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Post-harvest handling practices of Cowpea: A case study of Bauchi State, Nigeria.

MASTER'S THESIS

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Author: Fatihi Sidi Adamu

Chief supervisor: Ing. Klara Urbanova Ph.D.

Declaration

I hereby declare that I have done this thesis entitled "**Post-harvest handling practice of Cowpea: A case study of Bauchi State"** independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 26/04/2019

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Fatihi Sidi Adamu

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Abstract

This study was conducted to examine the cowpea post-harvest handling practices in Bauchi state Nigeria. Data was collected from the sample of 126 registered cowpea farmers selected through multi-stage sampling procedure using a semi-structured questionnaire and analysed using simple descriptive and Logit regression Model. The result showed that majority of the respondents (85.70%) are male with one form of formal education or the other (80.20%) and are in their productive age (98.10%). They have an average farming experience of 16.29 years, cultivating an average farm size of 1.98 hectare within an average income of ₦ 33,373.02 (91.43 USD). Most of them (65.10%) have access to extension service at least once a year. With regards to post-harvest handling practices of cowpea, all of them threshed cowpea manually and sun dry it (100%). While majority of them sort the cowpea before storage (94.4%), store it in sacks (65.10%) in a period between 3-6 months (55.6%). Majority use pesticide to store cowpea (70.63%). Gender, Education, Access to extension service and cost of pesticides were found to be the significant factors that determine the respondents' choice to use pesticide in storing cowpea as shown by the result of regression analysis ($P<0.05$), ($P<0.01$), ($P<0.05$) and ($P<0.1$) respectively. The study revealed that the cowpea handling operations in the study area, particularly the use of chemical pesticides by farmers is found to be within the recommended level. However, massive awareness campaign should be lunched in order for farmers to reduce the use of chemicals in storage and switch to Hermetics storage alternatives such as PICS bags that are found to be safe and effective in storing cowpea.

Key words: Post-harvest handling, Cowpea, storage, use of chemical pesticides, perceived effectiveness

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List of the abbreviations

BIC	BAUCHI INVESTMENT CORPORATION
BSADP	BAUCHI STATE AGRICULTURAL DEVELOPMENT PROGRAMME
CPC	CONSUMER PROTECTION COUNCIL
CULS	CZECH UNIVERSITY OF LIVE SCIENCES
EU	EUROPEAN UNION
FAO	FOOD AND AGRICULTIRAL ORGANISATION
FTA	FACULTY OF TROPICAL AGRICSCIENCE
IITA	INTERNATIONAL INSTITUTE OF TROPICAL AGRICULTURE
LSFSP	LIFELIHOOD FOOD SECURITY PROGRAMME
NAFDAC	NATIONAL AGENCY FOR FOOD AND DRUG CONTROL
NBS	NATIONL BURUEU FOR STATISTICS
NPC	NATIONAL POPULATION CENSUS
PICS	PURDUE IMPROVED COWPEA STORAGE
SON	STANDARD ORGANISATION OF NIGERIA
SSA	SUB SAHARAN AFRICA
UN	UNITED NATIONS
USD	UNITED STATE DOLLORS

1. Introduction and Literature Review

1.1. Introduction

One of the main global challenges today is how to sustainably provide food security to increasing world population. This population is predicted to reach to about 9.1 billion by 2050 (UN 2015), with the corresponding demand of about 70% food production increase to securely feed this population (Alexandratos & Bruinsma 2012). The expectation of this food production increase will occur in less developed countries including Africa, while Africa itself suffers from post-harvest loss valued about 4 billion dollar annually (IMWIC 2011).

The global response to tackle this issue of food security threat for both the present and the future, has been the development of high yielding varieties crops, early maturity varieties, drought and disease resistance, as seen in the Green Revolution Programme (Burney et al. 2010; Godfray et al. 2010). However, other compelling factors or issues apart from food production increase is how the food produced is being lost or wasted along post-harvest chain, mainly associated with reduction or deterioration in both quantity and quality of the food.

According to Parfitt et al. (2010) food losses refer to the decrease in edible food mass throughout the part of the supply chain that specifically leads to edible food for human consumption. These losses take place at production, postharvest and processing stages in the food supply chain, while food losses occurring at the end of the food chain (retail and final consumption) are rather called "food waste", which relates to retailers' and consumers' behaviour.

Gustavsson et al. (2011) and Rockefeller Foundation 2013 indicated that one-third of food produced meant for human consumption is being lost or wasted. These losses occur in developing countries along the postharvest chain while in developed countries it occurs at the consumption level (Dou et al. 2016). For developing countries, the loss is even higher at postharvest stage particularly at storage (Venkat 2011; Gustavsson et al. 2011)

Data showed that postharvest handling loss alone is responsible for food loss between 20-30% of food produced.

Therefore, the complementary approach alongside increased food production is to reduce post-harvest loss (Bradford 2018), which can be achieved through proper postharvest handling and management and efficient storage (Parfitt et al. 2010). In addition, Njoroge et al. 2019 opined that an improvement on post-harvest handling can help bridge food demand-supply gap without the need to employ additional resources such as land, water, seed and fertilizer. Even though, the loss depends on location and handling practice of farmers (Parfitt et al. 2010; Gills et al. 2015).

Stored grains of cereal and pulse suffer postharvest loss at storage stage of the postharvest handling chain. For this reason, effort is mostly directed toward the improvement of their storage. Pulse even suffer loss than cereals with the possibilities of losing up to 100% in just few months. While the use of insecticide for storing cowpea is prevalent in Nigeria, this chemical pose health challenges, hence the need for safer storage alternatives (Aitchedji 2004).

In SSA and Nigeria, the main cause of postharvest loss of cowpea is the insect pest bruchids (*Callosobruchus Maculatus* (F.), the damage done by this insect decreases the nutritional qualities and economic worth of the cowpea grain, making farmers in order to avoid loss after harvest to sell the cowpea when the cowpea price is at lowest (Murdock et al. 2003)

In Nigeria, several efforts have been made by successive Nigerian governments to tackle the problem of food loss, one of these measures for example was the rehabilitation and construction of several new silos in all part of the federation with combine capacity of 1.5 million metric tonnes for the storage of cowpea and cassava by-products (NAN 2011 in Abdullahi et al. 2016). Despite these efforts, there is considerable post-harvest loss with the consequent increase of food import bill in order to bridge supply-demand gap. This force farmers and hoarders to resort to using affordable and cost-effective technologies to mitigate the effect of insect infestation using tradition storage methods (Abdullahi et al. 2016). However, these tradition methods have been considered as being inefficient because of their limitation in storing large volume of grains.

1.2.Origin and Distribution of Cowpea

The origin of cowpea cannot be exactly told because of its being cultivated in many parts of the world, though De Candolle (1886) opined that the origin of a crop will be found where it grows wild. However, it is not certain to what extent the existing wild varieties and sub-species of v. unguiculata have contributed to the origin and diversity of cowpea.

Cowpea (*Vigna unguiculata* L. Walp.), an annual legume, is also commonly referred to as southern pea, blackeye pea, crowder pea, lubia, niebe, coupe or frijole. Cowpea originated in Africa and is widely grown in Africa, Latin America, Southeast Asia and in the southern United States. It is chiefly used as a grain crop, for animal fodder, or as a vegetable. The history of cowpea dates to ancient West African cereal farming, 5 to 6 thousand years ago, where it was closely associated with the cultivation of sorghum and pearl millet.

1.3.Cowpea production

Cowpea is the most popular legume in Africa with the largest share of production, produced in the African continent. Global cowpea production stands as 5.4 million tons, with Africa producing about 5.2 million tons (IITA 2015). The principal cowpea producing countries in Africa are Nigeria, Niger, Senegal, Ghana, Mali, and Burkina Faso (Golob 2009). Nigeria which is the largest producer and consumer, accounts for 61% of African production and 58% of the global production (IITA 2015). Cowpea serves as food security crop in the semi-arid zone of west and central African, by ensuring subsistence food supply during the dry period /season. It provides an affordable protein source particularly to low income earners. It is also regarded as crucial and dependable crop that provides income to small scale farmers and traders in Sub-Saharan African (Langyintuo et al. 2003). Apart from being food crop, farmers also get some income from the sales of stem and leaves of cowpea that are used as important protein rich animal feeds. Its high protein content, ability to be intercropped with other crops (mainly cereals: Millet, Sorghum etc), its versatility to

be grown in variety of soils types, its resistance to drought as well as its ability to improve soil fertility and prevent soil erosion makes it important crop in many developing regions (IITA 2015).

In the Nigeria, the production of cowpea is concentrated in the northern part of the country. Like most farmers in developing countries, farmers in Nigeria also face several challenges in terms of cowpea production, storage and marketing. This is so because of susceptibility nature of cowpea to insect attack that trails the crop from production up to consumption. This force farmers after production to sell the cowpea at very low price.

1.4. Economic and social impact

Cowpea is considered as the top economic importance indigenous leguminous African crop (Baribusta 2010). It serves as the source of livelihood to several millions of people in West and Central Africa. It provides food, animal feed as well as cash income to rural dwellers who constitute majority in the African sub region. Dugje et al. (2009) described cowpea as the major staple crop, particularly in West Africa and have big market potential for its grains and fodder. They further revealed that, in Nigeria cowpea producers that store the grain for sale at the peak of dry season can have their annual income increase by 25%. Traders also benefit from the sale of cowpea. Hoarders who usually keep the grain for up 9 months can make up to 30% profit, making them the largest beneficiaries in the post-harvest chain.

1.5. Prospect for cowpea marketing

Although Nigeria is largest producer of cowpea in the world, it is not being listed among the major cowpea exporting countries, this is because of the domestic demand; cowpea has become part of the meal of very Nigeria's household, inability of Nigeria's cowpea to compete with cowpea from other countries in the world as a result of high production cost, lack of production technology as well as the dominance of small-scale subsistence producers. In addition, one of the cowpea producers weakness is their

inability to serve specific market needs which can be attained by best practice in production and post-harvest operations. Therefore in order for them to avail themselves from the potentials of cowpea market, they have to understand and meet the need of the markets in relation to types of desired products, product quality and quantity of the demand (Bello 2009)

Nevertheless, with the increase in domestic production, processing and improvement of varieties with desired qualities which will consequently increase productivity of cowpea to competitive level, Nigeria will be exporting cowpea in near future to the global market (Bello 2009).

1.6. Agronomical Practice, Pest and Diseases

1.6.1. Cowpea Varieties Grown in Nigeria

There are several cowpea varieties grown in Nigeria from local to improved and hybrid varieties developed for higher yield, early maturing, drought, pest and diseases resistance.

1.6.2. Local Varieties

The use of local cowpea varieties is still in practice in most part of Nigeria despite the existence of improved varieties in what is describe as traditional cropping system. According to Ajeigbe (2010), traditional cropping system in Nigeria is characterized by lack of adequate input (fertilizer and pesticides) and use of traditional varieties which result in lower yield. The main aim of subsistence farmer is to sustain production, minimize risk as far as possible in order to satisfy his needs and when there is surplus, are taken to market.

Local varieties are usually associated with lower yield, lesser resistance to pests and diseases and longer period of maturity. Farmers are now switching from using local varieties to improved varieties that address such issues.

1.6.3. Improved Cowpea Varieties

Two varieties namely IT89KD-288 and IT89K-391 were recently developed with the proven higher quality characteristics over the recently developed varieties being cultivated by farmers in Nigeria. The objective of this is to address the challenges Nigerians farmers confront in growing cowpea. For example, the dual-purpose variety IT89KD-288 (now called SAMPEA-11) has a big white seed and a rough seed coat as well as with combined ability of resistance to main cowpea diseases such as leaf spot, scab and bacteria blight. It is also resistance to nematodes and tolerant to popular Nigerian parasitic weed " Striga gesnerioides" the weed that considerably lowers yield (IITA 2010). According to IITA Agronomist, Dr Alpha Kamara, the variety (SAMPEA-11) has a yield advantage over local grown variety to over 80% increase. With regards to the later variety IT89KD-391 (SAMPEA-12) also developed as dual-purpose variety but with rather medium to large brown seeds and a rough seed coat. This variety is preferred for commercial production in North-eastern Nigeria (IITA 2010).

The tables below show the White and Brown seed coat improved varieties for cultivation in Nigeria.

Figure 1: White seeded cowpea variety

Source: web image

Table 1:Selected White seeded cowpea varieties released in Nigeria.

Variety	Salient characteristics
TVX 3236	Medium maturing (80 days), small sized seeds, large brown eyes, resistant to thrips and many diseases, needs 3 sprays, yields about 1000–1200 kg/ha.
IT86D-719	Medium maturing (80–85 days), small sized seeds, large brown eyes, resistant to thrips and many diseases, needs 2–3 sprays, yields about 1000–1200 kg/ha.
IT90K-277-2	Medium maturing (75–80 days), medium sized seeds, some level of resistance to insects and diseases, needs 2–3 sprays, high grain yield about 1500-2000 kg/ha, high fodder yield.
IT93K-452-1	Extra-early maturing (60 days), medium sized seeds, some level of resistance to insect and diseases, yields1500 kg/ha, good for double cropping.
IT97K-499-35	Medium maturing (75–80 days), medium sized seeds, *Striga* and *Alectra* resistant, some level of resistance to insects and diseases, needs 2–3 sprays, high grain yield about 1500-2000 kg/ha, heat and drought tolerant, very good in dry season.
IT89KD-288	Photosensitive, dual-purpose, large sized seeds, resistant to insects and diseases, needs 3–4 sprays, very good as a relay with cereals, yields 1000–1500 kg/ha.

Source: Boukar & Ajeigbe 2010

Table 2: Selected Brown seeded cowpea varieties released in Nigeria.

Variety	Salient characteristics
Ife Brown	Medium maturing (75–80) days, semi-erect, medium sized seeds, moderately susceptible to insect pests and diseases, requires 3–4 sprays, yields about 800 kg/ha
IAR-48	Medium maturing, semi-erect, medium sized seeds, moderately susceptible to insect pests and diseases, needs 3–4 sprays, yields 1000–1300 kg/ha.
IT84S-2246-4	Early maturing (70 days), medium sized seeds, moderately resistant to insect pests and diseases, needs 2–3 sprays, good for dry season, yields about 1300 kg/ha.
IT90K-82-2	Early maturing (70 days), medium sized seeds, moderately resistant to insect pests and diseases, resistant to *Striga* and *Alectra*, needs 2–3 sprays, good for dry season, yields about 1500 kg/ha.
IT89KD-391	Medium maturing, dual-purpose, medium sized seeds, moderately susceptible to insect pests and diseases, needs 3–4 sprays, very good as a relay with cereals, yields 1300–1700 kg/ha.

Source: Boukar & Ajeigbe 2010

1.6.4. Selection of Varieties

The availability of good quality seeds preferred by farmer and adapted to the growing area is a valuable factor for good crop production (Boukar & Ajeigbe 2008).

Other qualities considered include early maturity, drought, weed, pest and diseases resistance character.

Table 3:Criteria in selecting a Cowpea variety for a particular environment.

Production limitation	Variety to use
Drought	Drought tolerant and early maturing
Heat	Heat tolerant
Striga infestation	*Striga* resistant
Short rainfall (300–500 mm/year)	Extra-early and early maturing (Look out for the varieties that have a maturity period that falls within 60–80 days.)
Pests and diseases	Resistant to some major pests and diseases

Source: IITA 2010

1.6.5. Growth Habit

There are different types of cowpea and are classified as Erect, Semi-erect, Prostrate (trailing) or climbing. Variability exist among these cowpea varieties. The growth habit can be indeterminate, fairly indeterminate, and the non-vining types which is more determinate. However, farmers generally classify cowpea into two categories base on their maturity period: the early maturity and the late maturity. The early maturity yields little or no fodder , while the late maturity yields a lot of fodder biomass and is photosensitive with a gushing growth habit. Their seed coat can either smooth or wrinkled of different colour; white, brown, black, buff, cream, green, and red. The seed can also be speckled, mottled or blotchy (Boukar & Ajeigbe 2010).

1.6.6. Climatic and Soil Requirement

Cowpea can be cultivated under rainfed and in irrigation condition or along river or lake flood plains that have residual moisture during the dry season on condition that the highest and lowest temperature ranges between 28 °C to 30 °C (day and night) throughout the growing period. With regards to rainfall, it does well where the rainfall

ranges are between 500 mm and 1200 mm per year as found in some agro-ecological zones. However, there are extra-early and early maturing cowpea varieties developed that can also grow well in rainfall amount of less than 500 mm per year (Dugje et al. 2009).

1.6.7. Soil Requirement

Cowpea yield best in well drained sandy loam to clay loam soil with the pH range between 6 and 7. However, being tolerant to drought, it is also well adapted to sandy and poor soils (Dugje et al. 2009). However, it should not be grown on poorly drained soil as it does not tolerate excessive wet condition or water-logged soil (Omoigui et al. 2018)

1.6.8. Cowpea Cultivation

1.6.8.1. Land Preparation

Area for cowpea cultivation can be prepared by using hoe to clear the field of shrubs and stubbles. Other alternative is using chemical to spray the field with Glyphosate (Round up) at the rate of 4 litres per hectare (about 2 1/3 milk tins of chemical in a 15-litre sprayer or 3 milk tins of chemical in a 20-litre knapsack sprayer and allow the field to at least 10 days to kill emerged weed. To ensure proper penetration of cowpea taproots when germination, the soil should be cultivated deeply enough since well-prepared soils ensure good germination and minimizes weed competition with the crop. However, where the land is fragile and liable to erosion, minimal or zero tillage should be used (Omoigui et al. 2018).

1.6.8.2. Seed Preparation for Planting

Wholesome seeds are selected for planting with absence of holes or wrinkles. Seeds that are stored in optimal condition have better germination . Also, to enhance good germination and provide protection to the seeds and seedlings from fungal infection after emergence, the seeds are dressed with chemicals before sowing. They are treated with Benomyl (50%) or Carbendazine, Captain or Thiram at the rate of 3g/ Kg (1 sachet) of

seeds, or with Apron plus at the rate of 10g/ 4-5 kg of seeds (1 sachet) or Apron star 42 water soluble (WS) at the rate of 10g/ 8kg of seeds / 1 sachet (Omoigui et al. 2018)

1.6.8.3. Planting Date

Timing of planting date is extremely important as it affects cowpea seeds yield and quality. It also determines the use of pesticides for controlling insect pests. Cowpea should be planted when soil moisture is sufficient that guarantees germinations. The planting should be after adequate rainfall amount (15mm and above) is obtained. Dry planting is not advisable. In Sudan savanna, the planting should start from end of June to early July, while in the Guinea savanna, planting may be in August (Boukar & Ajeigbe 2008). Table below shows the proper time to plant cowpea in different agro-ecological conditions of West and Central African Sub-regions.

Table 4: Rainfall distribution and planting dates of cowpea in WCA

Agro-ecological zone	Commencement of rains	Rainfall duration	Cowpea growth habit	When to plant after rain fully established
Sahel	May	June -August	Determinate (early and medium maturity	14-28 June
			Indeterminate (medium	20-25 June
Sudan	June	June-September	Determinate (early and medium maturity	25 June to 24 July
			Indeterminate (Medium and late maturity	16-20 July
Northern Guinea Savanna	July	July -October	Determinate (early and medium maturity	25 July to 8 August
			Indeterminate (Medium and late maturity	28 July to 3rd August
Southern Guinea Savanna	August	August-November	Determinate (early and medium maturity	15- 26 August
			Indeterminate (Medium and late maturity	18-22 August
Forest Transition Zone	April	April-November	Indeterminate (Medium and late maturity	1st week of September

Source : IITA 2010

1.6.8.4. Seed Rate

Depending on the variety to be grown, size of seeds and cropping system, about 15-30 kg of cowpea is needed to plant 1 hectare of land. When erect varieties are to be grown, more of seed are required due to closeness of spacing requirement of erect varieties. However, few seeds are needed when the cowpea is to be grown with other crops. The bigger the seeds, the more amount of seeds are required per hectare. The table below shows seed rate for different cowpea varieties (Dugje et al. 2009).

Table 5: Seed rate/ha based on recommended plant spacing.

Cowpea Type	Growth habit	Maturity	Cropping system	Spacing (cm)	Quantity of seed/ha
Erect	Determinate	extra-early, Early, and medium	Sole	50 cm row pacing and 20 cm within row spacing (50 x 20 cm)	30 kg (12 *mudus*)
Semi-erect	Indeterminate	Early and medium	Sole	75 cm row spacing and 30 cm within row spacing (75 x 30 cm)	20 kg (8 *mudus*)
Semi-erect	Indeterminate	Early and medium	Intercrop	75 cm row spacing and 25 cm within cereal stand (75 x 25 cm)	30 kg (12 mudus)
Prostrate	Indeterminate	Medium/late	Sole/inter crop	75 cm row spacing and 50 within row spacing (75 x 50 cm)	15 kg (6 *mudus*)

Source : Dugje et al. 2009

1.6.8.5. Sowing and Spacing

The sowing spacing of cowpea depends on the variety. For erect cowpea varieties, close spacing of intra and inter row spacing of 50 cm and 20 cm is recommended, particularly for early and extra-early maturing variety (55-75 days). In addition, to achieve high yield in these erect cowpea varieties, double row planting is recommended while doubling the seed rate per hectare. Because the recent study conducted by Kamara et al. (2016) revealed that higher seed yield of 2-fold had been achieved by using high plant population through double row planting on ridges. For semi erect, the intra and inter row spacing should be 25-30 cm and 75 cm respectively. While for creeping variety, the intra and inter row spacing should be 40 cm and 75 cm respectively. Cowpea planting

should be done manually or using mechanical planters on ridges or flat beds depending on field preparation (Omoigui et al. 2018).

1.6.8.6. Planting as sole crop and mixed with other crops

Cowpea can be grown as sole crop or intercropped with cereals, tubers and root crops. Cereals that are usually intercropped with cowpea include Maize, Millet and sorghum. It tolerates shades and is space loving crop. The spacing and seed rate varies when grown as sole crop and when intercropped with other crops.

Table 6: Cowpea Sole and Mixed spacing

Types of cropping	Plant type	Spacing	Seed rate
Sole Crop	Bushy	45 x 15	30-40
	Spreading	75 x 20	20-25
Mixed	Bushy	180 x 15	10-15
	Spreading	180 x 30	5-10

Source: (LFSP 2019)

1.6.8.7. Sowing depth

Seeds are sown at the depth of about 2.5 to 5 cm for most varieties; it is advisable for planting depth not to be more than 5 cm as this will delay emergence and cause root rot and uneven plant stands (IITA 2010).

1.6.8.8. Fertilizer Application

Like most legumes, cowpea forms symbiotic relationship with soil bacteria (*Rhizobium* spp.). Atmospheric Nitrogen is made available to plant through the process

called Nitrogen fixation. This fixation occurs when Rhizobium bacteria utilizes sugars produced by cowpea and captures atmospheric nitrogen.

With regards to application of inorganic nitrogen fertilizer to cowpea, application amount should be moderate as excessive Nitrogen results in full vegetative growth maturity, prolong maturity, reduce seed yield and adversely affect N-fixation , since it can perform well even in low nitrogen supply because of its ability to fix provided that other nutrients are available. Therefore, for soils with poor Nitrogen fertility, nitrogen of15 kg/ ha is enough for early plant development. With regards to inorganic fertilizer sufficient amount of organic fertilizer at the rate of at least 1 tonne per hectare will be of great advantage for cowpea production , which should be followed by basal application of 100kg/ha NPK (15-15-15) or 100kg/ha of SSP (Single Super Phosphate). Both the manure and inorganic fertilizer should be spread and mixed with the soil prior to planting.

Table 7: Recommended fertilizer rate for cowpea.

Fertilizer nutrient/ha	Quantity equivalent in bags/ha	Time of application	Remarks
15 kg N	2 bags of compound fertilizer (NPK 15:15:15)	Apply during land preparation or at planting by incorporating into the soil	This will also supply 15 kg each of nitrogen, phosphorus and potassium.
30 kg SSP	2 bags of single super phosphate (SUPA)	Same as above	This will supply 18 kg of phosphorus.

Source:IITA 2010

1.6.8.9. Weed Control

For better growth and high yield , weed control should be adequately provided. About 3-4 weeks after planting, the field should be kept weed free and another weeding

after additional 3 weeks. Recommended dose of pre-emergence herbicide such as Galex, Dual etc can be applied immediately after planting. When the herbicides are used, inter-row cultivations should be done (Boukar & Ajeigbe 2010).

1.6.8.10. Disease Control

Although many IITA improved varieties are resistance to common diseases, it is still recommended to provide seed treatment with Benlate Fernasan D, Apron star and others to ensure high protection. This can help to reduce losses from seedling mortality and root rot. Seed treatment is especially importance in high rainfall conditions and in soils where cowpea was cultivated in the previous season. Farmers are therefore advised to treat their seeds in such situation (Boukar & Ajeigbe 2010). They further advised that to reduce losses, they recommend these important control practice.

1) Treatment of high-quality seeds with Apron star
2) When cultivation, throwing soil against plant stem should be avoided.
3) Planting seeds into warm and well-prepared soils
4) Planting of certified seeds of resistance varieties
5) Adequate weed control should be provided
6) Removal of virus-infected crops
7) Spraying against Aphids

1.6.8.11. Insect Control

Improved cowpea varieties have a good level of resistance against many insect pest except *Maruca* pod borer and Pod sucking bugs. Due to problems of these two insects, 2-3 insecticides sprays are advised for cowpea production. The first spray at the beginning of flowering bud, the following spray when the flowering is full and at podding stage and the last spray should be after 10-14 days of the second spray. The frequency and kind of insecticides spray depends on nature and severity of the insect attack and the cowpea varieties (Boukar & Ajeigbe 2010).

1.6.8.12. Harvesting

Harvesting should be done when the pod reaches 80-90% dryness. The dry pods can be manually beaten and winnowed, in some varieties several picking is possible (Boukar & Ajeigbe 2010).

In an improved cowpea-cereal systems, cowpea normally matures before the other cereal crops, therefore harvested before the cereals particularly the northern Guinea savanna of Kaduna and Bauchi states, where the first cowpea planting is done in the month of May/ June and harvested in August when the rainy season is at its peak. It is advisable therefore that the harvesting is done on a clear sunny day and should be on time to avert the case of mature plant falling on damp soil. Several harvest are possible; the first harvest should be when the pod are 70% dried. The second harvest should be after 7-10 days. It is recommended to spread the pods under sunlight for it to dry after harvesting and threshing immediately. To avoid rotting of pods and grains due to activity of molds, heaping of the harvested grains should be avoided. Also, in the northern Guinea savanna when the second planting is done in the month of August and mature in October/ November , this harvest period allows for complete drying of the pod right in the field. Harvesting is done when over 90% of the crop grains are matured and dried. The pod is then dried in sunlight to a required moisture content (Ajeigbe et al. 2010).

In an improved cereal-cowpea cropping system of Sudan savanna, the improved cowpea is planted in June/July and harvested in September . Practice of harvesting and threshing is same as in second phase of cowpea cultivation in northern Guinea savanna. In this region, double cowpea cultivation in a single season is possible, where first cowpea cultivation is done at late May or early June and harvested in August, while the second crop is planted immediately. After harvest, threshing, the grain is sun-dried to a required moisture level (Ajeigbe et al. 2010)

1.6.8.13. Storage

Before storage, the cowpea should be well dried and properly and adequately cleaned. The seeds are then cleaned, graded, fumigated, packed and stored in airtight containers such as drum tins, clay pots, or double or triple polyethene bags and

periodically fumigated. However, dried cowpea stored in tripled bags need not be fumigated (Boukar & Ajeigbe 2010).

1.6.8.14. Storage pests management of cowpea

The main biggest challenges cowpea farmers and merchants face is how to store the grain effectively. Cowpea weevil (bruchid) called *callosobrachus maculatus* is the most important storage pest of cowpea because of the severe infestation it inflicts on cowpea during storage resulting to total grain loss. It is a field-to-store pest; adult insects lay eggs on pods (in the field) or on seeds (in store). After the eggs are hatched inside the seeds, the seeds cotyledons are eaten up, thereby causing expansive damage. Adult emerge from the seeds through the holes made by larvae. These holes are sign of infested seeds (Omoigui 2018)

Storage pests (weevils) – *Callosobruchus maculatus*

Callosobruchus maculatus is the most important storage pest of cowpea.

• Infestation in the store usually originates from the farm.

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• Larvae bore into the beans. Infested pods are harvested

and taken into the farm stores where further development

takes place.

• Eggs are laid in the pods by the female on the seed surface.

Each female lays up to 90 eggs. Hatching takes about 6 days.

• Larvae spend their entire life cycle within the beans. Larval

period is about 4–5 weeks.

Control

• Avoid growing cowpea very close to the farm stores.

• Harvest promptly in areas at risk to reduce attack levels.

• Dry the harvested pods well.

• Use triple bagging of cowpea for hermetic storage (nonchemical method)

• Use insecticidal protection.

• Use fumigants – such as phostoxin tablets in airtight sacks/ containers. Use one tablet/bag.

• Use neem oil at 2–3 mL/kg of cowpea seeds.

• Protect against weevils for up to 6 months with groundnut oil at 5 mL/kg of cowpea seeds (Ajeigbe et al. 2010).

1.7. Post-Harvest handling operations of cowpea

Post-harvest handling involves all the operations carried out after harvesting of a crop until it reaches the final consumer. For this research the main post-harvest operation to discuss include; Threshing, Drying, Sorting, Packaging, Storage and Transportation of cowpea.

1.7.1. Threshing

The main objective of threshing is to remove the grain from the pod after harvest. Before threshing, the pod is first allowed to air-dry for certain period of time for the pod to become brittle for easy threshing and also to avoid mold and decay (Ajeigbe 2009). It is done through rubbing, stripping, impact action or using combination of these actions. Threshing can be done mechanically (using machines) or manually beating the pod until the grains comes out. In developing countries, the manual operation is most common. In this stage grain losses occur through spillage, partial separation of grain from the pod (as in cowpea), the breakage of grains as a result of excessive striking (Khan 2010; Shah 2013). Immediately after harvest, threshing is essential in order to prevent the grain from being vulnerable to insects, rodents and bird attack which can constitute significant loss in both quantity and quality of the grains (Khan 2010).

1.7.2. Drying

The purpose of drying is to reduce the moisture content of a product as harvested grains contain certain level of moisture in them which is necessary in order to reduce losses due to shattering of the pod (Khan 2010). However, there is proper moisture content to achieve mostly below 13% in order for the grain to store long (Baloch 2010). Although for short-term storage (less than 6 months) in most of the crops the moisture level (content) should be less than 15%, because there is a potential grain losses as a result of mold growth in storage if the grain is not adequately dried before storage. For this reason, storage is an important post-harvest operation critical to ensure grain quality, reduce storage losses as well as reducing transportation cost (Kumar & Kalita 2017). Drying can be done naturally (Sun or Shade drying) or artificially (Mechanical dryers). In most developing countries (including Nigeria), natural drying mainly sun drying is most common which is the traditional and economic practice for drying harvested crops. Sometimes, the harvested crops are left in the farm to dry (then thresh there or taken to home for threshing and storage). The problem associated with sun drying include being whether dependent, labour intensive, slow and losses may be possible since the grain are left opened, exposed to birds, animals (livestock, rodents) and insects as well as contaminations from dust and other foreign materials (Kumar & Kalita 2017). For example about 3.5%-4.5% loss was reported during Maize drying in Zambia and Zimbabwe (Abass et al. 2014; Calverley 1996). Although some farmers use mats or plastics sheets to spread the grain on them, to effectively minimize contamination from dust and make grain collection easier, mechanical dryer addresses such problems encounter in using natural drying. The advantages include loss reduction, better control over hot air temperature and minimal use of space as compare to natural dryers. However, mechanical dryers are not seldom use in developing countries because of their high initial and maintenance cost, availability of small size dryers as well as technical know of how to operate them by small holders (Alavi et al. 2012).

1.7.3. Sorting

Sorting is done to separate the broken seeds from the full seeds and also to remove other debris in the grains. As broken seeds make the cowpea grain liable to infection by microorganism.

1.7.4. Packaging/ Bagging

Packaging of cowpea is done polyethene bags or jute bags immediately after threshing. Bagging starts as soon as the cowpea grains are sure to have achieved the right moisture content for storage. New dry bags should be used to avoid mold attack (Ajeigbe 2010). The bags must be sealed to prevent insect and rodents attack. They can be stored or sold in the market.

1.7.5. Storage

The main purpose of storage is to extend shelf life of a commodity. Depending of need storage can be short-term, moderate-term and long-term. In west Africa, grains are commonly stored in homes or farms confines in storage facilities such as polyethene bags, jute bags, raised flatforms (traditional granaries such as rumbus) conical structures and baskets (Abass et al. 2014; Hell et al. 2000). Other structures use developing countries of Africa and Asia to store grains included bags plastics, construction from locally available materials etc (Baloch 2010). For cowpea storage, the use of chemical pesticides together with storage facilities such as polyethene bags and jute bags is most common (Aitchedji 2004). However, now the use of Hermetics storage such as PICS bags is gaining momentum in most developing countries of Africa being more effective and safer as compare to the use of chemicals to preserve grains crops (Baribusta et al. 2010). Hermetics storage such as PICS have been observed to minimize losses in storage (less than 1% storage losses) during international conveyance of commodities (Viller et al. 2010).

1.7.6. Transportation

Transportation is valuable factor in the grain post-harvest chain as they are conveyed from one point to another such as from farm to processing station, from farm to storage place, from processing place to market and for home to the market. Losses can be incurred during transportation process as a result of lack of adequate transportation infrastructure such as good roads and multiple transportation due to grain spillage (Kumar & Kalita 2017)

1.8.Cowpea Storage Systems

Storage is the critical stage of grain and cereals storage where losses should be reduced and quality maintained as far as possible: To achieve this, appropriate technology must therefore be used. Various storage systems exist for small and medium farmers such as granaries , storehouses, metal drums, plastics or jute bags, metal silos etc. Factors that farmers or user need to consider in choosing these systems depend on availability, convenient of use, efficiency and analysis of its cost and benefit (FAO 2015).

In addition, the size and kind of storage facilities to use depend on

1. The total volume of the crop to be stored
2. The storage requirement of the crop to be stored
3. And the unit cost of the storage facilities (FAO 1994)

1.8.1. Metal Silos

There are two types of Metal Silos used in Nigeria, the large volume silos for National food reserve meant for cereals grain, legume and cassava products across the

federation and small farmer size silos with few kilograms' storage capacity/ volume.

Figure 2: Silos for National Food Reserve

Source: web image

Figure 3: Family-size Silos

Source: web image

1.8.2. Rumbus

This is a traditional storage facility use by African farmers to store farm produce of small quantity of about 2-3 tonnes. It is made of mud wall with thatched roof raise off the ground (FAO 2015). It can also be made of round stalked walls with thatched roof raise off the ground by rectangular wooden structure (legs). Produce are conveyed and carried out of the rumbus using a fixed ladder mounted on it.

Figure 4: Rumbus

Source: web image

1.8.3. Bags (Woven bags)

Bags are the most common storage methods for grain in many countries of the world. After it is filled with the grains, it is then stored in different sorts of building structure e.g. stone, local bricks, corrugated iron, and mud and wattle, with or without plastered walls and with earthen stone, or cement floor and corrugated or thatched roof. The form in which the crop produce is stored depend on the quality, harvest method, handling method moisture content and cost (FAO 2015).

1.8.4. Metal Drum

The use of sealed metal drum to store cowpea was developed by Dr. Dogo Seck, which can store cowpea up to 6 months with low seed infestation of the cowpea bruchids (Seck & Gaspar 1992). They are of different size, however, the one use in the study area is the metal drum with a capacity of 60 litres with a movable lid. They are filled with the cowpea grain and closely tightly the lid. Some chemicals are added to ensure perfect protection against cowpea pest.

According to Seck et al. 1996, the protection giving by the metal drum is as result of limited quantity of oxygen available for insect survival. Metal drum are classified under tight containers that deprive oxygen necessary for insect survival.

Figure 5: Metal Drum

Source: web

Figure 6: Improved Metal Drum

Murdock et al. 2003, revealed that despite its effectiveness in storing cowpea, it also has corresponding limitation such as rusting which can make perforation for air to go in.

In addition, a good quality metal drum is expensive, hence limits its adoption to numerous farmers.

1.8.5. PICS bags

The use of hermetic grain storage has been in practice since time immemorial before it is reintroduced in industrialised world to keep insect pest from damaging stored grains (De lima & Navarro in Murdock 2012). It is now being adopted in developing world (Murdock et al. 2003). PICS bag is a hermetic storage developed by Purdue University, USA through a project sponsored by the Bill and Melinda Gates foundation to help provide effective grain preservation with the aim of achieving 50% of farm-stored cowpea in hermetic storage without insecticide in developing countries of West and Central Africa by the year 2012. PICS are now being adopted by low income farmers in tens of thousands of villages across West and Central Africa to protect cowpea grain against insect pest bruchids (*callosobrachus maculatus* (F.)) (Baribusta et al. 2010). Purdue Improved Cowpea Storage (PICS) consist of dual liners of high-density polyethylene (HDPE) 80 microns thick enclosed by a woven polyethylene or nylon sack (Murdock et al. 2012). The principle by which hermetic works as in PICS bags was determined by Murdock et al. (2012) base on the finding that oxygen is not only the source of metabolic oxidation but also and indispensable source of metabolic water as established by Frankel & Blewett (1944). It means that insects trapped in hermetic containers of stored cowpea grain are not only killed by suffocation but also being killed by desiccation as a result of dehydration.

Figure 8: Cowpea Storage using PICS bags

Figure 7: PICS bag awareness campaign

1.8.6. Jerry can

Plastic Jerry can are also form of hermetic containers that are good in preserving cowpea. It is a container of different sizes ranges from 25 litres to 50 litres, which after it has been filled in with the cowpea, it is then tightly closed to prevent air into the container.

Figure 9: Jerry Can
Source: web image

1.8.7. Jute bags

Jute bags are bags that that are made from sisal stalk. They are used for storing grains.

Figure 10: Grains Storage using Jute bags

Source: web image

1.9. Factors that influence farmers to use chemical in cowpea storage

Individual behaviour and choice such as farmers willingness and choice to use chemical in storing cowpea can be explain by theory of rational choice.

According to Okodudu (2007) a "theory is seen as a body of rules, ideas, principles and techniques that is applied to a subject particularly when regarded as different from actual practices". Theories are also seen as a set of interrelated constructs, definitions and propositions that present a systematic view of phenomena in research. Theories help the researcher to navigate his way by helping a researcher in the identification of relevant variables and providing a focus of analysis (Namwata et al. 2010).

Rational choice theory, also known as choice theory or rational action theory, is a framework for understanding and often formally modelling social and economic behaviour (Lawrence & Easley 2008) . The basic premise of rational choice theory is that aggregate social behaviour results from the behaviour of individual actors, each of whom is making their individual decisions. The theory also focuses on the determinants of the individual choices (methodological individualism). It tries to deduce what will happen when individuals are faced with a situation such as farmers choice to use chemical in storing of cowpea (Okoruwa 2000).

1.10. Perceived Effectiveness

Most of the storage technologies developed to solve the problem of insect infestation in grains are not usually examined on farm, for this reason the possibility of adoption of such technologies and their acceptance by farmers as alternative to use of insect pesticide require a socio- cultural survey to find out their relative effectiveness under actual on-farm condition and farmers handling practice, tested across various Agro-ecological regions and with different insect species (Abbas et al. 2018).

This is because despite the perceived effectiveness of several storage facilities that are good in preservation of cowpea from traditional to improved cowpea storage bags,

there might be some factors that can prevent farmers from adoption of such technologies. According to Baoua, 2014, the level of adoption of these technologies is relatively low as a result of their limited availability and high investment cost.

One of such facilities that has been tested to effectively protect the cowpea grain is Purdue Improved Cowpea Storage bags (PICS bags), which comprises triple layers protection: the double layers of high-density polyethylene (HDPE) bags, fit into a standard polypropylene woven begs, (Baoua et al. 2012; Murdock et al. 2012).

2. Objectives

The main objective of this research, therefore, was to examine the postharvest handling practices and the use of different storage methods in the study area.

While the specific objectives are to;

1. describe post-harvest handling practices of cowpea carried out by farmers in the study area
2. determine the various factors influencing the use of chemical in cowpea storage by the farmers in the study area
3. compare the perceived effectiveness of farmers regarding to the various cowpea storage methods use in the study area

2.1.Statement of the Problem

Many cowpea chain agents and consumers are not sure of what postharvest handling practices and storage method can help protect the grain to an acceptable level that would not cause nutritional losses, pose health risk and overall preserve its edibility. The various stakeholders involved in the distribution chain therefore needs information on the various postharvest handling practices and storage methods and how they help to protect vital qualities of the product (David et al. 2017).

In Nigeria for example, there is an outcry on overuse and overdose in the use of chemical in cowpea storage by farmers and cowpea hoarders as against the prescribed

amount set by Standard Organization of Nigeria, National Food, Drug Law Enforcement Agency and Consumer Protection Council, the bodies responsible for regulation of foods and consumer goods in the country. In addition, in 2016, European Union put embargo on the importation of Nigerian cowpea due to presence of large amount of storage chemicals in cowpea imported from Nigeria which exceeds the standard limit regarded for safe human consumption. It was until recently when the EU partially relieved the embargo that allows the importation albeit on pilot bases. With the cut of exportation, the farmers will be discouraged or even make them cut its production since farmer may not produce if there is no market for their produce

While the post-harvest handling activities all have their corresponding importance, storage has been considered the vital factor that ensure the protection of quantitative and qualitative condition of cowpea.

It is in this regard that necessitate the need to assess the factors that influence farmers to use the chemical in storage of cowpea even though there are other alternatives methods available that have been proved to provide better and safest way of storing cowpea.

Meanwhile, the research was aimed to provide answers to the following questions

i. What are the postharvest handling practices of cowpea carried out by farmers in the study area?

ii. What are the various factors influencing farmers` to use chemical in cowpea storage in the study area?

iii. What are the farmers` perceived effectiveness of the various cowpea storage methods use in the study area?

2.2.Justification of Study

With the increase in Nigeria`s population which has an annual growth of 2.3%, there is need of a holistic approach to secure the nation of food within its available resources. While most efforts done by successive Nigerian governments are normally directed toward production, processing and some large storage facilities that are out of

reach to small scale farmers who are the main food producers. Reduction of post-harvest loss using appropriate post-harvest handling practice, particularly efficient storage methods has been described to be a complementary approach that will provide food security alongside increased food production. This study will therefore be of enormous importance to government regarding formulating of policy that will ensure affordability of chemical storage substitutes such as PICS bags, which are proved to provide a better and safe cowpea storage alternative.

2.3. Significance of Study

This study will be of significant importance to: farmers to be aware on how they should improve cowpea handling and storage: consumers to know about post-harvest handling activities with regards to safeness and quality protection: to the cowpea chain agents especially hoarders who add more chemical besides the one already added by farmers and to the government to develop the habit of periodic testing and assessment of cowpea quality in order to ensure safe consumption of the product and also to guarantee import quality standard.

3. Methodology

3.1.Study Area

Bauchi state is located between latitudes 9° 3' and 12° 3' North and longitudes 8° 50' and 11° East. It occupies a total land area of 49,119 km² representing about 5.3% of Nigeria's total land mass. The average precipitation is 287mm in August; the average temperature ranges between 37°C-13°C suitable for cowpea production. It has the population of 4,653,066 people (NPC 2006)

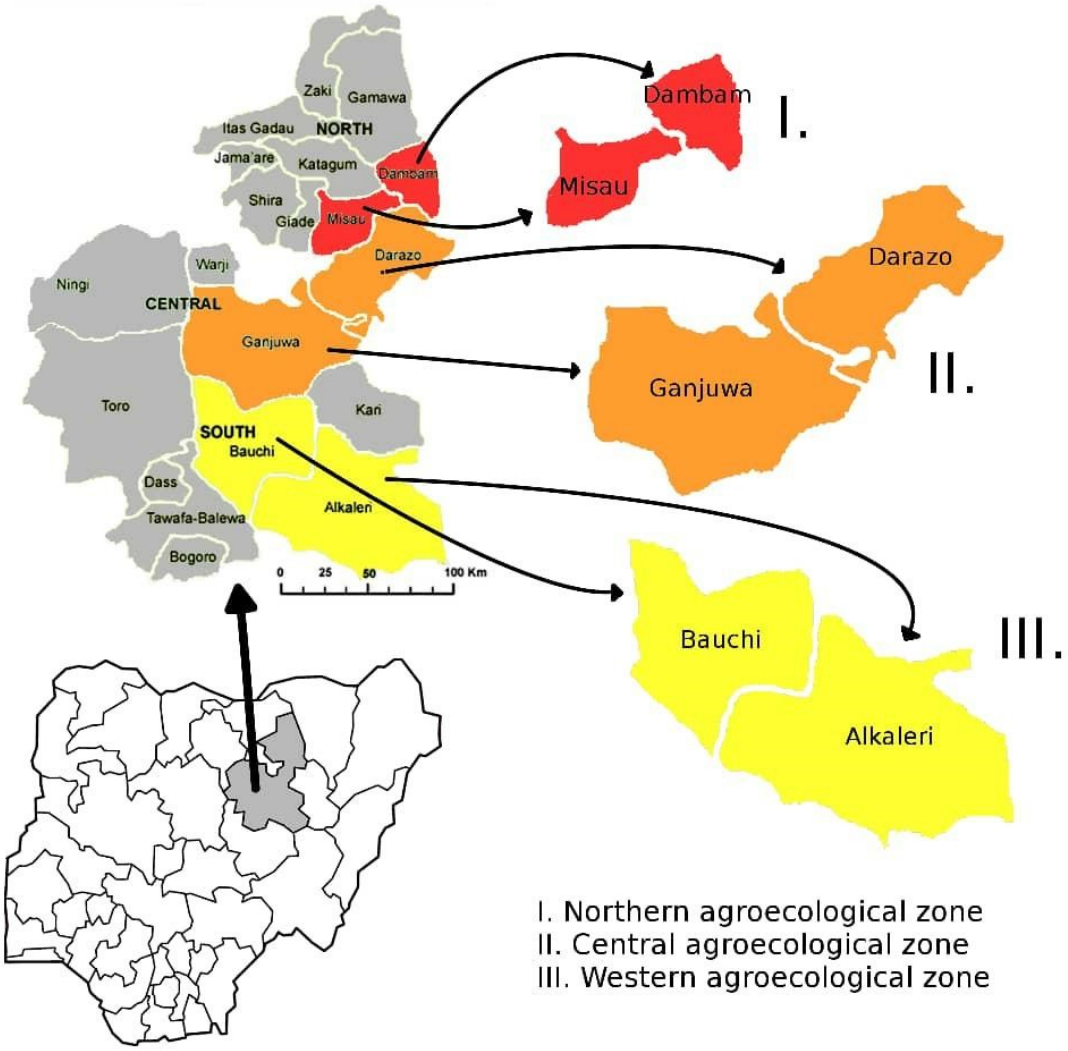

Figure 11: Map of Bauchi State, Nigeria.

With respect to Agroecological zones used in the study, the state is divided into three agricultural zones each with distinct climatic conditions, which include Western Agricultural Zone, Central Agricultural Zone and Northern Agricultural Zone.

3.1.1. Western agricultural zone

The Western zone is characterised with mountains with an annual rainfall between 1000 mm to 1300 mm per annum. It is located at 90 30' to 10^0 48' N and 8^0 45' to 10^0 15' E (Fabiyi & Hamidu 2011), with an estimated population of about 2.8 million people distributed across the zone. The seven local government areas that constitute the zone,

include: Alkaleri, Bogoro, Bauchi, Dass, Kirfi, Tafawa Balewa and Toro local government areas (NPC 2016).

Farming is the dominant activities in the area, where these crops are mainly cultivated maize, millet, sorghum, cowpea, soya beans and rice, while the following livestock such as goat, sheep, cattle are reared in the area (Abdullahi et al. 2010).

3.1.2. Central Agricultural zone

The zone vegetation type is Sudan savannah, the vegetation which is characterised with the coexistence of tree and grasses such as shea, baobab, locust bean tree. The main crops grown in this zone include: sorghum, millet, maize, cowpea and the abundant grasses that favours the traditional animal husbandry that serve as the major economic activities in the zone (BIC 2018; BSADP 2018).

The central agricultural zone of Bauchi state consists of four local government areas which include: Darazo, Ningi, Ganjuwa, and Warji (BIC 2018). The zone has an estimated population of 1.2 million where about 70% are farmers and live in rural areas (Gizaki et al. 2015).

3.1.3. Northern Agricultural zone

The zone falls in the Sahel savannah vegetation which is described as a semi-desert vegetation that comprises isolated stands of thorny shrubs (White 1983). The zone has two main seasonal climates consisting of rainy and dry seasons. The months of April is usually the hottest month of the year and December, the coldest. The zone has an average annual temperatures of 22.4 4°C and a minimum and maximum rainfall of 600-900mm per year (Bose 2018).

The Northern agricultural zone consists of eight local government area with an estimated population of 2.5 million people in which about 70% are farmers (NPC 2016; BSADP 2018). The local government areas include Dambam, Giade, Gamawa, Itas/gadau, Jama'are, Katagum, Misau and Zaki.

3.2. Sampling Procedure/ Sampling Size

Bauchi state has three (3) Agroecological Zones with their respective headquarters, namely: Western Zone with its headquarter in Nabardo (Toro Local Government Area), Central Zone with its headquarter in Miya (Ganjuwa Local Government Area), and the Northern Zone with its headquarter in Azare (Katagum Local Government Area). All these zones were incorporated in the study.

Multistage sampling procedure was used for the study.

STAGE I

Two top cowpea production local governments were purposively selected in each zone, to form six local government areas for the study.

STAGE II

Top three cowpea producer wards (farming community) were purposively selected in each local government making a total of 18 wards (farming community) for the research.

STAGE III

Seven registered cowpea farmers of each selected wards (farming community) were randomly selected to form the sample size for the study, making the total sample size of 126 respondents.

Table 8: Sample Frame

Zones	Local Government Areas	Wards (Farming communities)	Number of respondents
Western	Bauchi	Liman Katagum	7
		Zungur/Galambi	7
		Kengere/Tirwun	7
	Alkaleri	Akaleri	7
		Futuk	7
		Gwaram	7
Central	Darazo	Darazo	7
		Gabciyari	7
		Yautare	7
	Ganjuwa	Kafin Madaki	7
		Miya	7
		Yali	7
Northern	Misau	Akuyam	7
		Hardawa	7
		Beti	7
	Dambam	Gargawa	7
		Guraban	7
		Yanda	7
Total	6	18	126

Source: Filed Survey 2018.

3.3.Method of Data Collection

Primary and secondary data were used for the study. Semi-structured questionnaire were used as an instrument for primary data collection, which include socio-economic characteristics of the cowpea farmers, cowpea post-harvest handling practices, types of storage methods use in the study area and factors influencing the use of these different methods of storage, while secondary data were used to develop a literature review from Bauchi State Agricultural Development Program Production record, list of cowpea farmers, Journals, proceedings Web of Science, Scopus etc.

3.4.Method of Data Analysis

Description and Inferential statistics were employed in analysing the data collected.

Descriptive statistics

Descriptive statistics in form of mean, frequency, percentage etc. was used in achieving the objective I and objective III.

Inferential statistics

Logit regression regression model was used in achieving the objective II.

3.4.1. Data Analysis

The Logit model was used for the analysis of factors influencing the decision to use chemical in cowpea storage (1= use of chemical in cowpea storage and 0 non-use of chemical in cowpea storage)

$$LM=Ln\ (Pi\ /1-\ Pi) = Zi = \beta i + \beta \Sigma kXik + \varepsilon$$

Where:

Pi = probability that a farmer will use or not use chemical in storing cowpea grains ; Xik = K= 1, 2, ……n = independent variables (with ith observation)

ε = error term with zero mean’

Pi is non-linearly related to Zi

Thus, the dependent variable 'P' is 1 if a farmer is storing his cowpea grains using chemical pesticides and is '0' if not using chemical in storage. βi = constant term / intercept;βk = coefficients of explanatory variables;

The analytic tool usually employed in to access the adoption of decision study related to choice are: the binary (MNL) logit model , binary probit model, multinomial probit etc (Okoruwa et al. 2000) in all these models, the set of alternatives or choice must be mutually exclusive (Hensher et al. 2000). The instances of the use these models are in the following empirical studies to the influence of socio-economics variables on the farmers adoption decision by Hailu (1990), Kebede et al. (1990), Adesina (1996) Okoruwa et al. (2000), Ayedun et al. (2010), where probit model and Logit model were employed to access the influence of independent variables on the dependent variables. In the situation where more than one dependent variables are involved, the Multinomial Logit Analysis are used, as in the study conducted by Mobuodu et al. (2000) where the combined effect three variables factors are involved: socio-economic factors, technology characteristics and the farm specific factors on the use of four types of improved clay storage. Apart from Agriculture, Multivariate Probit Model and Multinomial Probit are used to analysis study involving choice. Kurkulasuriya and Meldelsohn (2006) used MLM to find out whether crop choice by farmers is climate sensitive. While Nhemachena and Hassan (2007) used Multinomial Probit Model to find the factors influencing the choice change adoption option. In addition, Multinomial Logit Model was employed by Deressa et al. (2009) to analyse the factors that affect the choice of adoption methods in the Nile Basin of Ethiopia. In this study therefore, Logit Model was employed to examine factors that influence farmers to use chemical pesticides in storage of cowpea

Table 9: Definition of Explanotory Variables Used in Empirical Studies

Variables	Definition	Measurement	Expected Sign
AGE	Age of the respondents	Years	±
GED	Gender of the respondents	1 for Male 0 for Female	±
MS	Marital Status	1 for single, 2 for Married, others	±
HH	Members of the household	Number of members	±
EQ	Educational qualification	Level	±
FE	Farming experience	Years	±
AES	Access to Extension Service	Frequency	±
QH	Quantity harvested	Kilogram	±
CP	Cost of pesticide	Naira	−

Source: Field Survey 2018

3.4.2. Description of Explanatory Variables

The use of chemical in storing cowpea in this study is the dependent variable. This is measure by asking the respondent whether they use chemical in storing cowpea or not. it is dummy variable giving the score of 1 for those that use chemical and 0 for those that do not use chemical

The explanatory variable that are expected to affect farmers decision to use or not use chemical in storing cowpea in this study are: Gender, Age, Marital Status, Household Size, Farming Experience, Educational Qualification, Cost of Pesticide and Quantity of Cowpea Harvested. Each of these aspects are briefly described below to provide the reason for their inclusion in the model.

Age: this is a continuous variable. Older age play an important role in decision making as a result of continuous observation, experience, and knowledge.

Gender: it is a dummy variable that takes the value of 1 female and 0 for male. It is included in the variables to differentiate male and female in the decision in use of chemical in cowpea storage. Various studies have indicated that is an important variable that affects adoption decision at farm level. For example, female have been found to be more likely to adopt natural resource and conservation decision (Dolisca et al. 2006: Bayard et al. 2007).

Marital Status: it is a multilevel variable with the score value of 1,2,3 and 4 for Single, Married, Divorced and Widow respectively. Married people are believed to engage in farming more than unmarried ones due to the burden of responsibility of feeding their families.

Household Members: The number of members in household has a direct relationship on input in farming

Farming experience: it is a continuous variable that defined farmers discretion on choice of whether to use chemical in storage or not, having judge the effectiveness and efficiency of different storage methods available.

Educational Level/ Qualification: Education is another important factor that creates a mental attitude towards adoption of technology such as the use of chemical in cowpea storage.

Cost of Pesticide: It is a continuous variable being an important variable that affects individual decision making. According to Asiedu et al. (2002) farmers make decision in the use of storage technique that is most affordable to them in a point in time.

Quantity of cowpea Harvest/ stored: Refers to quantity harvest by the farmers in kilogram.

4. Result

4.1. Descriptive Statistics

Description statistics such as frequency, percentage and standard deviation of the respondents socio-economics characteristics are presented in this section.

Socioeconomic characteristics of the respondents

Table 9 shows the socio-economics characteristics of the respondents. From the result most of the respondents are males 85.7% while females are 14.3%. Majority of the respondents 47.6% fall between 41-50 year. Others include those of 21-30 years of age 13.5% and those that are greater than 50 years 11.9%. Most of them are married 88.1% fallowed by single 5.6% while the divorce and the widow are 3.2%, 3.2% respectively. With regards to education, majority have high school education , seconded with those who have tertiary qualification education 22.2% those with lesser formal education attended elementary school 21.%? and those that have no any formal education are 19.8%. in term of access to extension service, most of them have extension contact at least once a year 65.1% and those who have no any are 34.9%

Table 10: Socio-economic characteristics of the respondents

Variables	Frequency	Percent
Gender		
Female	18	14.3
Male	108	85.7
Age		
21-30	17	13.5
31-40	60	47.6
41-50	34	27.0
>50	15	11.9
Average		
Marital Status		
Single	7	5.6
Married	111	88.1
Divorced	4	3.2
Widow	4	3.2
Education Qualification		
Non-Formal	25	19.8
Primary	27	21.4
Secondary	46	36.5
Tertiary	28	22.2
Access to extension service		
None	44	34.9
Once a year	59	46.8
Twice a year	19	15.1
Thrice a year	4	3.2

Source: Field Survey, 2018

With regards to household size, farming experience and average income, they have mean of 7.5 persons, 16.29 years, N 33,373.02 (91.43 USD) respectively. While the average cowpea size and average yield of cowpea are 1.98 ha and 8.55 (855 kg) respectively.

Table 11: Continuation on the Socio-economic characteristics of the respondents

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Household Size (Number of Persons)	119	2.00	22.00	7.50	4.19
Farming Experience (Years)	126	1.00	37.00	16.29	8.99
Average Income of **the respondents** (Naira)	126	13,000.00	90,000.00	33,373.02	15,695.98
Farm Size (ha)	126	1.00	9.00	4.59	1.94
Cowpea Farm Size	126	0.50	6.00	1.98	1.03
Cowpea Yield (in bags)	126	2.00	25.00	8.55	4.84

Source: Field Survey, 2018

Post-harvest handling of cowpea

Drying

The result shows all the respondents dry their cowpea through sun drying (100%). Half of them (50%) dry it within two weeks while other greater percentage 45.2% dry it within a week, while the rest dry it in more than two weeks 4.8 %.

Table 12: Drying of cowpea

Variables	Frequency	Percent
Drying Methods		
Sun Drying	126	100.0
Duration of Drying		
Within a week	57	45.2
Within 2 weeks	63	50.0
More than 2 weeks	3	2.4
More than a month	3	2.4

Source: Field Survey, 2018

Threshing

With respect to table 12 all the respondents (100 %) thresh the cowpea seed manually and the exercise mainly takes place at home 57.9 % and at farm 42.1%

Table 13: Methods and Place of Cowpea Threshing

Variables		Frequency	Percent
Method of Threshing	Manual	126	100.00
Place of Threshing	Farm	53	42.1
	Home	73	57.9
	Total	126	100.00

Source: Field Survey, 2018

Sorting

The table above shows that the respondents that sort the cowpea before storage are 94.% and those do not are only 5.6%.

Table 14: Sorting before storage

Variables		Frequency	Percent
Sorting	Yes	119	94.4
	No	7	5.6
	Total	126	100.0

Source: Field Survey, 2018

Storage

The results in the table below shows majority of the respondents store cowpea in Sacs 65.1%, seconded by those that store it using PICS bags 23.0%. Those that store it in Rumbus, and Drum are 4% and 4% respectively. For Jerry can and Jute bags are 2.4% and 1.6%

Table 15: Kind of storage Facilities Used

Variables	Frequency	Percent
Rumbus	5	4.0
Jute bag	2	1.6
Sacs	82	65.1
PICS bags	29	23.0
Drum	5	4.0
Jerry can	3	2.4
Total	126	100.0

Source: Field Survey, 2018.

The table below shows storage methods use, place and form of storing cowpea. The table indicated that majority of the respondents (88.1%) use modern storage methods only 11.9 use traditional methods and stored the cowpea at home 83.3% and at farm 9.5% mainly after it is threshed (dehulled) 96.8% and few store it in un threshed form 3.2%.

Table 16: Methods, Place and Form of Cowpea Storage

Variables	Frequency	Percent
Method of Cowpea Storage		
Modern	111	88.1
Traditional	15	11.9
Place of Storage		
Farm	12	9.5
Home	105	83.3
Others	9	7.1
Form of Cowpea Storage		
Dehulled	122	96.8
Undehulled	4	3.2
Total	126	100.0

Source: Field Survey, 2018

The table presents the duration of storage as reported by the respondent, 15.1% store in less 3 months period. Majority store cowpea between 3-6 months (55.6%), those that store for longer period 6-9 months are 23.8% while only 5.6 store it in more than 9 months.

Table 17: Duration of Cowpea Storage

Variables	Frequency	Percent
Less than 3 months	19	15.1
3-6 months	70	55.6
6-9 months	30	23.8
More than 9 months	7	5.6
Total	126	100.0

Source: Field Survey, 2018

Packaging

The use of sacs to package cowpea is most common 73.8%, followed by PICS bags 23% and those that store using jute bags are only 3.2%

Table 18: Methods of Cowpea packaging

Variables	Frequency	Percent
Sacs	93	73.8
Jute bags	4	3.2
PICS	29	23.0
Total	126	100.0

Source: Field Survey, 2018

Use of chemical in cowpea storage

Table 20 shows that majority of famers use chemical pesticide in storing cowpea 70.63% and more than half of the respondents 53.93% use the chemical pesticide in Liquid form. The corresponding names of the Liquid and Powder chemicals used are Actellic and Phostoxin.

Table 19: Use of Chemical, Form of Chemical and Name of Chemical Use

Variables	Frequency	Percentage
Using Chemical		
Yes	89	70.63
No	37	29.37
Form of Chemical		
Powder	41	46.07
Liquid	48	53.93
Name of Chemical		
Phostoxin	41	46.07
Actellic	48	53.93

Source: Field Survey, 2018

4.2.Inferential Statistics

The table shows age, education, access to extension service and cost of pesticide to be the main factors that determine farmers choice of using chemical pesticide in storing cowpea in the study area, significant at (P<0.05), (P<0.01), (P<0.05), and (P<0.1) respectively.

Table 20: Result of Regression analysis on determinants of use of chemicals

Variables	B	S.E.	t-value	Sig.
GED	-1.901	0.817	5.415	0.020 * *
AGE	0.259	0.533	0.237	0.626
MS	0.887	1.413	0.394	0.530
HHS	-0.014	0.105	0.019	0.891
EDU	-1.648	0.847	3.782	0.052 *
FEX	0.030	0.057	0.273	0.601
AES	-0.849	0.392	4.697	0.030 * *
QH	0.054	0.167	0.104	0.748
CP	1.135	0.275	17.055	0.000 * * *

* * * Significant 0.01%, * * Significant 0.05%, * Significant 0.1%.

Source: Field Survey, 2018

4.3. Descriptive Statistics

Respondents perceived effectiveness on different cowpea storage methods

The result shows that Hermetics storage methods are perceived to be more effective in storing cowpea 65.9%, 64.3% 46.8%, and 26.2% for PICS bags, Jerry can, Drum and Silos respectively. While the others are Sacs and Jute bags with perceived effectiveness of 11.1% and 0.8% respectively.

Table 21: Perceived effectiveness of different cowpea storage methods

Methods	Very Effective (%)	Effective (%)	Non- Effective (%)
Silos	33(26.20)	80(63.50)	13(10.30)
Rhombus	1(0.80)	75(59.50)	50(39.70)
Jute bag	2(1.60)	65(51.60)	59(46.8)
Sacs	14(11.10)	89(70.60)	23(18.30)
PICS bags	83(65.90)	41(32.50)	2(1.60)
Drum	59(46.80)	63(500)	4(3.20)
Jerry can	81(64.30)	43(34.10)	2(1.60)

Source: Field Survey, 2018.

5. Discussion

Table 9 shows that most of the respondents are males 85.7 %. This indicates that majority of the cowpea farming in the study area is dominated by males. This is can be attributed to traditional and religious belief that women should stay at home to carry out domestic activities for the households. This finding is in line with that of Shehu (2017) who found that males dominated cowpea farming in North-eastern Nigeria and also

agrees to the finding of Ayedun et al. 2010 who found that majority (91.8%) of legume farmers are males in Nigeria . The table also show that greater percentage of the respondents are between 31-40 years of age which indicates they are at their productive age and strength to carry out farming activities. David et al. (2017) also found that majority of cowpea farmers are between the age of 30-40 years. The result further show that the highest percentage of the respondents are married 88.1 % this also agrees to the finding of Shehu (2017) who found that married people engage in farming more than unmarried people in North East Nigeria because of the responsibility of feeding the family. Also, the respondents have one form of formal education or the other 80.1 %. On the access to extension service, most of them have access to extension service at least once a year (55.1%).

Table 10 presents the household size of the farmers with a mean of 7.5 persons and standard deviation of 4.19, while the mean and standard deviation of farming experience are 16.29 years and 8.99 respectively, indicating that the respondents have been in cowpea farming for long and are familiar with post-handling practice. This finding is line with that of Segun et al. (2014) who found that more than half of cowpea farmers have more than 10 years' experience in farming. Also found from the survey are average monthly income is found to be N 33,373.02 (91.43 USD) with the standard deviation of 15,695.98. The average farm size, cowpea farming portion and cowpea yield were 4.59 ha, 1.98 ha, and 8.55 bags (855 kg) respectively.

Table 11 presents the result of drying activities of cowpea carried out by farmers in the study area. It shows that all the farmers dry their cowpea under the sun (Sun drying) (100 %), this finding is in line with Kumar and Kalita 2017 report, who reported that in developing countries, the use of Sun drying to dry farm produce is most common. Also half of them (50 %) drying the cowpea in period of two weeks, this is so because it will enable the cowpea to be fully dried as required moisture content is essential for effective storage of the grains.

With respect to table 12 all the respondents (100 %) thresh the cowpea seed manually and the exercise mainly takes place at home 57.9 % and at farm 42.1%. Threshing is necessary because cowpea grains left in pods have high potential of getting damage because of insects attack (Khan 2010).

Table 13 Farmers sort out the cowpea grain to remove broken ones, remove debris etc as broken grains can cause easy microorganism attack. The finding indicates that majority of the respondents 94.4 % sort the cowpea before storage.

The result in the table 14 shows majority of farmers 65.1 % store their cowpea in Sacs (bags) usually with the addition of pesticide, this agrees with the finding of Segun et al. (2014) who found that majority of cowpea farmers in Kwara State, Nigeria also stored cowpea in Sacs . While the proportion of them 23 % store it in PICS bags. With regards to the use of hermetic storage methods, it can be seen that the use of PICS bags is 78.38%, showing it to have outnumbered that of other forms of hermetic storage combined together (21.62%), this is in line with the finding of Ayedun et al. (2010) who found that the use of PICS is 66.3% and others hermetic to be 33.7%. The use of PICS bag is becoming popular and is gradually being adopted because of its effectiveness and ability to store cowpea safely without chemical contamination (Baributsa 2010).

The table 15 shows storage methods use, place and form of storing cowpea. The table indicated that majority of the respondents (88.1%) use modern storage methods only 11.9 use traditional methods and stored the cowpea at home 83.3% and at farm 9.5% mainly after it is threshed (dehulled) 96.8% and few store it in un threshed form 3.2%.

The table 16 presents the duration of storage as reported by the respondent, 15.1% store cowpea for less 3 months period. Majority store cowpea between 3-6 months (55.6%), those that store for longer period 6-9 months are 23.8% while only 5.6 store it in more than 9 months.

The table 17 above indicated that majority of the farmers 73.8 % package cowpea in Sacs, this is because the use of sacs is common in storage and packaging and provide a convenient way for handling and transportation of grain than any other material. The PICS bags used in storage are always removed to be replaced by Sacs so that they will be used as storing material again.

Table 18 shows that majority of farmers use chemical pesticide in storing cowpea 70.63% and more than half of the respondents 53.93% use the chemical pesticide in Liquid form. The corresponding names of the Liquid and Powder chemicals used are Actellic and Phostoxin

The table 19 above shows that gender is significant at $P < 0.05$ with regression coefficient of -1.901, this implies that women are more likely to use chemical in storing cowpea than their male counterpart, this might be due to their lack of contact with the chemical to experience the possible danger it may pose. This finding is in contrary to that of Okoruwa who found no significant influence of gender on the use of chemical in storing cowpea. With respect to the educational level, the result shows that education is significant at $P < 0.01$ with regression coefficient of -1.648, it means that the higher the education of farmer the lower the likelihood to use chemical in storing cowpea, this is possible because educated people are more cautious on health hazards and know more of other storage alternatives than those with less knowledge. Access to extension service is found to be significant at $P < 0.05$ with regression coefficient of -0.849, meaning that farmers contact with extension agents make them to be aware of the side effect of using chemical in storing cowpea and adopt hermetic cowpea storage in alternative to use of chemical. Also found to be significant is the cost of chemical pesticides at $P < 0.1$ with regression coefficient of 1.135. This implies that increase in price of chemical leads to the increase of the use of chemical in storing cowpea. This is possible when there is proven effective chemical in the market. This finding is in line with of Okoruwa et al. (2000) who also found that cost of pesticide has significant impact on the use of chemical pesticide in South- western Nigeria.

Table 20 presents effectiveness of storage methods as perceived by respondents in the study area. From the table, the result shows that storing cowpea in PICS, Jerry Can, Drum and Silos are perceived to be very effective with the score of 83(65.9%), 81(64.3%), 59(46.8%) and 33(26.2%) respectively. This might be due to limited supply of oxygen and high temperature that will make the insect pest not to survive also Murdock et al. 2012 found that insect trapped in Hermetics storage containers actually died as a result of dehydration (desiccation). This finding agrees with that of Abdullahi et al. 2016, who found that air tight storage facilities are more effective in storing cowpea. While the use of Sacs mainly in combination with pesticide was found to be effective 89(70.6%) as compared to storing cowpea in Rumbus and Jute bags with the score of 75(59.5%) and 65(51.6%) respectively.

Limitation of study

(i) Study only examine the post-harvest handling of cowpea, it did not extend to other custodians of the grain such as hoarders and retailers, as there is recent viral use of illegal chemicals by hoarders to preserve cowpea grain while they hold it before selling.

(ii) The list of registered cowpea farmers obtained showed few farmers are registered with the organisation, hence large sample of the respondents should have been used.

6. Conclusions

The result shows that farmers in the study are mainly males with considerable level of literacy and experience in cowpea farming and are mostly married. The respondents give priority to practice that ensure good preservation of cowpea. Although they use chemical pesticide in preservation of cowpea, their usage of chemical is within the recommended level. The independents variables: Gender, Educational level, Access to extension service, and Cost of chemical pesticides have significant influence in the use of chemical in storing cowpea in the study area. Meanwhile, although the result shows that majority of the respondent use sacks and chemicals to store cowpea, majority of them reveal that they perceived hermetic storage to be more effective in storing cowpea.

7. Recommendation

The use of chemical pesticides is prevalent, though within the accepted level, we therefore recommend that awareness campaign on side effect of chemical is promoted in the study area as well as checking the activity of cowpea hoarders who can over use the chemical in attempt to not lose in the process. In order to reduce the use of chemical in storing cowpea in the study area, we recommend that awareness campaign should be lunched on the side effect of using chemical in cowpea storage especially to the women folks. In addition, there is need to increase women participation in cowpea production in the study area. Various researches have indicated that women play a vital role in agriculture and food security, they should therefore be encouraged to participate in cowpea production to ensure adequate food supply. Farmers education and extension contact should also be promoted as this can reduce the prevalent use of chemical since

other effective storage alternatives such as PICS bags are available. Meanwhile, government should make policy to make Hermetics storage such as PICS affordable to farmers to enhance wide adoption for both farmers and cowpea hoarders.

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9. Appendices

10. Appendices I: Questionnaire

11.Appendices II: Photo Documentation of survey

Questionnaire

Topic: Post-harvest Handling Practices of Cowpea (*Vigna unguiculata*): A Case Study of Bauchi State.

This study is a post-graduate research project in partial fulfilment for the requirement of MSc. aimed at identifying the various post-harvest handling practices of Cowpea in the rural areas of Bauchi State, Nigeria. Your response would be highly appreciated and would be treated confidentially.

Instructions: Please mark the boxes and fill in the blank spaces appropriately.

Section A.
Socio-economic characteristics of the respondent:

1. Name of Respondent (Optional) …….
2. Name of Local Government ……
3. Name of Ward (Community) …….....
4. Gender: a) Male [ ] b) Female [ ]
5. Age range: (a) 21-30 [ ] (b) 31-40yrs [ ] (c) 41-50 [ ] (d) >50 [ ]
6. Marital Status: (a) Single [ ] (b) Married [ ] (c) Divorced [ ] (d) Widow
7. What is your household size? …….
8. Level of Education (a) Non-formal Education [ ] (b) Primary/Basic [ ] (c) Secondary [ ] (d) Tertiary [ ]
9. Farming Experience (years)……
10. Average income per year (Naira) ……...
11. What is your farm size (ha)?.....
12. How many hectares of land do you cultivate Cowpea annually? ……..
13. How much of cowpea do you grow annually (in bags)?.....
14. Do you have access to extension service (a) Not at all [ ] (b) Once a year [ ] (c) Twice a year (d) Thrice a year

Section B. (Post-Harvest Handling Practices of Cowpea)

15. Which drying method do you use?

(a) Sun Drying [ ] (b) Shade Drying [ ]

16. How long does it take to dry before storage?
    a) Within a week [ ]
    b) Within 2 weeks [ ]
    c) More than 2 weeks [ ]
    d) More than a month [ ]
17. Where do you thresh the cowpea?
    (a) At farm [ ] (b) At home[ ]

    (c) Both [ ] (d) Others (specify)

18. How do you thresh cowpea?

    (a) Manually [ ] (b) Using Machine [ ]

19. How do you package cowpea grains after threshing …….?
20. Do you sort the cowpea before packaging?

    (a) Yes [ ] (b) No [ ]

21.Where do you store the produce?
(a)At farm [ ] (b) At home [ ]
(c) Both [ ] (d) Others (specify)

Section C. (Type of Storage Facilities)

21. What method of storage do you use?

(a) Modern [ ] (b) Traditional [ ]

22. In which form do you store the cowpea?

(a) Dehulled [ ] (b) Un-dehulled [ ]

23. Do you use chemical for cowpea storage?

(a) Yes [ ] (b) No [ ]

24. If yes which chemical do you use?
    …….
25. Which form is the chemical use?

(a) Powder [ ] (b) Liquid [ ]

26. Cost of chemical(pesticides)……
27. Amount apply to
    (kg)……

28.How long do you store cowpea?
    (a) Less than 3 months [ ] (b) 3-6 months [ ] (c) 6-9 months [ ]
    (d) more than 9 months [ ]

29.What is/are the cause(s) of loses during storage?

a) Amount of water content before storage
b) Humidity of the storage facility
c) Size of the storage facilities
d) Insect infestation
e) Others (specify)
……

(Factors that influence use of chemicals in storage)

30.What kind of storage facilities do you use?

a) Silos
b) Rhombus
c) Jute bag
d) Sac
e) PICS bags
f) Drum
g) Jerry can

31.Why do you choose these facilities? (multiple choices are allowed)

i) Low cost [ ] ii) Simplicity [ ] iii) Effective [ ] iv) Safe [ ] v) Availability [ ] vi) Small nature of operation [ ] vii) Large scale nature of operation [ ]

32.Any other facilities that you think to use in the future?

(a) Yes [ ] (b) No [ ]

33.If yes which facilities is it?.....

34.Why do you choose to use this facility in the future?.....

Section E. (Comparison of the perceived effectiveness.)

35. Rate these facilities base on effectiveness

Facility	Very Effective	Effective	Not Effective
a) Silos			
b) Rhombus			
c) Jute bag			
d) Sacs			
e) PICS bags			
f) Drum			
g) Jerry can			

Photos from the data collection

Source: Field survey

Source: Field survey