ANALYSIS OF THE PROFITABLILITY OF PICS BAGS FOR THE STORAGE OF ROSELLE GRAINS *(Hibiscus sabdariffa)* IN THREE REGIONS IN NIGER

by

Seyni Boureima, Ph.D.

Agronomist-consultant, Lecturer and Researcher, University of Maradi

Bokar Moussa, Ph.D.

Agro-economist, Project PICS INRAN Maradi

J. Lowenberg-DeBoer, Ph.D.

Working Paper #15-2

August 2015

Dept. of Agricultural Economics

Purdue University

ANALYSIS OF THE PROFITABLILITY OF PICS BAGS FOR THE STORAGE OF ROSELLE GRAINS *(Hibiscus sabdariffa)* IN THREE REGIONS IN NIGER

by
Seyni Boureima, Ph.D.
Agronomist-consultant, University of Maradi
Maradi, Niger
boureimaseyni@yahoo.fr
Bokar Moussa, Ph.D.
INRAN Maradi
Maradi, Niger
bokarmoussa@gmail.com
J. Lowenberg-DeBoer, Ph.D.
Department of Agricultural Economics, Purdue University
West Lafayette, IN 47907-2056
lowenbej@purdue.edu
Working Paper #15-2
August 2015

Abstract

Analysis of the Profitability of PICS Bags for the Storage of Roselle Grain (*Hibicus sabdariffa*) in Three Regions in Niger - Seyni Boureima, Bokar Moussa and J. Lowenberg-DeBoer

Roselle is a multipurpose crop produced for its grain, as well as flowers used in making teas and therapeutic preparations. The study is based on interviews with 164 randomly selected Roselle producers in Dosso, Maradi and Zinder Regions of Niger. Farmers store roselle grain in various containers, such as woven bags, plastic jugs, plastic bags, granaries, etc. which are mostly non-hermetic. Some store with the addition of wood ash, neem leaves (*Azadirachta indica*), sand or insecticide. Plastic jugs, granaries and plastic bags are used mainly for storing small amounts of roselle while metal drums and woven polypropylene bags are reserved for larger quantities. Overall the portion of roselle grain stored in 2012 in potentially hermetic containers was: Dosso, 22%; Maradi, 29% and Zinder, 26%. In 2012, the percentage reported stored in PICS triple bags was Dosso, 4%; Maradi, 2% and Zinder, 2%. The percentage of the grain quantity stored with insecticide in 2012 was Dosso, 26%; Maradi, 13%, and Zinder zero. The analysis of price fluctuations shows that about 7 months of storage is required for the producers to take advantage of price seasonality. Rozelle prices also vary widely from market to market. Consequently, marketing flexibility is key to profitable commercialization. In most cases storing into the next rainy season (i.e. 7 months) is the most profitable strategy. It is clear from this analysis that the PICS bags are a potential source of profitability for roselle producers in the study areas especially when the storage period is relatively long. For example, the simple rate of return is over 100% even when the PICS bag is only used one year compared to selling at harvest. PICS technology is much more cost effective than the traditional method of storage. After 7 months of storage without either insecticide or hermetic storage method, the return on investment is largely negative because of very high storage losses.

Keywords: Niger, Roselle, Hibiscus, storage, hermetic, profitability

JEL Codes: Q01, Q16, Q12

Introduction

Roselle (*Hibiscus sabdariffa*) is a versatile plant that fits several agro-ecological and socio-economic niches. It is cultivated as an intercrop with major crops. Roselle is a crop requires little care and is often considered a woman's crop. The overall objective of this study was to determine whether the use of PICS bags is a competitive technology for the storage of roselle grains. The specific objectives were to: (i) identify the seasonal fluctuations of roselle grain price, and determine if these fluctuations are significant enough to motivate the storage of grains; (ii) describe how these grains are actually stored and sold; (iii) assess the added value of the use of PICS bags compared to the traditional method of storage.

Literature Review

Taxonomy, origin and geographical distribution

The genus *Hibiscus* is represented by over 300 species of *Hibiscus sabdariffa* with two main varieties: *Hibiscus sabdariffa* var. *altissima* and *Hibiscus sabdariffa* var. *sabdariffa*. *Hibiscus sabdariffa L.* var. *sabdariffa* is a vascular plant belonging to the phylum of seed plants, angiosperms subphylum, class of Dicotyledons, the dialypetalous subclass, the Thalamiflores series on the order of Malvales and the Malvaceae family (Guignard, 1979).

Several vernacular names of the species are encountered: roselle (or rozelle), sorrel, red sorrel, Jamaican sorrel, Indian sorrel, Guinea sorrel, Queensland jelly plant, jelly okra, lemon bush, florida cranberry, sour-sour, bissap, foloré, pink tea of Abyssinia (Berhaut 1979; D'Heureux-Calix and Badrie, 2004; ASNAPP, 2003).

Hibiscus sabdariffa L. is a species that is native to tropical America (Berhaut, 1979). However, some authors such as Martin (1987) suggest that there are species of West African origin, and tropical Africa (Hainida et al. 2008). According to Rhoden et al. (1993) the roselles are native to the region extending from India to Malaysia. *H. sabdariffa* is currently cultivated in all the tropics including Africa, Central America, India and Malaysia (Berhaut, 1979, Morton, 1987; Pursglove 1968).

In Niger, two biological types are encountered, particularly the highly developed calyx type on top of the ovarian capsule (Photo 1. a) and the smaller calyx adhering to the capsule (Photo 1. b).

Photo 1 a : Biological type with a highly developed calyx (source Bakasso 2010)

Photo 1 b : Biological type with a smaller calyx (Source Bakasso 2010)

Production of roselle grain by region of Niger are given in Table 1. This Table 1 shows that the areas selected for the purposes of this study are the main areas of major roselle productions in Niger.

Table 1: Roselle grain production in different regions of Niger for the 2012 crop year

Region	**Area (ha)**	**Production (kg)**	**Yield (kg ha^{-1})**
Agadez	0	0	0
Diffa	665	207	289
Dosso	**40 911**	**9 229**	**226**
Maradi	**62 598**	**11 583**	**185**
Tahoua	12 741	2 597	204
Tillabéri	28 263	3 406	121
Niamey	NA	NA	NA
Zinder	**29 679**	**5 048**	**170**
Total	**174 857**	**32 056**	

Source : DSA/MDA, 2013

Socio-economic importance

Initially cultivated for its fiber, the species is currently being exploited in the tropics not only for its fiber, but also for its calices, its leaves and seeds. As a multipurpose plant, *H. sabdariffa* today has a considerable economic importance (Duke, 1983; D'happy-Calix and Badrie, 2004 Al-Kahtani and Hassan, 1990; Van Damme and Viaene, 1987; Purseglove, 1968). Demand in major industrialized countries such as Germany and the USA is mainly for dried flowers (RAISE, 2003), but in producing countries the grain is used as well. Roselle production is low input compared to cereals that consume more time, effort or require more investment (fertilizers, pesticides, labor at different phenological stages). During the rainy season, it is common to observe prices from 1000 to 1500 FCFA the "tia" (equivalent to a volume of about 2.5 to 3 dm^3 or 2.5 kg) while the same measure of millet or sorghum, the main food crop, is less than 500 FCFA (Bakasso, 2010).

- ***Food uses***

Roselle is grown mainly for its leaves, grains and calices for both human food and animal feed (Duke, 1983, Morton, 1987). The sour tasting leaves are consumed as a cooked vegetable and in a salad. They give a spicy flavor to the sauce (Fortin et al., 1990). The fleshy calices, picked unripe, is used to make good jellies and jams. It is mainly used in the manufacture of a very delicious refreshing drink called "bissap" whose flavor is reminiscent of gooseberry. This drink is very popular in many West African countries especially during ceremonies. The calyx is also used in the manufacture of an antiscorbutic syrup with a pleasant tart pomegranate taste. Fresh calices are sought to flavor rice. They contain water, cellulose, vitamin C, iron and thiamine (Pousset, 1989). The various organs of the plant are rich in carbohydrates, proteins and lipids (Tchiégang and Kitikil, 2004). Red calyx is used to produce « karkadé » which is a powder extracted from the dried calices. It is recommended as a mild laxative and a refresher.

In Niger, the grains are used to prepare the "Soumbala", an important condiment used to flavor sauces especially in rural areas. The grains have a very high oil content (16.8%) of very good quality, which is marketed. In some countries, such as Uganda, the grains are eaten roasted (FAO, 1990). They are also used in animal feed.

Roselle is a versatile plant that owes its sour taste to the presence of potassium oxalate (Anonymous, 2002). Its nutritional value can complement the unbalanced diet often found in developing countries by adding minerals and vitamins. In Niger, farmers are concerned about a reliable market for their products; indeed, the lack of reliable markets hinders the development of this crop. Thus, for these farmers it is important to have an appropriate and cheaper technology for storage of Roselle grain while awaiting for a prospective purchaser without affecting marketability. According to Bakasso (2010), sales prices are significantly higher during the planting season varying from 150 FCFA at harvest to more than 350 FCFA the local unit of measure of grain in before the next harvest.

- ***Therapeutic uses***

Roselle has several therapeutic properties:

- Leaves and fruits are components of many remedies against viral hepatitis, constipation and ascariose (Dupriez and De Leener, 1987).
- The decoction of the leaves or calyces is used against coughs, toothaches or as a light laxative and gall bladder bile flow stimulant.
- The juice of the leaves should be consumed by pregnant women in labor to hasten delivery.
- The juice is also used in the eyes as a treatment for inflammation.
- In addition, the roots and leaves are used to relieve sore throats.

Storage Systems

In general, the price fluctuations between periods of harvesting allows producers and buyers to capture gains from storage investment (Jones et al., 2011a and 2011b). However, it is still not economically feasible for small producers to take advantage of price seasonality of agricultural products because according to Stephens and Barrett (2009), most producers sell some or their entire crop immediately after harvest to resolve cashflow issues, repay debt or simply because they do not have adequate storage systems to protect their harvest to a more favorable sale period. In this situation, delaying sale of agricultural products to the lean period when prices are rising forces producers to cover current expenses of the post-harvest period by

alternative means (Jones et al. 2011a). This represents a cost especially that these funds are paid from revenue from other income generating activities.

Some storage methods are more effective than others for the preservation of grains that have a high water content which can facilitate rot and fungal contamination (Hel et al., 2000). Comparing methods of storage under hermetic and non-hermetic conditions, Quezada et al. (2006) showed that the growth of *Aspergillus ruber* is significantly reduced in airtight storage conditions of corn that had high moisture content (17 %). These authors reported an *A. ruber* infection rate of 94 % of the grains under non-hermetic conditions after 15 days of storage compared to only 1 % in hermetic conditions. Furthermore, Hell et al. (2010) showed that the use of triple bagging (PICS bags) keeps dry corn weight losses within 0.5 % on average after 6 months of storage with artificial and natural *Prostephanus truncates* infestations. Baoua et al. (2014) reported losses of 83.9 % due to *A. obtectus* in Niger after 7 months of storage in the laboratory without treatment.

Methodology

Study Area

To achieve the objectives of this project, surveys were conducted in three Nigerien regions namely Dosso, Maradi and Zinder, and data were collected for the month of July 2013. To make the most of scarce resources questions about both roselle and Bambara groundnut were asked since many farmers in this area produce both crops. Because both crops are included the gender statistics may be in part an artifact of sampling. The sample of respondents was selected from the list of Bambara nuts producers who also cultivate roselle, so it may reflect more Bambara groundnut reality in terms of gender than the roselle situation. In Dosso, 6 villages belonging to three different rural communities (Arewa , Dogondoutchi and Dosso) were targeted while in Maradi 5 villages belonging to three rural communities (Gazaoua, Aguié and Tessaoua) were covered by the survey.study. Also, in the region of Zinder, 5 villages spread in two rural communities (Mirriah and Magaria) were selected.

The regions of Dosso, Maradi and Zinder are located in the southern strip of Niger between the nomadic Sahelian zone (C3) and the Sudan zone (A1 & A2) according to the phytogeographical subdivision of SAADOU (1990) (Fig. 1). The nomadic Sahelian zone (C1, C2 & C3) is located in the north-center of the country and is characterized by an annual rainfall between 150 and 300 mm and a rainy season that lasts 1 to 2 months. It is ideally suited for nomadism, and the main activity is roaming livestock; but rainfed agriculture is practiced here and there in the north of this area. The sedentary Sahelian zone (B1, B2): Located in the south-center of the country, this area is characterized by a normal annual rainfall between 400 and 600 mm and a normal duration of the rainy season between 2 and 3 months. Area of rainfed agriculture by excellence, this area is predominantly agricultural, although livesock grazing is practiced here and there in the Northern border. The Sudanian zone (A1, A2): Located in the south of the country and of a relatively small extent, this area is characterized by a normal annual rainfall between 600 and 750 mm and a rainy season that normally lasts 3 to 4 months (Fig.1). The main activity is agriculture and this area is best suited for agriculture.

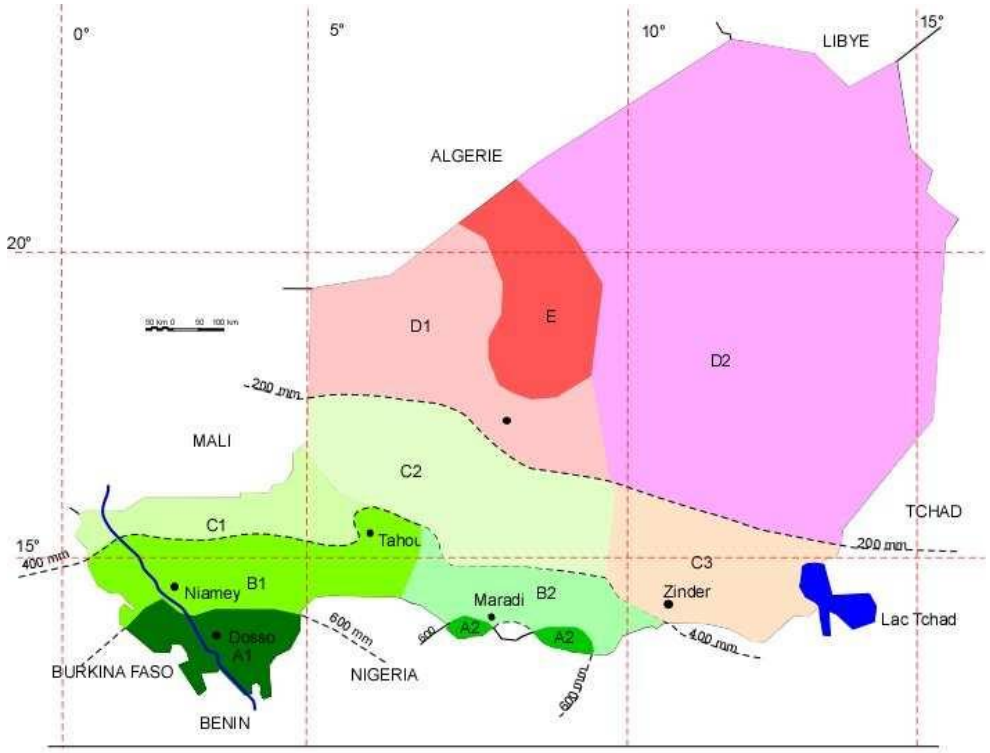

Figure 1 : Phytogeographic compartments in Niger (Source SAADOU, 1990)

Sampling and data collection

To gather statistically valid information, a 5 part divided questionnaire was developed. The first part concerns general information (region, town, site, etc...), the second is related to socio-economic characteristics of producers (name, sex, age, status, experience, etc...), the third part deals with planted areas and production, the fourth part concerned the used varieties and the fifth part focused on new storage methods. In each region, villages were randomly selected based on the list of roselle producing villages. The sample of producers was chosen randomly. An exhaustive list of all producers of Roselle has been established and the survey sample was randomly drawn on the basis of this list. Date was collected by personal interview conducted with the respondents.

Processing and data analysis

The data collected through the questionnaire were used to calculate the percentage of producers using each method of storage, shelf life and amount of Roselle grains stored using each method.

For the estimation of storage losses we referred to the data given by Baoua et al. (2015, submitted for publication) who estimated losses of Roselle grains at 83.9 % after 7 months of storage with the traditional method that is to say without improved technology. For the analysis of the sensitivity, gains on storage were calculated by considering ± 5 % of the rate of loss in storage. For PICS bags, we considered losses to 0.6 % as recommended by Jones et al. (2011b).

To calculate the gain on investment, we estimated the price of the PICS bag at 1000 F FCFA and 250 F FCFA for the ordinary woven bags used by producers. An Excel spreadsheet was used to calculate the basic statistics.

Results

Socio-economic characteristics of producers

Dosso region

Figure 2 shows that in Dosso Region mainly women are engaged in the cultivation of roselle. Women represent 77 % of those reporting Roselle production compared to 23 % for men.

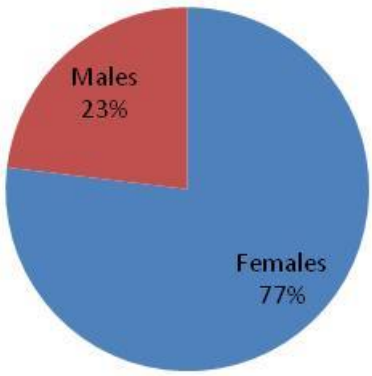

Figure 2: Sex distribution of the respondents in Dosso

It was observed that 12 % of the producers were aged between 20 and 29 years, 15 % between 30 and 39 years, 26 % between 40 and 49 years, 19 % between 50 and 59 years, 23 % between 60 and 69 years 3 % between 70 and 79 years and 2 % have an age above 80 years (Table 2).

Tableau 2: Age distribution of roselle producers in Dosso

Age	Number	% of respondents
20-29	8	12
30-39	10	15
40-49	17	26
50-59	12	19
60-69	15	23
70-79	2	3
80 and above	1	2

These results show that few producers are young. This shows that the production of Roselle in the Dosso region is not only women oriented, but is also predominately an activity

of the older farmers. The results in Figure 3 show that 86 % of these producers are illiterate, 8 % started primary school, 3 % have a secondary level and only 3 % have started a university education.

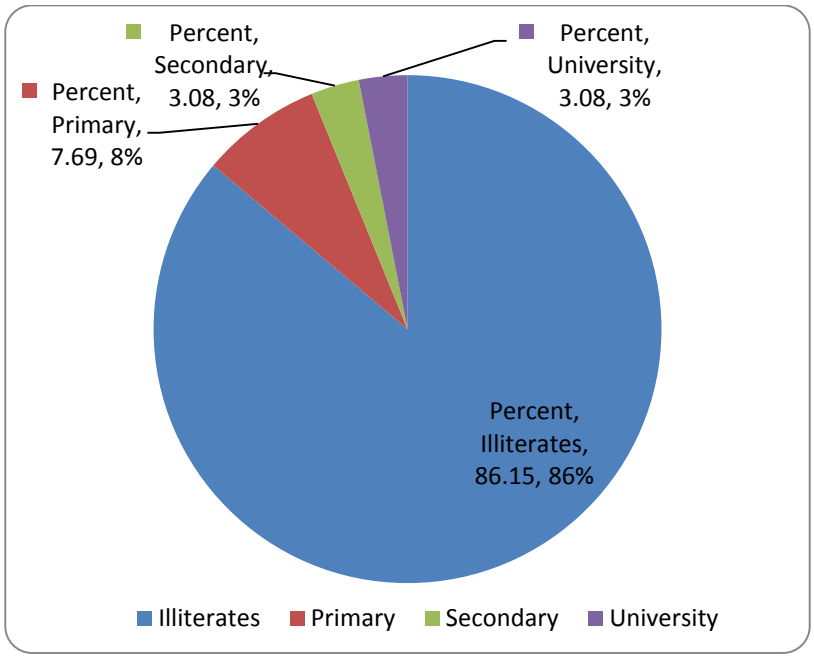

Figure 3: Level of formal education of producers at Dosso

These results show that the majority of producers have not received any formal education. This high rate of illiteracy among producers, among others, has certainly impacted the producers' ability to master the roselle production techniques and hence the low observed yield and precariousness of the storage systems.

Regarding marital status, 77 % of the producers are married and 23 % are divorced or widowed (Figure 4). The striking finding that emerges from Figure 4 is that there is no single producer. This can be attributed to a problem of land access or reinforces the idea growing Roselle is mostly an activity of older farmers.

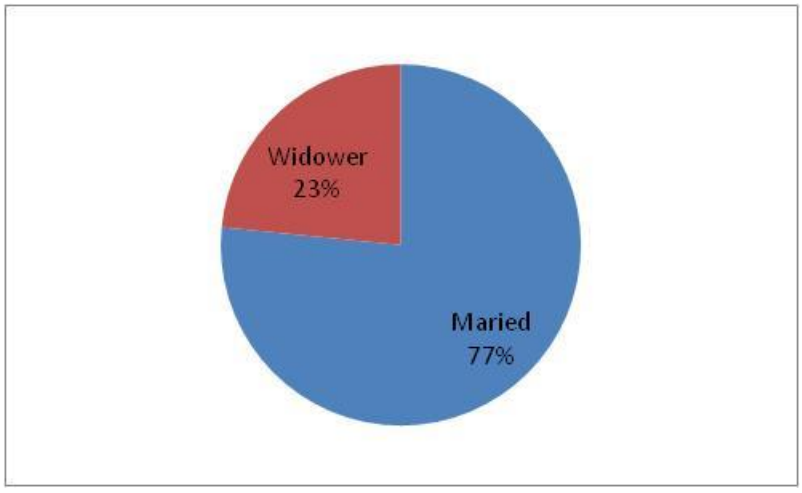

Figure 4: Marital status of the respondents at Dosso

For the producers' household size, it is observed that 18 % of producers have a household size ranging between 1 to 5 members, 35 % between 6 and 10 members, 23 % between 11 and 15 members, 15 % between 16 and 20 members, 6 % between 21 and 25 members and 1 % have a household size greater than or equal to 26 members (Figure 5).

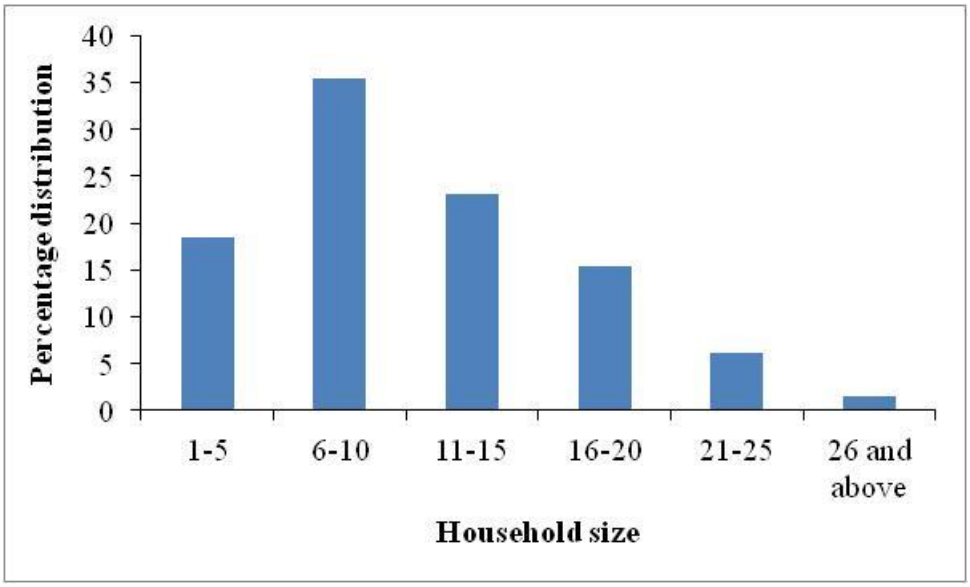

Figure 5: Household size of roselle producers at Dosso

Table 3 shows that most producers engage in other income generating activities secondary to agricultural production including roselle growing consisting mainly of trading and livestock breeding which engage 50 % and 28 % of the producers respectively.

Tableau 3: Secondary activities performed by the respondents

Secondary activity	% of respondents
Craft	4
Trade	50
Repairing Shoes	2
Pounding millet	2
Livestock breeding	28
Koranic treatment	4
Agricultural processing	7

Small business	2

Maradi region

In the region of Maradi Figure 6 shows that 82 % of roselle producers are men and 18 % women. This gender allocation is in part an artifact of sampling. The sample of respondents was selected from the list of Bambara nuts producers who also cultivate Roselle, so it reflects more Bambara groundnut reality in terms of gender than the Roselle situation.

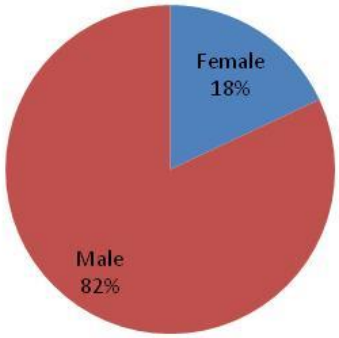

Figure 6: Sex distribution of respondents at Maradi

The age of farmers is given in Table 4, which shows that only 4 % of producers can be qualified as young with age ranging between 20 and 29 years. The age groups between 30 and 39 years represents 30 % of the producers and 8 % of the producers are in the fourth age group (70 and older). These results reinforce the idea that for both sexes, roselle production is an activity for older farmers.

Tableau 4: Age distribution of Roselle producers at Maradi

Age	Number of producers	% of producers
20-29	2	4
30-39	15	30
40-49	9	18
50-59	10	20
60-69	10	20
70 and above	4	8

Among the participants surveyed 74 % are illiterate, 15 % underwent a primary education and 11 % attended high school (Figure 7). Unlike Dosso, none of the producers have attended a university level. Regarding the marital status, Figure 8 shows that 96 % of the producers are married and 4 % are divorced. There are no a single (never married) individuals who grow Roselle in the sample.

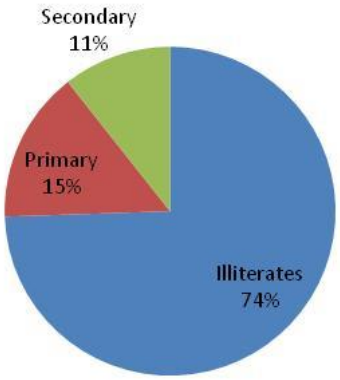

Figure 7: Level of formal education of producers at Maradi

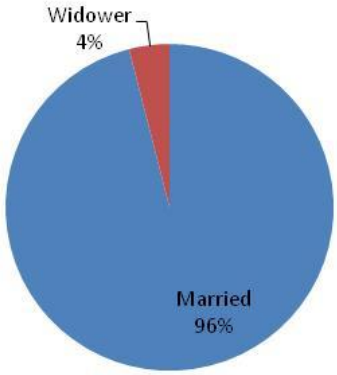

Figure 8: Marital status of the respondents at Maradi

For the producers' household size, Figure 9 shows that 42 % of the producers have a household size between 6 and 10 members , 28 % between 11 and 15 members , 22 % between 16 and 20 members , 6 % between 21 and 25 members and 2 % of households have a size greater than or equal to 26 members . It is found that at Maradi, the household size is relatively high which potentially influences negatively the production of roselle. The results show that especially midsize households engage more in the production of roselle (Fig.9).

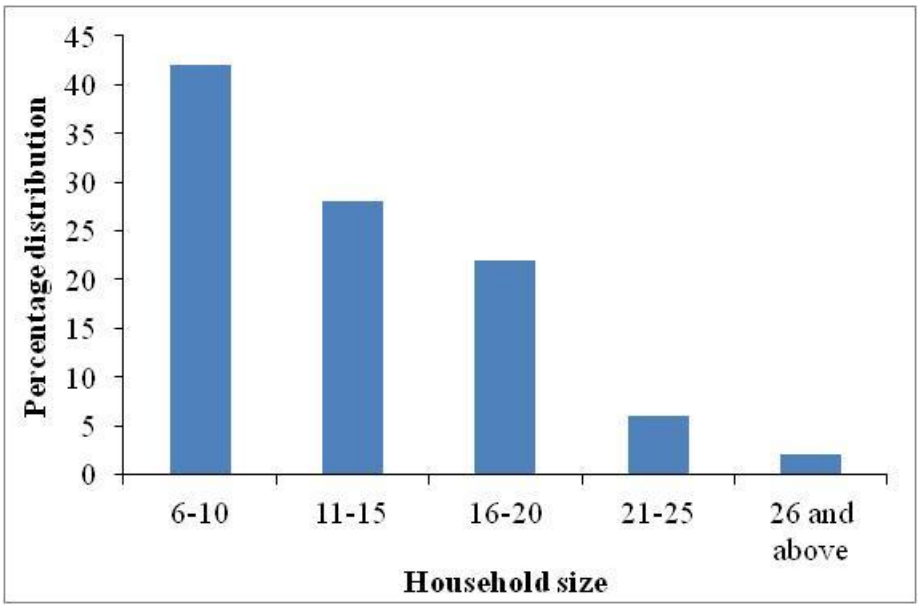

Figure 9: Household size of Roselle producers at Maradi

Producers also engage in other income generating secondary activities such as livestock breeding which engages 50 % of producers, trade (28 %) among others (Table 5).

Tableau 5: Secondary activities performed by the respondents

Secondary Activities	% of producers
Agriculture	3
Agriculture and Livestock breeding	3
Trade	28
Livestock breeding	50
Exodus	3
Fight	3
Small Business	3
Agricultural Processing	3
Timber Sale	3

Zinder region

The sample of roselle producers in Zinder is dominated by men who represent 80 % of the participants compared to 20 % for women (Fig. 10). Like for Maradi case this gender allocation reflects Bambara groundnut reality as explained in the previous section.

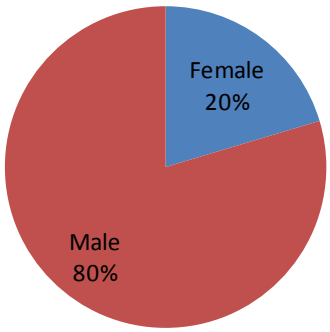

Figure 10: Sex distribution of the respondents at Zinder

Figure 11 shows the age distribution of the producers. It is clear from Figure 11 that similarly to Dosso and Maradi, it is mainly older people who engage in the production of Roselle. There is a strong dominance of the 40 to 49 years and 50 to 59 years age groups, representing respectively 35 % and 22 %. The 20 to 29 age group which can be called young represents only 6 %.

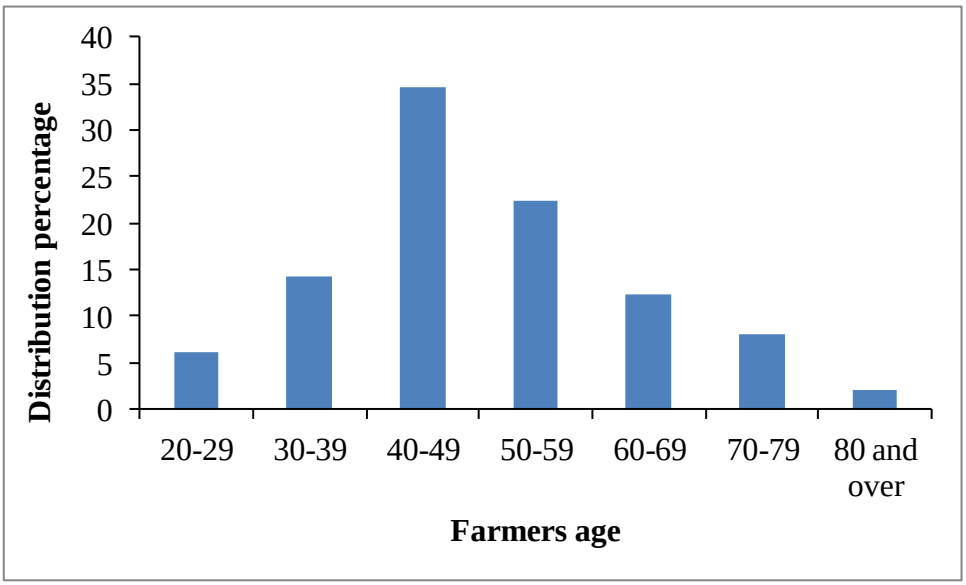

Figure 11: Age distribution of roselle producers at Zinder

In regards to the level of formal education of respondents, it is observed that 87 % of the farmers are illiterate, only 11 % have an elementary education and 2 % started secondary school (Fig. 12).

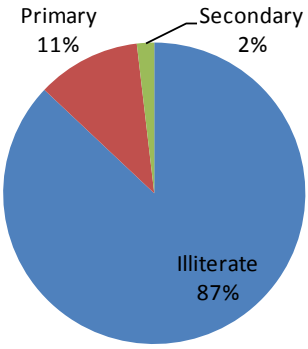

Figure 12: Level of formal education of producers at Zinder

The marital status of producers is given in Figure 13. It found that 96 % of the producers are married compared to 4 % who are divorced. No single (never married) was recorded among the sample participants.

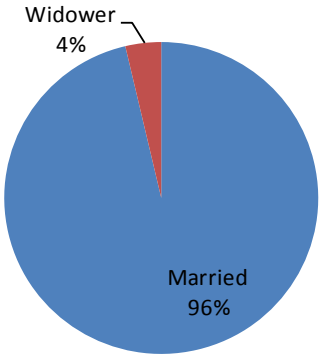

Figure 13: Marital status of the respondents at Zinder

For the producers' household size, Figure 14 shows that it is mostly medium-sized households who engage more in the production of roselle. Thus, households ranging in size from 6-10 people and 11-15 people account respectively for 41 % and 31 % compared to 7 % for small-sized households (1-5 people) and less than 2 % for a household size of more than 26 people. This could be explained by the fact that small households do not have enough family labor to care for both large and minor crops; whereas for large households, the availability of land could be a limiting factor for the cultivation of secondary crops.

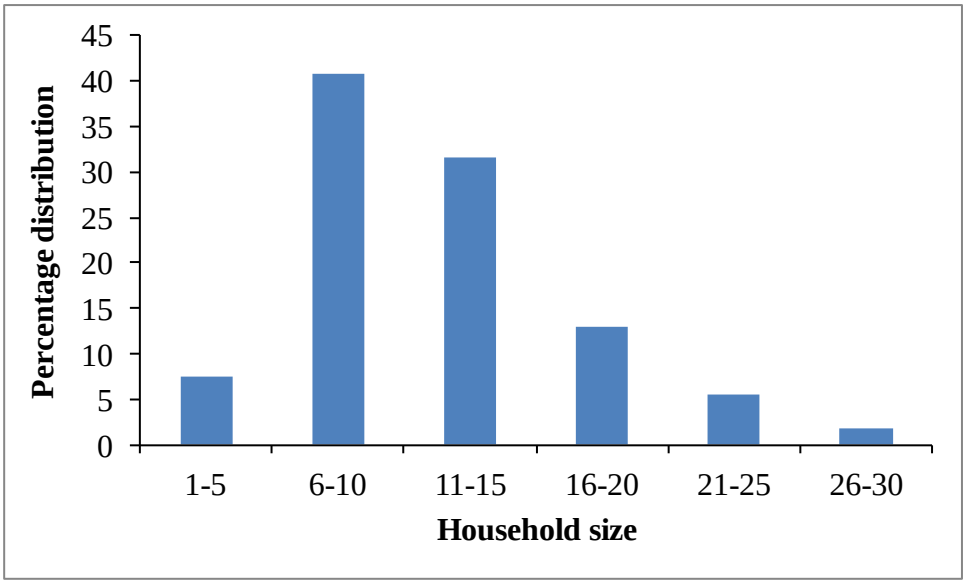

Figure 14: Household size of the producers at Zinder

The participants in the study area lead in parallel other income-generating activities including livestock breeding which engages 35 % of the respondents, trade with 22 % among others (Table 6).

Tableau 6: Secondary activities performed by the respondents at Zinder

Secondary activity	% of producers
Agriculture	10
Other	4
Hairdressing	2
Trade	22
Sales intermediary	2
Livestock breeding	35
Koranic education	2
Exodus	2
Forging	4
Masonry	2
Maraboutage	2
Radio repairing	2
Motorcycle taxi	2
Agricultural processing	8
Water sale at the fountain	2

Roselle grain storage method by region

Dosso region

In the region of Dosso, a sample of 55 producers were targeted during both 2012 and 2011 harvest season Table 7 shows that the simple woven bags and plastic jugs are the main containers used by participants to store their roselle grain harvest. The largest category was that of 36% of respondents who used the simple bags in 2012 compared to 35 % in 2011. Eleven participants representing 20 % of the sample, used plastic jugs in 2012 compared to 21 % in 2011. Other containers such as one layer plastic bags, metal drums and granaries are also used but to a lesser extent on the order of 5 %, 2 % and 2 % in 2012, respectively.

Storage techniques can be purely traditional, modern or mixed. It appears from this survey that some respondents in the study area use natural preventive methods such as plant ash or fine sand. The triple bag technology is also used by 2 to 3 % of the survey sample.

Table 7: Storage method and percentage of participants using these storage techniques in 2012 and 2011 in the region of Dosso

Storage Method	2012		2011	
	Number of participants	Percentage	Number of participants	Percentage
Plastic jug	11	20.00	11	21.15
Plastic jug + ash	2	3.64	2	3.85
Plastic	3	5.45	3	5.77
Double bagging	2	3.64	2	3.85
Metal drum	1	1.82	1	1.92
Granary + sand	1	1.82	1	1.92
Granary + insecticide	0	0.00	1	1.92
plastic + ash	2	3.64	1	1.92
Simple bag	20	36.36	18	34.62
Simple bag + ash	2	3.64	3	5.77
Simple bag + insecticide	9	16.36	8	15.38
Triple bagging	2	3.64	1	1.92
Total	**55**	**100**	**52**	**100**

A certain proportion of participants use mixed methods that combine traditional and modern methods in particular the addition of synthetic insecticide in simple woven bags and granaries.

The quantities of roselle grains stored in these facilities are given in Table 8. More than 5 tons of roselle were stored in 2011 and almost double in 2012 (9.985 kg) by the sample producers in the region of Dosso. Almost half of this production is stored in woven bags, 45 % in 2012 and 46 % in 2011. The improved storage system popularized in cowpea (triple bagging) is used only in small amounts for a total of 425 kg in 2012 (4 %) and 400 kg in 2011 or 8 % of the production of the participants. It is clear from Table 9 that the plastic jugs, granaries and plastics are mainly used to store small amounts of roselle while metal drums, single layer polypropylene bags or triple bags are reserved for large quantities.

In Dosso Region, 34% of the quantity stored was in potentially hermetic containers in 2011 and 22% in 2012. Those potentially hermetic containers include plastic jugs, metal drums, plastic bags, double bags and triple bags. About 20% of the roselle grain was stored with insecticide in 2011 and 26% in 2012.

Table 8: Amount of roselle stored per method in 2012 and 2011 in the Dosso region

Storage Method	2012		2011	
	Quantity (kg)	Percentage	Quantity (kg)	Percentage
Plastic jug	731.25	7.32	570	10.69
Plastic jug + ash	118.75	1.19	72.50	1.36
Double bagging	700	7.01	497.50	9.33
Metal drum	162.50	1.63	250	4.69
Banco granary	137.50	1.38	0.00	0.00
Plastic bag	22.50	0.23	10	0.19
Plastic bag + ash	17.50	0.18	7.50	0.14
Simple bag	4477.50	44.84	2436.25	45.68
Simple Bag + insecticide	2555	25.59	1040	19.50
Simple bag + ash	637.5	6.38	50	0.94
Triple bagging	425	4.26	400	7.50
Total	**9985**	**100**	**5333.75**	**100**

Table 9: Amount of roselle per storage technique and producer at Dosso

Containers	Total quantity (kg)	Quantity per respondent (kg)
Plastic jug	650.63	59.15
Plastic jug + ash	95.63	47.81
Double bagging	598.75	299.38
Metal drum	206.25	206.25
Banco granary	68.75	68.75
Plastic bag	16.25	5.42
Plastic bag + ash	12.50	6.25
Simple bag	3456.88	181.94
Simple bag + insecticide	1797.50	199.72
Simple bag + ash	343.75	114.58
Triple bagging	412.50	206.25

Maradi region

In Maradi, we find almost the same storage containers as in Dosso (Table 10). Single and double bags are the most commonly used containers at 16 % and 11 % in 2012, respectively; 23 % 8 % in 2011, respectively. In addition, roselle grains are sometimes wrapped in old cloths.

The traditional storage system "simple bag plus ash" is the most widely used technique in the region. Table 10 shows that 32 % of participants have used this technique in 2012 and 33 % in 2011. Mixed systems such as plastic jug plus insecticide, double bagging plus insecticide and simple bag plus insecticide are also used by some producers. The triple bagging technology was used by 8 % of the respondents in 2012 also 8 % in 2011.

A total of 4098.75 kg of roselle were stored in these facilities in 2012 and 4287.5 kg in 2011 (Table 11). Slight more than half of the production was stored using the traditional method of simple bag plus ash in 2011 and 9 % in 2012 (Table 11). Insecticide treatments were applied in small quantities stored in plastic jugs, plastic bags and simple bags.

Table 10 : Storage method and percentage of participants using these storage techniques in 2012 and 2011 in the region of Maradi

Storage method	2012		2011	
	Number of participants	Percentage	Number of participants	Percentage
Plastic jug	2	5.26	0	0.00
Plastic jug + insecticide	1	2.63	1	2.56
Plastic jug+ash	0	0.00	1	2.56
Double bagging	4	10.53	3	7.69
Double bagging + ash	1	2.63	1	2.56
Double bagging + insecticide	2	5.26	2	5.13
Metal drum + ash	2	5.26	2	5.13
Plastic bag	1	2.63	1	2.56
Simple bag	6	15.79	9	23.08
Simple bag + ash	12	31.58	13	33.33
Simple bag + insecticide	3	7.89	3	7.69
Triple bagging	3	7.89	3	7.69
Old cloth	1	2.63	0	0.00
Total	**38**	**100**	**39**	**100**

Table 11: Stored roselle quantity per method in 2012 and 2011 in the region of Maradi

	2012		2011	
Storage system	Quantity (kg)	Percentage	Quantity (kg)	Percentage
Plastic jug	10	0.24	0	0
Plastic jug + insecticide	15	0.37	95	2.22
Simple bag + ash	2005	48.92	2165	50.49
Double bagging	740	18.05	89375	20.85
Metal drum + ash	75	1.83	75	1.75
Plastic bag	57.5	1.4	130	303
Plastic bag + insecticide	220	5.37	95	2.22
Simple bag	563.75	13.75	496.25	11.57
Simple bag + insecticide	305	7.44	275	6.41
Triple bagging	77.5	1.89	62.5	1.46
Oldcloth	30	0.73	0	0
Total	**4098.75**	**100**	**4287.5**	**100**

Table 12 gives the quantity of roselle stored by system and respondent. It is noted that in Maradi, like Dosso, the plastic jugs and plastic bags are used to keep small amounts of roselle while large quantities are often stored in woven polypropylene bags. About 32% of the roselle grain quantity was stored in potential hermetic containers in 2011 and 29% in 2012. In 2011 11% was stored with insecticide and 13% in 2012.

Table 12: Average quantity of roselle per storage technique and producer at Maradi

Containers	Quantity (kg)	Quantity per respondent (kg)
Plastic jug	5	2.5
Plastic jug + insecticide	55	27.5
Simple bag + ash	2085	1042.5
Double bagging	816.88	408.44
Metal drum + ash	75	37.5
Plastic bag	93.75	46.88
Plastic bag + insecticide	157.5	78.75
Simple bag	530	265
Simple bag + insecticide	290	145
Triple bagging	70	35
Wrapped in old cloth	15	7.5

Zinder region

The majority of respondents in Zinder use plastic jugs (24 %), plastics (22 %), simple bags (22 %) and jars (17%) as grain storage for roselle grains (Table 13). The triple and double bagging are used only by two participants in 2012 and double bagging was used by one participant in 2011.

Table 13: Storage method and percentage of participants using these storage techniques in 2012 and 2011 in the region of Zinder

Storage system	2012		2011	
	Number of participants	Percentage	Number of participants	Percentage
Plastic jug	10	24.39	10	23.26
Double bagging	1	2.44	1	2.33
Jar, ash	0	0.00	1	2.33
Jar	7	17.07	10	23.26
Jar + ash	2	4.88	2	4.65
Plastic	9	21.95	7	16.28
Plastic + ash	1	2.44	1	2.33
Plastic + jar	0	0.00	1	2.33
Simple bag	9	21.95	9	2093
Bag + ash	1	2.44	1	2.33
Triple bagging	1	2.44	0	0.00
Total	**41**	**100**	**43**	**100**

Quantities of roselle grains stored by method are given in Table 14. These results show that, compared to Dosso and Maradi, roselle production is less important among participants targeted in the Zinder region. In total, 845 kg of roselle were produced stored in 2012 compared to 861.88 kg in 2011. Half of this quantity was stored in simple bags, 51 % in 2012 and 44 % in 2011. The other half was stored in small capacity storage containers such as jars, plastic jugs, bowls, old cloths and bags. About 22% of the roselle grain was stored in potentially hermetic containers in 2011 and 26% in 2012. No PICS bags were used in 2011 and 2% of the quantity was stored in PICS bags in 2012. No insecticide use was reported among the respondents in the Zinder region. The distribution of stocks by container type and producer (Table 15) shows that at Zinder it is the jars, canaries and simple bags that are used for large quantities unlike plastic jugs and plastic bags.

Table 14: Roselle quantity stored by storage technique in 2012 and 2011 in the region of Zinder

Storage system	2012		2011	
	Quantity (kg)	Percentage	Quantity (kg)	Percentage
Plastic jug	83.75	9.91	46.25	5.37
Double bagging	11.25	1.33	2.5	0.29
Jar	0	0.00	176.25	20.45
Jar + ash	110	13.02	81.25	9.43
Jar + sand	58.75	6.95	0	0.00
Plastic bag	26.25	3.11	20	2.32
plastic and canary	77.5	9.17	112.5	13.05
Plastic bag + ash	0	0.00	10	1.16
Simple bag	432.5	51.18	375	43.51
Simple bag + leaves	7.5	0.89	12.5	1.45
Bag	5.625	0.67	5.625	0.65
Bag + ash	5	0.59	2.5	0.29
Bowl	5	0.59	7.5	0.87
Cloths	2.5	0.30	10	1.16
Triple bagging	19.375	2.29	0	0
Total	**845**	**100**	**861.88**	**100**

Table 15: Roselle quantity by storage technique and producer in Zinder

Containers	Quantity (Kg)	Quantity per respondent (kg)
Plastic jug	65	6.5
Double bagging	6.875	6.875
Jar	88.125	10.37
Jar + ash	95.625	47.81
Jar + sand	29.375	-
Plastic bag	23.125	2.89
Plastic bag and jar	95	95
Plastic bag + ash	5	5
Simple bag	403.75	44.86
Simple bag + leaves	10	-
Thin Plastic Bag	5.625	-
Thin Plastic Bag + ash	3.75	3.75
Bowl	6.25	-
Fabric	6.25	-
Triple bagging	9.6875	9.69

Seasonal price fluctuations

The survey results in the 3 regions of Niger show that the prices of a kilogram of roselle (Fig. 15) are very low at harvest averaged to 85 FCFA, 79 FCFA and 79 FCFA for the month of November in the regions of Dosso, Maradi and Zinder, respectively. In all three regions of the country, prices begin to rise from March to reach their maximum in April at Dosso and May in the regions of Maradi and Zinder, 7 to 8 months after harvest. Price fluctuations between the time of harvest and the lean period are very high in all three study regions with a much higher tendency in Maradi. The ratio between the price of a kilogram of roselle during the lean season (price peak) and the price at harvest was 2.5 in Dosso; 2.84 in Maradi and 2.58 in Zinder.

According to the survey respondents, the harvest is generally sold either on site or in the weekly markets in the surrounding villages which may be located some 90 km for some participants with a cart as the main means of transportation. For others, the product is delivered to the market after a one to a three hour walk. No producer in the sample exports roselle grains for sale.

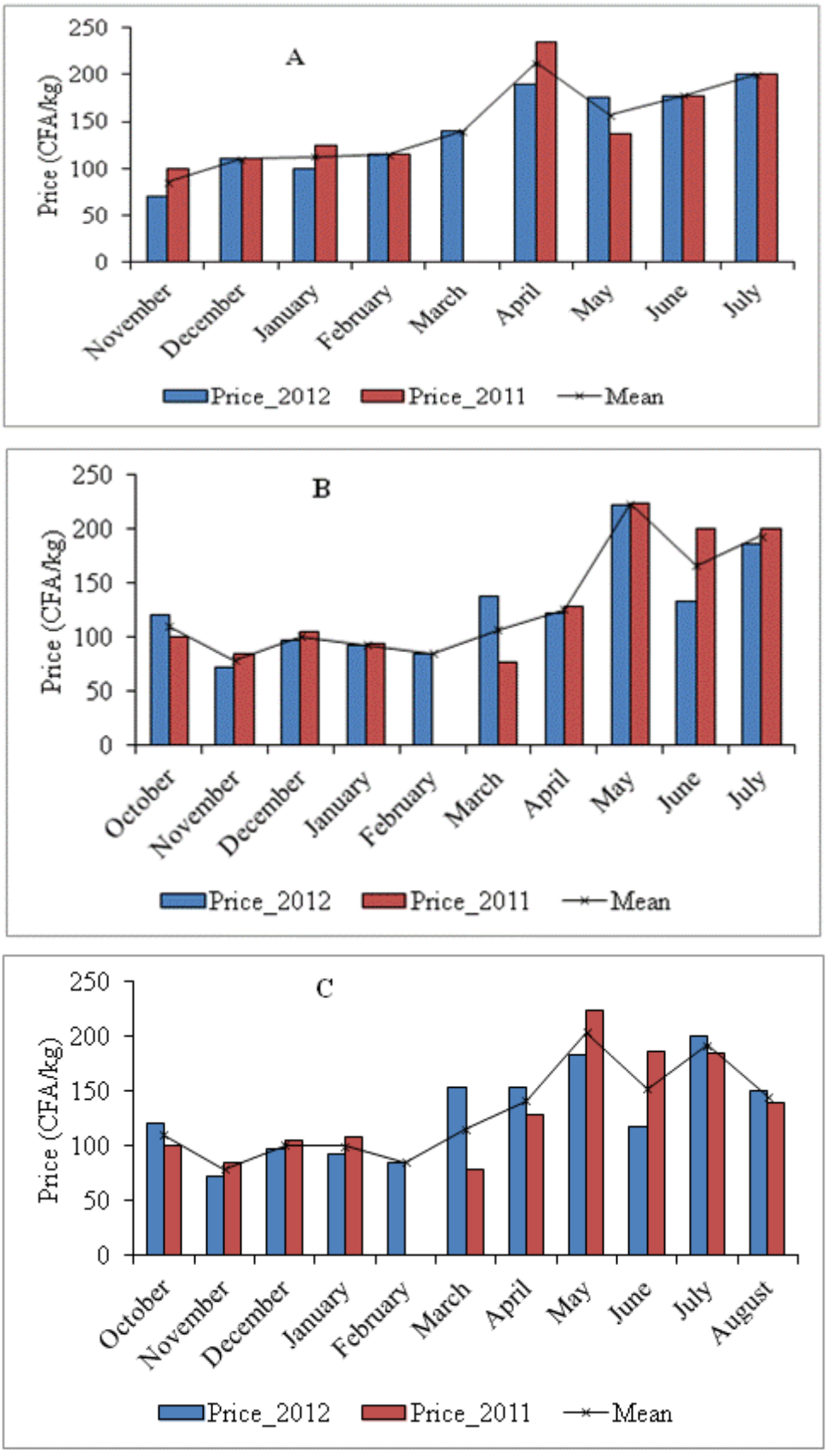

Figure 15: Seasonality of roselle prices at Dosso **(A),** Maradi **(B)** and Zinder **(C)**

Grain processing by the respondents

All participants surveyed said that they transform roselle grains to "soumbala" for seasoning sauces. The grains are boiled and pounded before being left to dry. Note that this forms an important part of the marketing of grains that should be taken into account in subsequent studies.

Profitability analysis of PICS bags

Socio-economic studies have shown that most farmers are illiterate in all three regions surveyed. The use of insecticides by these producers to store their products is therefore a problem not only for the health of consumers but also for the person applying the product. Moreover, the traditional grain storage in unsealed containers is not profitable due to the high pest pressure which causes losses of up to 83.9 % (Baoua et al., 2014) but also the storage period (7 months). That is why it is necessary to find an alternative to the traditional storage method (with or without insecticide) that is more profitable but also healthier.

Tables 16 and 17 give the process of calculating the return on investment after 7 months of storage comparing traditional methods of storage without insecticide, with insecticide and with the PICS bag with opportunity costs of capital (OCC) of 25 and 35 %. The net income and the gain on storage in Tables 16 and 17 are based on a harvest conducted in November and sold in May, when prices are highest whether it is at Dosso, Maradi or Zinder. Because of the large price increases from the harvest period to the most favorable period for sales (May), storage with PICS bags can generate high returns for roselle producers.

Table 16: Net income for roselle producers during harvest and when prices are highest with different storage methods.

Selling period	Harvest	Traditional storage method				PICS bags storage	
	November	Without insecticide			With Phostoxin	1 year	2 years
		May					
Stock (kg)	100	100	100	100	100	100	100
*Storage loss (%)	-	88.90	83.90	78.90	1	0.60	0.60
Commercial quantity (Kg)	100	11.10	16.10	21.10	99	99.40	99.40
Selling price (FCFA/Kg)	81	213.33	213.33	213.33	213.33	213.33	213.33
Total income (FCFA)	8100	2368	3435	4501	21120	21205	21205
Costs							
Bag	0	250	250	250	250	1000	500
Insecticide cost	-	-	-	-	450	-	-
Total cost of storage	0	250	250	250	700	1000	500
Net income	8100	2118	3184	4251	20420	20205	20705

*83,9 ± 5 % of losses

Indeed, the net income after 7 months of storage with PICS bags (one year of use) is 20,205 FCFA per 100 kg of stock. This net income is comparable to that obtained with the method of storage with insecticide (20 419 FCFA) but significantly higher than the net income at harvest (8100 FCFA). In the case where the PICS bag is reused for a second season, the generated net income is higher than that obtained using a phostoxin insecticide treatment.

The net income without the opportunity cost of capital after 7 months of storage with the traditional method without insecticide is 3,184 FCFA f compared to 8,100 FCFA f if the production is sold at the time of harvest (Table 16).

Table 17 shows that even with an opportunity cost of 35%, a roselle producer who chooses to store its production with the PICS bags to sell during the lean period, could double his or her annual revenue on storage with a gain of 113% for a single use and 126% for a dual-use of PICS bags. With the traditional method without insecticide, there is a loss even with a relatively low opportunity cost of 25% due to the very high loss rate (83.9% after 7 months of storage).

For the sensitivity test we considered ± 5 % of the estimated loss by Baoua et al. (2014) but in no case can the producer make a profit by choosing to store their harvest for 7 months

without some improved technology. The only choice available to the producer is to sell off the production at harvest with less favorable prices at the risk of losing everything after 7 months of storage.

Table 17: Net gain and return on storage for roselle producers (OCC 25 and 35 %)

Selling Period	Sale at harvest	Traditional storage method				PICS bags storage	
	November	Without insecticide			With Phostoxin	1 year	2 years
		May					
Net income	8100	2118	3185	4251	20419.67204	20205	20705
Storage losses (%)	-	88.9	83.9	78.9	1	0.6	0.6
OCC 25%	-	1217.71	1217.71	1217.71	1283.33	1327.08	1254.17
Net gain on storage	-	-7200	-6133	-5066	11036	10778	10866
Return on storage (%)	-	-86%	-73%	-60%	125%	118%	123%
OCC 35%	-	1705	1705	1705	1797	1858	2434
Net gain on storage	-	-7687	-6620	-5554	10523	10247	10171
Return on storage (%)	-	-92%	-79%	-67%	120%	113%	115%

Conclusion

Post-harvest handling and storage is a key aspect of food security through Africa and especially in Niger. In that context this study considered the storage of dry roselle grains. The study is based on interviews with 164 randomly selected roselle producers in Dosso, Maradi and Zinder Regions of Niger.

Farmers store their harvest in various small structures like simple bags, plastic jugs, plastic bags, granaries, wrapping in old cloths etc. which are mostly non-hermetic. Storage methods range from simple use of these containers only, to the addition of ash, neem leaves (*Azadirachta indica*), sand or insecticide. Plastic jugs, granaries and plastic bags are used mainly for storing small amounts of roselle while metal metal drums and polypropylene bags are reserved for larger quantities. Overall the portion of roselle grain stored in 2012 in potentially hermetic containers was: Dosso, 22%; Maradi, 29% and Zinder, 26%. In 2012, the percentage reported stored in PICS triple bags was Dosso, 4%; Maradi, 2% and Zinder, 2%.

The percentage of the quantity stored with insecticide in 2012 was Dosso, 26%; Maradi, 13%, and Zinder zero.

The analysis of price fluctuations shows that about 7 months of storage is required for the producers to take advantage of price seasonality. Roselle prices also vary widely from market to market. Consequently, marketing flexibility is key to profitable commercialization. In most cases storing into the next rainy season (i.e. 7 months) is the most profitable strategy. It is clear from this analysis that the PICS bags are a potential source of profitability for roselle producers in the study areas especially when the storage period is relatively long. For example, the simple rate of return is over 100% even when the PICS bag is only used one year compared to sales at harvest. This technology is also much more cost effective than the traditional method of storage. After 7 months of storage without either insecticide or hermetic storage method, the return on investment is largely negative because of very high storage losses. We believe that for future studies, one should take into account the amount of roselle processed and sold because in rural areas it is in this form that the majority of the production is marketed, especially in the region of Dosso.

References

AL-Kahtani H. A. & Hassan B. H., 1990. Spray drying of roselle (*Hibiscus sabdariffa* L.) extract. Journal of Food Science, 55, 1073-1076.

Anonyme, 2002. Memento de l'Agronome. Ed CIRAD-GRET-Ministère des Affaires Etrangères. Paris (France), 1691 pp.

ASNAPP, 2003. Market survey: *Hibiscus sabdariffa*. Agribusiness sustainable Natural African Plant Products. Available at http://www.herbs.org/africa/hibiscus.html.

Bakasso Y., 2000. Ressources génétiques des roselles (*Hibiscus Sabdariffa* L.) Du Niger : évaluations agromorphologique et génétique. Thèse d'Etat ès-sciences, Université Abdou Moumouni, Niamey, 109 pp.

Baoua I., Amadou L., Abdourhamane M., Bakoye O., Baributsa D., and Murdock L.L. 2015. Grain Storage Insect Pests and Associated Losses in Rural Niger. Submitted to *Journal of Stored Products Research*. Volume 64, Part B, October 2015, Pages 8-12

Berhaut J., 1979. Flore illustrée du Sénégal tome VI : Linacées à Nympheacées, Dakar : gouvernement du Sénégal, Ministère du Développement Rural et de l'Hydraulique, Directions des Eaux et Forêt, 1979 ; pp. 205-207.

D'Heureux-Calix F., Badrie N., 2004. Consumers acceptance and physicochemical quality of processed red sorrel/roselle (*Hibiscus sabdariffa* L.) sauces from enzymatic extracted calyces. *Food Service Technology*, 4: 141-148.

DSA/MA, 2012. Rapport provisoire de la campagne agricole 2012/2013. Direction de la statistique, Ministère de l'Agriculture, Niamey, Niger, 42 pp.

Duke J. A. 1983: *Hibiscus sabdariffa* L. Handbook of Energy crops, (Unpublished).

Dupriez H., De Leener P., 1987. Jardin et vergers d'Afrique, P. 270.

FAO, 1990. Utilisation des aliments tropicaux : fruits et feuilles. Rome, 66 pp.

Fortin D., LO M., Maynart G., 1990. Plantes médicinales du sahel.CECI,164 – 166.

Guignard J.L., 1979. Abrege de botanique, 4ieme edition; Masson : p 127-152.

Hainida E. K.I., Amin I., Normah H., Mohd.-esa N., 2008. Nutritional and amino acid contents of differently treated Roselle (*Hibiscus sabdariffa* L.) grains. Food Chemistry 111: 906–911.

Hell K., K.E. Ognakossan, A.K. Tonou, Y. Lamboni, K.E. Adabe, and O. Coulibaly 2010. Maize Stored Pests Control by PICS-Bags: Technological and Economic Evaluation. Presentation at the 5th World Cowpea Conference, Saly, Senegal, 27 September – 1 October 2010.

Jones Michael, Alexander Corinne and Lowenberg-DeBoer James, 2011a. An initial investigation of the potential for hermetic purdue improved crop storage (pics) bags to improve incomes for maize producers in sub-saharan Africa. Working Paper #11-3, Dept. of Agricultural Economics, Purdue University, 44 pp.

Jones Michael, Alexander Corinne and Lowenberg-DeBoer James, 2011b. Profitability of Hermetic Purdue Improved Crop Storage (PICS) Bags for African Common Bean Producers. Working Paper #11-6, Dept. of Agricultural Economics, Purdue University, 29 pp.

Morton J. F., 1987. Fruits of warm climates Roselle, In: C.F. Dowling (ed).. Greensboro, NC: Media, Inc. pp. 281-286.

Pousset J. L., 1989. *Hibiscus sabdariffa* : Diurétique. Antiseptique urinaire. In : plantes médicinales africaines. Utilisation pratique. Eds Ellipses. ACCT : pp 87 – 88.

Purseglove J. W., 1968. Tropical Crops Dicotyledons 2. Longman Green Ltd, London.

Quezada M. Y., J. Moreno, M.E. Vázquez, M. Mendoza, A. Méndex-Albores, E. Moreno-Martínez (2006). Hermetic storage system preventing the proliferation of *Prostephanus truncatus* Horn and storage fungi in maize with different moisture contents. *Postharvest Biology and Technology* 39: 321-326.

RAISE, 2003. Market survey: Hibiscus sabdariffa. Rural and Agricultural Incomes with a Sustainable Environment. http//www.raise.org/natural/pubs/hibiscus/hibiscus.stm

Rhoden EG., David P., Small T., 1993. Effect of nitrogen nutrition on Roselle. In New Crops, Janick J, Simon JE (eds). Wiley: New York; 583-584.

Saadou M. 1990. La végétation des milieux draines nigériens à l'Est du fleuve Niger. Thèse de doctorat, Université de Niamey, 395 pp.

Stephens, E.C. and C.B. Barrett. (2009). Incomplete credit markets and commodity marketing behavior. Cornell University Working Paper.

Tchiegang C., Kitikil A., 2004. Données ethno-nutritionnelles et caractéristiques physicochimiques des légumes feuilles consommées dans la savane de l'Adamaoua (Cameroun), 18 pp.

Van Damme P., and Vianne, 1987. Optimal proportions between N, S and P and between K, Ca and Mg in fertilization of Roselle (*Hibiscus sabdariffa* L.). *Tropical Agriculture,* 64 (4):279 –282.