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Traditional processes of food products bio conservation based on plants extracts in south and central-Benin

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Abstract

This study aims to diagnose the traditional processes of bio conservation of food products based on plant extracts. A semi-structured survey was conducted among 240 state and private actors in agricultural and citrus production and practitioners of this method of conservation in the communes of Za-Kpota and Klouékanmè in Benin. The data collected (type of conservatives, plant used, products conserved, production technology of the bioconserver) were subjected to a descriptive analysis and analysis of variance (ANOVA) followed by the Student Newman Keuls test at 5%. The results indicate that the respondents in the commune of Za-Kpota are ($p<0.05$) the oldest (43.32±2.03 years). In all survey areas, orange and chili are the plants most used for post-harvest conservation (43.8%). Chili fruits combined with orange peels are frequently used for the conservation of harvested products (56%) and the products conserved are mainly cowpeas (37.9%), maize (26.2%) and groundnuts (15.4%). The conservatives used to control pests are introduced at the beginning and end of the drying process before the commodities are put into storage. Conservatives operate most often by repulsion (57.1%). The maximum duration of harvested products using conservatives is three months (67.1%) and 73.8% of stored products are accepted by consumers. It is therefore necessary to define the production parameters of orange tree-based bioconservatives in order to optimize this technology.

Keywords: Bio preservation; Post-harvest; Agricultural products; Citrus fruit; Peelings

1. Introduction

Post-harvest losses of agricultural products are still a problem for most farmers in Benin and West Africa [1]. For some crops, this results in current yields that are far below expectations for national food coverage [2]. Despite the efforts made on both sides to increase agricultural production, the context of food insecurity is still marked by significant post-harvest losses of agricultural products. Given the seriousness of post-harvest losses caused by insects, it can be said that in Africa, the farmers works for the insects [3].

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In the face of the danger posed by pests to agricultural stocks, the main response is the use of pesticides and other synthetic chemicals. Under optimal conditions of use, their effectiveness in controlling stock pests is certain. However, there are complaints about the habituation of insects and the selection of resistant strains [4], food poisoning, environmental pollution and ecological disorders [5]. Consumer reluctance towards products treated with pesticides can also be noted. These grievances push the tolerable limits of pesticides to infinitesimal values. In order to cope with the constant renewal of new insecticide molecules that are not to be abandoned, integrated management is encouraged [6]; [7]. This makes the search for less polluting non-chemical alternatives mandatory. In this context, the use of biological molecules from plants with an insecticidal effect seems to appeal to the research community. Thus, several parts and organs of plants are exploited in order to limit post-harvest losses. This new approach is gaining momentum in research programs in Africa and worldwide [8]. According to the same authors, 43 plant species belonging to 33 genera of 15 families have been identified and tested for biotoxicity and insect toxicity on stored commodities by researchers of the Bruch Network (REARB), based on publications and communications

Producers who focus on the use of plant parts and extracts for post-harvest preservation often fail to comply with the standards for the dosage and production technologies of plant-based preservatives. It is therefore necessary to identify the practices adopted by the actors involved in the post-harvest storage of foodstuffs in order to optimize and model them. This study therefore aims to diagnose the different traditional processes of bio conservation of post-harvest stock food products. Specifically, it was a question of: 1) determine the socio-economic profile of actors using plant extracts for the bio conservation and storage of post-harvest products; 2) determine the post-harvest stock pests identified by producers as well as the production techniques of bioconservers and 3) analyze the bio conservation practices of products in relation to the socio-professional categories of actors.

2. Material and methods

2.1. Presentation of the study area

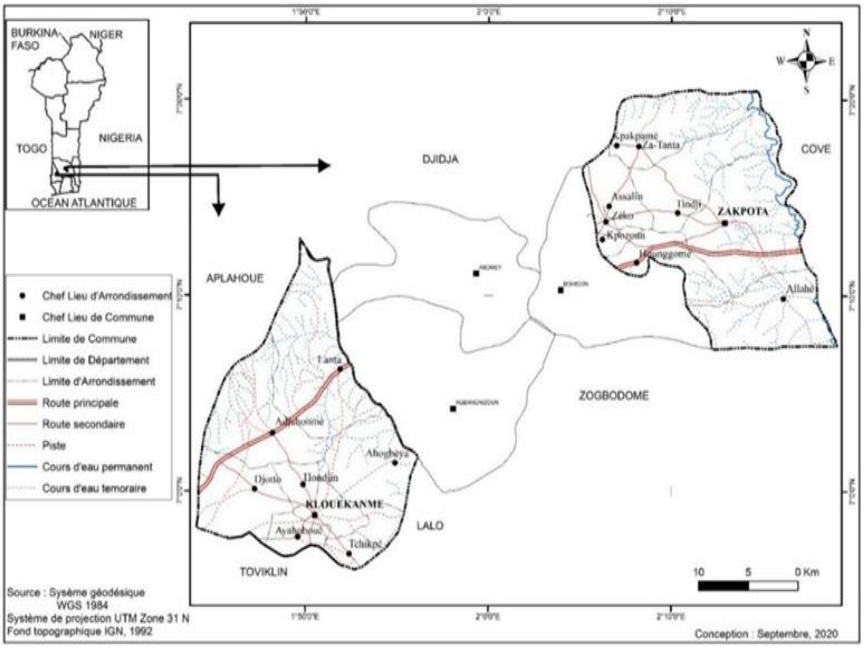


Figure 1 Geographical location of the municipalities surveyed

The diagnostic study took place in the communes of Klouekanme (Couffo department) and Za-Kpota (Zou department) (Figure 1). These departments were chosen because agriculture and citrus production play an important role in income and because socio-economic studies have already been carried out on improved storage systems for agricultural products [9], on citrus production in general and on orange production in particular [10].

Indeed, Klouekanme is located 94 km from Cotonou as the crow flies but 160 km from the same city by land, with Latitude: 6.98028 and Longitude: 1.84222, i.e. geographical coordinates 6° 58′ 49″ North, 1° 50′ 32″ East. It covers 250.00 km^2 with an estimated population of 128,597 according to the 2013 census (RGPH-4). In altitude, the commune of Klouekanme is at 174 m. It has a savannah climate [11. The commune of Klouekanme is bounded to the north by the

commune of Abomey, to the south by those of Djakotomey, Lalo and Toviklin, to the east by the commune of Agbangnizoun and to the west by that of Aplahoue. It is crossed by the Couffo River. The commune is made up of eight arrondissements, 51 villages and 10 districts. According to the Direction de la Statistique Agricole (DSA), in 2020, Klouekanme sowed an average of 18,000 hectares of arable land with a production of 1,660t of maize, 1,5363t of cowpeas and 1,1283t of groundnuts. Klouekanme in Couffo is the third largest citrus-producing commune in Benin after Za-Kpota and Cove in Zou with an area of 815 ha [12].

Za-Kpota is located 99 km from Cotonou as the crow flies but 155 km from the same city by land. The commune covers 600 km2 and has a population of 132,818 according to the 2013 census (RGPH-4) [13]. Its Latitude: 7.23028, Longitude: 2.21528 are of geographical coordinates 7° 13′ 49″ north, 2° 12′ 55″ east. In altitude, Za-Kpota is at 103 m and enjoys a dry savannah climate [11]. According to statistical data from the [14], the commune of Za-Kpota produced 7447t of maize, 5012t of cowpea and 5796t of groundnut on a cultivable area of 10500 hectares. The orange tree (*Citrus sinensis*) is the most cultivated citrus group in Za-Kpota (76.85%). The total quantity of oranges produced in the commune is about 2,612,280 tons/year [15]

2.2. Sampling

Table 1 Number of surveys per district, per municipality and per region

Survey areas	Commune	Arrondissements	Number of respondents
South Benin	Klouekanme (120 respondents)	ADJAHONME	19
		AHOGBEYA	18
		AYAHOHOUE	11
		DJOTTO	15
		HONDJIN	22
		KLOUEKANME	19
		LANTA	6
		TCHIKPE	10
Center-Benin	Za-Kpota (120 Respondents)	ALLAHE	21
		ASSANLIN	17
		HOUNGOME	25
		KPAKPAME	17
		KPOZOUN	12
		ZA-KPOTA	9
		ZA-TANTA	6
		ZEKO	13
TOTAL Respondents			240

The quota method [16] was used to determine the number of target persons to be surveyed in each district. For this purpose, statistics from the National Institute of Statistics and Economic Analysis of Benin [17] were used. In total, 240 people were surveyed, including 33 women and 207 men, all of whom are post-harvest conservation actors. The number of people surveyed in each arrondissement of each commune and by survey zone is recorded in Table 1.

2.3. Data collection

The study is conducted in two phases. The first is an exploratory phase which was conducted in focus groups. This phase was carried out both in Klouekanme in the south and in Za-kpota in central Benin. Using an interview guide, a group interview was organised in the 16 arrondissements of the two communes, with eight per commune. The focus groups were composed of adopters and non-adopters (men and women) of post-harvest agricultural bio conservation systems.

These groups consisted of 7 to 10 men and 3 to 5 women. Due to the availability of actors, two focus groups were organised in five survey districts. In total, 21 focus groups were conducted in 16 districts of the two communes.

The second phase, the actual survey phase, was carried out using a structured survey in all 16 districts.

The individual survey was carried out using the 'snowball' method developed by Goodman in 1961 [18] and involved 240 post-harvest bio conservation actors. The young, adult and old respondents (men and women) were male and female producers, dealers and traders who store maize (*Zea mays*), cowpeas (*Vigna unguculata* L.) and groundnuts (*Arachis hypogaea*) using plant derivatives. The elements collected relate to socio-cultural characteristics (gender, age, level of education, occupation, religion, ethnicity); type of preservative (chemical or vegetable); vegetable and parts used; preserved products, remanence and production technology of the bioconservative. Finally, secondary data were also collected such as the recognition and identification of microorganisms in agricultural stocks.

2.4. Statistical analysis of the data

The collected data were coded, entered and processed with the Statistical Package for Social Sciences (SPSS) software version 20.0 for the determination of descriptive statistics in terms of percentage and mean [19]. Quantitative data were then subjected to analysis of variance (ANOVA) using the PROC GLM procedure in SAS (Statistical Analysis System) version 9.2 according to [20]. Multiple mean comparisons were performed using the Student Newman-Keuls test [21].

Table 2 Numbers associated with the 14 main socio-professional groups studied (N = 240)

SOCIO-PROFESSIONAL GROUPS	CODES	NUMBERS
Illiterate citrus grower Adja	AAA	1
Illiterate Fon farmer	AAF	3
Primary level Fon farmer	APF	1
Trader Illiterate Adja	CAA	5
Illiterate Fon trader	CAF	4
Primary level Adja trader	CPA	1
University level Fon trader	CUF	1
Illiterate Adja producer	PAA	102
Illiterate Fon producer	PAF	83
Primary level Adja producer	PPA	16
Primary Fon producer	PPF	17
Producer Adja Secondary	PSA	3
Secondary Fon producer	PSF	2
Higher level Adja producer	PUA	1
Total 240		

In Benin and more generally in Africa, local perceptions of phenomena and practices are very much influenced by habits and customs, which are themselves dependent on socio-cultural groups [22]. As a result, the subjects surveyed were grouped according to the three main professional group's identified, namely citrus growers, traders and agricultural producers. Within each group, the subjects were grouped according to their level of education (No level, Primary, Secondary and University) and the ethnic groups to which they belonged (the Fon, who are in the majority in the commune of Za-kpota, and the Adja, who are mainly represented in the commune of Klouekanme). Thus, in total, 14 socio-professional categories (instead of the potential 24) taking into account the combination of the main professional groups, level of education and ethnic groups were considered (Table 2)

This was due to the absence of some respondents in the study sample who met combinations of occupational group, educational level and ethnicity.

For each respondent, the perception index of each organoleptic characteristic as well as the perceptions on the modes of action of bioconservatives and others were determined. For each of the 14 categories, an average perception index is calculated for each characteristic from the average value of the perception indices of this characteristic by the individuals composing the group considered. A matrix of perception indices of organoleptic characteristics and acceptability of preserved products before and after cooking is established. This matrix was subjected to a Principal Component Analysis (PCA) according to [32], in order to describe the relationships existing between the perceptions related to the changes of state of the different organoleptic characteristics and to assess the quality of the preserved agricultural product. The statistical analysis was done with Minitab 19 software. The same analytical approach related to the establishment of socio-professional groups was carried out for the appreciation of preservatives in relation to preserved products. For each group, the number of people who opted for the different plants and plant organs and others was calculated. The resulting contingency table was subjected to simple correspondence factor analysis (CFA) using Minitab 19 software.

3. Results

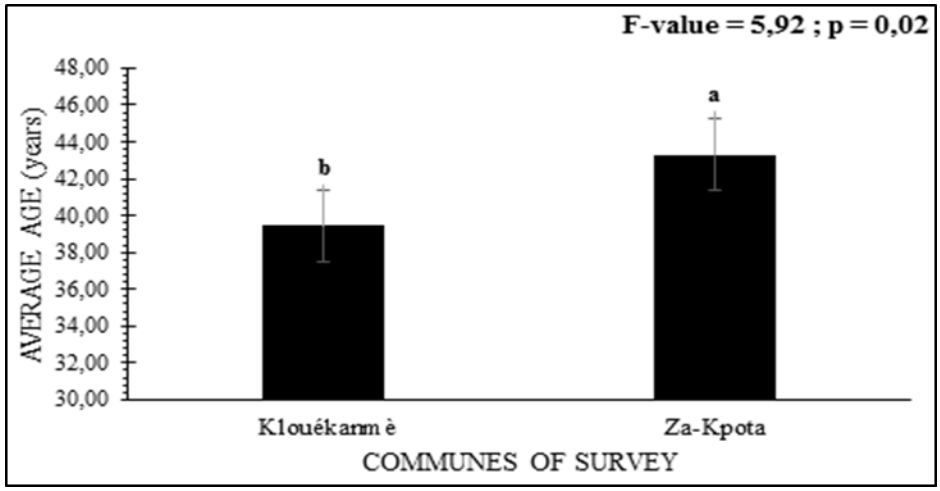
3.1. Socio-demographic profiles of actors involved in the biopreservation and storage of post-harvest products

Table 3 Socio-demographic characteristics of post-harvest product conservation actors surveyed by study commune

Percentage (%)				
Variables	**Modalities**	**Klouékanmè (n=120)[1]**	**Za-Kpota (n=120)[1]**	**Total**
Category of respondent	Citrus farmers	0.0	4.2	2.1
	Traders	5.8	4.2	5.0
	Farmer	94.2	91.7	92.9
Age	0≤âge<50 ans	80.50	67.5	74.2
	50ans≤âge<70ans	16.2	30.8	23.3
	70ans≤âge	3.3	1.7	2.5
Gender	Male	86.7	85.8	86.2
	Female	13.3	14.2	13.8
Ethnie	Adja	96.7	11.7	54.2
	Fon	3.3	88.3	45.8
Educational level	None	83.3	85.8	84.6
	Primary	13.3	11.7	12.5
	Secondary	2.5	1.7	2.1
	Higher	0.8	0.8	0.8

[1] Number of people surveyed

Table 3 presents the results of the descriptive analysis of the socio-demographic variables of the preservers according to the two citrus and agricultural production communes visited in Benin. In general, men preserved more post-harvest produce than women (86.2% versus 13.8%). Across the study area, the age of the conservation actors surveyed ranged from 18 to 79 years with an average of 41 years. Analysis of variance and the Student Newman Keuls test showed that stakeholders residing in central Benin (Za-Kpota) were significantly ($p<0.05$) older than those in southern Benin (Figure 2). The age of the majority of post-harvest preservers surveyed (86.28%) was between 18 and 50 years, and they were mostly producers (92.9%). The majority of conservatives are illiterate (84.6%).



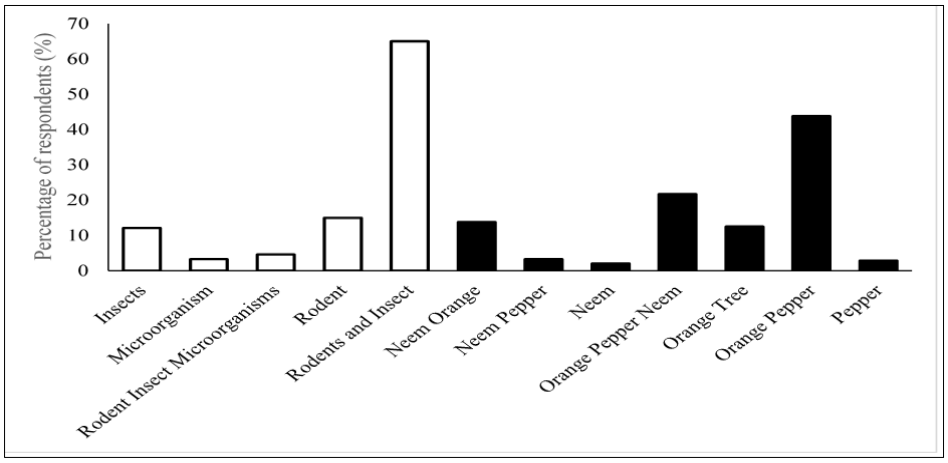
Error bars followed by the different alphabetical letters are significantly different (p> 0.05) according to the Student Newman-Keuls test.

Figure 2 Quantitative data (mean values ± standard errors) on the age of bio conservation actors in the two survey areas

3.2. Identification of post-harvest stock pests and response techniques adopted by bio conservation actors in central and southern Benin

3.2.1. Post-harvest stock pests and plants used by agricultural bio conservation actors

Figure 3 presents the identified stock pests and the plants used by the bio conservation actors. Analysis of the diagram shows that the most common pests found in post-harvest stores were rodents and insects (65%). Microorganisms were also sometimes found in post-harvest stocks according to the respondents. The proportions of responses related to bio conservation techniques (plants used) indicate that stakeholders are generally unanimous about the use of plants to control pests in post-harvest stocks of agricultural products. Indeed, in all survey areas, orange and chilli are the plants most used for post-harvest conservation (43.8%).



The light bars indicate stock pests and the black bars indicate plants used to counteract pests

Figure 3 Percentage of respondents in relation to stock pests and plants used for post-harvest conservation

The results of the Correspondence Factorial Analysis (CFA) performed on the data related to stock pests and plants used against their effects in post-harvest stocks allowed the description of the relationships between the socio-professional groups and plants used for crop bio conservation. These results indicate that the first two axes explain nearly 60% of the total information (Table 3). These results showed that uneducated Adja citrus farmers used chilli in combination with neem to preserve their post-harvest produce against rodents, insects and microorganisms, while uneducated Adja primary traders, Fon university students and Adja university producers used orange or chilli only, or a combination of these two plants with neem to control insects in their agricultural stocks. Both Adja and Fon high school farmers and

Fon no-academic level citrus farmers used orange-pepper/neem tree combinations or neem tree alone to control microorganisms and rodents in agricultural produce stocks (Figure 4).

Table 4 Eigen value of the first five principal components

PC Axis	Inertia	Proportion	Cumulative Proportion
1	0.1161	0.4133	0.4133
2	0.0470	0.1672	0.5806
3	0.0384	0.1365	0.7171
4	0.0288	0.1024	0.8195
5	0.0198	0.0703	0.8898

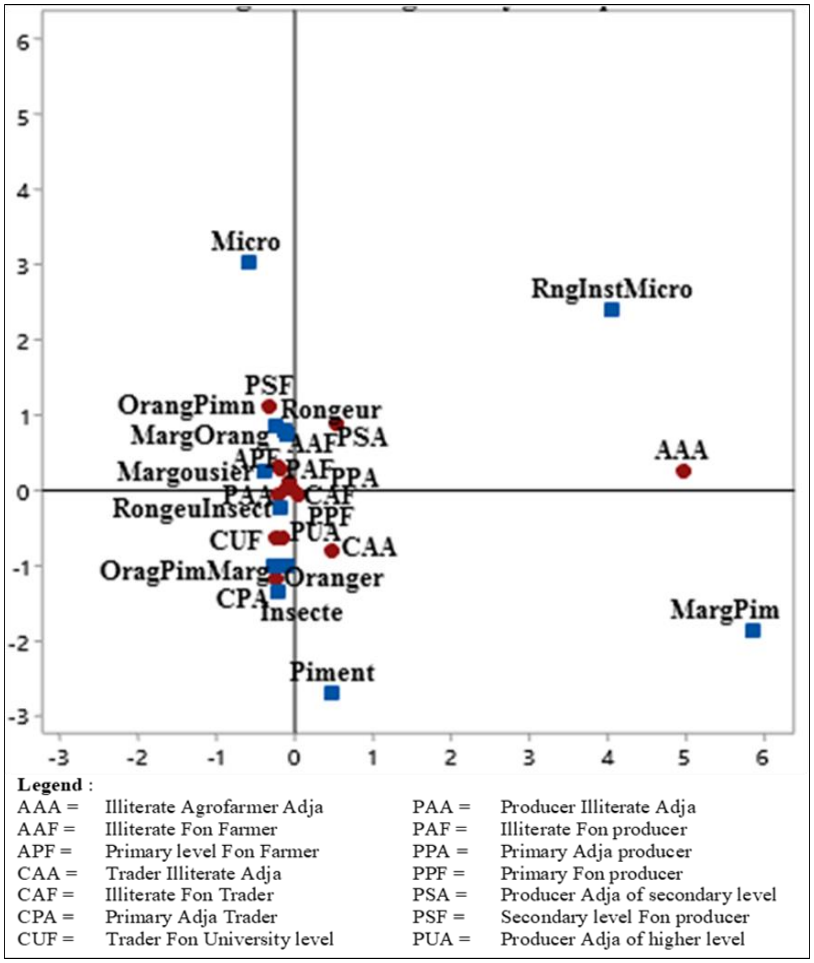


Figure 4 Response to stock pests through the use of plants: projection of socio-cultural groups in the factorial axis system following a Correspondence Factor Analysis (CFA)

3.2.2. Plant parts used and agricultural products conserved by bio conservation actors

Histograms (a) and (b) in Figure 5 refer to the plant parts used and the agricultural products conserved respectively. From the analysis of the figure, it appears from the bio conservation actors that chilli fruits combined with orange peels are frequently used for the conservation of harvested products (56%). According to the same actors, the conservation of cowpeas (37.9%), maize (26.2%) and groundnuts (15.4%) is more common in the areas surveyed.

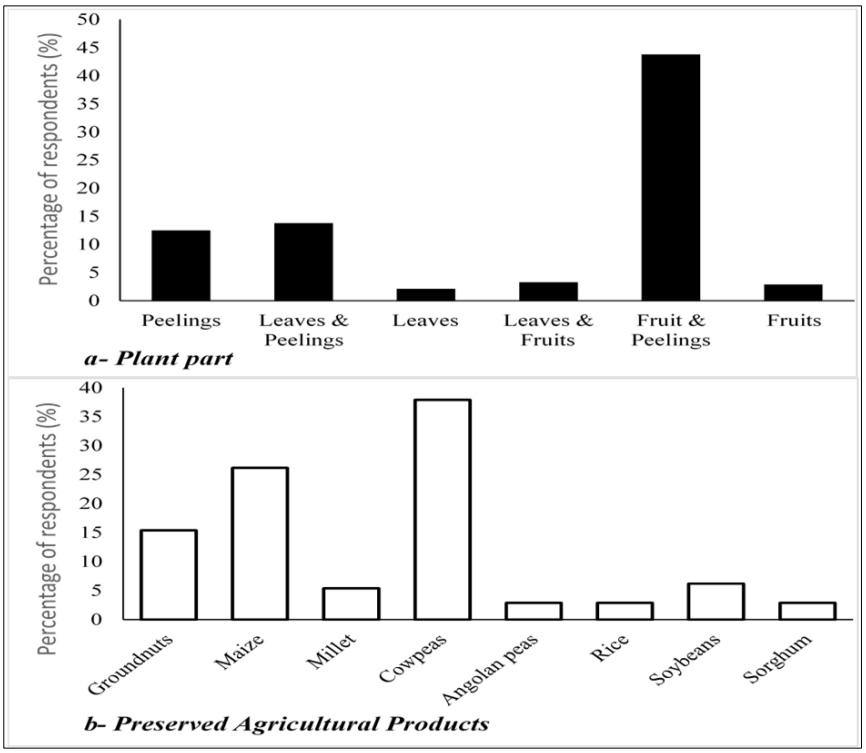


Figure 5 Plant parts used (a-) and agricultural products preserved (b-) by bio conservation actors

The results of the Correspondence Factor Analysis (CFA) performed on the data related to harvested agricultural products and plant parts used for their conservation allowed describing the relationships between socio-professional groups and plant parts used in bio conservation. These results indicate that the first two axes explain 53.38% of the total information (Table 5). The analysis of the results shows that illiterate Adja citrus farmers, who are in the majority in southern Benin, use neem leaves combined with chilli fruits to preserve maize. On the other hand, Fon traders at university level and Adja traders at primary level or with no schooling at all, and Adja university-level producers use peelings alone or in combination with leaves and fruits to preserve cowpeas and soya. Both Adja and Fon secondary level farmers, Fon uneducated citrus farmers and Fon uneducated primary level farmers and traders used fruit in combination with peels to preserve maize, groundnuts and millet (Figure 6).

Table 5 Eigen value of the first five principal components

Axis	Inertia	Proportion	Cumulative Proportion
1	0.0820	0.3039	0.3039
2	0.0620	0.2299	0.5338
3	0.0383	0.1419	0.6756
4	0.0253	0.0936	0.7692
5	0.0205	0.0760	0.8453

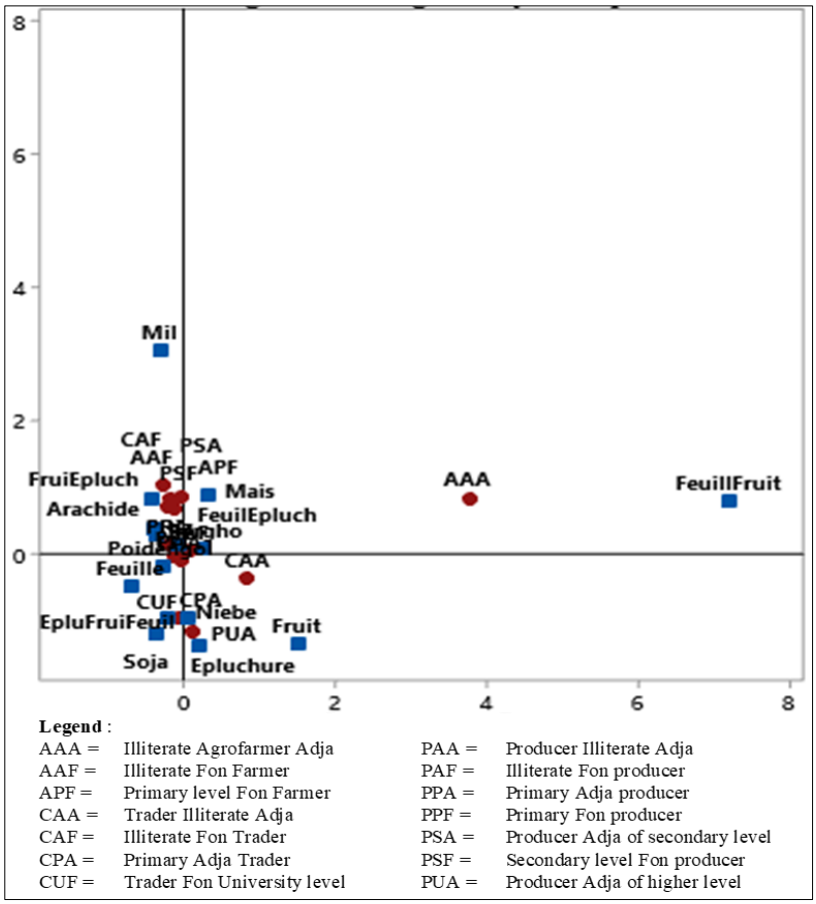


Figure 6 Conservation of agricultural harvested products through the use of plant parts: projection of socio-cultural groups in the factorial axis system following a Correspondence Factorial Analysis (CFA)

3.3. Analysis of the practices of bio conservation of products in relation to the socio-professional categories of the actors.

3.3.1. Time of application, mode of action, shelf life and acceptability

Table 6 presents the results of frequency analysis on the mode of action of preservatives and the perception of acceptability of the agricultural product after the preservation period. From the analysis of the table, it appears that according to the bio conservation actors in central and southern Benin, the preservatives used to control stock pests were mostly introduced at the beginning and end of the drying process (96.6%). According to the same actors, preservatives act more often by repulsion (57.1%). The majority of respondents stated that the maximum shelf life of harvested products using preservatives was three months (67.1%). The majority of these same respondents (73.8%) stated that the products concerned were accepted by consumers before and after cooking.

The results of the Principal Component Analysis performed on the data of the bio conservation techniques allowed to describe the relationships between socio-cultural groups and the time of application, mode of action, shelf life and acceptability. These results indicate that the first two axes explain 55.2% of the total information (Table 7). Thus, according to traders at all levels, of all ethnicities and in all survey areas, bioconservatives that are introduced into agricultural products at the beginning or end of the drying process act by repelling or contacting the insects; this allows agricultural products to be preserved for six to nine months. However, according to these traders, these preserved products are rejected by consumers before and after cooking. Uneducated Adja citrus farmers in the South and Fon farmers in Central Benin said that preservatives act by repulsion and allow post-harvest products to be stored for up to six months. They also reported that products preserved in this way were rejected before and after storage. In the case of uneducated and primary producers in the South and Central-Benin, preservatives were introduced at the beginning and during the drying process. These products acted by contact, repulsion and/or ingestion. According to these actors, products preserved in this way for up to three months were accepted before and after cooking (Figure 7, Table 8).

Table 6 Total percentage and by area of quotation of the time of application, mode of action, shelf life and acceptability of preserved products

Percentage (%)				
Variables	**Modalities**	**Klouekanme (n=120)[1]**	**Za-Kpota (n=120)[1]**	**Total**
Time of introduction of the preservative	Start & End Drying	94.2	95.0	94.6
	Start Drying	1.7	2.5	2.1
	End Drying	1.7	0.8	1.2
	Drying time	2.5	1.7	2.1
Mode of action of the preservative	Contact	1.7	0.8	1.2
	Contact et Ingestion	8.3	10.8	9.6
	Ingestion	7.5	9.2	8.3
	Ingestion Repulsion	8.3	5.8	7.1
	Ingestion Repulsion Contact	10.0	11.7	10.8
	Repulsion Contact	6.7	5.0	5.8
	Repulsion	57.5	56.7	57.1
Shelf life	0 à 3 months	68.3	65.8	67.1
	3 à 6 months	25.8	26.7	26.2
	6 à 9 months	5.8	7.5	6.7
Before cooking	Accepted	74.2	73.3	73.8
	Rejected	25.8	26.7	26.2
After Cooking	Accepted	74.2	73.3	73.8
	Rejected	25.8	26.7	26.2

[1] Number of people surveyed

Table 7 Eigen value of the first five principal components

PC AXIS	Eigen value	Proportion	Cumulative Proportion
1	6.2612	0.348	0.348
2	3.6725	0.204	0.552
3	2.1873	0.122	0.673
4	1.4515	0.081	0.754
5	1.2937	0.072	0.826

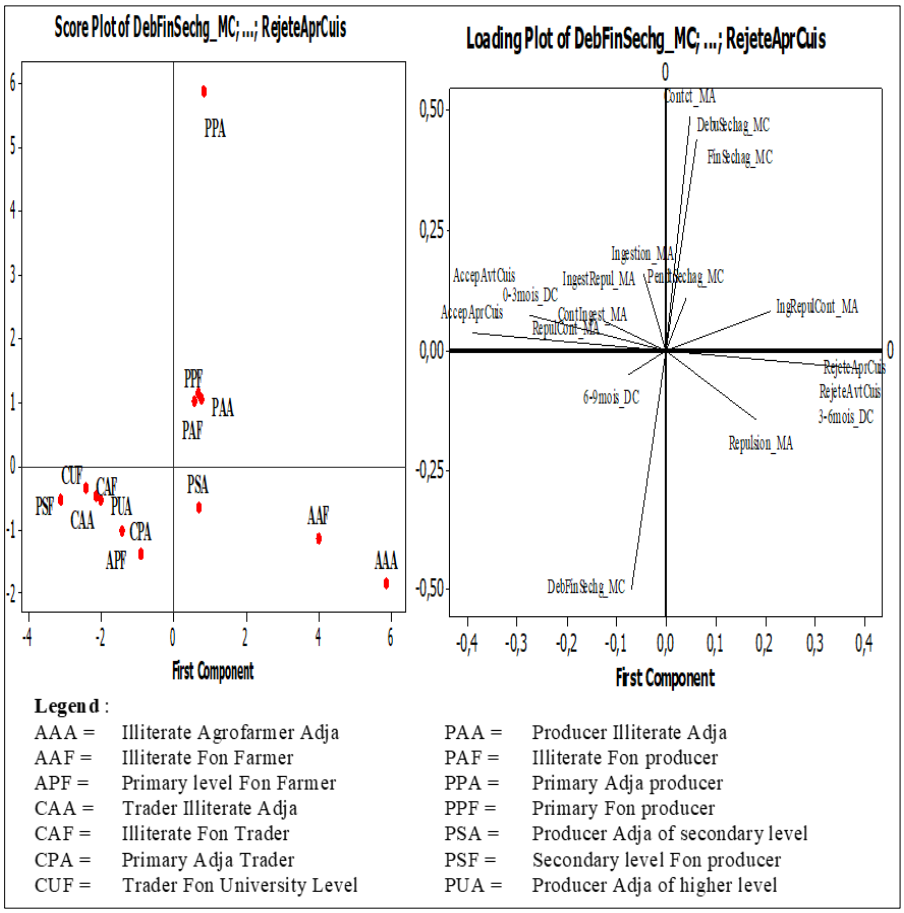


Figure 7 Acceptability of the preserved agricultural product from a Principal Component Analysis (PCA): projection of Time of application, mode of action, duration of preservation and acceptability and socio-cultural groups in the factorial axis system

Table 8 Correlation between variables and axes

Variable	PC1	PC2	PC3
DebFinSechg_MC	0.069 ns	0.499*	-0.018 ns
FinSechag_MC	-0.050 ns	-0.488*	0.065 ns
DebuSechag_MC	-0.061 ns	-0.438*	0.052 ns
Contct_MA	-0.050 ns	-0.488*	0.065 ns
ContIngest_MA	0.123 ns	-0.004 ns	-0.524*
RepulCont_MA	0.199 ns	-0.004 ns	-0.421*
Repulsion_MA	-0.183 ns	0.148 ns	0.407*
3-6mois_DC	-0.389*	0.037 ns	-0.118 ns
6-9mois_DC	0.075 ns	0.050 ns	0.430*
AccepAvtCuis	0.389*	-0.037 ns	0.118 ns
RejeteAvtCuis	-0.389*	0.037 ns	-0.118 ns
AccepAprCuis	0.389*	-0.037 ns	0.118 ns
RejeteAprCuis	-0.389*	0.037 ns	-0.118 ns

* = significant correlation at the 30% threshold; ns = non-significant correlation at the 30% threshold

3.3.2. Shelf life; organoleptic quality perceptions and acceptability

Table 9 refers to elements such as the origin and type of preservative and perceptions of organoleptic quality (Hardness, Colour, Odour, and Taste) of preserved agricultural products. From its analysis, it emerges that according to the bio conservation actors, the preservatives used to fight against stock pests are mostly of vegetable and chemical origin (96.7%). According to these same actors, plant preservatives are produced while chemical preservatives are purchased on the local market (96.7%). The respondents also stated that preserved products are generally hard (67.1%), keep their colour before preservation (91.2%) and their smell and taste are unchanged from the original (91.7%).

Table 9 Origin, type of preservative and organoleptic qualities of preserved agricultural products

Pourcentage (%)				
Variables	**Modalities**	**Klouekanme (n=120)[1]**	**Za-Kpota (n=120)[1]**	**Total**
Origin of preservative	Purchase Production	96.7	96.7	96.7
	Purchase	1.7	0.8	1.2
	Production	1.7	2.5	2.1
Type of preservative	Chemical	1.7	0.8	1.2
	Chemical and vegetable	96.7	96.7	96.7
	Vegetable	1.7	2.5	2.1
Hardness	Hard	68.3	65.8	67.1
	Powdery	25.8	26.7	26.2
	Soft	5.8	7.5	6.7
Colour	Changed	9.2	8.3	8.8
	Identical	90.8	91.7	91.2
	Unchanged	91.7	91.7	91.7
	Odour of preservative	8.3	8.3	8.3
Taste	Acidic	1.7	0.8	1.2
	Bitter	9.2	8.3	8.8
	Unchanged	89.2	90.8	90.0

[1] Number of people surveyed

The results of the Principal Component Analysis performed on the appraisal data of preserved products allowed the description of the relationships between the perceptions on organoleptic quality, shelf life and acceptability of preserved products. These results indicate that the first two axes explain 100% of the total information (Table 10). Thus, according to the bio conservation actors in central and southern Benin, products preserved between zero and three months retain their initial organoleptic quality and are therefore accepted before and after cooking (Figure 8, Table 11). On the other hand, from three months to nine months of conservation, the products become soft or powdery with an acid or bitter taste, change colour and are rejected before and after cooking.

Table 10 Eigen value of the first three principal components

PC AXIS	**Eigen Value**	**Proportion**	**Cumulative proportion**
PC 1	9.1653	0.655	0.655
PC 2	4.8347	0.345	1.000
PC 3	0.0000	0.000	1.000

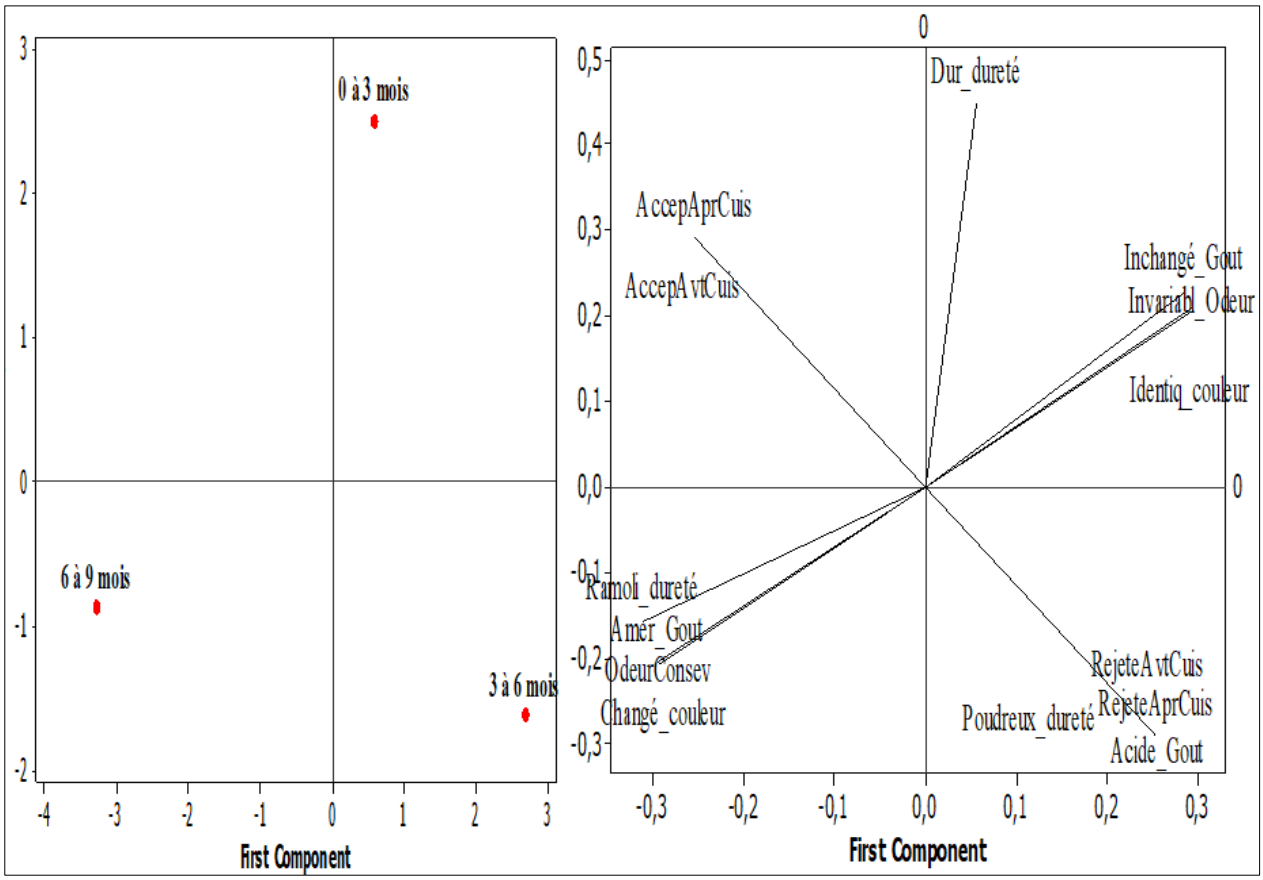


Figure 8 Shelf life of preserved agricultural product from Principal Component Analysis (PCA): organoleptic quality and acceptability projection and in the factorial axis system

Table 11 Correlation between variables and axes

Variable	PC1	PC2	PC3
Hardness	0.056ns	0.448*	0.043ns
Softened hardness	-0.31*	-0.157ns	-0.182ns
Same color	0.295ns	0.206ns	0.353*
Unchanged taste	0.286ns	0.228ns	-0.521*
Rejete bfreCook	0.254ns	-0.291ns	-0.645*

* = significant correlation at the 30% threshold; ns = non-significant correlation at the 30% threshold

4. Discussion

4.1. Socio-economic profiles of actors involved in the bio conservation and storage of post-harvest products

The results of the survey reveal a high rate of male respondents compared to female respondents. This result can be explained by the fact that men, in addition to being heads of households, are also heads of farms. In most African societies, access to land favours men over women. Thus, according to IIED [24], land tenure does not favour women's access to agricultural land.

In the study areas of Klouekanme in southern Benin and Za-kpota in central Benin, most of the actors surveyed were between 18 and 50 years old, followed by those between 50 and 70 years old. This shows that fieldwork, in this case bio

conservation practices, are therefore relegated to young people and adults. As Sanou [25] has pointed out, unemployment and low literacy levels mean that the majority of producers in this age group return to the land to meet their basic needs. These uneducated young people engage in traditional farming practices without adequate training. In these study areas, very few farmers are over 70 years of age. This could be due to the fact that the physically weak old age group is no longer willing to work in the field.

Across the study area, the age of the bio conservation actors surveyed ranged from 18 to 79 years with an average of 41 years and these post-harvest agricultural conservation actors are mostly producers; animists. Bio conservation actors are mostly uneducated. This result therefore shows that the bio conservation and storage of post-harvest products in southern and central Benin are not subject to any socio-cultural prohibition or specific to a socio-professional group and involve people of both sexes, of all ages (young people, adults, and children) without distinction of religion, intellectual level or category of activity. Many researchers have reached similar conclusions. According to Arouna et al [26], the introduction of improved maize storage systems in southern Benin has reduced the use of labour from diverse origins and ethnicities. According to Jelle [27], methods of preserving food crops by drying can be used by all actors in family farming. These findings corroborate those of Hassan and Nhemachena [28] who showed that age and gender are not necessarily the determinants of adaptive strategies developed at the local level, but rather the farming experience of farmers and the capacity of households to access credit and the market.

4.2. Identification of post-harvest stock pests and response techniques adopted by bio conservation stakeholders in central and southern Benin

The most conserved agricultural products according to the respondents are cowpeas (38%), maize (27%) and groundnuts (15%). The most common pests found in post-harvest stocks are rodents and insects (65.0%) but sometimes microorganisms according to the respondents. To counteract these pests, farmers resort to the use of plant species. Indeed, in all the survey areas, orange and chilli were the plants most used for post-harvest conservation (43.8%), but neem was also used. As for the parts of the plants used, the respondents declared that they used the fruits of the chilli and the orange peelings for the conservation of cowpeas, while the leaves of the neem tree were used for the storage of maize. These same findings have been made by several researchers. Chougourou and Alavo [29] revealed through surveys that ash and plants (fruits of Capsicum frutescens L., dry leaves of neem (*Azadirachta indica* A. Juss) and *Hyptis suaveolens* (L.) Poit) were used by farmers for cowpea preservation in central Benin. In addition, surveys and experiments conducted by Srinivasu and Naik [30] among 20 rural households in Dharwad, India, on different storage systems for stock pest control of sorghum, wheat, rice, cowpea, pigeonpea and chickpea, showed that sun-drying supplemented with the addition of dry neem leaves or ash from a neem organ was more frequent and more effective than the application of insecticides or fumigation. Sun-drying was practised by 75-100% of households surveyed. Insecticide application was least used.

Momar et al [31] stated that the susceptibility of cowpea to pests is probably the reason for the large number of studies on this commodity. According to these authors, *Acanthoscelides obtectus* (Say), *Callosobruchus rhodesianus* (Woodpecker) and especially *C. maculatus* were the major insects responsible for almost all the damage observed on cowpea. According to these authors, groundnut and cowpea were more susceptible to pest infestation. On groundnut, Guèye (2000) located around April, the period when the emergence of adults of *C. serratus* (Olivier) is at its maximum level, which coincides with a strong heat wave. Considering weight loss, tests in closed stocks showed that field pre-infestation of peanuts by *C. serratus*, even if low, could be sufficient to completely destroy seed stocks in only four months of storage [2].

4.3. Analysis of product bio conservation practices in relation to the socio-professional categories of the actors.

Through the various responses of the respondents, we note that the different socio-professional groups (citrus growers, traders and producers) Adja or Fon, educated or not, used neem leaves, chilli fruits and orange peelings in association or alone, to preserve their cereal and legume stocks (maize, cowpea, groundnut, millet, sorghum). These practices reflect the fact that producers are becoming increasingly aware of the harmful effects of the chemicals often used in the conservation of post-harvest products. In this regard, authors have revealed that many grievances are made about chemical storage products. Benhalima et al [32] mentioned insect habituation and the selection of resistant plant strains, while Regnault-Roger [5] mentioned poisoning, environmental pollution and ecological disorders.

These different plant parts were mostly introduced at the beginning and end of the drying process of the agricultural products to be stored and acted by repulsion. Thus, they only retained the organoleptic and nutritional qualities of the agricultural products for three months after harvest. The repulsiveness of plant parts in cereal and legume stocks can be explained by the fact that plants, which are autotrophic, often produce essences by chlorophyll synthesis that become volatile under certain conditions and are unbearable for insects. In this respect, several authors have proven the

insecticidal and insect repellent effects of several plants. Indeed, Kpatinvoh et al [33] showed that the essential oils of *Cymbopogon citratus* (L.), *Cymbopogon nardus* (L.), and *Eucalyptus saligna* (S.) had insecticidal effects on *C. maculatus* of cowpea. Nyamador [34], showed that the essential oil of *Cymbopogon giganteus* is an insecticide that can protect agricultural stock

5. Conclusion

At the end of this study, it should be noted that according to the perception of the agricultural producers of Kloukanme and Zakpota, the pests of post-harvest stocks of maize, cowpea, and groundnut were rodents, insects and microorganisms. To combat these pests of agricultural products, various conservation techniques were adopted by the stakeholders. These included the introduction of orange peelings and chilli fruits at the beginning of drying in cowpeas to repel insects that were harmful to them, and neem leaves, which were used to store maize and groundnut crops, and which also prevented the proliferation of insect pests in these stocks. The preservation of cereals and pulses using these plant-based techniques did not follow any conventional biopreservative production technology and the shelf life was usually no longer than three months. But the products preserved during these three months kept their good organoleptic quality and were therefore accepted by consumers before and after cooking.

In the future, it is possible to draw up a technological diagram for the production of bioconservatives, while optimising and modelling the parameters for the production and use of these bioconservatives; the microbicidal and insecticidal effect can be checked, and the natural bioactive substances in the bioconservatives produced can be identified through screening. After the bio conservation, organoleptic and nutritional tests of the preserved foodstuffs will be carried out to verify their acceptability.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors agree no conflict of interest.

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