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Perception on post-harvest practices and storage constraints of tamarind fruits, *Tamarindus indica* L. in the Hauts Bassins and Centre regions of Burkina Faso

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ABSTRACT: Food security is a major challenge for developing countries. Non-Timber Forest Products (NTFPs) are a source of income for families, improving their living conditions. Tamarind is a NTFP used for many purposes, both for food and industrial purposes. However, it suffers from pest attacks. This study aimed to evaluate the post-harvest practices of tamarind fruits and the constraints related to its storage in the communes of Bobo-Dioulasso and Ouagadougou. A survey conducred in the form of a semi-structured interview toward 113 respondents in Bobo-Dioulasso and 138 in Ouagadougou. The participatory diagnosis showed that the majority of respondents in Bobo-Dioulasso (70.19%) and Ouagadougou (57.33%) considered insects to be the main cause of damage to the pods. We observe a preponderance of perforated beans (63.16%) in Ouagadougou, while in Bobo-Dioulasso the percentage was 29.85. After collecting the pods, 78.95% of the farmers in Ouagadougou dehull the pods immediately and then keep the pulp without further drying, in contrast to Bobo-Dioulasso (16.67%) where only a minority practice this. More than half of the interviewers sell tamarind to meet specific needs. As for control methods, the main ones are steaming of tamarind used by 72.92% of farmers in Ouagadougou, while in Bobo-Dioulasso only 25.64%. These results show that tamarind pods are highly exposed to insect attacks. It is therefore necessary to investigate the improvement of traditional control methods by including other natural alternatives in order to minimize losses and promote tamarind exploitation.

KEYWORDS: Perception, post-harvest, practices, *Tamarindus indica,* storage constraints.

1 INTRODUCTION

Our world is facing a danger, food insecurity which is a huge problem for developing countries. Indeed, 95 million people could go hungry as a result of COVID-19 [1], [2]. Globally, today's food systems do not produce affordable, safe, and sustainable food for all [1]. In sub-Saharan Africa, food insecurity affects 153 million people or about 25% of the population [3]. Hunger is on the rise, undoing decades of progress, making it worthwhile to look for other alternatives. The forest offers us two types of products namely non-timber forest products (NTFPs) and timber forest products (TFPs). NTFPs contribute considerably to rural needs and to the national economy of several Sub-Saharan African countries [4]. In Burkina Faso, one of the NTFP-providing plants, the tamarind tree (*Tamarindus indica* L.), belonging to the subfamily Caesalpinioideae, is quite important in rural and urban areas. The pulp of the fruit is mainly used for food, but is also used for therapeutic purposes [5]. Most of the production in Burkina Faso is destined for marketing, with 518 tons of tamarind fruit exported in 2005 to countries in the sub-region [6]. In agrosystems, the average economic potential has been estimated at 4,366,796,230.01 F CFA for *T. indica* fruits in Burkina Faso [7]. However, tamarind fruits are attacked while they are still on the tree until storage. Thus, insect activity on seeds before dispersal significantly reduces their germination rate [8], which could cause consequences for the natural regeneration of the plant. *Caryedon serratus,* one of the main insect pests of tamarind, uses it as a food source and contaminates it with its waste, causing damage ranging from weight loss to reduced grain quality [9] and sometimes loss of germination capacity [10].

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Faced with pest pressure, several control methods are used against stored food pests such as hermetic storage, the use of biopesticides and chemical products. The knowledge of the problem of the storage of *T. indica* seeds in the farming environment is essential in order to propose suitable solutions for the conservation of the seeds in the long term and on a large scale. Little is known about the post-harvest practices of this speculation. Then this study aims to deepen the knowledge on the practices related to the post-harvest management of *T. indica* fruits. Specifically, it aimed to: (i) know the methods and structures of storage of tamarind pods; (ii) estimate damages and biotic constraints on tamarind pods; and (iii) determine the time spent to maintain the quality and the price.

2 METHODOLOGY

2.1 DESCRIPTION OF THE STUDY SITE

The survey took place in the Hauts-Bassins and Centre regions, more specifically in the communes of Bobo-Dioulasso and Ouagadougou, which represent the main areas of tamarind exploitation and consumption. Bobo-Dioulasso is located in the southwest of Burkina Faso in the southern Sudanian zone. It has an annual rainfall of more than 1,000 millimeters and a rainy season of about 6 months [11]. Bobo-Dioulasso has a population of approximately 887,778 [12].

The commune of Ouagadougou is located in the northern Sudanian zone with a rainfall of between 600 and 900 mm and a rainy season of about 5 months [11]. The population of Ouagadougou is approximately 2,684,052 [12]. The survey was conducted in thirteen (13) markets and among a few collectors and traders in the two communes (Figure 1).

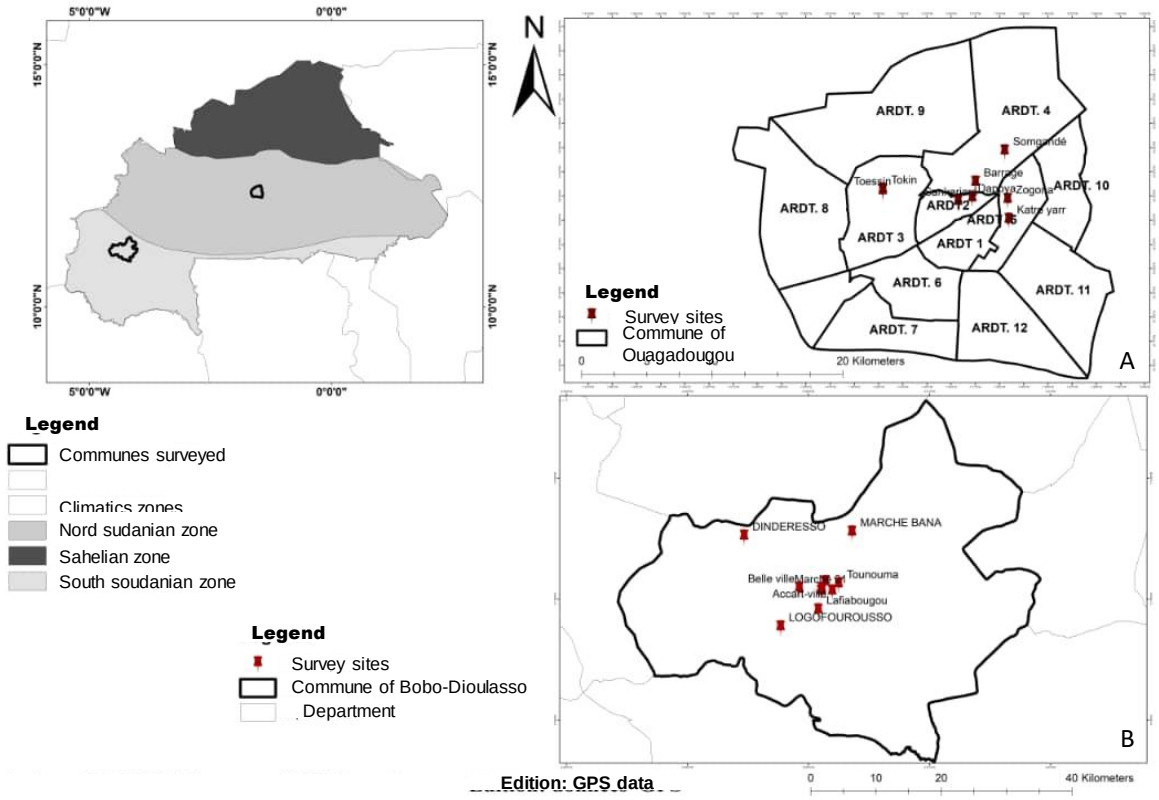

Fig. 1. Maps of the communes of Bobo-Dioulasso (B) and Ouagadougou (A) showing the markets surveyed

2.2 DETERMINING OF THE SAMPLE SIZE

We used the method described by [13] to determine the sample size. A pre-survey was conducted by means of a questionnaire to 100 people in each commune. This allowed us to determine the percentage of people who consider insects to be an challenge to tamarind conservation. The 92% in Bobo-Dioulasso and 90% in Ouagadougou who said that insects are a hindrance to tamarind conservation were used to calculate the sample size using the following formula proposed by [13]:

$$N = \frac{\mu^2_{1-\alpha/2} Pi(1-Pi)}{d^2}$$

Where N = total number of people to be surveyed representing the sample size;

μ1-α/2 represents the value of the normal random variable for a risk α equal to 0.05.

(μ1-α/2 =1.96);

d = margin of error considered in the survey, 1% < d < 15%. We will take d = 0.03;

Pi = proportion of those who said that insects depreciate *T. indica* stocks in the absence of a conservation method.

The sample size to be surveyed is 113 in Bobo-Dioulasso and 138 in Ouagadougou. The number of people to be surveyed per market was determined by taking into account the size of the market. Thus, in the commune of Bobo-Dioulasso, we surveyed 17 traders at Accart-ville market, 16 at the fruit and vegetable market, 20 at the big market, 15 at Lafiabougou market, 14 at Tounouma market, 16 at Logofourousso, and 15 at Bana market. In the urban commune of Ouagadougou, we surveyed 28 women traders in Nabi market, 19 in Sabin market, 21 in Tounkin market, 12 in Sankar market, 26 in Zogona market, and 32 in Toèssin market. The total number of markets visited was seven in Bobo-Dioulasso and six in Ouagadougou.

2.3 DIAGNOSIS OF THE POST-HARVEST MANAGEMENT OF *T. INDICA* SEEDS IN THE FARMING ENVIRONMENT

The surveyed markets were selected randomly. A questionnaire was developed to collect information on knowledge related to post-harvest management of tamarind. The questionnaire included information on the characteristics of the respondents, tamarind-related practices from harvest to storage, storage structures, and methods of protecting stocks. The interview was semi-structured (interviewer-assisted questionnaire methodology) and was administered in the presence of the respondent on a one-on-one basis.

2.4 STATISTICAL ANALYSIS OF DATA

The Excel 2016 spreadsheet was used to enter the data collected during the survey and to calculate the proportions of responses. Statistical processing was carried out with the R software version 4.1.0 as well as the construction of some graphs. The Shapiro - Wilk test was used to check the distribution of the data by using the Shapiro.test function on the price of a Yoruba dish, a can of tomato and the shelf life of tamarind pods in order to choose the appropriate test. Thus, the Mann - Whitney - Wilcoxon test was performed with the Wilcox-test function at the 5% probability threshold.

3 RESULTS

3.1 GENERAL CHARACTERISTICS OF RESPONDENTS

The majority of respondents in Bobo-Dioulasso (97.35%) and in Ouagadougou (89.13%) (Table 1) are women. The age group most represented in Bobo-Dioulasso is between [40-60] (Table 1); on the other hand, the age group between [18-40] is the most represented in Ouagadougou (Table 1). In both communes, the majority of tamarind traders surveyed are illiterate.

Table 1. Characteristics of the population surveyed in Bobo-Dioulasso and Ouagadougou

	Frequency		Percentage (%)	
	Bobo-Dioulasso	**Ouagadougou**	**Bobo-Dioulasso**	**Ouagadougou**
Sex				
Male	3	15	2.65	10.87
Female	110	113	97.35	89.13
Age				
[10-40 [	47	60	41.59	43.48
[40-60 [	59	53	52.21	38.11
≥60	7	25	6.19	18.12
Level of education				
None	64	83	56.64	56.64
Franco-Arabic	10	29	8.85	8.85
Literate	1	10	0.88	8.88
Primary	28	14	24.78	24.78
Secondary	10	2	8.85	8.85

3.2 ANALYSIS OF POST-HARVEST PRACTICES OF TAMARIND

3.2.1 POST-HARVEST PRACTICES CARRIED OUT BEFORE THE CONSERVATION OF PODS

The majority of tamarind farmers in the commune of Ouagadougou (78.95%) shell the pods immediately after harvesting and then preserve the seeds without further drying (Table 2). However, those in Bobo-Dioulasso still dry the pods before storing them (27.78%) (Table 2). Two other practices are highly represented in the Bobo-Dioulasso zone: drying the pods, shelling and then further drying (1) (20.37%) and shelling the pods immediately after harvesting and then drying (3) (20.37%). In addition, in the Ouagadougou zone, pod drying followed by shelling before seed conservation (2) (10.53%) is in second place, followed by the other practices with a percentage of 3.5 each. Drying of the pods generally takes place at home for respondents in Bobo-Dioulasso (69.09%) and at the place of trade (100%) for those in Ouagadougou (Table 2).

Table 2. Post-harvest practices carried out before seed conservation (Bobo-Dioulasso and Ouagadougou)

Post-harvest practices	**Post-harvest operations**	
Post-harvest operations	**Bobo-Dioulasso**	**Ouagadougou**
Drying of pods, shelling then additional drying (1)	20.37	3.51
Drying of pods then shelling before seed conservation (2)	11.11	10.53
Pods shelled immediately after harvest and dried (3)	20.37	3.51
Shelling of pods immediately after harvest and then seed storage without further drying (4)	16.67	78.85
Drying and storage of pods (5)	27.78	3.51
Crushing of immature pods then drying (6)	3.70	0
Place for drying the pods		
Field	10.91	0
Household	69.09	0
Place of trade	20	100

3.2.2 POST-HARVEST DRYING TIME OF PODS

In the opinion of the respondents in both communes, the majority of them claim to dry tamarind for an average of 1 to 7 days after collection (Figure 2). Then those who dry for 7 to 14 days, and to a lesser extent for 14 to 21 days in the Bobo-Dioulasso area (Figure 2).

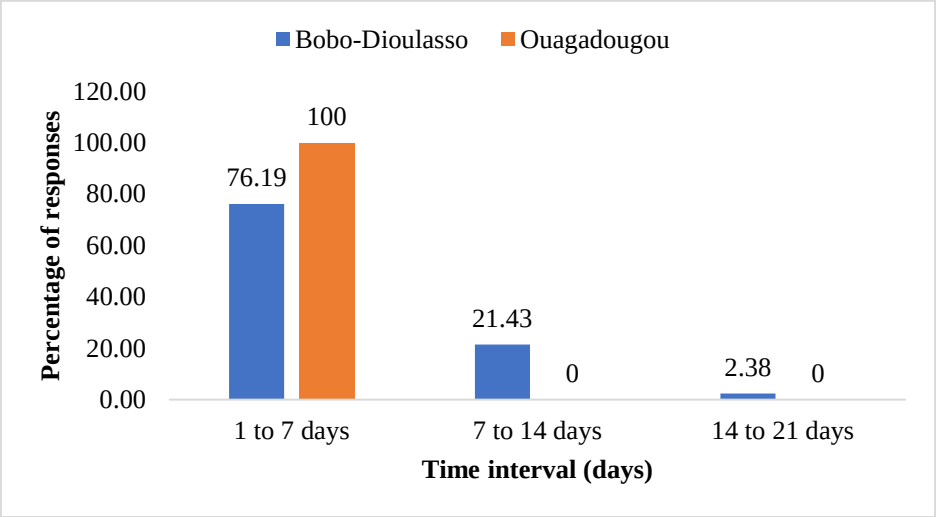

Fig. 2. Distribution of respondents' answers on the duration of drying of tamarind pods before conservation

3.3 STRUCTURES AND STORAGE METHODS FOR TAMARIND PODS

3.3.1 POD STORAGE STRUCTURES

The types of storage structures found in the communes of Bobo-Dioulasso and Ouagadougou are used in different proportions (Figure 3). Most of farmers in both communes use polypropylene bags with or without plastic bags (Figure 3). In Bobo-Dioulasso, plastic or aluminum dishes (5.61%) are used in second place, followed by a minority who use plastic drums or baskets. In contrast, in Ouagadougou, plastic drums (15.13%) come second, followed by baskets and dishes (Figure 3).

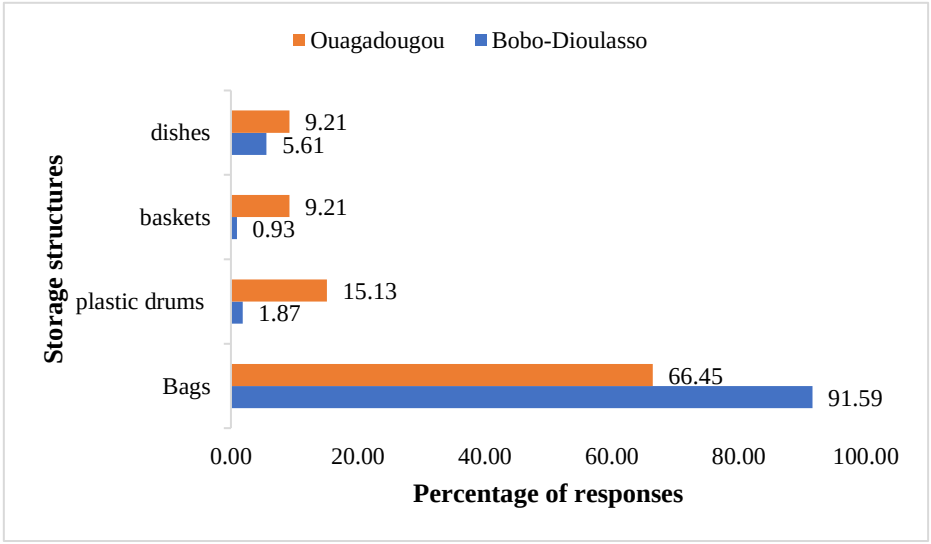

Fig. 3. Distribution of responses from respondents in the communes of Ouagadougou and Bobo-Dioulasso on T. indica pods storage structures

3.3.2 METHODS OF STORING TAMARIND PODS

The majority of respondents in Bobo-Dioulasso (67.29%) and Ouagadougou (67.91%) store tamarind without mixing it with other commodities (Figure 4). The remainder practice mixed storage by storing tamarind pods most often with maize and millet (Tables 3).

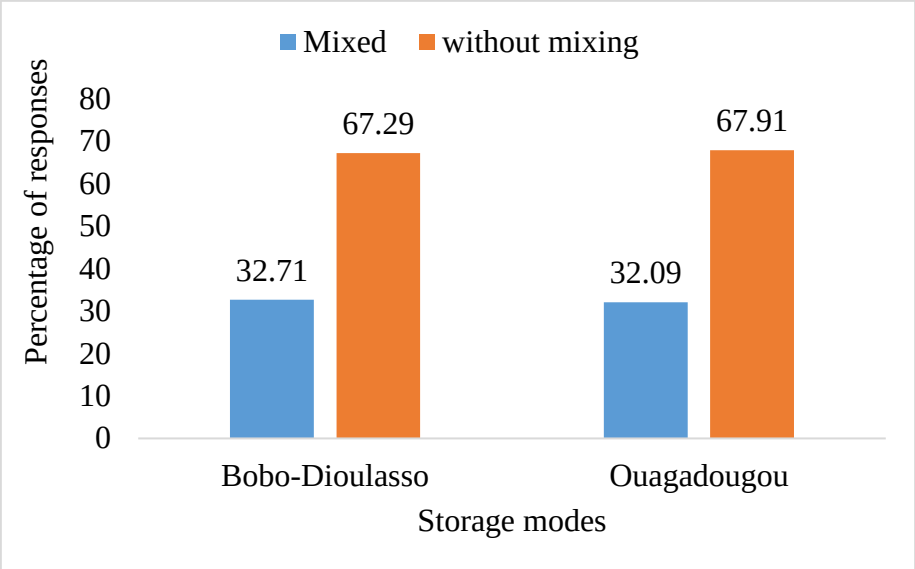

Fig. 4. Distribution of respondents' answers on the storage method for T. indica

Table 3. Commodities associated with T. indica pods for mixed storage in Bobo-Dioulasso and Ouagadougou

Commodity	Frequencies		Percentages (%)	
	Bobo-Dioulasso	Ouagadougou	Bobo-Dioulasso	Ouagadougou
Peanuts	2	2	2.82	2.27
Bissap	9	18	12.68	20.45
Cola	3	0	4.23	0
Coffee	3	0	4.23	0
Ginger	4	8	5.63	9.09
Jujube	0	2	0	2.27
Maize	17	19	23.94	21.59
Millet	16	19	22.54	21.59
Cowpea	6	2	8.45	2.27
Monkey bread	6	0	8.45	0
Sweet pea	0	2	0	2.27
Rice	5	0	7.04	0
Sesame	0	2	0	2.27
Sorghum	0	2	0	2.27
Voandzou	0	8	0	9.09

3.4 BIOTIC CONSTRAINTS AND NATURE OF LOSSES ASSOCIATED WITH POD STORAGE

3.4.1 PESTS OF TAMARIND POD STOCKS

Among the agents responsible for damage cited by the respondents, insects are in the majority in both communes (Figure 5) followed by rats and rodents. In Bobo-Dioulasso area, molds come before termites, while in Ouagadougou, damages due to termites come before molds (Figure 5).

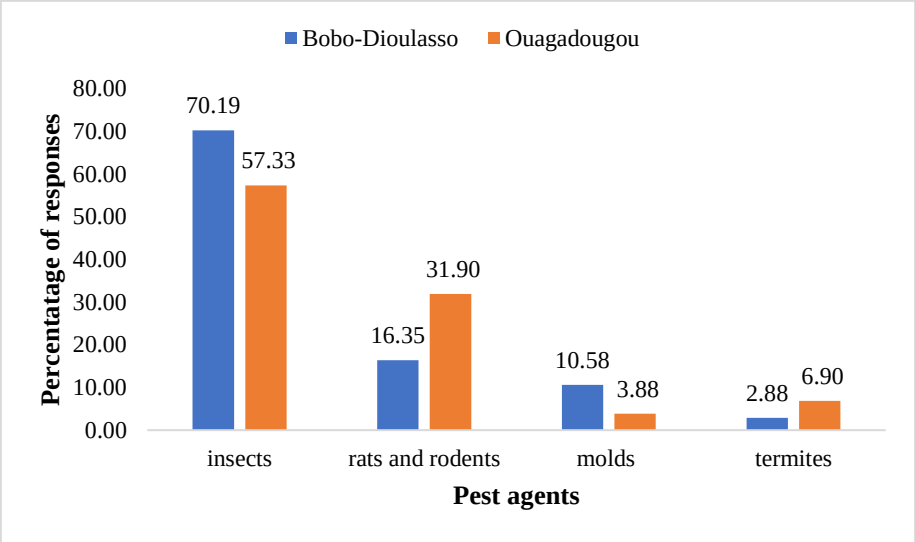

Fig. 5. perception of respondents in the two communes on the pests stocked in T. indica

3.4.2 NATURE OF DAMAGE TO TAMARIND PODS BY PESTS

According to the farmers, damages caused by pests are multiple (Figure 6). In the commune of Ouagadougou, the most represented are perforated seeds (63.16%) and broken seeds (32.06%), while in Bobo-Dioulasso, broken seeds are more often cited (36.57%) than perforated seeds (29.85%). Then we have rotting and loss of germination capacity.

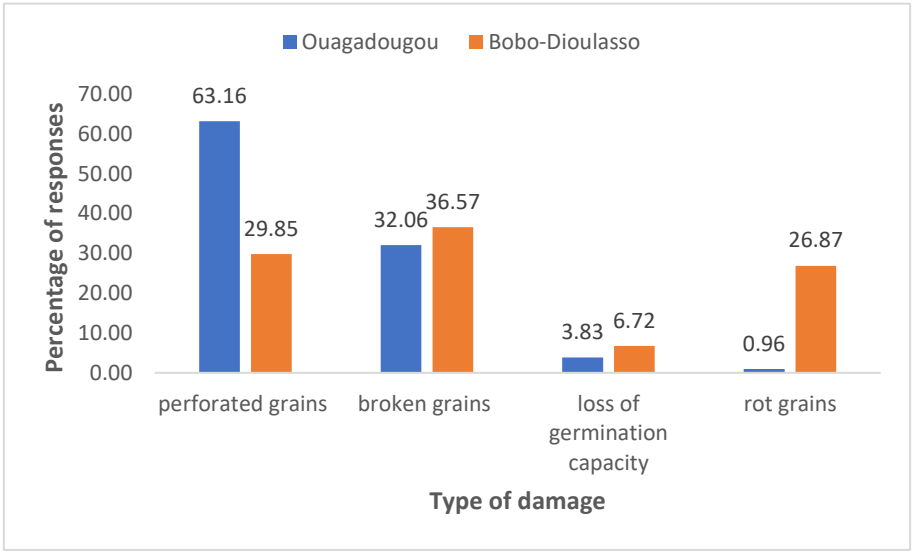

Fig. 6. Perception of the responses on the nature of the damage observed on T. indica stocks

3.4.3 METHODS OF PROTECTION OF TAMARIND POD STOCKS

Three types of protection methods are used by the respondents; the percentage of use of these methods varies according to locality (Figure 7). In Bobo-Dioulasso, hermetic storage (51.28%) is the most common, followed by steaming the tamarind and storing the bags on racks. However, in Ouagadougou the majority method is steaming (72.92%), followed by hermetic storage (14.58%) and storage of bags on racks (12.50%).

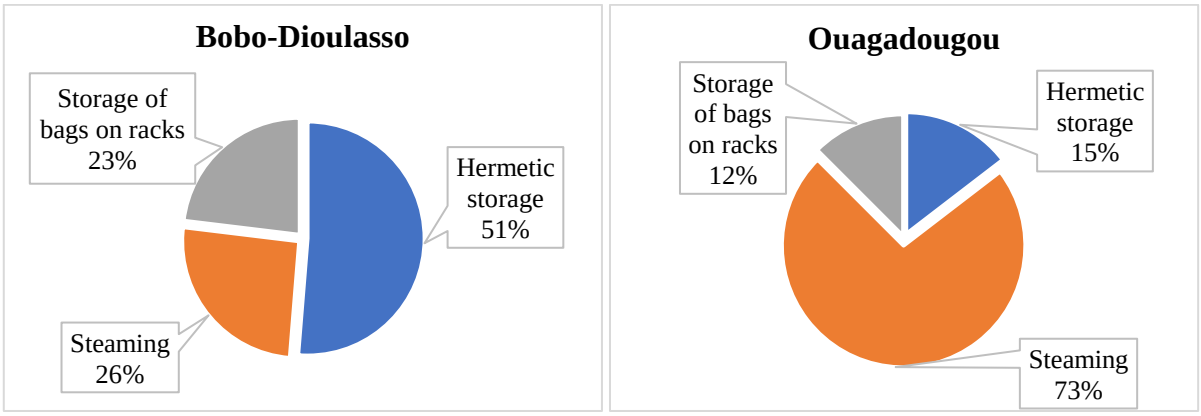

Fig. 7. Respondents' responses on methods of protecting T. indica stocks in Bobo-Dioulasso and Ouagadougou.

3.4.4 STORAGE TIME

The time of storage of *T. indica* pods in good condition varied significantly in the presence or absence of control methods among farmers in Bobo-Dioulasso (W = 8243.5, P< 0.0001; Figure 8) and Ouagadougou (W =13823, P< 0.0001; Figure 8). The average time of storage of pods in good condition in the presence of control methods is 390 days (13 months) in Bobo-Dioulasso and 720 days (24 months) in Ouagadougou, while it is 120 days (4 months) in Bobo-Dioulasso and 150 days (5 months) in Ouagadougou in the absence of control methods. It should be noted that the minimum shelf life of *T. indica* pods without the application of any method is 30 days in Bobo-Dioulasso and 15 days in Ouagadougou.

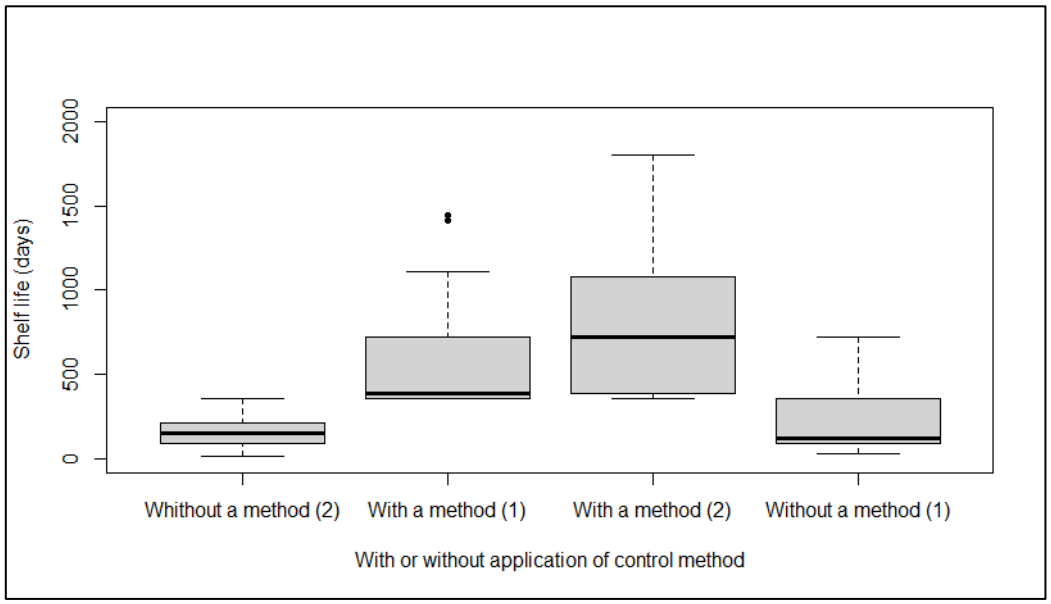

Fig. 8. Average shelf life of tamarind pods with or without the application of methods in the Bobo-Dioulasso and Ouagadougou zones

3.4.5 REASONS FOR STORING TAMARIND PODS

Each respondent had an objective in exploiting tamarind. The majority of respondents in both communes sell tamarind to provide for their needs, while others store it for family consumption throughout the year (47.43% of respondents in Ouagadougou and 28.68% in Bobo-Dioulasso) (Figure 9). Stored tamarind pods are rarely used during ceremonies. Few farmers store tamarind for resale when selling prices increase.

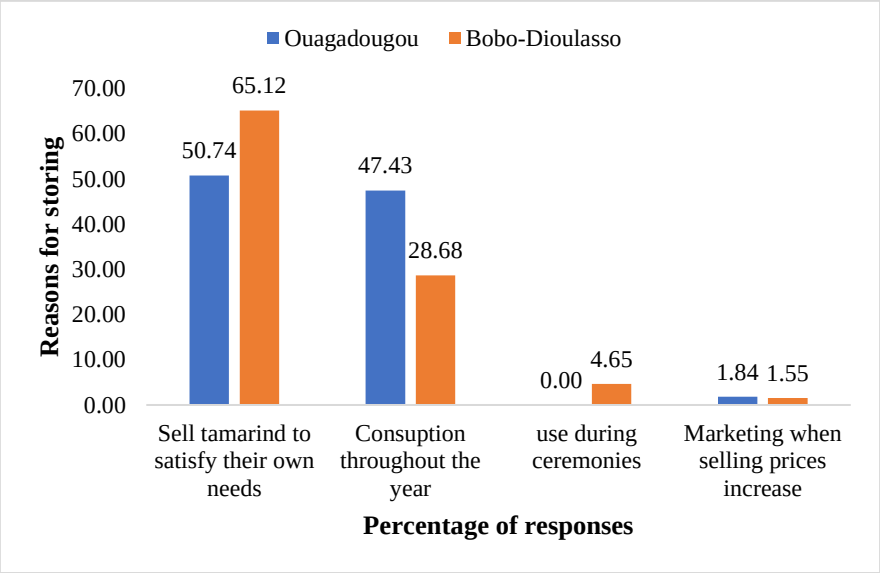

Fig. 9. Proportion of respondents' answers on reasons for storing T. indica

3.4.6 TAMARIND PRICES

In August, the average price of a tomato can of *T. indica* (W = 9059; P < 0.0001; Figure 8) and a dish yoruba of *T. indica* (W = 4917.5, P < 0.0001; Figure 9) increases significantly. The average price of a can of *T. indica* tomato varies from 300 CFA francs in December to 500 CFA francs in August; similarly, a yoruba dish of *T. indica* increases from 1250 CFA francs during the harvest period in December to 1500 CFA francs in August during the lean season. The maximum selling price in August is 650 CFA francs in Bobo-Dioulasso and 2500 CFA francs in Ouagadougou.

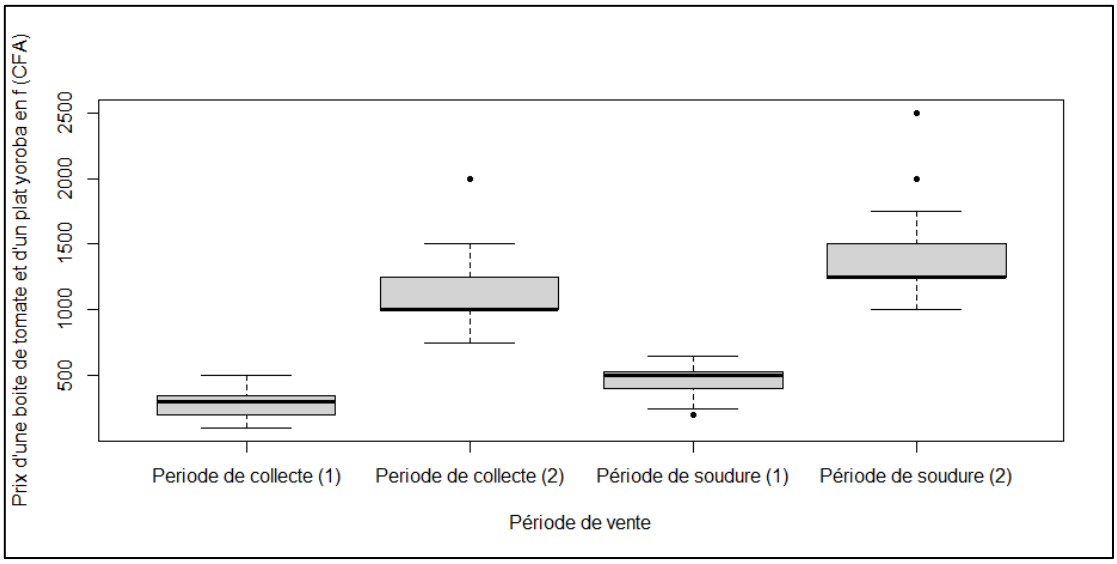

Fig. 10. Average selling price of a can of tomato and a yoruba dish of T. indica in the Bobo-Dioulasso and Ouagadougou areas

4 DISCUSSION

Most of the surveyed populations in this study are non-literate women. They interact from the collection of the pods to its sale, which makes tamarind a source of income for them. A few men involved in the sector export tamarind to countries in the sub-region. The majority of farmers in Ouagadougou shell the pods immediately after harvesting and then store them without further drying, while those in Bobo-Dioulasso dry and store the pods. Drying time most often varied from 1 day to 7 days in

both study areas; corroborating the work of [14]. Drying took place in the markets or at home and this action aims to protect the pods from mold by decreasing the moisture content [15]; which will allow to keep its nutritional value and germinative capacity. After the application of the different practices, the vast majority of pods are stored in 50 kg polypropylene bags lined with plastic bags [14]. Similarly [16] showed that 59.17% of respondents in central Benin use 50-100 kg jute bags to store legume seeds. Others use plastic drums, plastic or steel baskets and dishes. A minority of respondents in both locations use mixed storage with other commodities such as maize, millet and bissap. This mixed storage system could be harmful to the conservation of stocks because insects could move from one commodity to another. According to [17] and [18] the main pest of cowpea (*Vigna unguiculata* L. Walp) seeds in storage *Callosobruchus maculatus* is transferred from cowpea to voandzou (*Vigna subterranea*) in the case of mixed storage where it adapts very quickly. Despite the practices employed on *T. indica,* some biotic constraints cause multiple pod damage.

The most frequent constraints according to the respondents are perforated pods and seeds where insects are pointed out as the primary culprits. A similar survey conducted by [14] on *Senegalia macrostachya* seeds in Boulkiemdé province in Burkina Faso showed that the majority of damage to stocks is due to insects. This applies for cowpea and voandzou stocks in the Hauts Bassins region [19] and cereal stocks of producers in the South Sudan zone [20]. Then, the presence of broken seeds in the stocks is significant which would be due to the action of rats and rodents. In order to minimize the damages caused by predators, tamarind farmers used methods to store the pods.

Steaming the tamarind is the most common method in Ouagadougou; according to respondents, the hot steam kills the insects. Similar work was done by [16] in central Benin where hot water was used as a treatment for the preservation of seed legumes and voandzou pods. The hermetic storage practiced mainly by farmers in Bobo-Dioulasso inhibits the development of insects characterized by a decrease in oxygen levels (hypoxemia) and an increase in carbon dioxide levels (hypercarboxyemia) by reducing their metabolic activity [21], [22]. In addition, hermetic storage limits losses and preserves the germinative capacity of seeds [23], [24], [25], [26]. Storing bags on pallets or rocks is another method used by respondents to protect the stock from moisture. Throughout our investigation no respondent reported using chemicals for protection of *T. indica* pods as it is consumed directly without prior cooking. These methods used by farmers allow them to protect the stock for a period of 13 months on average by those in Bobo-Dioulasso and 24 months on average by those in Ouagadougou. The purpose of all these practices to keep the tamarind in good condition is essential for the farmers.

Most respondents report selling tamarind to meet their specific needs and also consume it throughout the year, whether in Bobo-Dioulasso or Ouagadougou. According to [27], NTFPs (*T. indica* fruits or *V. paradoxa* kernels) are sold by 73% of households not for savings or to make a considerable profit but rather to meet pressing financial needs. Similarly, a study conducted in Central Africa by [28] also showed that NTFPs constitute a real "life preserver" for many farmers who do not have sufficient resources. The selling price of a can of tomato and a yoruba dish of *T. indica* increases significantly from December (collection period) to August (lean season) in Bobo-Dioulasso and Ouagadougou. In addition, *T. indica* is used throughout the year by craftsmen and industrially for processing into juice that is exported to Senegal. In view of its importance, a good mastery of the sector would make it possible to provide solutions to better protect the tamarind. This could be an alternative to fight against poverty in order to increase the income of the families who exploit it.

5 CONCLUSION

This study allowed us to assess the post-harvest management of *T. indica* fruits and the constraints related to its conservation in the localities of Bobo-Dioulasso and Ouagadougou. After collection of the tamarind, the dried pods are shelled and stored immediately without further drying in Ouagadougou, but in Bobo-Dioulasso, they are dried for about 1 to 7 days and stored without shearing. Among the storage structures for *T. indica* pods, polypropylene bags are the most popular. Insects are the most voracious among the pests that cause various and important damages to *T. indica* stocks. The most common damage encountered was grain perforation in both study areas. To remedy this situation, the most frequent method is steaming the tamarind. Despite the increase in prices during the lean season, farmers sell their stocks before this time to provide for specific needs. To make the most of the tamarind pods, it would be wise to put in place an effective method of stock protection. As well, in order to get succeed in this challenge, it is necessary to have a more in-depth knowledge of the insects responsible for the damage.

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