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Post-harvest Handling Practices of Sesame (*Sesamum indicum* L.) in Rural Areas of Nigeria: A Case Study of Bauchi State

MASTER'S THESIS

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Author: Ibrahim Zailani, BSc.

Chief supervisor: doc. Ing. Jan Banout, Ph.D.

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DIPLOMA THESIS ASSIGNMENT

B.Sc. IBRAHIM ZAILANI

Tropical and Subtropical Agriculture

Thesis title

Post-harvest Handling Practices of Sesame (Sesamum indicum L.) in Rural Areas of Nigeria: A Case Study of Bauchi State.

Objectives of thesis

The broad objective of the study is the assessment of postharvest losses of sesame in the rural areas of Nigeria, while the specific objectives are to:
i. Identify the various postharvest handling practices of sesame in the study area.
ii. Identify the various forms of postharvest losses of sesame in the study area.
iii. Measure the extent of postharvest losses of sesame at different levels of postharvest handling practices in the study area.
iv. Analyse the factors affecting the postharvest losses of sesame in the study area.

Methodology

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 sesame production. A Multi Stage Sampling Procedure will be adopted for the ultimate selection of good sesame farmers: Stage I: Two (2) LGAs will be selected purposely from each agricultural zone to form six (6) selected LGAs. Stage II: Two (2) Wards will further be selected randomly from each selected LGA making twelve (12) wards for the study. Stage III: Fifteen (15) farmers will be selected purposely from each ward selected to form a sampling size of one hundred and eighty (180) farmers for the study area.

The proposed extent of the thesis

40-60

Keywords

Post-harvest, Handling, Sesamum indicum, Rural areas, Bauchi, Nigeria.

Recommended information sources

Basavaraja et al. (2007}, Agricultural Economic Research Review Vol. 20, pp117-126.
D. Bedigian and J. R. Harlan, (1986), “Evidence for cultivation of sesame in the ancient world”, Economic Botany, Vol. 40, No. 2, pp, 137-154.
N M. Nayer, K. L. Mehra, (1970), Economic Botany, Vol. 24, No.1, pp. 20-31.

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doc. Ing. Jan Banout, Ph.D.

Supervising department

Department of Sustainable Technologies

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doc. Ing. Jan Banout, Ph.D.
Head of department

Electronic approval: 8. 4. 2019
doc. Ing. Jan Banout, Ph.D.
Dean

Prague on 22. 04. 2019

Declaration

I hereby declare that I have done this thesis entitled "Post-harvest Handling Practices of Sesame (*Sesamum indicum* L.) in Rural Areas of Nigeria: 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, 27 April 2019

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Ibrahim Zailani

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Abstract

Sesame has become one of the most important cash crops in Nigeria, however its cultivation is faced with challenge of postharvest losses. The broad objective of the study is the assessment of postharvest losses of sesame in the rural areas of Nigeria, while specifically to identify the various postharvest handling practices of sesame, identify the various forms of postharvest losses of sesame, identify the perceived factors responsible for postharvest sesame and to analyse the factors affecting the postharvest losses of sesame in the study area. The study was conducted at Bauchi state, a part Savannah vegetation type of Nigeria. All the data were collected between between Jul-Sept. 2018. 120 farmers were selected conveniently for the research with the aid of a semi-structured questionnaire. Both descriptive and regressive statistics were adopted for analysing the data collected. Also, a field trial was conducted to know the actual average yield obtainable in 1 m^2 plots of sesame and the measurement of the actual weight of the of sesame. The result revealed that, apart from transportation all other postharvest operations were found to be manual. The majority (85%) of the farmers perceived that, drying is the major means of postharvest loss of sesame in the study area, however the losses were found in all the handling practices but considered negligible. Wind, pest, poor handling, Rainfall, pest and others, wind and others and early harvest, are the major factors that were found responsible for a post-harvest lost in the study area. Age and household size of the farmers, postharvest handling practices as well as the factors responsible for loss were found to significantly affecting postharvest losses in the study area. Result of field trial revealed that up to 1.2 Mt could be obtained per hectare and, we found that the actual weight of sesame bag is 85 kg. This finding is relevant and important to my field of science in the sense that all the findings could be beneficial to both the farmers and the researchers as well as policy makers.

Key words: Postharvest, Handling, *Sesamum indicum*, Rural areas, Bauchi, Nigeria.

Preface

Background of the study

Sesame (*Sesamum indicum* L.) is a broadleaf crop belonging to the botanical family Pedaliaceae commonly called beniseed in Nigeria. It is an important oilseed crop believed to have originated from tropical Africa, where you have the greatest genetic diversity (W.C.B. 1895). Sesame is among the important oil yielding plants originated in Africa grown mainly for its seeds that contain approximately 50% oil and 25% protein and the crop is being harvested for the whole seed usage or for cooking oil extraction. It is also utilized for medicinal purpose (Khazaei & Mohammadi 2009).
Ali et al. (2015). Stress that sesame has a large potential to enhance agribusiness development and generate employment opportunities that will lead to significant impact in the rural sector, particularly for households in Northern Nigeria. Sesame seeds contain more oil than many other oilseeds. Oil content varies with genetic and environmental factors. Sesame oil contains about 80% unsaturated fatty acids. Oleic and linoleic acids are the major fatty acids and are present in (Hegde 2012). The postharvest handling practices involves a series of operations like; harvesting, transportation, drying, threshing, winnowing, packaging and storage and of course there is appreciable loses in each of the stages depending on how its handled (Basavaraja et al. 2007).

The post-harvest and marketing system are a chain of interlinked activities starting after the harvest time and continuing until the delivery of the food product to the consumers. An efficient post-harvest system ensures that the harvested product reaches the customer in the shortest possible time interval without compromising the volume, quality, and safety of the product (Gardas et al. 2018).
Bauchi State Agricultural Development Programme (BSADP) has established partnership with Olam International Ltd., which leads to increase of sesame production in Bauchi state by about 300 percent. This alliance which started in 2008, had raised the production per hectare in the state, from 264 kg/ha in 2008, to 850 kg/ha in 2016. (SundiataPost. 2017). According to the FAO (2014) assessment of food loss and waste its scale, underlying mechanisms and options for reduction has been receiving increasing attention since the reduction of loss and waste has been put on the top of political agendas for addressing Sustainability in food production and consumption in a broad sense.

Problem statement

Post-harvest losses consist of produce that it lost or wasted between harvest and the moment of human consumption, anywhere along the value chain. Post-harvest loss statistics is worthy of debate at the whole, but not its adverse effect (FAO, 2017).

Nowadays, the biggest challenge for the agricultural sector is to feed a population of over 9.1 billion by 2050 (Parfitt et al. 2010). There would be a tremendous demand from this rapidly increasing population, to meet which, cereal production must increase from 2.1 billion tons to 3 billion tons annually, and the production of meat must increase to 470 million tons per annum. It is predicted that by 2050, net imports of cereals in developing economies would be about 135 million tons to 300 million tons (Gardas et al. 2018).

Gardas et al. (2018) observed that the losses were considerable at the immediate post-harvesting stage in the developing countries and these losses were quite significant for the perishable foods. A survey was also conducted, which revealed that the poor skills and knowledge of the farmers regarding post-harvest losses were largely responsible for the food loss (An & Ouyang 2016).

Improper handling of the food products causes serious damages and affects the quality of the products, which in turn causes significant postharvest losses. The greatest challenge to the agricultural production in Nigeria is how to ensure increased food production and value addition of agricultural products. (Umar et al. 2010). The major obstacles to sesame's expansion are its low yields and the absence of non-shattering cultivars suitable for machine harvest (Hegde 2012).

Sesame is produced mainly in the savanna agro-ecological zones of Nigeria by small holders' farmers on relatively poor soils with limited inputs, thereby resulting in low average yield. However, in southern guinea savannah zone of Nigeria, the sesame should be sown towards the end of the rainy season in order to avoid excessive vegetative growth which might lead to crop failure (Eifediyi et al. 2016).

Significance of the study

This information would be useful for researchers, farmers, scientists, technologists, policymakers, administrators and industrialists.

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List of the abbreviations used in the thesis

BSADP	Bauchi State Agricultural Development Programme
EPL	Estimate of Postharvest Losses
FAO	Food and Agricultural Organization
FAOSTAT	Food and Agriculture Organization Corporate Statistical Database
FLW	The Global Food Loss and Waste Protocol
FRL	Factor Responsible for Loss
FS	Farm Size
HH	Household
ICM	Integrated Crop Management
LGA	Local Government Areas (Third tier of Nigerian Government)
LOE	Level of Education
MLR	Multiple Linear Regression
MOA	Membership of Organization/Group
NAA	Naphthaleneacetic acid
PSCA	Parliamentary Standing Committee on Agriculture
SPSS	Statistical Package for the Social Sciences
VAR	Variety of sesame
WRI	The World Resources Institute

1. Introduction

Sesame (*Sesamum indicum*) popularly known as "Beniseed" in Nigeria is an oil producing annual herbaceous crop from the family Pedaliaceae. It is believed to have originated from tropical Africa, where you have the greatest genetic diversity (W.C.B. 1895). And distributed to West Asia, China and Japan, which later became secondary centres of diversity (Kafiriti & Mponda 2010). Also later some evidence showed that it is among the earliest domesticated plants of India (Kushahwah et al. 2018). However, Fuller DQ (2003) found that most wild related species of the genus Sesamum are originated from sub-Saharan Africa where also the domesticated sesame originated. The sesame seed is known for providing high quality oil. The oil may be used for cooking purposes, aromatics, flavouring agents, pharmaceuticals and cosmetics, as well as for the manufacture of soap, paint and insecticides. The meal is used for feeding animals and manure. Sesame is also reported to be one of good natural antioxidant source such as sesamol, sesamin, sesamolin and tocopherols that are widely utilized as dietary supplement. It also has anti-cancer properties and used to cure cardiovascular diseases (Asghar et al. 2014).

Postharvest loss refers to both qualitative and quantitative, measurable food losses in the post-harvest system, while the post-harvest system includes the sequence of related activities from the time of harvesting to the customers final decision. These losses can occur at any stage of the supply chain, and markets value reduction of the products could also be another form of financial losses. (Hodges et al. 2011). lacking researches on harvest and post-harvest loss leads to its abundance (Martins et al. 2014). In order to maintain rapid social and economic development in most developing countries in the future, food security must be ensured (Qi et al. 2018). This section of the paper focuses on the papers published in postharvest system and losses.

1.1. Agriculture in Nigeria

In the 1950s and 1960s, agriculture constitutes the mainstay of the Nigerian economy but the discovery of crude oil succeeded in putting agriculture into state of oblivion (Lawal & Oluwatoyin 2011). In recent years, trade in agriculture has not only attracted growing attention but is being viewed as the vehicle for global growth and equity. World trade and expanding markets by removing distortions could facilitates competition leading to hunger and poverty in developing countries like Nigeria. Provision of enabling environment for most poor people of the world such as creating opportunities to improve their incomes is the main goal of agricultural trade. (Felix et al. 2013).

In terms of employment, agriculture is the most important sector of Nigeria's economy, engaging about 70% of the labour force. Agricultural holdings in Nigeria are generally characterized by small and scattered; farming is often of the subsistence variety, and the use of simple tools and shifting cultivation. About 80% of the total food production are achieved through these small farms produce. Also 33% of Nigeria's land area i.e. about 30.7 million hectares, are under cultivation. Nigeria's diverse climate, from the tropical areas of the coast to the arid zone of the north, make it possible to produce virtually all agricultural products that can be grown in the tropical and semitropical areas of the world. The economic benefits of large-scale agriculture are recognized, and the government favours the formation of cooperative societies and settlements to encourage industrial agriculture. Large-scale agriculture, however, is not common. However, the productivity is restricted despite a favourable climate and abundant water supply due to inefficient methods of cultivation and low fertility of the soils (Nations Encyclopedia 2018). The Nigerian economy is been hindered by institutional weakness and corruption (Felix et al. 2013). There is a great opportunity for private sector to invest in crop production in Nigeria. Also to improve efficiency of institutional agencies for agricultural development, the government should increase funding of agricultural sector (Olukunle, 2013). Abimbola (2014) suggested that, farmers in Nigeria should also be sensitized on the benefit of small household size especially on its positive effect on per-capita income and household welfare.

1.2. Sesame production

Sesame varieties have adapted to many soil types. The high-yielding crops thrive best on well-drained, fertile soils of medium texture and neutral ph. However, these have low tolerance for soils with high salt and water-logged conditions. Commercial sesame crops require 90 to 120 frost free days. Warm conditions above 23 ^{o}C (73 F) favor growth and yields. While sesame crops can grow in poor soils, the best yields come from properly fertilized farms. Higher sesame yield depends on the plant population (Ahmed et al. 2010). Majority of the cultivated varieties of sesame mature in 80 to 100 days. Sesame is one of the most important crop that thrive well under drought condition, but however, the more the moisture, the more yield obtained (Grichar et al. 2012). The suitable nitrogen application method will provide an optimum yield of sesame (Kashani et al. 2016).

There is significant difference between cultivars in respect of capsule length, number of seeds per capsule and seed size. A capsule may contain 50 to 100 or more seeds. Seed weight is around 3 g/1000 seeds. The seeds mature 4–6 weeks after fertilization (Hegde 2012). Producers, marketers, food industries, and human nutritionist particularly from sesame growing areas could benefit from the scientific information generated from research on sesame. (Zebib et al. 2015).

Sesame grows well on wide range of soils from high sandy soils to black cotton and clay soils, but it thrives best in well-drained, moderate fertile soils of medium texture. Shallow soils with impervious subsoil are not suitable. Soils with neutral reaction are preferred, although good results have been obtained in slightly acidic and slightly alkaline soils. Sesame does not thrive on acid soils. It will grow in soils of pH 5.5–8.0 but, at higher pH, soil structure becomes increasingly important. (Hegde 2012). The sesame crop is known to resist pests and diseases and it has little or no damage from both wild and domesticated animals as well as wild birds (Grichar et al. 2012). A recent research discovered that there is antidiabetic activity due to the presence of dietary fibre and phytosterol in the sesame seeds well as antioxidant potential (Bigoniya et al. 2012).

According to (Singh et al. 2014) the maximum average number of capsules per plant, the number of seeds per capsule, the maximum average test weight of sesame seeds as well as benefit cost ratio could be obtained under improved technology over to farmer's practices. The oil quality obtained from sesame seed is as the same as that of other vegetable regards to acceptable standards (Ogbonna & Ukaan 2013). Sesame attracts international market; however, its production is challenged by poor handling practices, adverse weather conditions and insect pests (Gebregergis et al. 2016).

1.2.1. Global production of sesame

Sesame was widely dispersed by people both westward and eastward, reaching China and Japan which themselves became secondary distribution centers. Dawood (2016) observed that, a combined application of nitrogen (N) and naphthaleneacetic acid (NAA) along with recommended doses of other fertilizer would play a significant role in the increase of the sesame seed yield. Sesame is an important cash crop for small and marginal farmers in several developing countries. It is cultivated for its seeds which contain 38–54% oil of very high quality and 18–25% protein. The great diversity of sesame types, their wide environmental adaptation and considerable range of seed oil content and characteristics make an exceptional gene pool which must be harnessed to produce better cultivars to extend the range and profitability of sesame growing. The major obstacles to sesame's expansion are its low yields and the absence of non-shattering cultivars suitable for machine harvest (FAOSTAT, 2016).

Table 1. Sesame production

Country	**Production** (Tones)
Tanzania	940,221
Myanmar	812,952
India	797,700
Sudan	721,000
China	647,893
Nigeria	460,988
World	**6,111,548**

Source: FAOSTAT, 2016.

In 2016, world production of sesame seeds was 6.1 million tons, led by Tanzania, Myanmar, India, and Sudan (table above).

The white and other lighter-coloured sesame seeds are common in Europe, the Americas, West Asia, and the Indian subcontinent. The black and darker-coloured sesame seeds are mostly produced in China and southeast Asia. The name sesame is used in Literature worldwide. It is also known as "simsim" in East Africa, "Till" in India and "Gingely" in Sri-Lanka. The Hausa, Ibo, Yoruba, major tribes of Nigeria call it "Ridi", "Ekuku" and "Isasa" respectively. Other tribes in Nigeria also have names for it (W.C.B. 1895).

1.2.1.1. Sesame production in Nigeria

Among the traditional sesame growers in Nigeria more especially in the north central part of the country, fertilizer application has not been a common practice because it is considered as a crop that can do well even on poor soils (Haruna 2011). An ideal rates of poultry manure, nitrogen and phosphorus is therefore recommended for increased yield of sesame in agroecological zones of Nigeria (Haruna, 2011). Various studies revealed that sesame production is profitable which help diversifying the livelihood of Nigerians. However for sustainability, the extension workers and other relevant organization should provide training for sesame farmers on how to boost their production. (W.C.B. 1895).

1.2.1.2. Sesame production in Bauchi state

The farmers in Bauchi are experiencing some changes in the yield and general characteristics of the crop they grow due to changes in rainfall and temperature, therefore affecting local food supply as well as the nation in general. This situation also affects the income of the farmers as well as the economy of the state and the country at large (Anagement et al. 2015). Good performance of the implementing agencies, high adoption rates, lack of access to credit and markets has been identified as characteristics of Bauchi state in terms of sesame production (Gizaki et al. 2014).

Collaborative effort between Olam International Limited which is a global integrated supply chain manager, processor and trader of soft commodity with main headquarter in Singapore, and Bauchi State Agricultural Development Programme (BSADP) has helped boost sesame production in Bauchi state by about 300 percent. Collaborative relationship, which started in 2008, had raised the production per hectare in the state, from 264 kg/ha in 2008, to 850 kg/ha in 2016. (SundiataPost, 2017).

Table 2: Crop production estimates of sesame in Bauchi state

Local Government Area (LGA)	Area cultivated (Ha)	Production weight (Mt)	Yield/Ha/Tones
Alkaleri	11,169.97	6,901.53	0.62
Bauchi	-	-	-
Bogoro	-	-	-
Dambam	4,397.87	2,770.22	0.63
Darazo	7,233.39	3,297.25	0.46
Dass	314.53	164.18	0.52
Ganjuwa	11,734.81	3,753.90	0.32
Gamawa	11,651.43	3,690.52	0.32
Giade	5,141.84	3,110.96	0.61
Itas Gadau	11,449.67	4,723.14	0.41
Jama'are	282.87	66.89	0.24
Katagum	4,676.20	1,536.07	0.33
Kirfi	975.29	386.25	0.40
Misau	9,436.40	4,714.70	0.50
Ningi	38,363.07	18,427.54	0.48
Shira	8,572.50	2,500.35	0.29
Tafawa Balewa	231.06	1,492.97	0.70
Toro	20,955.91	25,725.25	1.23
Warji	7,256.23	2,850.80	0.39
Zaki	5,421.94	2,429.43	0.68
Total	**159,264.98**	**88,541.95**	**9.13**

1.2.1.3. Sesame trade

Japan is the world's largest sesame importer. Sesame oil, particularly from roasted seed, is an important component of Japanese cooking and traditionally the principal use of the seed. China is the second-largest importer of sesame, mostly oil-grade. China exports lower-priced food-grade sesame seeds, particularly to southeast Asia. Other major importers are the United States, Canada, the Netherlands, Turkey, and France. Sesame is an important crop to Nigerian agriculture, it is quite extensively cultivated, it yields in relatively poor climatic conditions, and widely used within Nigeria and is an important component of Nigeria's agricultural exports. As a small holder crop, often intercropped with others, the extent of cultivation is poorly known and there is little information on yields or productivity (W.C.B. 1895).

1.3. Postharvest handling practices of sesame

Almost all the post-harvest handling practices of sesame in Nigeria are manual and quite labour intensive. A better post-harvest system ensures that the product harvested reaches the final customer in the shortest possible time interval without concession of the volume, quality, and safety of the product (Gardas et al. 2018). Basavaraja et al. (2007) reported that postharvest handling practices involves a series of operations like; harvesting, transportation, drying, threshing, winnowing, packaging and storage and of course there is appreciable loses in each of the stages depending on how its handled. As Inappropriate postharvest handling practices cloud be classified drying surfaces, poor threshing and winnowing methods, use of inappropriate storage facilities and storage (Tibagonzeka et al. 2018). Due to lack of knowledge and skills by the farmers in developing countries like Nigeria, still postharvest handling practices is still inappropriate which is leading to postharvest losses (Olayemi et al. 2011). Muhammad et al. (2012) reported that variations of postharvest handling practices may even lead to a postharvest loss.

1.3.1. Harvesting

The optimum harvesting period is of great importance in sesame, since harvesting even a few days earlier or later can cause large yield reductions. The sesame crop should be harvested when the leaves turn yellow and start drooping while the capsules are still greenish. Time of harvesting sesame is when about 50% the plant turns yellow from green in colour (Tunde-Akintunde et al. 2012). At maturity, leaves and stems tend to change from green to yellowish and then reddish. If the harvesting is delayed and the crop can completely dry, there is loss in yield due to bursting and shattering of capsules. Capsules ripen irregularly from the low stem upwards, the topmost often being only half matured at harvesting. The drying period before harvesting allows the seed to ripen without loss from mature capsules. The plants are cut with sickles or uprooted. The harvested plants are carried to the threshing yard and stacked for a week. During this period, the capsules burst open and leaves are shed almost completely. Then plants are dried in the open sun and threshed by gentle beating of plants with sticks. Threshing can also be done by simply turning the plant upside down and shaking or beating lightly. The seeds are cleaned with the help of a special type of sieve designed for this purpose. Later, seed is cleaned by winnowing.

The yield of sesame depends on the season and method of cultivation as well as the variety and up to few hundred to 3000 kg/ha in different countries is obtainable. For example, in India, an irrigated field give higher yield than rainy season according to season. A well-managed crop can yield 500–600 kg/ha under rain-fed condition and 900–1000 kg/ha under irrigated condition. And according to the season, 375–500 kg/ha during winter and 500–750 kg/ha during summer may be expected. (Kader 1992).

1.3.2. Transportation

Transportation in sesame production involved the movement of farm produce from the farmland after harvesting to a drying place. Sesame crops are usually transported away from the farmland for security purpose specifically to avoid theft or to ease further handling practices such as threshing, packaging and storage. Transportation of harvested sesame is accomplished through human labour, the use of hand pulls cart, animals' cart, and vehicles. Sesame is generally transported in bags after postharvest handling practices to market or store. Among the limiting factors in transportation of sesame that lead to both qualitative and quantitative losses are inadequate and inefficient transportation system.

1.3.3. Drying

Sesame crop plant after harvesting are tied in bundles and kept upright (staking) to avoid release of seeds during drying. The main method of crops drying is sun drying on bare soil ground and the use of some low-cost materials such as mats, tarpaulins, and racks made from local materials. However, there is limited adoption of using such local materials for drying by the farmers because of lack of incentives which in turn affect the quality and marketability of their produce. Also the farmers are experiencing difficulties in drying crops during rainy seasons (Tibagonzeka et al. 2018). Sesame seeds are cleaned and dried in the sun to bring down the moisture content to 5% before storage to prevent attack from storage fungi and insect pests (Hegde 2012). Also harvesting sesame below 6% is critical as any moisture above that is problematic (Langham 2017). According to Imoudu and Olufayo (2000) for better result of sun-drying of grains by small farmers in developing countries, the grains should be kept under sunny condition to lower the moisture content.

1.3.4. Threshing and Winnowing

After drying, the sesame is threshed manually by gently biting the bunch of sesame with sticks on spreading materials such mats to enable the release of seeds. The seeds are usually cleaned and hulled through winnowing which is also done manually. Winnowing becomes necessary for better quality by consumers and sell for a higher price.

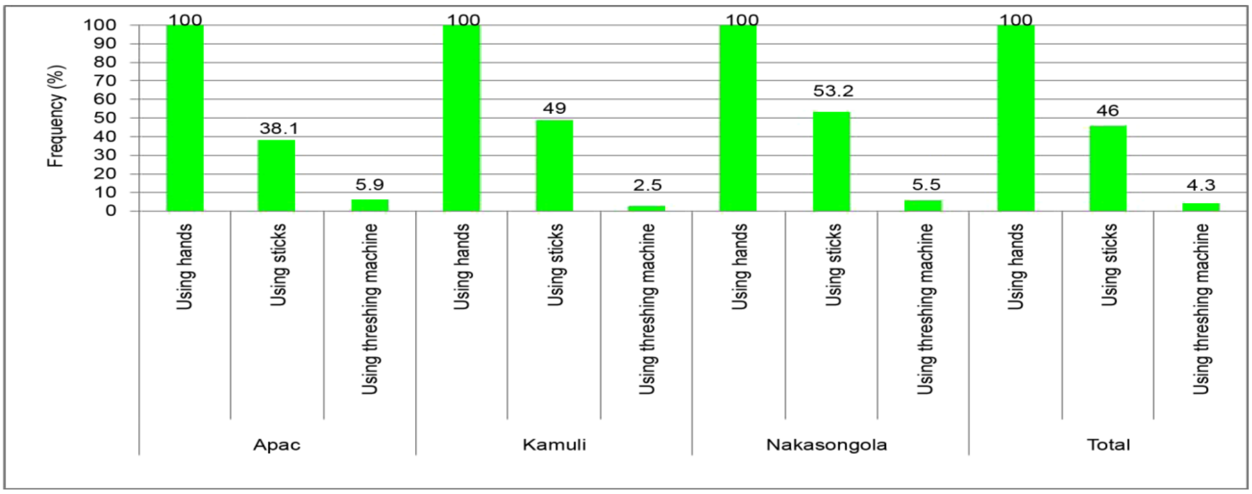

Fig. 1: Methods used in Threshing crops.
Source: (Tibagonzeka et al. 2018).

1.3.5. Packaging

A physical protection against contamination, damage or handling losses during transportation of Sesame seed could be achieved through packaging. It plays an important role in marketing of produce. In Nigeria, a unique material used in packaging sesame after threshing is nylon bag (sack). The farmers themselves filled the bags and sealed it to ease transporting it to market or store. The capacity of the bag (sack) is 85 kg. The plastic bag (sacks) is more suitable than other packaging materials like metal and earthen bins in terms of regulating temperatures and maintaining viability of stored grains (Chattha et al. 2012). Polyphenylene bags such as the sacks are traditionally used as packaging materials for storing grains in Ethiopia although has a limitations like grains weight loss during storage, decrease germinability and more susceptibility to insects (Kalsa et al. 2019).

1.3.6. Processing

Presently, the seeds are mainly consumed as snacks in Nigeria, but they are increasingly being processed for vegetable oil and livestock feed. Drying is one of the operations employed in the post-harvest processing of sesame seed. The design of effective drying and storage systems for the seed requires a knowledge of its energy requirements and the state and mode of moisture sorption within it (Aviara 2002).

For a better performance of feeding broiler chicks, cooking and dehulling methods of processing sesame seeds is recommended. And processed sesame seed serve as a very good source of plant protein for livestock feed (Onainor et al. 2018).

Sesame seeds are mostly used without removing the cuticle or the seed coat. This is especially the case in areas where sesame is processed for its oil. The cuticle contributes to the colour, bitterness and fibre and oxalate contents of the resultant screw-pressed meal. Such meal is not useful as a source of protein for humans and other monogastric animals and can be used mostly as a cattle feed or manure. Therefore, sesame seed is dehulled in order to improve its quality and utilization as a source of human food. Some of the important operations involved in processing sesame seed are described below very briefly (Hegde 2012).

The cake is the by-product obtained after the extraction of oil. When it is powdered, the cake is converted into the meal and such process will not change its the chemical composition. Four types of meals can be obtained from sesame seeds, namely whole seed meal, dehulled seed meal, defatted whole seed meal and dehulled–defatted meal. Of these, the dehulled–defatted meal is the most common. The meals or flours obtained from dehulled seeds contain more proteins, phosphorus and less ash, crude fibre, calcium and oxalic acid than those obtained from whole seeds. (Hegde 2012). Sesame seeds are protected by a capsule which only bursts when the seeds are completely ripe. This is called dehiscence. The dehiscence time tends to vary, so farmers cut plants by hand and place them together in an upright position to continue ripening until all the capsules have opened. Since sesame is a small, flat seed, it is difficult to dry it after harvest because the small seed makes movement of air around the seed difficult. Therefore, the seeds need to be harvested as dry as possible and stored at 6% moisture or less. If the seed is too moist, it can quickly heat up and become rancid (Langham 2017). Processing sesame seed in different product and blended with concentrated fruits should be carried out in order to utilize it as functional food for human nutrition (Zebib et al. 2015). A 1212–1241 kgm^{-3} has been found as a real density of a sesame seed which indicates that its heavier than water and this could be used in order to design cleaning process for seeds as the lighter ones would be floated (Akintunde & Akintunde 2004).

1.3.7. Storage

Storage provides protection against any type of infestation and contamination such as adverse weather conditions, moisture, insect pests, micro-organisms, rodents (rats), birds and in turn protects the quality and stabilized market prices. Seed that heats or is contaminated by extraneous material produces discoloured or rancid oil. Sesame seed can be stored more economically than many other oilseeds because of its small size (Hegde 2012). Farmers the opportunity to increase their market prices of processed products is being deprived by manual processing and during storage that cause losses which is worsening poverty (Abass et al. 2014).

1.4. Postharvest losses

The postharvest loss of grains refers to the waste of labour, water, cultivated land and chemical fertilizer in the process of grain production in. Because in most developing countries like China, agricultural production mostly depends on manual operation (Postler et al. 2017). International attention ebbed away, as the real commodity prices resumed their historical downward trend and the economic gains from preventing postharvest loss decreased (Kaminski et al. 2014). The harvest time is little, labour is few, mature grain cannot do the particle positions; spike off the field, not only meet the eye everywhere. In addition, the farmers are lack of drying equipment for the post-harvest grain which encountered constant rain and therefore mildew and buds occurred frequently (Postler et al. 2017). High postharvest losses in developing countries opposes the efforts geared for improving food security. The need to address post-harvest value chain constraints leading to food losses has increased significantly to provide adequate nutrition to the growing population. Therefore, the measures for loss reduction must be taken at all stages to have maximum effect as in most cases the origin of the spoilage cause is in a preceding stage. Monitoring of food losses and continuous reporting are vital to track progress and evaluate the impact of the interventions (Parmar at al. 2017). Gardas et al. (2018) observed that the losses were considerable at the immediate post-harvesting stage in the developing countries and these losses were quite significant for the perishable foods. The current study revealed that in the North-west part of Ethiopia the post-harvest loss of sesame exceeds up to 12% (Haruna & Abimiku 2012). A farmers and stakeholders should be involved in the investment in development and disseminating simple and cheap technologies for drying, threshing and storage in order to reduce the costs incurred. (Chegere 2018). To achieve effective reduction of food losses, several actors should be collaborated. Food donations in attempt to reduce food losses and could also be beneficial socially and ecologically (Beretta et al. 2013). According to Abimbola (2014) Priority should be given the postharvest losses in order achieving food self-sufficiency even though it has not been recognized as one of the major factors responsible for food insecurity in Nigeria.

1.4.1. Postharvest losses and food security

Food loss refers to food deliberately produced for human consumption but that was lost at any stage along the food supply chain (Redlingshöfer et al.S 2017). "The Global Food Loss and Waste Protocol (FLW Protocol) was developed as a global standard for reporting on the amounts and destinations for food losses and waste. The World Resources Institute (WRI) FLW reporting protocol (WRI, 2016a) contains an appendix on data collection methods but allows each user to select their own data collection methods and develop their own protocols, with examples provided in a lengthy appendix (http://flwprotocol.org/flw-standard/tools-resources/)". The reporting protocol itself is focused mainly on the destination of quantitative losses (the reported weight of discarded foods) and does not capture qualitative or economic losses due to weight loss if food is eaten or sold (Kitinoja et al. 2018).

High postharvest losses in developing countries negates the efforts destined for improving food security. Therefore, postharvest handling and processing provide alternatives to reduce postharvest losses and improve food safety and security (Tibagonzeka et al. 2018). Identification of value chain restrictions in connection with the specific food losses is a key to developing better mitigation strategies for food security in developing countries (Parmar et al. 2017).

To achieve food availability increase, the losses occurring during production and harvest as well as postharvest levels is the best solution, and it has been a matter of consideration to researchers and government agencies (Jha et al. 2015). The loss reduction measures must be taken at all stages simultaneously to have maximum effect as in most cases the origin of the spoilage cause is in a preceding stage. However, more effort should be complemented with effective government policy at institutional and regulatory levels. The involvement of all the value chain actors such as consumers, policy makers, and development organizations is crucial in developing a sustainable food systems with negligible losses (Kaminski et al. 2017).

The 2007–2008 global food crisis has renewed interest in postharvest loss, but in Sub-Saharan Africa estimates remain scarce. (Paper et al., 2014). Procedures for increasing food security by reducing postharvest losses and waste include use of varieties with longer postharvest life, use of an integrated crop management (ICM) system that boost yield and quality, and use of proper harvesting and postharvest handling procedures to maintain quality and safety of crops products (Kader 1992). Harvesting and threshing practices should be standardized and employing the use of machines to reduce the loss (Jha et al. 2015). The farmers particularly smallholder households should be educated on improved postharvest storage technologies and also employ appropriate policies that can reduce market obstacles other market risks in order to reduce loss (Abass et al. 2014). Sensitization programs to the farmers on postharvest handling practices would serve as a good measure in reducing the postharvest losses in food grains (Basavaraja et al. 2007). To ensure increase in food availability and national food security through the reduction in post-harvest losses, farmers welfare is the key (Abimbola 2014).

1.4.2. Factors responsible for postharvest losses in sesame production

The weather conditions during the harvest and harvest time, harvest maturity degree of pest, field transportation, threshing and cleaning mode and other factors have potential impact on the extent of the loss (Postler et al. 2017). The major problem with grains such as the sesame was found to be insect damage (Tibagonzeka et al. 2018).
The influence of different factors on grain harvesting losses, can more clearly understand that the different harvest time, mode of transportation, threshing way on grain harvesting losses caused by the smaller, better small harvesting loss (Postler et al. 2017). Un-uniform maturity is also contributing the losses in sesame production. The capsules in the secondary branches usually mature later than the primary branches and the poorly filled seeds have lesser weight and they are lost while winnowing. One of the major factors for such low national productivity is the use of unimproved cultivars. Like other crops, productivity and associated increase in production of sesame could be achieved through development of improved varieties which have less shattering problem and by using better cultural practices. Selection is an integral part of breeding program by which genotypes with high productivity in a given environment are selected. However, selection for high yield is made difficult in Sesame production (Menzir 2012).

Postharvest loss and quality of crops usually occurred because of the use of inappropriate harvesting equipment, improper care, and inadequate motivation and interest to improve the harvesting and handling techniques periodically (Kasso & Bekele 2018). Low agricultural productivity and high postharvest losses among smallholder farmers occur due to climate variability (Abass et al. 2014).

1.4.3. Estimate of postharvest losses

Estimates of harvest and post-harvest losses of crops products provide the relevant information about the losses in different postharvest operations and even market channels. It helps in identifying the operations and channels where losses are occurring and at the levels that is higher. It also helps in adopting strategies to reduce the losses (Kitinoja et al. 2018).

Increasing agricultural production is one aspect of fulfilling food demand. Delivering food to the consumers by saving produced commodities from losses in fields, transport, storage, retailing, processing etc. without straining our fields, water and environment seems much better option. After production, agricultural produce undergoes series of post-harvest unit operations, handling stages and storage before they reach to the consumers. Each operation and handling stage results into some losses. These post-harvest losses result into decrease in food availability. A recent study showed that 4.7-6.0% cereals, 6.4-8.4% pulses, 3.1-10% oilseeds, 6.7-16% fruits, and 5-12 % vegetables are lost during harvest, post-harvest operations, handling and storage in India (Jha et al. 2015).

A huge quantity of agricultural production is reduced from the food chain. A grain saved is considered as a grain produced. Therefore, it becomes inevitable to identify the operations and channels where losses are considerable. Improvement in technology in future for these operations and channels will lead towards more availability of produce. The farmer can save his valuable produce and get more prices in the market. The reduction in losses in different channels will help in providing the quality produce for the consumers and hence all stakeholders including farmers, marketing persons and consumers will be benefited. Reduction in post-harvest losses will also be helpful in ensuring food security of the country. Consistent and contemporary data on extent of post-harvest losses of different crops and livestock produce at all India level were collected in year 2005-07 by All India Coordinated Research Project on Post-Harvest Technology on the recommendations of Parliamentary Standing Committee on Agriculture (PSCA). This report provided trustworthy estimates of harvest and post-harvest losses of crops and commodities at national level for the first time. As the previous study provided foundation data on estimates of harvest and post-harvest losses, with passage of about 5-6 years it was not sure whether the losses are increasing or decreasing after technological interventions. Recently it was also felt that the channels in harvest and post-harvest operations in which substantial losses are taking place need to be identified for further technological interventions (Jha et al. 2015).

2. Objectives of the thesis

The broad objective of the study is the assessment of postharvest losses of sesame in the rural areas of Nigeria, while the specific objectives were to:

- Identify the various postharvest handling practices of sesame in the study area.
- Identify the various forms of postharvest losses of sesame in the study area.
- Identify the perceived factors responsible for postharvest sesame loss in the study area.
- To analyses the factors affecting the postharvest losses of sesame in the study area.

3. Materials and Methods

3.1. Study area

Bauchi state is located between latitudes 9° 3' and 12° 3' North and longitudes 8° 50' and 11° East. It has a total land area of 49,119 km² representing about 5.3% of Nigeria's total land mass. The total cultivable land is 4,283,700 ha and average cultivated land of 15,798.33 ha.

Bauchi state has two distinctive vegetation zones, namely, the Sudan savannah and the Sahel savannah. The Sudan savannah type of vegetation covers the southern part of the state. Here, the vegetation gets richer and richer towards the south, especially along water sources or rivers, but generally the vegetation is less uniform, and grasses are shorter than what grows even farther south, that is, in the forest zone of the middle belt.

The Sahel type of savannah, also known as semi-desert vegetation, becomes manifest from the middle of the state as one moves from the state's south to its north. This type of vegetation comprises isolated stands of thorny shrubs.

On the other hand, the southwestern part of the state is mountainous because of the continuation of the Jos Plateau while the northern part is generally sandy.

3.1.1. Climatic conditions

The climate of the area is semi-arid. The soil is sandy loam with low fertility. Annual rainfall is 900 - 1200 mm. Average temperatures varied between 24.9˚C - 35˚C most of the year. The vegetation types as described above are conditioned by the climatic factors, which in turn determine the amount of rainfall received in the area. For instance, the rainfall in Bauchi state ranges between 1,300 millimetres (51 in) per annum in the south and only 700 millimetres (28 in) per annum in the extreme north. The average precipitation is 287mm in August. the average temperature ranges between 13°C - 37°C suitable for sesame production. (BSADP, 2017).

This pattern is because in the West Africa sub-region, rains generally come from the south as they are carried by the south westerlies. There is therefore a progressive dryness towards the north, culminating in the desert condition in the far north. So also, is the case in Bauchi state. Consequently, rains start earlier in the southern part of the state, where rain is heaviest and lasts longer. Here the rains start in April with the highest record amount of 1,300 millimeters (51 in) per annum. In contrast, the northern part of the state receives the rains late, usually around June or July, and records the highest amount of 700 millimeters (28 in) per annum. In the same vein, the weather experienced in the south and the north varies considerably. While it is humidly hot during the early part of the rainy season in the south, the hot, dry and dusty weather lingers up north. In addition to rainfall, Bauchi state is watered by several rivers. They include the Gongola and Jama'are rivers.

Table 3: The climatic conditions of Bauchi state.

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Record high ^{o}C	38.3	39.4	39.4	40.6	39.4	37.8	33.3	32.2	33.9	35.6	36.1	36.7	40.6
Average high ^{o}C	31.6	33.9	36.4	36.6	34.6	31.6	29.2	28.6	29.7	32.2	33.0	31.4	32.4
Daily mean ^{o}C	22.4	24.6	28.1	30.0	28.4	26.3	24.6	24.3	24.7	25.5	24.1	22.1	25.4
Average low ^{o}C	13.1	15.3	19.6	22.3	22.2	20.9	20.1	19.9	19.7	18.8	15.2	12.8	18.3
Record low ^{o}C	7.2	8.9	11.7	16.1	16.7	16.7	17.2	17.2	16.1	12.2	9.4	6.1	6.1
Average rainfall (mm)	0.5	0.5	0.5	36.0	94.0	147	254	340	183	36.0	1.0	0.0	1,095
Average relative humidity (%)	42	35	40	63	79	86	92	94	93	88	65	51	69
Meam daily sunshine hours	8.9	9.5	8.8	7.5	8.1	7.6	6.0	5.0	7.2	9.1	10.0	9.9	8.1

Source: Deutscher Wetterdienst 2018)

The average hourly wind speed in Bauchi is experience a significant seasonal variation over the course of the year and the predominant average hourly wind direction in Bauchi varies throughout the year. The wind is most often from the north for 4.3

months, from November 18th to March 27th, with a peak percentage of 69% on January 1st.

Fig. 2: Map of Nigeria showing Bauchi State among the 36 State of the Federation. Source: (Wikipedia 2014).

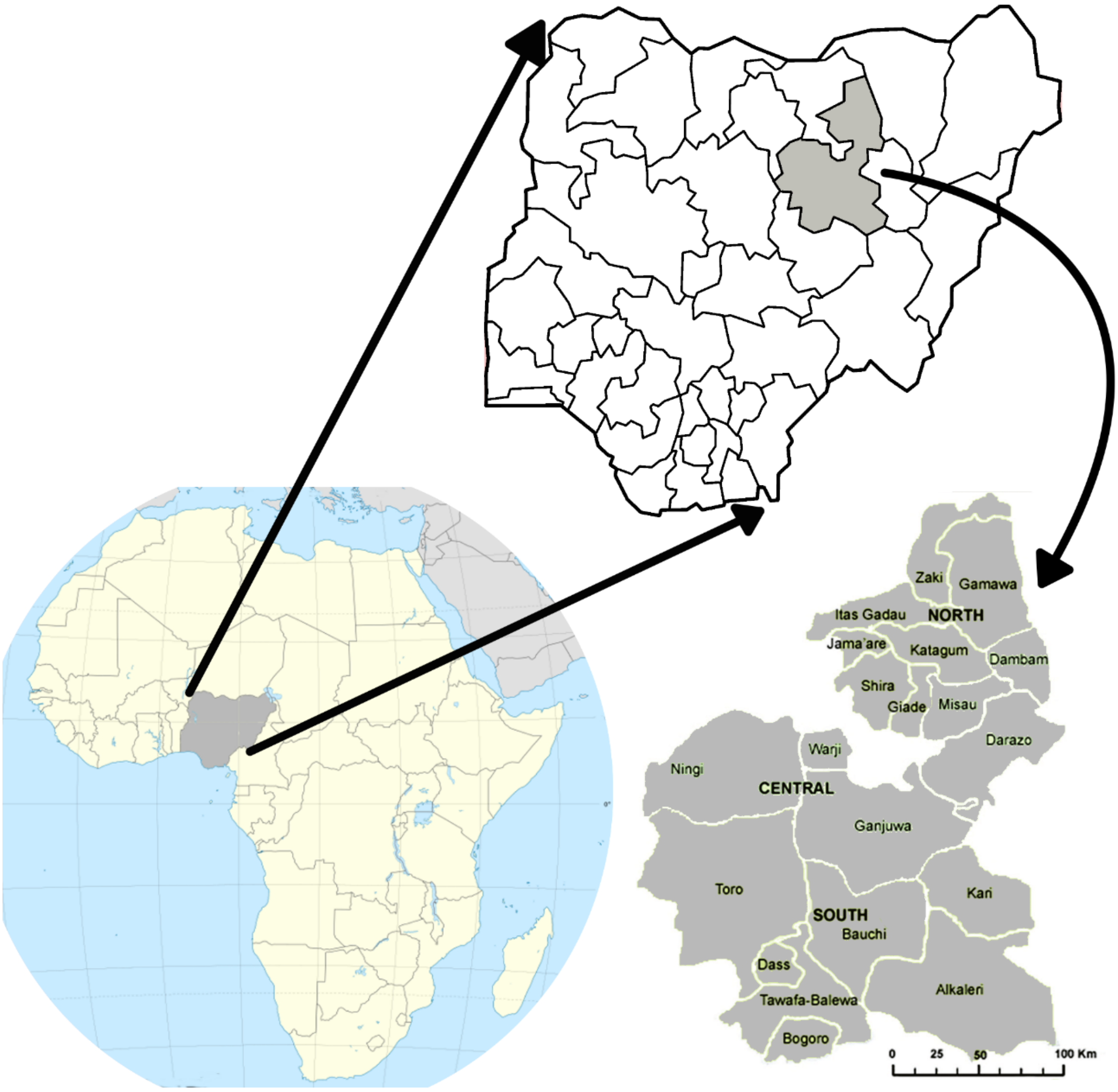

Fig. 3: Map showing the locations of the study area

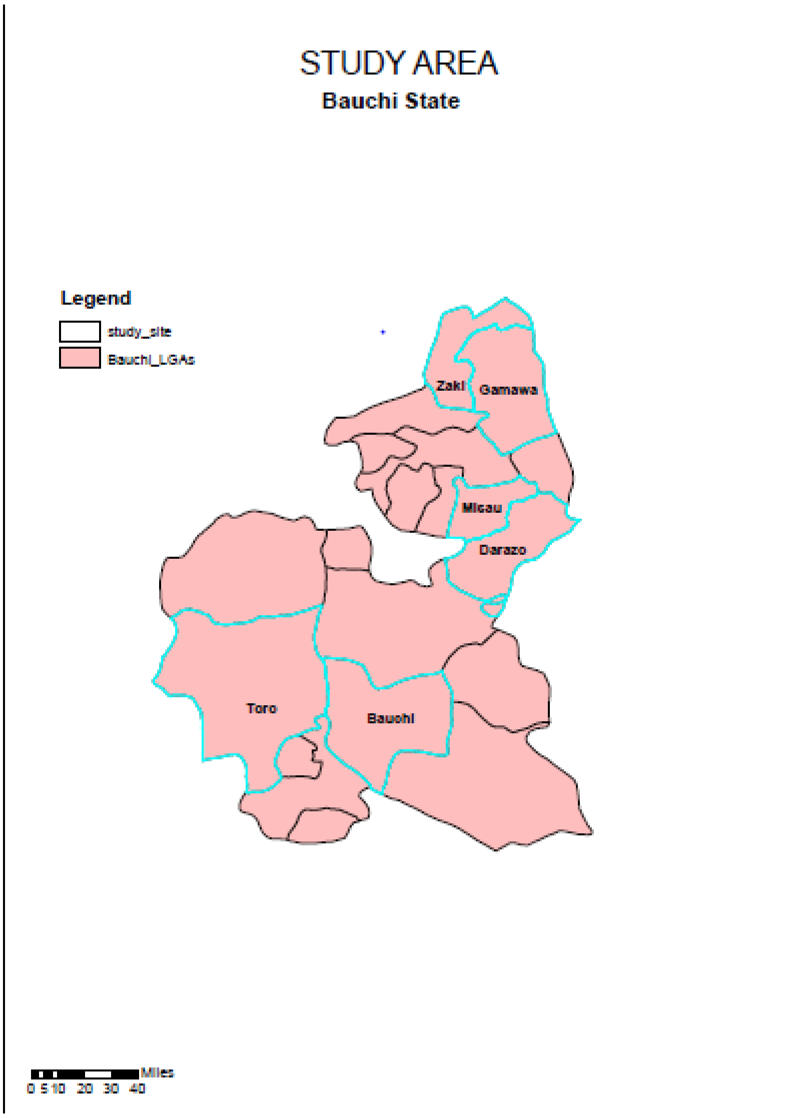

Fig. 4: Map showing the selected LGAs for the study.

3.2. Data collection:

The primary data were collected for the study by using structured questionnaire. The questionnaire consists of three sections; Section A, is the socioeconomic characteristics of the farmers, section B, the post-harvest handling practices of sesame and section C, which is the post-harvest losses. All the data were collected between between Jul-Sept. 2018. The data collected from the farmer respondents include; the general information about the cultivation of sesame more especially methods of postharvest handling practices such as methods of harvesting, transportation, drying, place of drying, threshing, winnowing, mode of packaging, storage and losses that occur during post-harvest operations as well as identifying the factors affecting postharvest handling in the study area.

Sampling and sampling procedure of the data collection is, Bauchi State has Twenty Local Government Areas (LGAs) and they are divided in to three main Agricultural zones: Northern, Central and the Western zones respectively. Gamawa and Zaki LGAs were selected from Northern zone, Misau and Darazo LGAs from Central zone and Bauchi and Toro LGAs from Western zone. The total number of registered sesame farmers in the study area is one thousand, two hundred and fifty-four (1,254).

Multi Stage Sampling Procedure was adopted for the ultimate selection of good sesame farmers in the study area: First stage, two LGAs were purposely selected from each agricultural zone to form six (6) selected LGAs. This was due to the concentration of sesame producers in the area. In second stage, a proportionate random sampling was employed due to select 10% out of the registered farmers in the selected LGAs, making of one hundred and twenty-four (124) farmers for the study.

A semi-structured questionnaire was used to distributed to the farmers and they were duly filled and returned to the researcher successfully. However, four (4) questionnaires were discarded due to abnormalities in their filling.

Table 4: Sampling frame and sampling size

Local Government Areas (LGAs)	Sample frame	Sample size
Bauchi	81	8
Darazo	214	21
Gamawa	291	29
Misau	263	26
Zaki	101	10
Toro	304	30
Total	**1,254**	**124**

Fig. 5: The picture of the researcher during data collection.

A field data collection was conducted during 2018 rainy season harvest period at Gamawa Local Government, Bauchi state. The sesame plants were harvested, dried, threshed, winnowed packed and finally measured. The measurements were done using measuring scale for taking actual yield of from the farmers field. A Mechanical Weighing Scale type, Model FTS-10, with measurement accuracy of 50 g was used.

Fig. 6: Mechanical weighing scale.

The measurement of the weight of one bag of sesame was taking to compare between the perception of farmers on the weight of sesame bag and the actual weight. BM Series Height and Weight series type of scale, Model ZT-120, with the range of measurement ranges minimum of 500 g to 120 kg was used.

Fig. 7: Caption of measurement of the weight of sesame bag during data collection in a study area.

3.3. Data analysis:

A combination of descriptive and inferential statistics was used for analysing the data with the aid of Statistical Package for the Social Sciences (SPSS 22).

The former in form of mean, mode, percentage and standard deviation were used to achieve objectives 1, 2 and 3, while regression analysis was used to achieve objective 4. For regression analysis is to analyse the factors affecting the postharvest losses of sesame in the study area. To control the effects of all the other independent variables, the regression coefficient of each independent variable provides an estimate of its influence on the dependent variable.

$y = a + b_1x_1 + b_2x_2 - - - b_nx_n + e$

Where y = dependent variable which is the estimate of postharvest losses in percentage

$x_1 – x_n$ = independent variables

as:

x_1 = Sex of the farmers (male=1,

x_2 = Age of the farmers

x_3 = Level of Education

x_4 = Household size

x_5 = Group Membership

x_6 = Farming Experience

x_7 = Farm Size

x_8 = Handling Practices

x_9 = Variety

b_1 - b_n = coefficients

a = constant term

e = error term

Table 5: Description of variables used in the MLR

Variable	Description	Min.	Max.	Mean	Std. Deviation
Estimate of Postharvest Losses (EPL)	Estimate of Postharvest Losses in percentage Scale	5	30	14.71	6.361
Sex (SEX)	Sex (Gender) of the sesame farmer, (1=Male, 2=Female) Nominal	1	2	1.07	0.250
Age (AGE)	Age of the sesame farmer, (<20yrs=1, 20-31=2, 30-40=3, 41-50=4, >50yrs=5). Nominal	1	5	3.29	0.999
Level of Education (LOE)	Farmer’s Level of Education, (No formal Education=1, Primary/Basic=2, Secondary=3, Tertiary=4). Nominal	1	4	3.38	0.989
Household size (HH)	Household size of the farmer, Scale	2	30	9.52	6.345
Membership of organization/ group (MOA)	Membership of organization/group, (Yes=1, No=2). Nominal	1	2	1.34	0.476
Farming experience (FE)	Farming experience, Scale	2	50	8.20	6.149
Farm size (FS)	Farm size, Scale	0.5	20.0	4.738	4.4187
Main factors responsible loss (FRL)	Main factors responsible loss, (Wind=1, Rainfall/Dew=2, Pest=3, Theft=4, Poor handling=5, Early harvesting=6, Late harvesting=7, Wind and others=8, Pest and others=9). Nominal	1	13	3.94	2.705
Variety of sesame (VAR)	Variety of sesame, (Kenana 4=1, Ex-Sudan=2, NCRIBEN=3, Others=4). Nominal	1	4	1.80	0.616

Source: Author, based on data analysis

4. Results and Discussion

This part of the thesis encompasses results and the discussion of the Post-harvest Handling Practices of Sesame (*Sesamum indicum* L.) in Rural Areas of Nigeria: A Case Study of Bauchi State, after subjecting the data collected from the study area to statistical analysis. The data collected from one hundred and twenty (120) sesame farmers in six (6) Local Government Areas of Bauchi State, Nigeria. And all the questionnaires were returned100% successfully. A combination of descriptive and inferential statistics was used for analysing the data with the aid of Statistical Package for the Social Sciences (SPSS 22).

4.1. Result of postharvest handling practices of sesame

Table 6 shows the various postharvest handling practices of sesame in the study area. For sesame plant harvesting stage it revealed that 70% of the respondent farmers harvest when plant is 100% yellowing than at 50% yellowing stage which is 30%. For drying place, the result shows that majority of the farmers 64.20% to transport their sesame to home after harvesting for drying and further postharvest handling practices. This might be the preventive measures against thieves. For length of maturity (days) which revealed that the sesame farmers started harvesting at minimum 85 days to the maximum of 115 days. But however, the result revealed that majority of the respondent farmers (about 85%) harvest their sesame at 90 to 100 days.

As shown by the result, almost 70% of the farmers are harvesting their sesame when 100% of the sesame leaves turns yellow, which is the indicator of the maturity, however 30% of the farmers still responded that they are harvesting when 50% of the sesame leave turns yellow and this may result in pre-mature harvesting. However, the minority are in line with the finding of Tunde-Akintunde, (2012) which indicated that the time of harvesting sesame is when about 50% the plant turns yellow from green in colour. Regards to the drying place, the result showed that most of the farmers transported their sesame plant to the home. In this situation also, the differences in the methods of transportation i.e. lack of standardized or efficient methods of transportation might be the reflection of poor handling practices. And lastly the length of maturity of sesame i.e. the days sesame takes before harvesting. The result revealed that the minimum days that sesame takes is 85 days and the maximum of 115 days, however farmers mentioned 7 different times (days) of harvesting their sesame. These variations in various operations might be due to the fact that the sesame farmers in the study are lacking the knowledge on the appropriate postharvest handling practices. And this is synonymous to the research finding of Olayemi et al. (2011) which indicated that, due to the lack of knowledge and skills by the farmers in developing countries like Nigeria, postharvest handling practices is still inappropriate. Also, the finding of Muhammad et al. (2012) showed a similarity as variations of postharvest handling practices may even lead to a postharvest loss.

Table 6: Postharvest handling Practices of sesame (n=120)

Variables	Frequency	Percentage
Harvesting stage		
50% Yellowing of sesame	36	30.00
100% Yellowing of sesame	84	70.00
Drying place		
Home	77	64.20
Farm	43	35.80
Length of maturity period (Days)		
85	2	1.70
90	49	40.80
95	9	7.50
100	45	37.50
105	6	5.00
110	7	5.80
115	2	1.70

4.1.1. Methods of transporting harvested sesame

Figure 8 showed the various methods of transporting sesame after harvest to the drying place. The result showed that, 48% of the farmers are using motor vehicle, 40% animal cart, motorcycle 9.33% and hand pull cart 1.33% as their means of transporting sesame. The result revealed that, majority of farmers use animal cart and vehicles (48% and 40% respectively) as their means of transporting sesame, followed using motorcycle 9.33%. This showed that farmers pay more attention on transporting sesame to home as only less than 2% of the farmers are using hand pull cart as a mean of transportation. However, research conducted by Abimbola (2014) on postharvest losses on tomato in Nigeria stressed that, improvement of linkage roads and Nigerian rail transportation system to help curb losses during transportation.

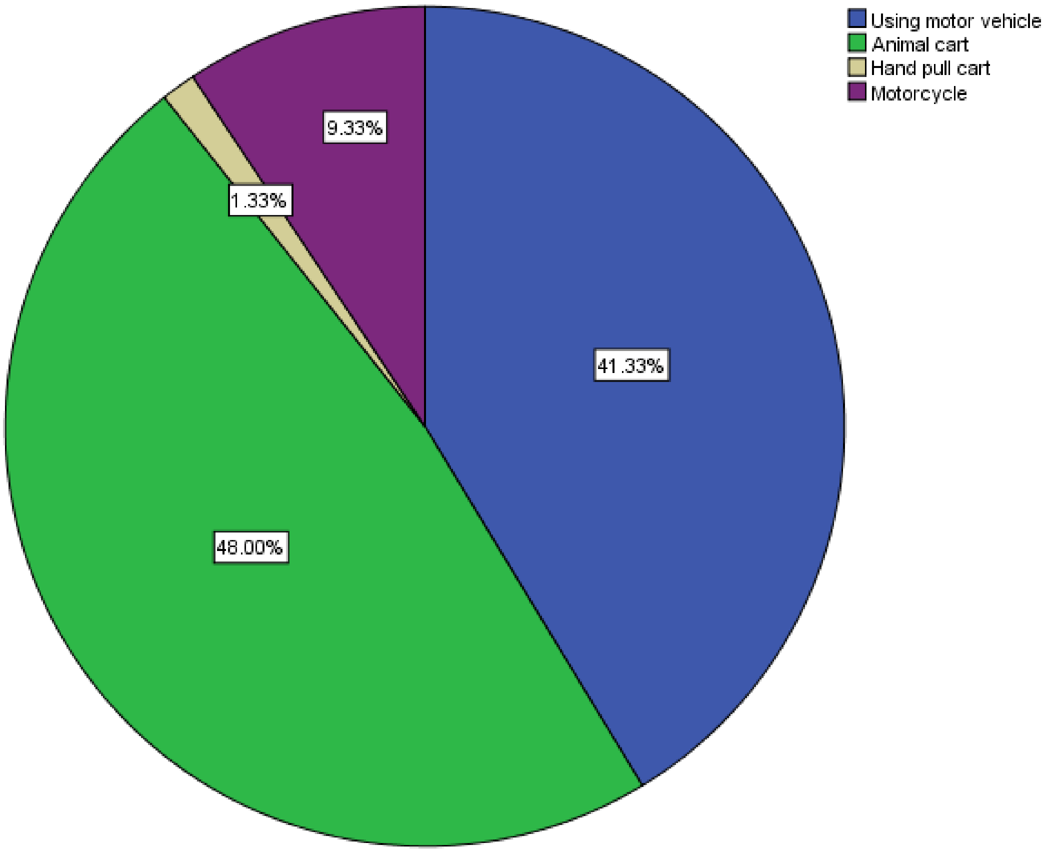

Fig. 8: Methods of transporting of harvested sesame

Fig. 9: A capture of methods of transporting harvested sesame (using hand carts) during the data collection in Gamawa LGA, Bauchi state.

Fig. 10: A capture of methods of transporting harvested sesame (using animal cart) during the data collection in Gamawa LGA, Bauchi state.

4.1.2. Perceived reasons for drying sesame seeds

Figure 11 showed the perceived reasons for drying sesame seed by the farmers. The result revealed that, 68% of sesame farmer dry their sesame to ease threshing operation, 30% to avoid damages or waste of the seeds while 0.8% of the farmers for high yield and for good oil content respectively. Based on the result the sesame farmers have their perceived reasons for drying sesame seed and most of them are drying in order to ease threshing. This might be due to the fact that sesame is grown during the rainy season in the study area and also are harvested prior to the end of the rainfall. This is found to be synonymous to the work of Tibagonzeka et al. (2018) which indicated that the farmers are experiencing difficulties in drying crops during rainy seasons (Tibagonzeka et al. 2018).

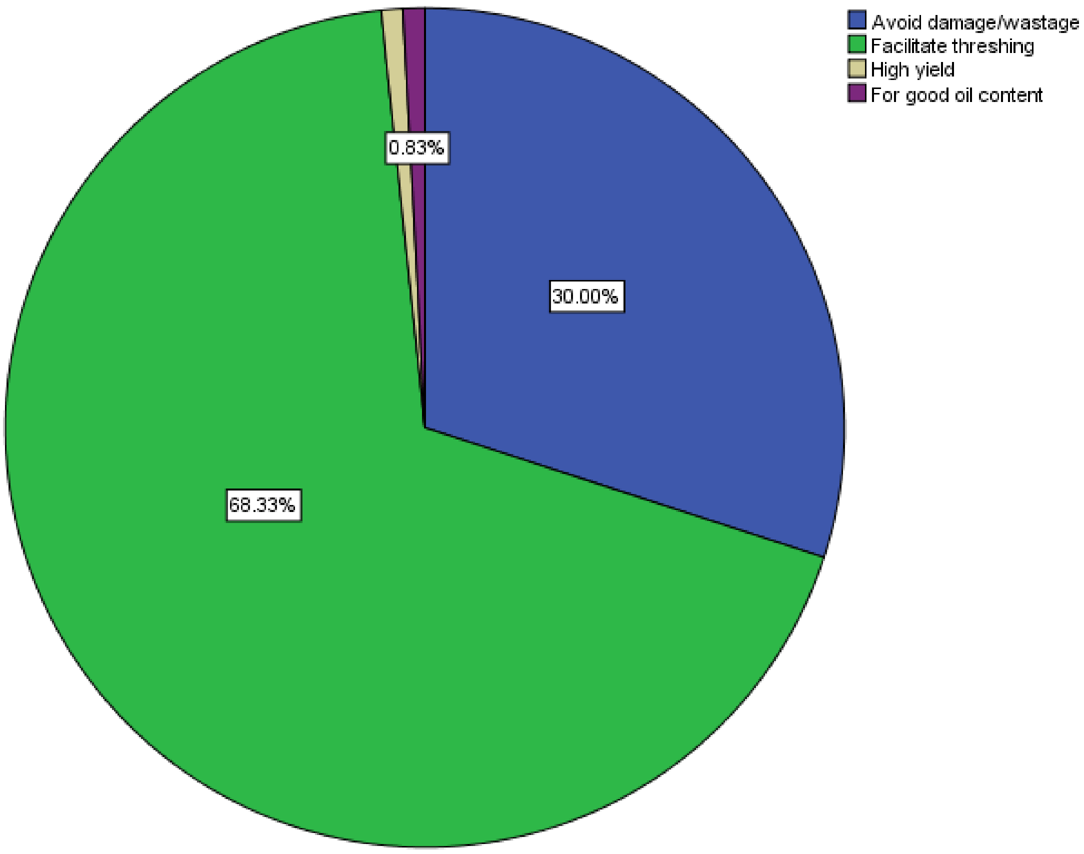

Fig. 11: Perceived reasons for drying sesame seed

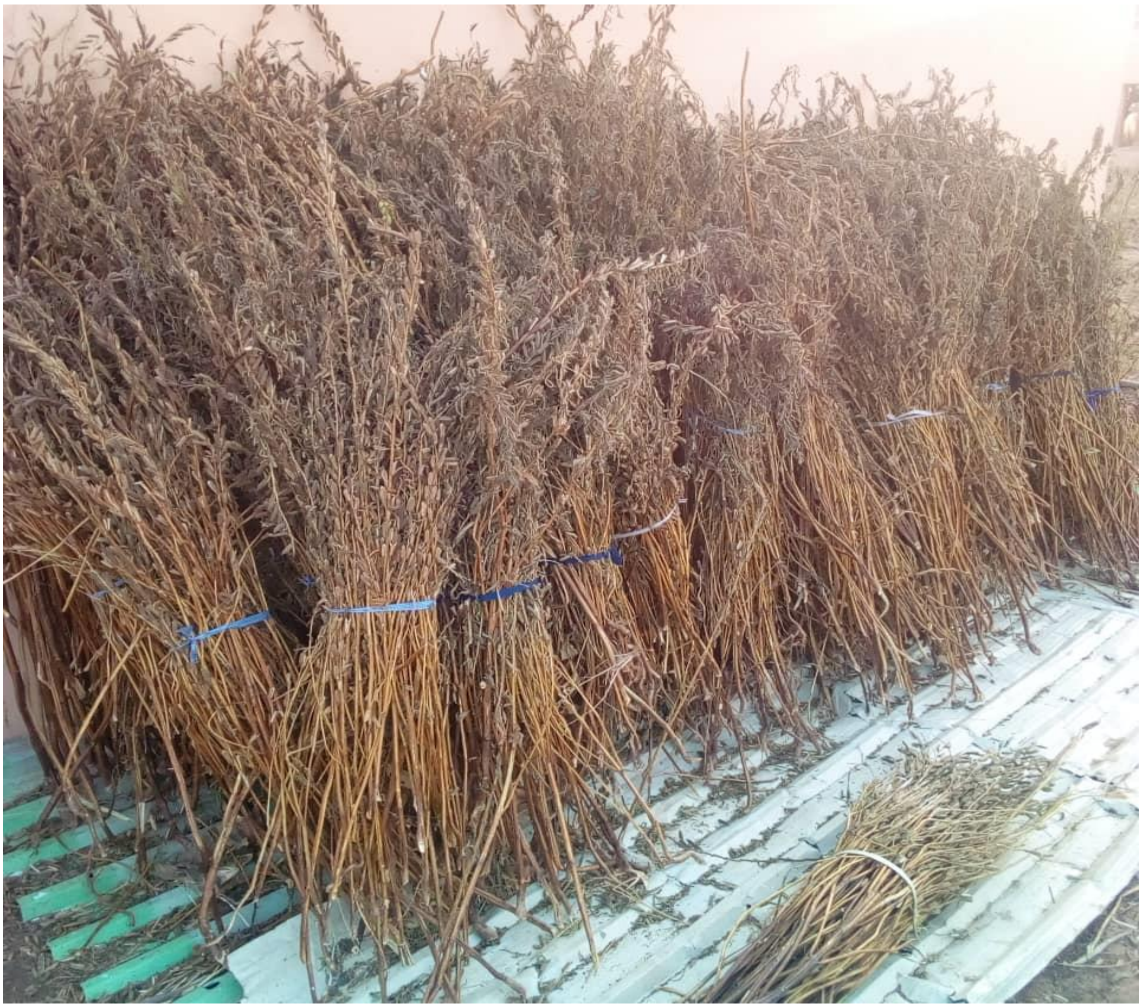

Fig. 12: A caption showing the method of drying of sesame in the study area

Fig. 13: A caption showing manual method of threshing of sesame in the study area

Fig. 14: A caption showing manual method of winnowing of sesame in the study area

The results revealed that the postharvest handling practices of sesame available in the study area were drying, transportation, threshing and winnowing, packaging and storage. This result is corroborated to the work of Basavaraja et al. (2007) which found that postharvest handling practices are harvesting, transportation, drying, threshing, winnowing, packaging and storage.

It has been found that, apart from transportation operation, all other postharvest handling practices are manual. This result is in line with the finding of Gardas et al. (2018) which indicated that almost all the post-harvest handling practices of sesame in Nigeria were manual and laborious.

4.2. Perceived postharvest handling practices responsible for loss

Table 7 revealed the Perceived Postharvest Handling Practices responsible for loss. The frequency in the table above indicates the number of farmers responded for each postharvest handling practices responsible for loss. Majority (85%) perceived that drying the major means of postharvest loss of sesame in the study area. This might be since the study area is windy during the harvest of sesame. Meaning that, there is prevalence of strong wind in the area which blows the seed since the sesame seed if small and very light. That was why the respondents perceived it to be major sources of the loss. Sun-drying is continuing to be practice in developing counties as discovered by Imoudu and Olufayo (2000). They further stressed by saying for better result of sun-drying of grains by small farmers in developing countries, the grains should be kept under sunny condition to lower the moisture content. According to Langham (2017) revealed that sesame will dry in 8 – 10 days after harvest depending on the level of maturity and other related factors. Sesame seeds are cleaned and dried in the sun to bring down the moisture content to 5 % before storage (Hegde 2012). Drying to lower the moisture content of the sesame to 6 percent or even less is necessary because, the seed is difficult to aerate in a storage (Hansen 2011). The study further revealed that the farmers perceived the other sources of lost to be minimal in its effect such as threshing (4.2%), winnowing (2.5%), transportation (1.7%), packaging (5%) and storage (0.8%). The average perceived lost was 1.7 and the standard deviation was 1.3 that showed there was little variation between their perception regarding lost due to the postharvest handling practices. This also is in line with the finding of Kossa and Bekele (2018) which revealed that, Postharvest loss and quality of crops usually occurred as a result of use of inappropriate harvesting equipment, improper care, and inadequate motivation and interest to improve the harvesting and handling techniques periodically.

Table 7: Perceived Postharvest Handling Practices responsible for loss (n=120)

Postharvest Handling Practice	Frequency	Percentage
Drying	102	85
Threshing	5	4.2
Winnowing	3	2.5
Transportation	2	1.7
Packaging	6	5
Storage	1	0.8

4.3. Perceived factors responsible for postharvest loss in sesame

Table 8 shows that the factors that were responsible for a postharvest lost were wind (27.5%), pest (20%), poor handling (13.3%), Rainfall (8.39%), pest and others (7.5%), Wind and others (5.8%) and early harvest (4.2%). The average lost was 3.84% per harvest, with standard deviation 2.6 which shows high variation within the variables. However, the factors mentioned as pest and others and wind and others means that the farmers mentioned more than one factors. For pest and others, the farmer mentioned pest as a main factor and added with other factors and the same applied to wind and others. The result corroborated with the research finding of Poster et al. (2017) which indicated that, the weather conditions during the harvest and harvest time, harvest maturity degree of pest, field transportation, threshing and cleaning mode and other factors have potential to increase the loss.

Table 8: Factors Responsible for Postharvest Lost (n=120)

Factors	Frequency	Percentage
Wind	33	27.5
Rainfall	10	8.3
Pest	24	20
Theft	6	5.0
Poor handling	16	13.3
Early Harvesting	5	4.2
Wind and Others	7	5.8
Pest and others	9	7.5

4.4. Perceived ways for reducing loss in sesame

Figure 16 showed the ways of reducing loss in sesame. The result revealed that 44.17% responded that postharvest losses of sesame can be reduce by careful handling. This agrees with the work of Tibagonzeka et al. (2018) which stated that proper postharvest handling and processing provide alternatives to reduce postharvest losses and improve food safety and security. Other measures include 15.83% use of pesticide, 7.5% each of determining threshing time and provision of security, 5.83% split harvesting, 5% drying on spreading material, 4.17% use of mechanical harvest, 1.67% use of groundnut cake to control pest, 0.83% cleaning and fumigation of stores. The result also coincided with the work of Jha et al. (2015) which stated that, harvesting and threshing practices should be standardized and employing the use of machines to reduce the loss.

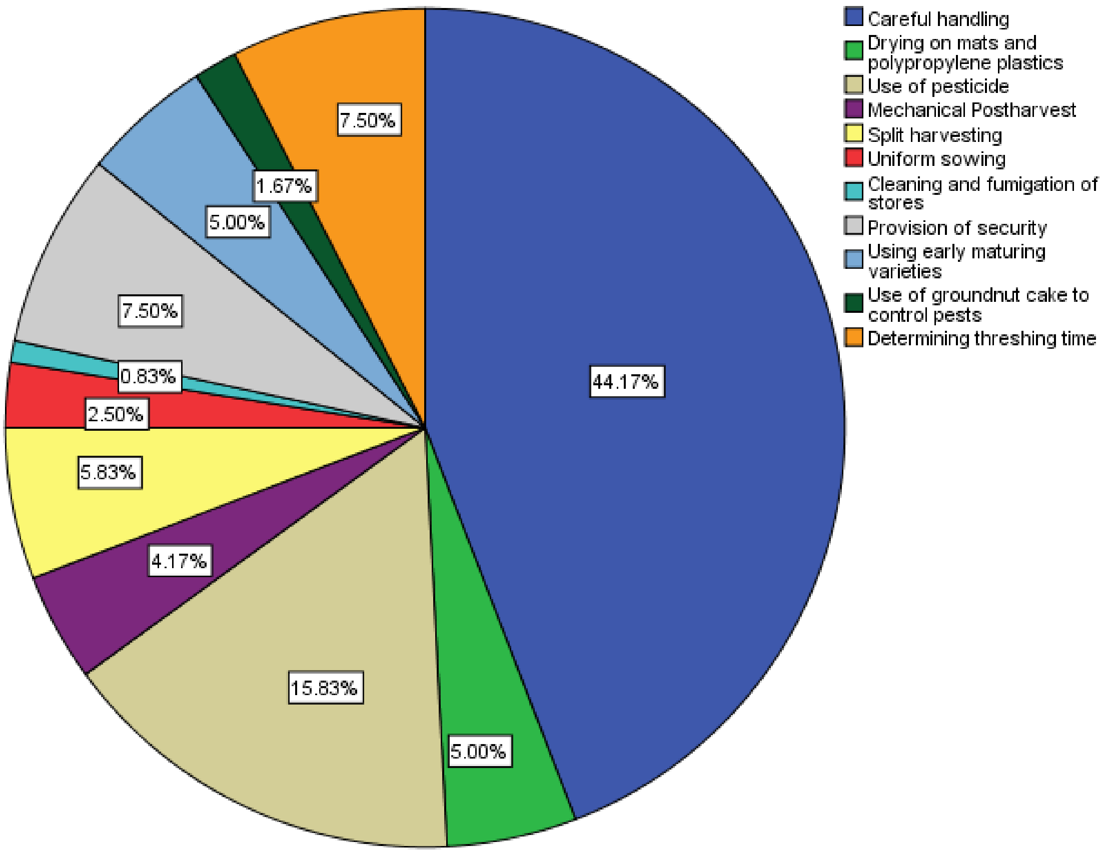

Fig. 15: Way of reducing the loss

4.5. Factors affecting postharvest lost.

Table 9, multiple regression was used to determine the factors affecting postharvest lost. The result revealed that F-statistic was 0.0194 ($p \leq 0.01$) this showed that the model was reliable. Deterministic coefficient (R^2) was found to be 29.7%, this showed that 30% of the variation of lost was due to the explanatory variables involved in the model.

Household size, handling practices and variety were found to be positively significant and age was negative but significant.

Age was negative but significant ($p < 0.05$). Its regression coefficient was found to be -1.76, this showed that when Age increases by one-year Sesame lost will reduce by 1.76 kg. This might be since older farmers had more experience in handling practices however, educating farmers especially by extension workers could help in maintaining the balance between the youth and elder farmers. This is in line with the finding of Qi et al. (2018) which stressed that, the yield of a crop is affected by the type of farmers and their handling practices

Household size was found to be positively significant ($p<0.05$). This implies that as the household size increases, the sesame lost will also increase. Its coefficient was found to be 0.26, this implies that as household size increases by one-person Sesame lost will increase by 0.26 kg. This is possibly since, people with large household size had bigger farms and therefore, sesame lost tend to be higher. A correlation test was conducted between the household size and the farm size and found to be highly significant at the ($p<0.01$) level. The detail is shown in Table 11 below.

In line with this result, Abimbola (2014) suggested that, farmers should be educated on the dividends of small household size especially regards to their income (per-capita) and welfare of the household, for self-sufficiency and sustainability.

Some Handling practices was found to be significantly different, Rainfall/dew was found to be positively significant at $p< 0.05$. This showed that Rainfall/dew was higher and as it increases, the postharvest lost increases. This agreed with the finding of Abass et al. (2014) which said that, low agricultural productivity and high postharvest losses among smallholder farmers occur due to climate variability (Abass et al. 2014).

Theft was found to be positively significantly different with wind at $p< 0.05$, this showed that increase in theft activities will lead to the increase in postharvest losses of sesame in the study area. According to the farmers perceptions, wind is more responsible for the postharvest loss of sesame but after analysis the result showed that, the theft was found significantly different with wind. This is also a clear reason why sesame farmers are transporting their sesame to more secure place reparably at home.

The postharvest lost was also different across the varieties found in the study area, Ex-Sudan, NCRIBEN were found to be significantly different with Kenana 4 t $p< 0.05$ which the others were not different the Kenana 4 in terms of postharvest lost.

Table 9: Factors Affecting Postharvest loss of Sesame (n=120)

Variable	Coef.	Std. Err.	T	P>|t|
Sex	-2.065113	2.561447	-0.81	0.422
Age	-1.762143	0.821725	-2.14	0.035
Level of Education	0.3501911	0.677038	0.52	0.606
Household size	0.2613499	0.130448	2	0.048
Group Membership	-1.765275	1.367353	-1.29	0.2
Farming Experience	0.019502	0.119832	0.16	0.871
Farm size	0.0153529	0.181062	0.08	0.933
Handling Practices				
Rainfall/Dew	4.881024	2.47853	1.97	0.052
Pests	1.948405	2.132946	0.91	0.363
Theft	5.582708	2.766693	2.02	0.047
Poor handling	2.055532	2.503904	0.82	0.414
Early harvesting	2.046216	2.795697	0.73	0.466
Late harvesting	-5.039339	3.656255	-1.38	0.171
Wind and others	0.4029206	2.607773	0.15	0.878
Pests and others	5.387031	2.448278	2.2	0.03
Variety				
Ex Sudan	3.29064	1.361749	2.42	0.018
NCRIBEN	4.919223	2.461422	2	0.049
Others	-2.643715	6.569785	-0.4	0.688
DTM	0.0044754	0.009518	0.47	0.639
_cons	18.06565	5.346002	3.38	0.001
LOS	-0.0154564	0.009707	-1.59	0.115
F(20, 91) =	1.93			
Prob > F =	0.0194			
R-squared =	0.2974			

4.5.1. Association between the household and the farm size

Table 10 showed the result of correlation between the household size and the farm size which revealed that, there is association between the two variables. This table is to support the statement in table 10 above which stated that, people with large household size had bigger farms and therefore, sesame lost tend to be higher.

Table 10: Association between Household size and Farm size

		Household size	Farm size
Household size	Pearson Correlation	1	.383**
	Sig. (2-tailed)		.000
	N	118	118
Farm size	Pearson Correlation	.383**	1
	Sig. (2-tailed)	.000	
	N	118	120

**. Correlation is significant at the 0.01 level (2-tailed).

4.6. Result of the field trial

Table 11 revealed the result obtained direct from the farmers farms. An average of 0.12 kg per 1 m^2 which is equivalent to 1200 kg (1.2 Mt) per hectare. Although it is a trial, but it differs from various yields both cultivated and experimentally. such as the research conducted by Kashani et al. (2016) on the suitable nitrogen application method will provide an optimum yield of sesame and up to 810.3 kg per ha was recorded. However, it corroborates with the finding of Ahmed et al. (2010) which indicated that, higher sesame yield depends on the plant population.

Also, bags (sacks) of packaged seeds were weighed and found an average of 85 kg per bag. It is the unique structure used for packaging of sesame and other grains in the study area. The rationale behind measuring the weight of sesame bag is that, sack nylon bag is generally acceptable in Nigeria for packaging grains, therefore for most grains like millet, sorghum, maize among others weighed 100 kg per bag. So, farmers perceived that even bag of sesame is having the same weight of 100 kg, while after conducting this research we found that it weighs less than and found an average weight of 85 kg. This information would be beneficial to researchers and sesame retailers.

Kalsa et al. (2019) reported that polyphenylene bags such as the sacks are traditionally used as packaging materials for storing grains in Ethiopia although has a limitation like grains weight loss during storage, decrease germinability and more susceptibility to insects.

Table 11: Weight of sesame from the field trial

Sesame samples	Weight (g)	Weight of sesame bag (Kg)
1	0.1	86
2	0.1	83
3	0.1	85
4	0.2	-
5	0.1	-
Total	0.6	254
Average	**0.12**	**84.6**

1. Weight (g) = weight of sesame samples 1 × 1 m^2 plots. **2**. Weight (kg) = weight of package (bag) of sesame samples.

5. Conclusions

This study focused on postharvest handling practices and losses occurring in sesame production in rural areas of Bauchi state, Nigeria. It has been concluded that, the postharvest handling practices of sesame available in the study area were drying, transportation, threshing and winnowing, packaging and storage. And apart from transportation, all other postharvest operations were found to be manual. The majority (85%) of the farmers perceived that drying the major means of postharvest loss of sesame in the study area, however the losses were found in all the handling practices but considered negligible. Wind, pest, poor handling, Rainfall, pest and others, wind and others and early harvest, are the major factors that were found responsible for a post-harvest lost in the study area. Age, household size among other socio-economic characteristics of the farmers, postharvest handling practices as well as the factors responsible for loss were found to significantly affecting postharvest losses in the study area. The farmers themselves could practice their various ways of reducing the loss with their cheap and available local materials. Also, a reasonable yield of sesame could be obtained with good plant population. A researchers and other stakeholders should not rely on what the respondents perceive on the weight of bags a product especially grains, rather they should consult a relevant literature or conduct the measurements themselves.

6. References

Abass AB, Ndunguru G, Mamiro P, Alenkhe B, Mlingi N, Bekunda M. 2014. Post-harvest food losses in a maize-based farming system of semi-arid savannah area of Tanzania. *Journal of Stored Products Research 57*:49–57. https://doi.org/10.1016/j.jspr.2013.12.004

Abimbola OA, 2014. Post-harvest losses and welfare of tomato farmers in Ogbomosho, Osun state, Nigeria. *Journal of Stored Products and Postharvest Research 5*(2):8–13. https://doi.org/10.5897/jsppr2014.0160

Ali A, Salawu AJ, Sani RM. 2015. Factors Influencing Sesame (*Sesamun Indicum* L) Marketing in Jigawa State, Nigeria *Journal of Agricultural Extension* 19(2) http://dx.doi.org/10.4314/jae.v19i2.11

An K, Ouyang Y. 2016. Robust grain supply chain design considering post-harvest loss and harvest timing equilibrium. *Transportation Research Part E: Logistics and Transportation Review, 88*:110–128. https://doi.org/10.1016/j.tre.2016.01.009

Anagement M, Fo, A, Vi O. 2015. OURNAL OF A PPLIED S CIENCE AND pregnancy in Albino rat ., 12–14.

Asghar A, Majeed MN, Akhtar MN. 2014. A review on the utilization of sesame as functional food, *2*:21–34. https://doi.org/10.5251/ajfn.2014.4.1.21.34

Aviara NA, Ajibola OO, Dairo UO. 2002. Thermodynamics of Moisture Sorption in Sesame Seed, *83*:423–431. https://doi.org/10.1006/bioe.2002.0124

Basavaraja H, Mahajanashetti SB, Udagatti, NC. 2007. Economic analysis of post-harvest losses in food grains in india: a case study of karnataka. *Agricultural Economics Research Review 20*(June):117–126.

Beretta C, Stoessel F, Baier U, Hellweg S. 2013. Quantifying food losses and the potential for reduction in Switzerland. *Waste Management 33*(3):764–773. https://doi.org/10.1016/j.wasman.2012.11.007

Bigoniya P, Nishad R, Singh CS. 2012. Preventive effect of sesame seed cake on hyperglycemia and obesity against high fructose-diet induced Type 2 diabetes in rats. *Food Chemistry 133*(4):1355–1361.

https://doi.org/10.1016/j.foodchem.2012.01.112

BSADP 2017. Bauchi State Agricultural Development Programme, Statistical Database 2017.

Chattha SH, Jamali LA, Ibupoto KA, Mangio AHR. 2012. Effect of Different Packing Materials and Storage Conditions on the Viability of Wheat Seed (Td-1 Variety), *31*(1):10–18. Retrieved from http://docsdrive.com/pdfs/std/std/2012/10-18.pdf

Chegere MJ. 2018. Post-harvest losses reduction by small-scale maize farmers : The role of handling practices. *Food Policy*, *77*(May 2017):103–115. https://doi.org/10.1016/j.foodpol.2018.05.001

Dawood, MG. 2016. Influence of osmoregulators on plant tolerance to water stress. *Scientia Agriculturae*, *13*(1), 42–58. https://doi.org/10.15192/PSCP.SA.2016

Deutscher Wetterdienst. 2018. Available at https://en.wikipedia.org/wiki/Deutscher_Wetterdienst

E. N. C. 2013. Creative commons User License: CC BY-NC-ND, (April 2008):167–180.

Eifediyi KE, Ahamefule EH, Ojiekpon FI, Agbede TM, Remison US, Aliyu HT, Bangura AK. 2016. RESPONSE OF SESAME (Sesamum indicum L.) TO MULCHING AND INORGANIC FERTILIZER APPLICATION IN A SOUTHERN GUINEA SAVANNAH ZONE OF NIGERIA. *The Journal "Agriculture and Forestry," 62*(2). https://doi.org/10.17707/agricultforest.62.2.18

El AM, Entisar N, El M, Ahmed AA. 2010. Effect of Plant Density on the Performance of Some Sesame (Sesamum indicum L) Cultivars under Rain fed, *6*(4):498–504.

FAO 2014. Conceptual Framework for Estimating Postharvest Losses in Food Supply Chains: The Case of Plantain Fruits in Nigeria

FAO 2016. FAOSTAT: World Production of Sesame Seeds. Available at https://en.wikipedia.org/wiki/Sesame

FAO 2007. Brief Description of Sesame by Ecocrop. Available at http://ecocrop.fao.org/ecocrop/srv/en/cropView?id=1937

FAO 2017. Food and Agricultural Organization of the United Nations. Post-harvest losses: Prevention is the cure 2017, Available at: http://www.fao.org/cfs/home/blog/blog-articles/article/en/c/1052829/

Felix A, Nnaemeka U, Ikeme M. 2013. The impact of trade liberalisation on the Iranian economy. *Journal of Economics and Sustainable Development 8*(4):14–24. https://doi.org/10.1111/j.1746-692X.2006.00031.x

Fuller DQ. 2003. Further Evidence on the Prehistory of Sesame. *Asian Agr-History Journal,* 7:127-137.

Gardas BB, Raut RD, Narkhede B. 2018. Evaluating critical causal factors for post-harvest losses (PHL) in the fruit and vegetables supply chain in India using the DEMATEL approach. *Journal of Cleaner Production 199*:47–61. https://doi.org/10.1016/j.jclepro.2018.07.153

Gebregergis Z, Assefa D, Fitwy I. 2016. Assessment of Incidence of Sesame Webworm Antigastra catalaunalis (Duponchel) in Western Tigray, North Ethiopia. *Journal of Agriculture and Ecology Research International 9*(4):1–9. https://doi.org/10.9734/jaeri/2016/28483

Grichar WJ, Dotray PA, Langham DR. 2012. Sesame (*Sesamum indicum* L.) Growth and Yield as Influenced by Preemergence Herbicides. *International Journal of Agronomy 2012*:1–7. https://doi.org/10.1155/2012/809587

Haruna IM. 2011. Growth and yield of sesame (Sesamum indicum L.) As affected by poultry manure, nitrogen and phosphorus at Samaru, Nigeria. *Journal of Animal and Plant Sciences 21*(4):653–659.

Haruna IM, Abimiku MS. 2012. Yield of Sesame (Sesamum indicum L.) as Influenced by Organic Fertilizers in the Southern Guinea Savanna of Nigeria. *Sustainable Agriculture Research 1*(1), 66. https://doi.org/10.5539/sar.v1n1p66

Hegde DM. 2012. Sesame. *Handbook of Herbs and Spices: Second Edition 2*:449–486. https://doi.org/10.1533/9780857095688.449

Hodges RJ, Buzby JC, Bennett B. 2011. Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use. 149:37-45. https://doi.org/10.1017/S0021859610000936

Imoudu PB, Olufayo AA. 2000. The effect of sun-drying on milling yield and quality of rice. *Bioresource Technology 74*(3):267–269. https://doi.org/10.1016/S0960-8524(99)00128-5

Jha SN, Vishwakarma RK, Ahmad T, Rai A, Dixit AK. 2015. Assessment of quantitative harvest and post-harvest losses of major crops and commodities in India, (January):1–174. https://doi.org/10.13140/RG.2.1.3024.3924

Kader AA. 1992. Postharvest biology and technology: an overview. In: Kader AA (ed) Postharvest technology of horticultural crops. UC Publication No. 3311. University of California, Division of Agriculture and Natural Resources, Oakland, pp 15–20. *J. Appl. Sci. Technol. (Special Issue*, *8*(1). https://doi.org/10.1111/j.1745-4557.2007.00165.x

Kafiriti E, Mponda O. 2010. Growth and Production of Sesame. Available at: E Kafiriti, O Mponda - Encyclopedia of Life Support Systems, 2010 - eolss.net

Kalsa KK, Subramanyam B, Demissie G, Mahroof R, Worku A, Gabbiye N. 2019. Evaluation of postharvest preservation strategies for stored wheat seed in Ethiopia. *Journal of Stored Products Research 81*:53–61. https://doi.org/10.1016/j.jspr.2019.01.001

Kaminski J, Christiaensen L. 2014. Post-Harvest Loss in Sub-Saharan Africa What Do Farmers Say? Policy Research Working Paper 6831. elibrary.worldbank.org

Kashani H, Shahab-U-Din, Kandhro MN, Ahmed N, Saeed Z, Nadeem A. 2016. Seed yield and oil content of sesame (Sesamum indicum L.) genotypes in response to different methods of nitrogen application. *Indian Journal of Science and Technology 9*(30). https://doi.org/10.17485/ijst/2016/v9i30/89371

Kasso M, Bekele A. 2018. Post-harvest loss and quality deterioration of horticultural crops in Dire Dawa Region, Ethiopia. *Journal of the Saudi Society of Agricultural Sciences*, *17*(1):88–96. https://doi.org/10.1016/j.jssas.2016.01.005

Khazaei J, Mohammadi N. 2009. Effect of temperature on hydration kinetics of sesame seeds (Sesamum indicum L.). *Journal of Food Engineering*, *91*(4):542–552. https://doi.org/10.1016/j.jfoodeng.2008.10.010

Kitinoja L, Tokala VY, Brondy A. 2018. Challenges and opportunities for improved postharvest loss measurements in plant-based food crops, *06*(4):16–34.

Kushahwah RS, Kumar R, Sharma UC, Bhadauria NS, Kushwaha NK, Kumar C, Kendra V. 2018. Impact of Frontline Demonstration Technologies on Sesame Crop Yield in Bhind District, *18*(2):2012–2015.

Langham DR. 2017. Sesame Producer Guide, (May).

Lawal T, Oluwatoyin A. 2011. National development in Nigeria : Issues , challenges and prospects. *Public Administration*, *3*(November):237–241. https://doi.org/10.5897/JPAPR11.012

Martins AG, Goldsmith P, Moura A. 2014. Managerial factors affecting post-harvest loss: the case of Mato Grosso Brazil. *International Journal of Agricultural Management*, *03*(4):1–10. https://doi.org/10.5836/ijam/2014-04-03

Menzir A. 2012. Phenotypic variability, divergence analysis and heritability of characters in sesame (Sesamum indicum L.) *10*(10):117–126. https://doi.org/10.3109/10884602.2010.515691 http://www.sciencepub.net/nature

Muhammad R, Hionu G, Olayemi F. 2012. Assessment of the post harvest knowledge of fruits and vegetable farmers in Garun Mallam L.G.A of Kano, Nigeria. *International Journal of Development and Sustainability* 1: 510-515. Available Online. isdsnet.com

Ogbonna PE, Ukaan SI. 2013. Chemical composition and oil quality of seeds of sesame accessions grown in the Nsukka plains of South Eastern Nigeria. *African Journal of Agricultural Research* *8*(9):797–803. https://doi.org/10.5897/AJAR12.1702

Olam International. 2018. Information on Sesame Cultivation in Bauchi State. Available at: https://www.olamgroup.com/about-olam.html

Olayemi F, Adegbola J, Bamishaiye E, Daura A. 2011. Assessment of post-harvest challenges of small scale farm holders of tomotoes, bell and hot pepper in some local government areas of Kano State, Nigeria. *Bayero Journal of Pure and Applied Sciences* *3*(2):39–42. https://doi.org/10.4314/bajopas.v3i2.63217

Olukunle TO. 2013. Challenges and Prospects of Agriculture in Nigeria: The Way Forward. *Journal of Economics and Sustainable Development* *4*(16):37–45. Retrieved from www.iiste.org

Onainor ER, Sorhue GU, Uguru JO. 2018. Effect of Processing Method of Sesame (Sesamum indicum Linn .) Seeds on the Growth Performance and Nutrient Utilization of Broiler Chicks *8*(1):10–15. https://doi.org/10.5923/j.ijaf.20180801.03

Parfitt J, Barthel M, MacNaughton S. 2010. Food waste within food supply chains: Quantification and potential for change to 2050. *Philosophical Transactions of the Royal Society B: Biological Sciences, 365*(1554):3065–3081. https://doi.org/10.1098/rstb.2010.0126

Parmar A, Hensel O, Sturm B. 2017. Post-harvest handling practices and associated food losses and limitations in the sweetpotato value chain of southern Ethiopia. *NJAS - Wageningen Journal of Life Sciences 80*:65–74. https://doi.org/10.1016/j.njas.2016.12.002

Post-harvest Profile of Sesame Contents. Available at: docplayer.net/25484502-Post-harvest-profile-of-sesame-contents.html

Postler T, Schulz T, Oberhoffer R. 2017. Skipping hearts macht schule: Kurzzeiteffekte des Projekts. *Deutsche Zeitschrift Fur Sportmedizin 68*(6):148–155. https://doi.org/10.1016/j.procs.2017.11.426

Qi X, Wang RY, Li J, Zhang T, Liu L, He Y. 2018. Ensuring food security with lower environmental costs under intensive agricultural land use patterns: A case study from China. *Journal of Environmental Management, 213*:329–340. https://doi.org/10.1016/j.jenvman.2018.02.048

Redlingshöfer B, Coudurier B, Georget M. 2017. Quantifying food loss during primary production and processing in France. *Journal of Cleaner Production 164*:703–714. https://doi.org/10.1016/j.jclepro.2017.06.173

Singh R, Upadhyay AK, Shrivastava P, Singh VK, Singh SK, Nehru J, Vidyalaya KV. 2014. Productivity Enhancement of Sesame (Sesamum Indicum L.) Through Improved Production Technologies. *N Save Nature to Survive*, *9*(1):107–110. Retrieved from http://thebioscan.in/Journals_PDF/9122 1940_RUDRASEN SINGH.pdf

SundiataPost 2017. Available at: https://sundiatapost.com/2017/07/08/bauchi-records-300-increase-in-sesame-production/

The Nations Encyclopedia: Available at The Nations Encyclopedia: Available at https://www.nationsencyclopedia.com/Africa/Nigeria-AGRICULTURE.html

Tibagonzeka JE, Akumu G, Kiyimba F, Atukwase A, Wambete J, Bbemba J, Muyonga JH. 2018. Post-Harvest Handling Practices and Losses for Legumes and Starchy Staples in Uganda. *Agricultural Sciences* *09*(01):141–156. https://doi.org/10.4236/as.2018.91011

Tunde-Akintunde TY, Akintunde BO. 2004. Some physical properties of sesame seed. *Biosystems Engineering* *88*(1):127–129. https://doi.org/10.1016/j.biosystemseng.2004.01.009

Tunde-Akintunde TY, Oke MO, Akintunde BO. 2012. Sesame Seed. Available at: TY Tunde-Akintunde, MO Oke, BO Akintunde - Oilseeds, 2012 - intechopen.com

Umar HS, Luka EG, Rahaman SA. 2010. Gender Based Analysis of Labour Productivity in Sesame Production in Doma Local Government Area of Nasarawa State, Nigeria. 6 (2): 61-68. Available at: www.patnsukjournal.net/currentissue

W.C.B. 1895. Changes in country life. *Notes and Queries*, *s8–VIII*(208), 485. https://doi.org/10.1093/nq/s8-VIII.208.485-a

Wikipedia. 2018. Sesame free encyclopedia: Available at: https://en.wikipedia.org/wiki/Sesame#cite_note-esopl-8

Zebib H, Bultosa G, Abera S. 2015. Physico-chemical properties of sesame (Sesamum indicum L.) varieties grown in northern area, Ethiopia. *Agricultural Sciences*, *6*(January), 238–246. https://doi.org/10.1089/sur.2009.012

Appendices (if applicable)

List of the Appendices:

1. **Research qustionnaire**

Appendix 1: Questionnaire

Czech University of Life Sciences Prague
Faculty of Tropical AgriSciences

Questionnaire

Topic: Post-harvest Handling Practices of Sesame (*Sesamum indicum* L.) in Rural Areas of Nigeria: A Case Study of Bauchi State.

This study is a post-graduate research project in partial fulfilment for the requirement of M.Sc. aimed at identifying the various post-harvest handling practices of sesame and to access and analyse the factors affecting the Post-harvest losses of sesame in the rural areas of Bauchi State, Nigeria. Your response would be highly appreciated, and it would be treated confidentially.

Thank you.

Instructions:

Please tick/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: Male ☐ Female ☐

5. Age range:
Less than 20 yrs. ☐ 21-30 yrs. ☐ 31-40 yrs. ☐ 41-50 yrs. ☐ Above 50 yrs. ☐

6. Level of Education:
No Formal Education ☐ Primary/Basic ☐ Secondary ☐ Tertiary ☐

7. What is your household size? ……………………….

8. Are you a member of a farmer-based organisation or group? Yes ☐ No ☐

9. Is farming your main source of income? Yes ☐ No ☐

10. Is sesame a main source of income? Yes ☐ No ☐

11. How long have you been in to sesame farming? ……………………………………………

12. How many Hectares of land do you cultivate annually? ……………………… ha

13. Which variety of sesame you grow? …………………………………………………….

14. Which method of sowing of sesame you use? Sole cropping ☐ Intercropping ☐

15. How many Kg or (Metric tonnes) of sesame you harvested every year (approximately)?
……………………………………………

16. Do you use: Chemical weed control ☐ Manual weed control ☐ No control ☐

17. Do you use fertilizer? (Like NPK): Yes ☐ No ☐

18. If yes, how much (approximately)? ………… Kg/ha

Section B.
Post-Harvest Handling Practices of Sesame:

1. When do you grow sesame? Rainy season ☐ Dry season (Irrigation) ☐

2. Date of the sesame harvest ……………………………………………………………

3. When do you harvest sesame?
   When 50% of the capsules turn yellow in colour from green ☐
   When 100% of the capsules turn yellow in colour from green ☐
   When 10% of the capsules turn yellow in colour from green ☐

4. How long does it take you to harvest? …………………………………………………..

5. Which method of harvesting do you use? Manual ☐ Mechanical ☐

6. If mechanical: Hand held harvesters ☐ Combined harvesters ☐

7. What is your yield? ……………… Kg/ha.

8. Do you use: Manual threshing ☐ Mechanical threshing ☐

9. Can you estimate the revolutions of the threshing rotor in case of mechanical threshing.

……………. (RPM revolution per minute).

10. Do you use: Manual (winnowing, manual sieves) ☐ Mechanical cleaning ☐

11. How you recognize that the sesame seeds need to be dried? ....

12. Do you use:

Sun drying (open air drying under sun) ☐
Solar Drying (solar dryer box or solar drier facility is used) ☐
Any other drying facility operated by electricity, gas or other fuel please specify ☐

....

13. In case you use any other Post-harvest handling step please specify? ……………………………………………………………………………………

14. How do you get the harvested sesame from the field to postharvest handing place?

……………………………………………………………………………………

15. Do you use packaging? Yes ☐ No ☐

16. If yes, what material you use for packaging? ……………………………………………………

17. Where do you keep harvested sesame after harvesting? ………………………………………

18. How long (days) you store the sesame before selling to the market (or middle man, or any other customer)

…………………………………………………………………………………

19. Do you sell your harvest?

Directly from the farm or household ☐
Transport it to the market place. ☐

20. If yes what is the usual distance of transportation in (km): ………………………………………….

Section C.
Post-harvest losses:

1. Can you estimate your Post-harvest losses in percentage (%)? ………………………………..

2. Which Post-harvest handling practice is the most responsible for loss? ………………………………..

3. What are the main factors that are responsible for loses?

……………………………………………………………………………………………

4. How do you reduce the losses? ……………………………………………………………………………………………

5. Do you have some harvest returns (losses) from the customer because of spoilage?
Yes ☐ No ☐

6. Do you have some harvest returns (losses) from the customer because of dust or any other mechanical particles presented in the seeds of sesame? Yes ☐ No ☐

7. How many Kg (or metric tonnes) or sesame you selling to the market every year (approximately)?
……………………………………………………………………………..

8. Do you sell 100% of your production? Yes ☐ No ☐

9. If no, how much from total year production you sell to the market in percentage (%)?

…………………………………………………………………………………………