocarpus camansi per house/plantation

Of the 300 people surveyed, 78.3% had *Artocarpus altilis* , 15.0% *Artocarpus camansi* and 6.7% both. In total, in houses and plantations, the owners of *Artocarpus altilis* represented 85.0% and those of *Artocarpus camansi* 21.7% (Table IV).

Table 4 Number of people owning the *Artocarpus altilis* tree and/or *Artocarpus camansi* per house/plantation in southern Benin

	Number (n)	**Frequency (%)**
Artocarpus altilis and *Artocarpus camansi*	2 0	6.7
Artocarpus camansi	45	15.0
Artocarpus altilis	23 5	7 8.3

Table 5 Trees per concession/plantation and fruits per tree/year in South Benin; 2023 (N=300)

	Artocarpus altilis		***Artocarpus camansi***	
	Number of trees	**Number of fruits**	**Number of trees**	**Number of fruits**
Median	2	260	2	205
Interquartile range	[1-3]	[130-475]	[1-2]	[110-250]
Minimum-Maximum	1-1000	105-120000	1-8	100-850

At the level of houses and plantations, the number of plants varied between 1 and 1000 with a median number of plants of 2 and an interquartile range of [1-3]. In houses or in plantations, 1 to 8 *Artocarpus camansi trees* were planted. The median *Artocarpus camansi* tree number was 2 with an interquartile range of [1-2]. The number of fruits produced per year per concession was 105 to 120,000 with a median production of 260 (Table V). The interquartile range was [130-475]. Compared to *Artocarpus camansi* the number of fruits produced was 100 to 850 with a median production of 205 and an interquartile range was [110-250] (Table V). The number of trees and the quantity of fruits per year per concession/plantation of the species *Artocarpus camansi* is much lower compared to *Artocarpus altilis* (Tables IV and

V). This low cultivation rate of the species *A. camansi* is justified by the little-known food value of the fruit, the low supply of the fruit by traders unlike the species *A. altilis* where demand greatly exceeds supply.

3.4. Year of fruit production and season of availability

The average age of first fruit production of *Artocarpus altilis* and *Artocarpus camansi* was 4.2±1.3 years and 4.8±0.9 years, respectively. The species *Artocarpus altilis* and *Artocarpus camansi* reach their maximum production from 5.8±1.2 years and 6.1±0.9 years respectively (Table VI). This result obtained in terms of the average age of production of the first fruits for *Artocarpus altilis* corroborates that obtained in Hawaii. In this country *A. altilis* gave its first fruits after 4 years [14]. Another study revealed that the first fruits are obtained between 3 and 4 years of age [15]. We could deduce that *A. alitis* has similar production potential from one region to another, and could thus be planted in other regions of Benin, but the species is not yet present in order to provide fruits for food. Concerning the species *A. camansi,* the number of years of production of the first fruits was lower than those of other studies which indicated that the production of fruits per tree was 8 to 10 years [16,17]. This slightly lower number of years of fruit production per tree obtained is a definite advantage for ensuring the food security of populations more quickly and could for this purpose be exploited.

The fruits of both trees are available throughout the year and abundant during the rainy season (Table VII). The results obtained are confirmed by previous studies which highlighted that the availability of the fruit covered the whole year and was abundant in the rainy season [7,18,19]. Availability throughout the year can be crucial information for consumption and marketing planning.

Table 6 Year of fruit production; communes of South Benin; 2023 (N=300)

	Artocarpus altilis		***Artocarpus camansi***	
	average	**standard deviation**	**average**	**standard deviation**
Production of first fruits (year)	4.2	1.3	3.8	0.9
Maximum fruit production (year)	5.8	1.2	6.1	0.9

Table 7 Season of availability and high production of fruits; South Benin; 2023 (N=300)

	Artocarpus altilis	***Artocarpus camansi***
	not(%)	**not(%)**
Season of fruit availability		
Dry season	29(11.4)	3(4,6)
Rainy season	38(14.9)	10(15.4)
All year	119(73.7)	52(80.0)
Peak fruit production season		
Dry season	13(5.1)	4(6,2)
Rainy season	242(94.9)	61(93.8)

3.5. Mechanism of spread and type of treatment

The propagation mechanisms of *Artocarpus altilis* (Figure 1 and 2) identified were root shoot (86.4%) and cutting (55.7%). For *Artocarpus camansi*, the propagation mechanisms were seeds (30.7%), root shoots (81.5%) and cutting (27.7%).

According to the respondents, trees of both species were grown in houses, baffons and river banks. Watering (31.4%) and cow dung (9.4%) were used by the owners as treatment to grow *Artocarpus altilis* plants. Concerning *Artocarpus camansi*, watering and fertilizer were used by 29.2% and 10.8% respectively. These results show that the humid environment is favorable to the development of both species, which was consistent with the result of a previous study

[10]. The diversity of propagation methods of the two Artocarpus spieces is consistent with previous work [4, 15, 5] which also identified seeds, root shoots and cuttings as commonly used means. The propagation mechanisms were similar for both species with the exception of the seed in *Artocarpus camansi.*

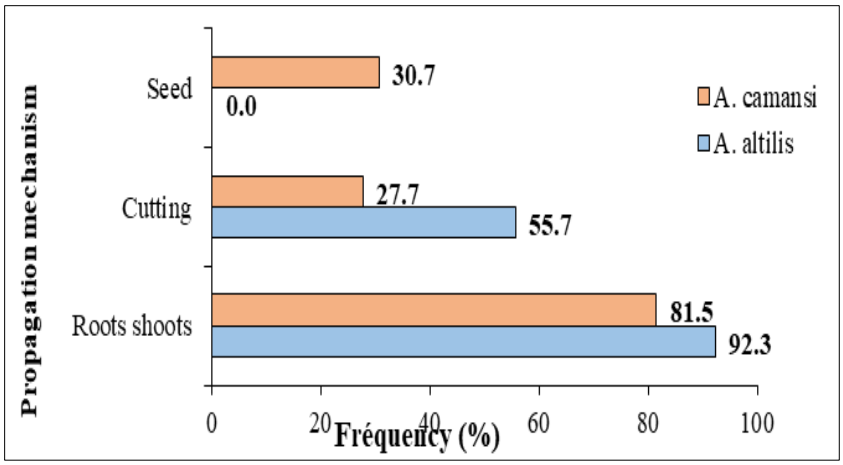

Figure 2 Propagation mechanism of *Artocarpus altilis* and *Artocarpus camansi* in Southern Benin

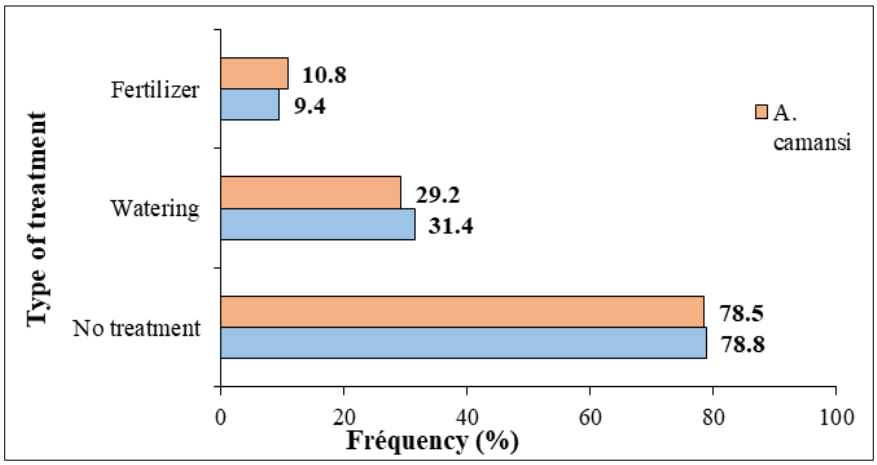

Figure 3 Type of treatment of *Artocarpus altilis* and *Artocarpus camansi* in southern Benin

3.6. Fruit varieties of both species

Fruit varieties are differentiated based on the shape of the fruits. There are two forms of fruit. These include the round and oval/oblong (100%) form of *Artocarpus altilis* and *Artocarpus camansi*. The color of the pulp of *Artocarpus altilis* is yellow when it matures (5.5%) (Table VIII).

Table II Varieties of fruits of *Artocarpus altilis* ; Southern Benin; 2023 (N=255)

	Number (n)	**Frequency (%)**
Artocarpus altilis		
Round and oval/oblong shape with yellow pulp	0	0.0
Round and oval/oblong shape with white pulp	2 55	100.0
Artocarpus camansi		
Round and oval/oblong shape with yellow pulp	0	0.0
Round and oval/oblong shape with white pulp	65	100.0

3.7. Food, medicinal and other uses of the organs of both species

According to the respondents, the fruit and leaves of the two species are used for human and animal food. The root, bark, leaves and latex are used for the treatment of certain symptoms/diseases (Table IX and X)

Both species have medicinal uses in common (Table X). This can be explained by the non-random theory of Moerman (1979) which shows that species belonging to the same family, therefore sharing certain characteristics inherited from common ancestors, are likely to have similar uses. This corroborates with previous studies that have highlighted that the species *Artocarpus camansi* probably has therapeutic properties similar to *Artocarpus altilis* [20]. The results revealing the use of the trees for food and health purposes correspond to previous studies highlighting the food and medicinal properties of the species Artocarpus. Yellowed or deteriorated leaves are boiled and used to relieve hypertension and control diabetes [21]. Leaf and stem bark extracts of *A. altilis*, and *A. camansi*, have also been reported to have effective antimalarial activity against *P. falciparum* and *P. berghei* [22]. The trunk and branches of the *A. altilis* and *A. camansi* tree are often used in house construction and also as firewood [11, 4, 23].

Table III Food uses of *Artocarpus altilis* and *Artocarpus camansi* ; Southern Benin; 2023

			Artocarpus altilis	***Artocarpus camansi***
			Number (frequency %)	**Number (frequency %)**
Fruit	Pulp	Human food	255(100)	4(6.2)
		Animal feed	-	-
	Seed	Human food	-	61(93.8)
		Animal feed	-	-
	Peels	Human food	-	-
		Animal feed	44(17.2)	3(4,6)
Leaves		Human food	-	-
		Animal feed	67(26.3)	7(10.8)

Table IV Medicinal and other uses of *Artocarpus altilis* and *Artocarpus camansi* ; Southern Benin; 2023

		Artocarpus altilis	***Artocarpus camansi***
		Number (frequency %)	**Number (frequency %)**
Leaves (infusion)	Hypertension	8(3.1)	-
	Diabetes	4(1.6)	-
	Malaria	27(10.6)	1(1.5)
	Typhoid fever	20(7.8)	4(6.2)
Root (infusion)	Gastric disorders	67(26.3)	11(16.9)
	Anti-asthmatic	18(7.1)	-
	Tooth pain	26(10.2)	2(3,1)
	Anemia	49(19.2)	8(12.3)
Latex (Directly applied)	Incurable wounds	40(15.7)	2(3.1)
Bark (infusion)	Bathing newborns	80(31.4)	7(10.8)
	Scabies	6(2.4)	1(1.5)
	Measles	10(3.9)	2(3.1)

Drink (Directly used)	Firewood	67.0	33(50.7)
	Formwork wood	26(10.2)	2(3,1)
	Handicrafts	62(24.3)	9(13.8)

3.8. Forms of consumption

The fruit pulp of *Artocarpus altilis* was eaten cooked in several forms. These shapes were also appreciated (Figure 4, a). The fruits of *Artocarpus camansi* were consumed in 3 forms (Figure 4, b). The species *Artocarpus altilis* was consumed in association with bean + frying + oil, bean + oil, oil in 43.3%, 22.9%, 14.9% respectively (Figure 4, c). The species *Artocarpus camansi* was consumed in association with frying + gari and bean + oil by 68.9% and 20.9% respectively (Figure 4, d). The different forms of consumption of the fruits obtained are similar to the forms mentioned by other authors. The pulp of the fruit of altilis is consumed fried, boiled, steamed, baked or roasted. It is used in several traditional meals such as porridge, fritters, flour, snacks, pounded pulp, stews or in soups.....etc [24,8,16,7, 23]. Camansi seeds are a very tasty nutritious snack in the Caribbean and Africa.....etc [25,26]. Regarding the pulp of the camansi species, it is consumed in other forms. It is used to make milk-based drinks. It is also thinly sliced and boiled as a vegetable in soups or stews [27,26].

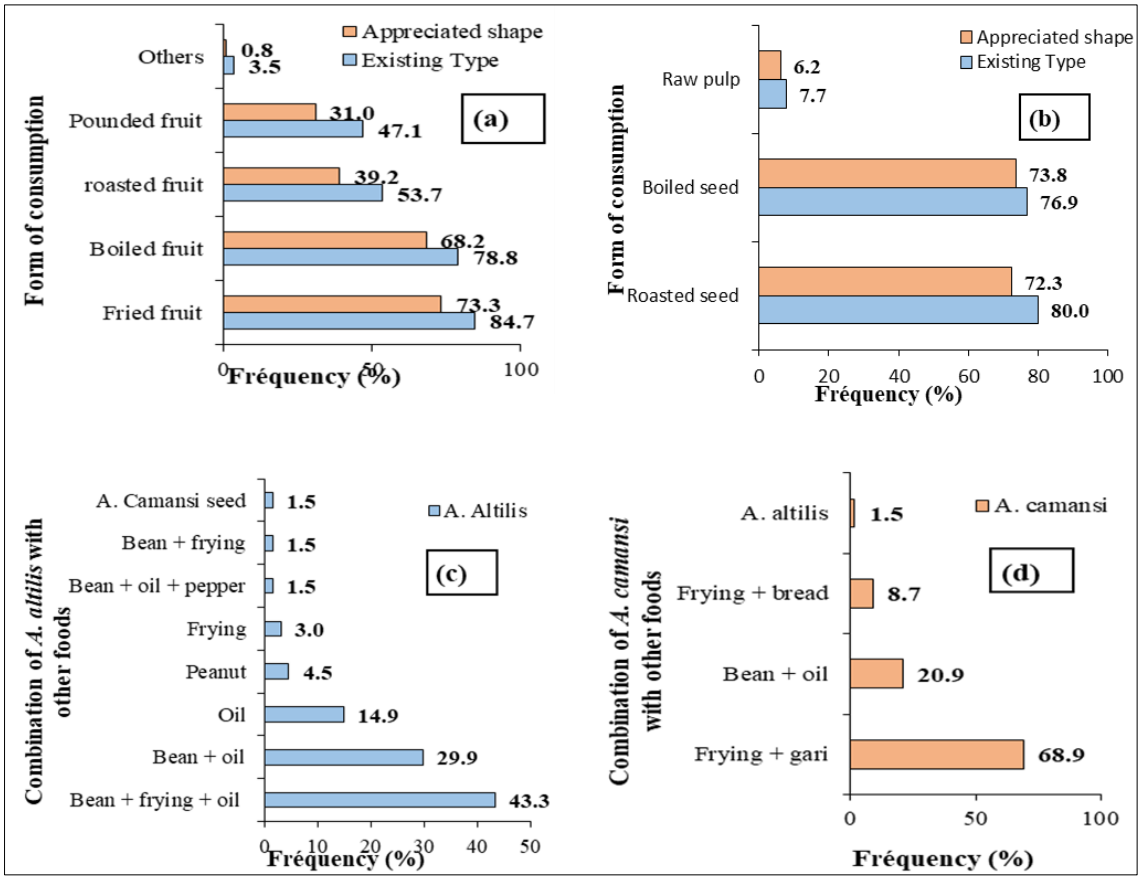

Figure 4 Form of consumption of fruits of *A. altilis* (a) and *A. camansi* (b), and foods consumed in association with *A. altilis* (c) and *A. camansi* (d)

3.9. Methods, duration and problems encountered during conservation

Many methods of conservation of *Artocarpus altilis* were noted. These were open air storage 85.5%; in water (9.8%) and in the refrigerator (4.7%). Concerning the conservation of *Artocarpus altilis fruits*, 71.4% managed to preserve the fruits for a period of 4 to 6 days.

Two different conservation methods were used for *Artocarpus camansi* by the respondents. These were conservation in the open air (89.2%) and in water (10.8%). The shelf life of *Artocarpus camansi fruit* was 2-4 days according to 92.3% of respondents (Table XI).

Preserving the fruits of *Artocarpus altilis* causes some problems. Among the latter we have fruit rotting (89.8%), taste change (9.4%). Whereas preserving the fruits of *Artocarpus camansi* several problems are encountered. These are fruit rotting (81.5%) and taste change (7.7%). Table XI presents informations about this conservation problems.

The different conservation methods obtained are in agreement with the results of other authors [7]**.** Commonly encountered problems, such as rotting and taste change, highlight the practical challenges of preserving these fruits. These conservation methods and the problems encountered in this process have also been observed in previous studies [28,29,30].

Table V Methods, duration and problems encountered during the conservation of the fruits of *Artocarpus altilis* and *Artocarpus camansi* ; Southern Benin; 2023 (N=300)

	Artocarpus altilis	***Artocarpus camansi***
	Not (%)	**Not (%)**
Conservation Methods		
In the refrigerator	12(4.7)	0(0.0)
In water	25(9.8)	7(10.8)
Outdoors	218(85.5)	58(89.2)
Fruit shelf life (days)		
[2-4[	51(20.0)	60(92.3)
[4-6[	182(71.4)	5(7.7)
[6-8[	22(8.6)	0(0.0)
Problems encountered during conservation		
Germination of the seed	-	4(6.2)
Change in taste	24(9.4)	5(7.7)
Rotten fruit	229(89.8)	53(81.5)
Others	2(0.8)	3(4.6)

3.10. Multiple correspondence analysis

The analysis of multiple correspondences carried out respectively on the forms of consumption of *Artocarpus altilis* and *Artocarpus camansi* according to ethnic groups show that the first two axes retain 50.40% and 83.91% of the information collected (figure 5 and 6). The information contained at the level of the two axes is sufficient at the level of the multiple correspondence analyzes to interpret the results. By considering the other axes we have less information to explain this variability, which means that these two axes are sufficient to interpret our results.

Rosted and boiled forms characterize the consumption of *Artocarpus altilis fruits* among the Wémènou, Toli and Yoruba while the Goun, Fon, Nagot and Idaatcha prefer pounded and fried. The Wémènou, Toli and Yoruba are therefore opposed to the Goun, Fon, Nagot and Idaatcha due to their consumption at the level of *Artocarpus altilis* (Figure 5).

The Wémènou and the Toli are characterized by the consumption of *Artocarpus camansi seeds* in roasted and boiled forms (Figure 9).

The Wémènou, Toli and Yoruba assimilate *Artocarpus altilis* to yam tubers as evidenced by the numerous names that the population gives it in these localities. This leads to the fact that the forms of yam consumption are transferred to *Artocarpus altilis* which could justify the braised and boiled forms [11]. In Nigeria, *Artocarpus altilis* was largely consumed in pounded and fried form by the Nagots [31]. The latter transferred them to Nagot du Bénin because of the proximity and familiarity linking them. The cohabitation of the Nagots with the Gouns, the Fons and Idaatchas led to the transfer of culinary habits. The Wémènou and the Tolinou are isolated from other ethnic groups by consuming the seeds of *Artocarpus camansi in* roasted and boiled form. The common name of *Artocarpus camansi* fact that it is considered the peanut hence the roasted and boiled forms of consumption.

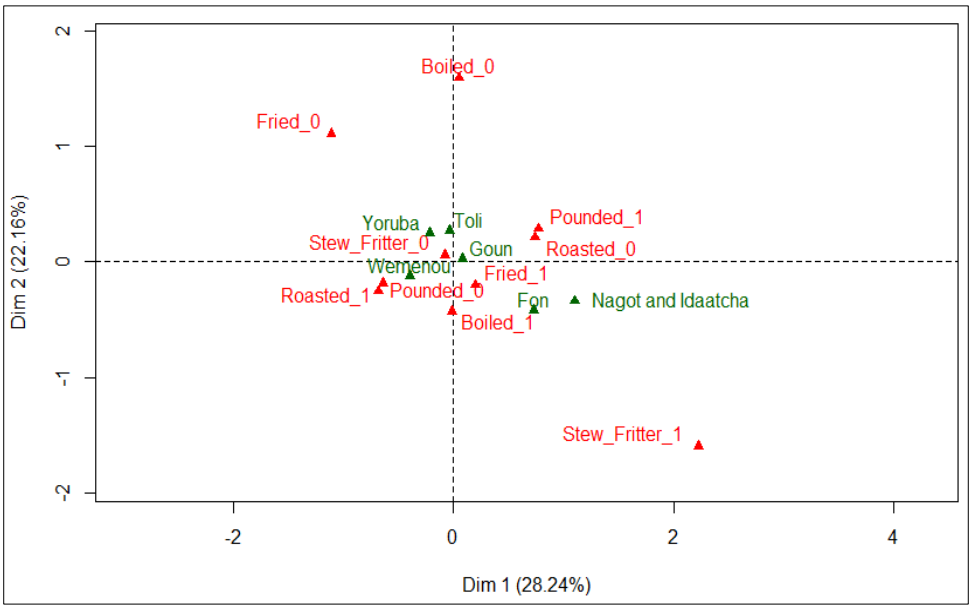

Figure 5 Multiple correspondence analysis on the distribution of forms of use of *Artocarpus altilis* according to ethnic groups ; 2023; (N=255)

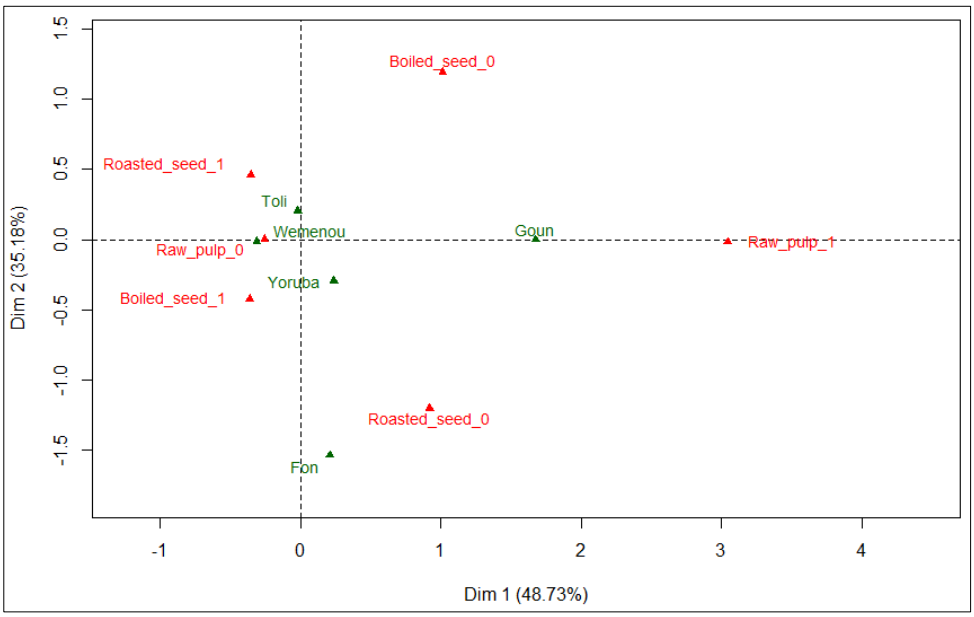

Figure 6 Multiple correspondence analysis on the distribution of uses of *Artocarpus camansi* according to ethnic groups

4. Conclusion

The study showed that *A. Altilis* and *A. camansi* constitute a food source for the populations of the study area. An in-depth study on the organization of fruit production of both species will help design appropriate strategies that would improve the availability of fruits, their marketing and their contributions to food security in Benin. Among these strategies to be put in place we can cite raising farmers' awareness of the economic and nutritional importance of the fruits of the two species, encouraging farmers to cultivate plants of both species, strengthening the capacities of farmers in terms of production techniques for plants of the two species, the development and promotion of products based on the fruits of the species. Considering the conservation problem noted in this study, future studies should be oriented on that aspect in other to tackle this problem and solving it.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no competing interests.

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