ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIALS ENGINEERING

DEPARTMENT OF CHEMICAL ENGINEERING

MODIFICATION AND PERFORMANCE EVALUATION OF STORAGE FACILITY FOR HARICOT BEAN AROUND ADAMA DISTRICT

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ACRONYMS

ASTU	Adama Science and Technology University
CSA	Central Statistical Agency
FAO	Food and Agriculture Organization
GR	Germination Rate
LSD	List Significant Difference
RCBD	Randomized Complete Block Design
SD	Storage Duration
SS	Storage Structure
TKW	Thousand Kernel Weight

ABSTRACT

Haricotbean is an important legum in Ethiopia and mainly used for the preparation of diffrent food products. Some green haricot beans before full maturity are consumed as vegetables and being used as exporte commudity. Quantitative and qualitative haricot losses due to traditional methods of storage are enormous. A problem associated with postharvest losses of haricot beans, especially during storage in the major producing area of Adama District was dealt with. A field survey was carried out in randomly selected six (6) villages and thirty-six (36) farmers in the Rift Valley region around Adama town where haricot bean grows extensively. The comparative study was conducted at Adama Science and Technology University on the performance of improved metal bin and polythene sacks storages using randomized complete block design in triplicates. Various pests attacked the haricot bean during storage. The respondent farmers from the village confirmed that pests like insects, weevils, rodents, birds, molds, and fungus caused a significant amount of postharvest losses to the crop. The worst attack of the pests was occurring during the storage period. Haricot bean was stored in improved metal bin and polythene sacks for 12 months. Crop temperature, moisture content, germination rate, weight loss, crude ash content, crude protein content, crude fiber content, and thousand kernels weight were the parameters used to evaluate the performance of storage structures. Temperature, moisture content, and weight loss of the crop were increased with storage duration. Germination rate, the nutrient quality, and thousand kernels' weight were negatively affected as the storage duration was prolonged. A combined mean analysis of variance across storage structure and storage duration has indicated a significant difference at the ($p<0.05$ and $p<0.001$) among metal bin and polythene sacks storage structure at a given parameter.

Keywords: Haricot bean, Metal bin, Polythene sack, Storage.

1. INTRODUCTION

1.1. Background and Justification of the Study

Postharvest technology is a multidisciplinary field that includes various treatments and operations carried out on harvested crops for preservation or enhancement of quality for marketing and consumption. In this operation, a considerable amount of product is lost which needs to be minimized. The factors responsible for these losses include insufficient harvesting, threshing, and handling, drying methods, poor processing techniques, and inadequate value-adding methods. The unavailability of sufficient quantity and quality of food has been one of the major constraints in the socio-economic progress of many developing countries like Ethiopia. The rapid increase in population, low agricultural productivity, frequent reoccurring drought, and inadequate postharvest food handling and value-adding systems are identified as the main reasons for the present food shortages in Ethiopia (Tekola Yonas 1997). The sharp rise in prices of agricultural inputs has restricted the use of fertilizers, insecticides, and pesticides. These have furthermore complicated the improving of food supply as well as increasing the yield of food crops.

Food crop losses occur during production, harvesting, drying, storage, marketing, processing, transporting, distribution, and consumption. Conservative estimate reports that about 30 to 40% of crops harvested in developing countries never reach the consumer (Tadesse et al., 2008, Salunkhe et al, 1985 and, Yemane and Yilima 1986).

On the other hand, a huge amount of losses occurs at different stages after crops are harvested and before consumption, after a large investment of time, labor, and money in the production process. Kaminski and Christiansen (2014) estimated losses to be as high as 37% in sub-Saharan Africa. A recent report by Kumar et al. (2017) indicated that more than one-third of food is lost every year in the postharvest operations.

If these losses are eliminated through improved and appropriate postharvest technology, the world food supply can be increased by 30 to 40% without cultivating any additional area of land or incurring additional expenditure on improved seed, fertilizer, irrigation, and plant protection measures to grow these crops (Fekadu Lemessa 1994 and Salunkhe et al, 1985).

According to the Central Statistics Authority of Ethiopia for the year 2017/18, the production of major crops for private holding farmers accounts 87.48% for cereals and 2.79% for oilseeds. The production of pulses is estimated to be 9.73% of the total production of the major crops. Pulses grown in 2017/18 covered 12.61% (1,598,806.51 hectares) of the grain crop area and 9.73% (about 29,785,880.89 quintals) of the grain production was drawn from faba beans, haricot beans (white), haricot beans (red), faba beans, and chickpeas (CSA, 2018).

However, it has been found that all that is produced does not reach the consumption stage. A great proportion of the postharvest losses of cereals and legumes in Ethiopia was found to be during storage (Yemane and Yilma, 1986). Owing to the inadequacy of preservation methods, large quantities of food spoil and as time goes on, this problem will be aggravated by the growing dietary needs of the country.

In Ethiopia, this problem exists with many pulses and oilseeds, which cannot be marketed fast enough owing to their limited keeping ability. Large quantities of these crops spoil owing to inadequate storage infrastructure, insufficient processing capacities, and growing marketing difficulties caused by poor infrastructure and poor marketing as well as distribution systems. Low cost and improved storage structures for these products could help solve these problems to some extent.

The lack of strong research programs on pulses handling and processing has impeded the generation of relevant information. Haricot beans valued for their protein and starch and low fat (Salunkhe and Kadam, 1989). High moisture content, extended storage period, and high storage temperatures, however, contributed to impaired legume cook ability (Mulei et al., 2011).

Haricot beans are used in the preparation of different traditional products in Ethiopia. They are consumed as cooked legumes called *Nifuro*, in soups, and in Ethiopian stew called *Shirowat*. Dehulled dry beans flour is used to make stew (*wat*) in some parts of Ethiopia (Fekadu, 2004). Some green haricot beans before full maturity are harvested and used as vegetables and also exported.

The dry seeds of haricot beans are stored by farmers and traders in traditional storage structures till the next harvest. Some researches were undertaken in the past to increase production but no work appears to have been carried out on the effect of traditional processing on the nutritional composition of haricot bean varieties in Ethiopia. Generally, the consumption of cereal crops doesn't vary greatly year to year as the demand for grain is inelastic. The supply, on the other hand, depending on the harvest season, is concentrated within a specific period of the year. Moreover, the fluctuation of grain supply varied from year to year depending on the climatic condition and production of a given year. This irregular pattern of supply of haricot bean, calls for the establishment of a reliable post-production chain, which comprises harvesting, transporting, storing, and further processing.

However, it has been found that all that is produced is not reaching the consumption stage. Losses at different stages of the postharvest chain contribute to the reduction of products after harvest. Causes for postharvest losses may be ill-pre-harvest and post-harvest practices. The pre-harvest factors include the genetic characteristics of a grain variety, mechanical damage, and insect infestation during growing, early harvesting which causes high moisture content and deterioration, and late harvesting which causes cracking as a result of over-drying. The postharvest losses are mainly caused by inadequate preparation of the product for storage (like drying), failure to provide appropriate storage environment during the storage period, and appropriate primary and secondary processing (Lemessa et. al., 2000).

1.2. Statement of the Problem

Haricot bean is among the legumes, whose entire production and processing are accomplished manually, harvested by hand; sun dried in the field, threshed and winnowed manually, and stored in traditional storage. Both quantitative and qualitative grain losses due to traditional methods of postharvest operations are enormous. Regarding postharvest grain losses, various figures have been reported by different authors, but information on its real magnitude is not available from reliable source (Kaminski and Christiansen 2014; Kumar et al. 2017). About 70% of the total post-harvest losses of cereal crops occur during storage. In Ethiopia, there is no sufficient information indicating magnitude of postharvest losses of haricot bean during storage.

In this study, a problem associated with postharvest losses of haricot beans, especially during storage in the major producing area of Adama District was dealt with. In doing so, the performance of the existing storage structures among farmers was evaluated. qualitative and quantitative losses under these stores were quantified. Based on the results of the evaluation of the stores, a new design was made and its performances were assessed.

1.3 Objectives

1.3.1 General Objectives

To evaluate the performance of modified storage structure for haricot bean and suggested appropriate solution with special reference to storage

1.3.2 Specific Objectives

i. To assess the current potential demand for storage facility of haricot bean and quantify the qualitative and quantitative losses during storage by farmers community

ii. To modify and develop appropriate storage facilities for haricot bean, and evaluate their performance

iii. To determine the quantitative and qualitative losses and nutritional value of haricot bean in newly modified and developed storage structures

2. MATERIALS AND METHODS

The study area includes Adama Districts around Adama town where haricot beans are grown extensively. Six villages and thirty-six private farmers were randomly selected for the study. The following table shows then name of the villages where the field study was carried out.

Table 1. The study areas, level of education and the state of respondents

Parameters		Frequency (N)	Percent (%)
Villages	Bati Bora	5	13.89
	BatiGarmama	6	16.67
	Dibibisa	5	13.89
	Gedamsa	5	13.89
	GurajaFurda	10	27.78
	Kobo Luto	5	13.89
Level of education	Primary School	26	72.22
	Secondary School	10	27.78
State and number of farmers	Private	36	100.00

Phase I

2.1. Assessment of Users' View for Having and Using Storage Facility

To meet the first two objectives cited, it is necessary to conduct surveys in the haricot bean main growing areas. During the survey selected stores were visited and evaluated on the field. To understand farmers' views concerning problems associated with storing products and owning stores, information was gathered with the help of questionnaires. About forty-one different questionnaires were distributed to small scale farmers for the evaluation of haricot bean losses incurred through various storage and handling methods in Adama District to the vicinity of Adama town (see Appendix I).

Farmers were interviewed regarding the existing storage facilities and information was collected whether the farmers keep the existing storage structure or opt for a new improved one. The information gathered and recorded were the following.

- Pre-storing activities and in-store treatments.
- Cost of stores currently in use.
- The quantity stored, store capacity, and way of storage.
- Frequency of product removal from the store.
- Storage losses, severity and causes of losses, and usage of damaged grain.

- Quantity sales of grain without being stored, reasons for sales, price situations, buyers', and transportation.

PHASE II

2.2. Determination of Quantitative and Qualitative Losses in Metal Bins and Sacks

Metal bins have been the focus of numerous promotional campaigns across Africa in recent years. In some African countries, it has been reported that too much emphasis was put on local fabrication and distribution of metal and not on the training of extension services in the proper utilization of the technology (Rick and Tanya, 2015).

Different storage types were reported in a wide range of different construction materials, plastics of various sorts, metal, concrete, mud, and wood. Among the hermetic grain bags, there is an option of a single impermeable bag or two impermeable bags one inside the other bags, and bioplastics bags. Impermeable grain bags are typically high-density polyethylene and interestingly there is a biodegradable version. Bioplastics bag, although it appears not to have been very extensively tested yet. Based on the preliminary research conducted in phase I, the design and development of new and improved metal bin storage structures for the haricot bean were constructed and evaluated.

Construction of Metal Bin

Three metal bin storage structures with 4mm thickness of galvanized metal sheet were designed and constructed at Adama Science and Technology University in Chemical Engineering Department's laboratory with a capacity of about 200 kg. The vertical height from top to base and diameter of the metal bin was 100 cm and 80 cm, respectively. Furthermore, the length and width of the upper and lower openings were 20 cm and 20 cm, respectively. During construction, the metal bins were sealed and checked for their airtight and watertight performance.

A 4 mm thickness galvanized sheet metal sheet was selected due to:

- Its strength
- Easily flexible to modify
- Has no reaction with grain duringb storage
- Easily available with reasonable price

- It is being used in many developing countries

Three polyethylene sacks with a capacity of 50 kg were purchased from Mojo Lome Farmer Association, for parallel storage purposes and to compare its performance with a metal bin (Fig. 2 and 3).

Locally produced haricot bean was purchased from Mojo Lome Farmer Association and stored in the newly constructed metal bins and polyethylene sacks to run the experiment. Physical parameters of the haricot beans (temperature, moisture, germination, and weight loss) were measured at the start of the storage period. Samples of the stored crops were taken at interval of three months for quantifying the qualitative and quantitative losses of the haricot beans for twelve months of storage duration. The experiment was repeated three times and an average result was recorded.

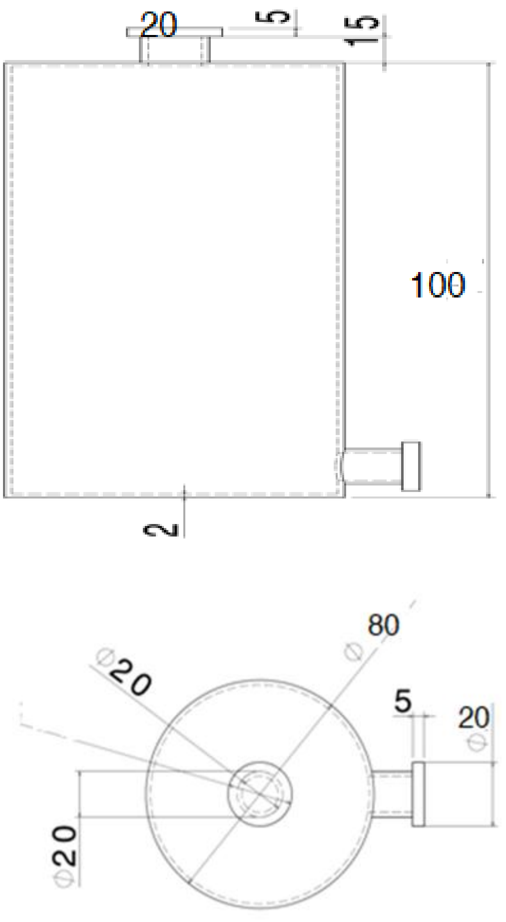

Figure 1. Improved metal bin storage structure design

Figure 2. Improved metal bin storage structure

Figure 3. Polythene Sacks

2.3. Sampling Procedures

Haricot bean samples were taken from each metal bins and polyethylene sacks starting from the first day of storage through the total storage duration (12 months) at every two months interval with the help of a one-meter long double tier tube sampling probe with four openings of heavy metal opening. A sample of 1 kg each was taken from the center, side, and bottom of each metal bins and polyethylene sacks. The crop samples were thoroughly mixed to get a composite sample. The composite samples were kept in airtight plastic bags for subsequent laboratory analysis. These samples were used for the test designated below.

2.4. Measurement of Haricot Bean Moisture Content

The crop moisture content was determined after the collection of samples by digital moisture meter (HOH express HE 50, Germany).

2.5. Measurement of Haricot Bean Temperature

The temperature was measured in each metal bin and sack with a one-meter long digital electronic thermometer attached to HOH express HE 50, Germany. Measurements were taken at the top, side, middle, and bottom of each bin and sacks and the average was recorded.

2.6. Germination Test

For the germination test, 400 seeds were employed from each metal bins and sacks on each sampling day. The seeds were kept in a Petri dish which was lined with moist filter paper using distilled water in three replications and incubated at room temperature for seven to ten days.

2.7. Weight Loss

The method involves the separation of grain samples into damaged and undamaged or sound grains, counting and weighing each, and calculating the percentage weight loss. This method seems the easiest to conduct since no moisture control readings are necessary (Adams and Schulten, 1978; Salunkhe et al., 1985) and it involves a smaller sample. The Count-Weight-Method with the following formula was used to determine the weight loss in each metal bin and sack. The weight loss can indicate the quantity loss of the haricot bean in percentage during the period of storage.

$$Weight\ loss\ \% = \frac{UNb - BNu}{U\ x\left(Nb + Nu\right)} x100$$

Where,

U = Weight of undamaged grain (g)

Nb = Number of the damaged grain

Nu = Number of the undamaged grain

B = Weight of the damaged grain (g)

2.8. Nutritional Quality Loss

Determination of crude protein, crude fiber, crude ash, and thousand kernels weight was by ICC Standard Method No. 166 and No.123 at Ethiopian Institute of Agricultural Research Centre, Bishoftu.

2.9. Data Analysis

A separate analysis of variance for temperature, moisture content, germination rate, and weight loss as well as for crude ash, crude fiber and crude protein was used for each storage structure using MINITAB statistical software. Mean separation was done using LSD. Two-way factorial analysis consisting of the storage structure and storage duration as main effects were conducted for temperature, moisture, germination, weight loss, and nutrition (crude protein, crude fiber, and crude ash) loss.

3. RESULTS AND DISCUSSION

3.1. Questionnaires Results

The most cultivation area of haricot bean was the Rift Valley Region in the East Shoa Zone, around Adama City in different villages. Most of the farmers in these villages use traditional storage structures to store their crops. These storage structures are very old, not air and watertight, and easily attacked by insects and microorganisms. The storage has less life span when compared with the improved storage system. This may affect the income of the farmers since they sell their products at cheap prices during harvest and harvesting season. To avoid postharvest losses of the crop, modification, and improvement of the old storage structures are highly required. To this effect, experimental assessments through questionnaires were carried out to the randomly selected villagers and the results of the questionnaires were collected and recorded according to data collection techniques from different farmers.

3.1.1. Sample size and level of education of the farmers

The questionnaires were randomly distributed to 36 farmers from six villages of the Rift Valley region in East Shoa Zone namely Bati Bora, Bati Garmama, Dibibisa, Gedemsa, Guraja Farda and Kobo Luto (Table 1). The education level of the farmers, 26 (72.22%), and 10 (27.78%) of the farmers completed primary and secondary school respectively.

3.1.2. Harvesting and storage practices

There was an experience of harvesting haricot bean using machinery, handpick, and sickle in our study area. And, about 92% of the farmers use handpicking harvesting mechanism (Table 2). The ecological status of the storage area is dominantly plain and the types of storage dominantly (about 81%) in use are sacks made from polyethylene which have got a life span of less than one year (Table 3). According to the response of the farmers, each year they are required to purchase new polyethylene sack which incurs extra additional cost per year (Table 3).

Table 2. Methods of harvesting and the current storage phenomenon

		Frequency (N)	Percent (%)
Harvesting methods.	Machine	1	2.78
	Hand Pick	33	91.67
	Sickle	2	5.56
Ecological condition of the storage area.	Plain	33	91.67
	Mountains	1	2.78
	Sloppy	2	5.56
Types of storage in use.	Wooden	3	8.33
	Mudbrick	1	2.78
	Sack	29	80.56
	Basket	2	5.56
	Metal Bin	1	2.78
The shape of the store.	Rectangle	3	8.33
	Round	27	75.00
	Others	6	16.67

Table 3. The estimated storage life and cost

		Frequency (N)	Percent (%)
The estimated life of the store (in months).	1.00	1	2.78
	2.00	1	2.78
	5.00	1	2.78
	6.00	3	8.33
	7.00	5	13.89
	8.00	1	2.78
	9.00	4	11.11
	10.00	1	2.78
	12.00	18	50.00
	18.00	1	2.78
The estimated cost of the store per sack (in ETB).	9.00	1	2.78
	10.00	17	47.22
	11.67	1	2.78
	12.50	3	8.33
	15.00	4	11.11
	20.00	2	5.56
	25.00	6	16.67
	30.00	2	5.56

Farmers from different villages were requested about how to know dried crops to store. Most of them replied that they identify dried crops by breaking with their teeth. They also transport their crop by donkey to the threshing areas. All the interviewed farmers responded that they required about fifteen days for harvesting and threshing. They also store the haricot bean for about 12 months maximum (Table 4).

Almost all of the farmers would not store the new grain on the top of the old grain. Most of the farmers store grain for food and seed purposes. The quantity of crops in the store used for food is not more than 100 kg. Most of the farmers store nearly 200 kg for seed and 2000 kg of the crop for sale (Table 6). Most of the farmers use ventilated storage to store haricot bean and remove regularly about 5 kg of the crop from the store monthly for the household purpose (Table 6).

According to the response of the villagers, different pests attack the harvested and stored haricot bean in the region. The respondent farmers confirmed that pests like insects, weevils, rodents, birds, molds, and fungus cause the number of postharvest losses to the crop. The worst attack of the pests occurred during the storage period. The store of the farmers under the study area was protected from insects by traditional and chemical methods. Some farmers used to fumigate where the others used tablet chemicals to kill the insects. The dosage of this chemical which applied to the crop to protect from insects was 50 g/quintal (Table 8). In some areas, locally made traps were used to control rodents to protect crops from damage.

An increment in moisture and temperature caused crop spoilage at the bottom of the storage (Table 9). The total estimated crop loss during storage ranges from 1 kg to 25 kg per sack (Table 10).

In general, most of the respondent farmers were requested for an improved storage structure that can protect their product from postharvest loss causing agents and harsh environments.

Table 4. Knowledge of crop dryness, transportation and storage durations

		Frequency (N)	Percent (%)
How do you know when the crop is dry enough to store?	By breaking with teeth	15	41.67
	By visual observation	5	13.89
	By breaking with teeth and visual observation	6	16.67
	By testing by hand and teeth	5	13.89
	Local estimation	5	13.89
How is the crop transported from the field to the threshing area?	By animals	2	5.56
	By donkey	26	72.22
	By horse	2	5.56
	By donkey and horse	6	16.67
What is the time gap between harvesting and threshing (in days)?	10	3	8.33
	10 – 15	3	8.33
	11 – 15	1	2.78
	14	5	13.89
	15	7	19.44
	15 – 20	4	11.11
	20	2	5.56
	30	1	2.78
	6 – 10	1	2.78
	7	4	11.11
	7 – 10	1	2.78
	7 – 11	1	2.78
	8 – 10	2	5.56
	9 – 11	1	2.78
How long do you store your haricot bean (in months)?	0.25	1	2.78
	1.00	2	5.56
	2.00	2	5.56
	7.00	3	8.33
	8.00	2	5.56
	9.00	6	16.67
	10.00	2	5.56
	12.00	15	41.67
	18.00	1	2.78
	24.00	1	2.78
	50.00	1	2.78

Table 5. The storage practices of haricot bean and its purposes

		Frequency (N)	Percent (%)
Do you store new grain on the top of old grain?	No	36	97.22

For what purpose do you store the grain?	For food	5	13.89
	For seed	3	8.33
	For sale	2	5.56
	For food and seed	20	55.56
	For food, seed, and sale	6	16.67
Amount of the crop in the store used for food (in kg).	0.50	1	2.78
	1.50	1	2.78
	20.00	1	2.78
	25.00	3	8.33
	50.00	5	13.89
	75.00	2	5.56
	100.00	7	19.44
	150.00	6	16.67
	200.00	6	16.67
	250.00	3	8.33
	300.00	1	2.78

Table 6. The quantity of the crop used for seed and sell

		Frequency (N)	Percent (%)
Amount of the crop in the store used for seed (in kg).	1.00	1	2.78
	50.00	1	2.78
	75.00	1	2.78
	85.00	1	2.78
	100.00	12	33.33
	150.00	5	13.89
	200.00	12	33.33
	300.00	1	2.78
	500.00	1	2.78
	950.00	1	2.78
Amount of the crop in the store used for sale (in kg).	3.50	1	2.78
	250.00	1	2.78
	300.00	1	2.78
	400.00	2	5.56
	800.00	2	5.56
	1300.00	1	2.78
	1400.00	1	2.78
	1500.00	5	13.89
	1600.00	2	5.56
	1700.00	4	11.11
	1800.00	2	5.56
	2000.00	8	22.22
	2500.00	4	11.11
	3000.00	1	2.78
	4000.00	1	2.78

Table 7. Storage use and management

		Frequency (N)	Percent (%)
Do you use ventilated storage?	Yes	26	72.22
	No	10	27.78
Do you use storage for haricot bean?	Yes	29	80.56
	No	7	80.56
The pattern of removal of the crop from the store.	Once a day	6	16.67
	Once a week	7	19.44
	Once a month	21	58.33
	Other	2	5.56
Amount of crop removed from the store on the pattern used (in kg).	1.50	2	5.56
	1.75	1	2.78
	2.00	3	8.33
	2.50	2	5.56
	3.00	3	8.33
	3.50	2	5.56
	4.00	1	2.78
	5.00	10	27.78
	6.00	2	5.56
	7.00	6	16.67
	10.00	1	2.78
	25.00	1	2.78
	200.00	1	2.78
	300.00	1	2.78
Do farmers sell as much as they can and risk buying back later in the season?	Yes	14	38.89
	No	22	61.11

Table 8. Pests, infestation period and controlling mechanisms

		Frequency (N)	Percent (%)
What type of pests attacks the crop in the store?	Insects	11	30.56
	Mice	2	5.56
	Insects and rats	15	41.67
	Insects and mice	4	11.11
	Rats and mice	2	5.56
	Insects, rats, and mice	2	5.56
At what time of the year is the pest attacks worst?	During the storage period	20	55.56
	Towards the end of the storage period	13	36.11
	At anytime	3	8.33
How do you protect your store from insects?	By traditional method	5	13.89
	By chemicals	27	75.00
	By other methods	4	11.11
What type of traditional method do you	Other	32	88.89

use?	Fumigation	4	11.11
What type of chemicals do you use?	Actaliries	15	41.67
	Tablets	12	33.33
	Other	9	25.00
What is the dosage of the chemicals used (in g) per quintal?	50	15	41.67
	Other methods	21	58.33

Table 9. Spoilage agents and controlling mechanisms

		Frequency (N)	Percent (%)
Do you control rodents?	Yes	34	94.44
	No	2	5.56
What type of rodent control methods are used?	By chemicals	5	13.89
	Trap	31	86.11
Do you have a problem with crop spoilage due to much moisture?	Yes	34	94.44
	No	2	5.56
In which part of the store does the moisture spoilage occurs?	Top	5	13.89
	Bottom	29	80.56
	No response	2	5.56

Table 10.The estimated crop loss during storage

		Frequency (N)	Percent (%)
The total estimated crop loss (in kg) during storage.	0.00	1	2.78
	1.00	3	8.33
	1.50	6	16.67
	2.00	2	5.56
	2.50	3	8.33
	3.00	1	2.78
	5.00	2	5.56
	5.70	1	2.78
	10.00	11	30.56
	15.00	1	2.78
	25.00	1	2.78
	No response	4	11.11

Table 11. Suggested improvements to the existing storage structures

		Frequency (N)	Percent (%)
What type of improvement would you like to make to the store?	None	4	11.11
	Basket and wooden	1	2.78
	Metal silo	2	5.56
	Metal silo and plastic bags	6	16.67
	Metal silo, sack and wooden	3	8.33
	Plastic bags	3	8.33
	Sack and wooden	7	19.44
	Sack and plastic bags	1	2.78
	Sack, wooden and basket	1	2.78
	Sack, wooden and plastic bags	6	16.67
	Sack, wooden, basket, metal silo and plastic bags	2	5.56

3.2. Physicochemical and Nutritional Changes in New Developed Structures

The average temperature in both storage structures (metal bin and sack) was recorded and analyzed. The average temperature ranged from 20.67℃ to 26.10℃ in metal bin and 22.43℃ to 27.80℃ in the sack (Table 12). A combined mean analysis of variance across storage structure indicated a significant difference at the 0.05 and 0.001 level between metal bean and sack storage structure for a given parameter (Table 14).

However, significant variation was observed in temperature within storage structure over the duration. The highest temperature in the metal bin and sack was at 12 months of storage and it was 26.10 ℃ in the metal bin and 27.80 ℃ in the sack (Table 12). The maximum temperature was recorded in sorghum stored in Gotera (Fekadu Lemessa 2008). The effect of temperature was different across the two storage structures during the storage period (Table 14). The haricot bean stored in the metal bin remained cooler as compared to that stored in sacks.

3.2.1. Moisture content

Generally, there was an increase in moisture content as the storage duration increased in both storage structures (Table 12). The moisture content of the haricot bean in sacks was higher than in the metal bin. The highest moisture contents for metal bins and sacks were 11.47% and 12.40%, respectively at twelve months of storage (Table 12). Generally, after 10 months of storage, the crop moisture content was found to increase more significantly in sacks compared to the metal bin. Moreover, the crop near the sides and bottom parts of the sacks showed relatively higher moisture content; probably because the crop absorbed more moisture from the sides and bottom of the sacks. The increase in moisture content in underground pits was reported earlier, either due to attack by insects and microorganisms (Lemessa et al., 2000 and Kamel, 1980) and/or absorption of moisture by the crop from the walls of the pits. This indicates that the grain stored in the metal bin remained drier as compared to the crop stored in sacks.

In generally, there is an increasement in moisture content in both storage structures throughout the storage duration significantly. This is due to development of the fungus and moulds during storage period (see table 12).

3.2.2. Germination rate

Mean germination rate of 66.73% and 62.67% was recorded for metal bin and sacks respectively (Table 12). The germination rate of the haricot bean was decreased as the storage duration increased in both storage structures with a more significant reduction in sacks. At the end of the storage period, 26.10% and 21.67% germination rates were recorded in metal bins and sacs, respectively (Table 12). The relatively lower germination rate in sacks may be due to the attack of the haricot bean embryo by fungus, molds, and insects (Fekadu et al., 2000). Fortunately, farmers of Rift Valley region do not store crops used for seed not more than six months in sacks.

At the beginning (zero time) storage time temperature, moisture and germination rated of the metal bin and sacks should be the same, but as indicated in Table 12. The values wresv different. The reading was recorded within same day, in the morning in metal bin and in the afternoon in sacks. The different in reading might be due to different room temperature and humidity which might be fluctuated in the morring and afternoon.

3.2.3. Weight loss

An average of 9.63% weight loss was recorded in the metal bin; while 10.20% weight loss was recorded in a sack over the twelve months of storage period. The greater weight loss in sacks might be due to high moisture content and temperature in sacks, which favored the growth of molds, fungus, and insects.

The decrease in weight loss was due to the decrease of endosperm, which is made up of protein, lipid and fiber. In other words, the endosperm was attacked by fungus and mould in sacks

According to Mohammed and Tadesse (2018), the average weight losses were recorded for different crops as 8.3–21.4%, 6.2–32.9%, 9.5–27%, 23%, 11.8–25.2%, and 16.3–21% for maize, sorghum, wheat, barley, haricot beans, and teff, respectively. And, our result is in a close agreement with this report.

Table 12. Storage temperature, GR, weight loss and moisture content of the crop

Duration (Months)	Storage Structure							
	Metal Bin				Sack			
	Temperature (°C)	Moisture (%)	Germination (%)	Weight loss (%)	Temperature (°C)	Moisture (%)	Germination (%)	Weight loss (%)
0	21.83±0.29^{E}	9.53±0.58^{F}	97.00±1.00^{A}	1.45±0.44^{H}	22.43±0.31^{DE}	9.70±0.100^{F}	97.67±0.58^{A}	1.57±0.11^{H}
3	20.67±0.58^{F}	9.70±0.200^{F}	84.00±1.00^{B}	2.60±0.200^{G}	23.33±0.58^{D}	9.87±0.58^{EF}	82.00±1.00^{B}	2.70±0.200^{G}
6	23.00±1.00^{D}	10.17±0.15^{DE}	71.67±1.53^{C}	3.70±0.200^{F}	25.00±0.500^{C}	10.60±0.100^{C}	66.00±1.00^{D}	4.07±0.15^{E}
9	25.00±1.00^{C}	10.53±0.25^{CD}	51.33±1.53^{E}	5.73±0.21^{D}	26.67±0.15^{B}	11.23±0.25^{B}	46.00±2.00^{F}	6.47±0.25^{C}
12	26.10±0.36^{B}	11.47±0.45^{B}	29.67±1.15^{G}	9.63±0.15^{B}	27.80±0.100^{A}	12.40±0.36^{A}	21.67±1.53^{H}	10.20±0.36^{A}
Mean	23.32±2.15	10.28±0.75	66.73±24.73	4.62±2.98	25.05±2.09	10.76±1.04	62.67±27.68	5.00±3.18

Data are the mean ± standard deviation. Values within a column with different superscript letters indicate a significant difference ($P<0.05$) within and between the groups.

Table 13. Crude ash, fiber, protein, and TKW of the crop

Duration (Months)	Storage structure							
	Metal Bin				Sack			
	Crude Ash (%)	Crude Fiber (%)	Crude Protein (%)	Thousand Kernel Weight (g)	Crude Ash (%)	Crude Fiber (%)	Crude Protein (%)	Thousand Kernel Weight (g)
0	4.10±0.17^{A}	7.09±0.10^{D}	18.90±0.34^{AB}	184.00±0.50^{A}	4.05±0.10^{A}	9.20±0.25^{B}	18.32±0.18^{CDE}	184.00±0.25^{A}
3	4.20±0.10^{A}	7.11±0.19^{D}	19.00±0.50^{A}	174.00±0.50^{B}	4.40±0.44^{A}	9.40±0.20^{AB}	18.50±0.25^{BCD}	172.00±0.50^{C}
6	2.40±0.25^{B}	7.20±0.22^{D}	19.10±0.20^{A}	171.00±1.00^{D}	4.06±0.90^{A}	9.30±0.25^{AB}	18.10±0.15^{DE}	170.00±0.50^{E}
9	4.30±0.15^{A}	7.35±0.15^{CD}	18.20±0.20^{DE}	170.00±0.50^{E}	4.11±0.07^{A}	9.40±0.20^{AB}	18.00±0.40^{E}	169.00±0.50^{F}
12	4.40±0.20^{A}	7.60±0.30^{C}	18.70±0.20^{ABC}	165.00±0.50^{H}	4.12±0.22^{A}	9.60±0.20^{A}	18.11±0.27^{DE}	166.00±0.25^{G}
Mean	3.88±0.79	7.27±0.26	18.78±0.42	172.80±6.55	4.15±0.23	9.38±0.23	18.21±0.29	172.20±6.44

Data are the mean ± standard deviation. Values within a column with different superscript letters indicate a significant difference ($P<0.05$) within and between the groups.

Mean Calculation indicates how much variation there is from the average (mean). A low standard deviation indicates that the data points tend to be close to the mean, whereas a high standard deviation indicates that the data are spread out over a large range of values. In Table 12 and 13, values within a column with different superscript letters indicate a significant difference (P<0.05) within and between the groups.

3.2.4. Crude ash

The storage structure had a significant (p<0.05) impact on crude ash content (Table 15). The higher ash content was found for the samples drawn from sacks than in metal bins. The higher ash content in sacks may be due to the attack of insects on the inner part of the haricot bean. The maximum crude ash content in metal bin and sacks was recorded at 12 months of storage duration and it was 4.4% in a metal bin and 4.12% in sacks (Table 13).

3.2.5. Crude fiber

At the end of the storage period, 7.60% and 9.60% content of crude fiber were registered in metal bin and sacks, respectively. Generally, there was a higher crude fiber content in sacks than in metal bins (Table 13).

3.2.6. Crude protein

The average crude protein content was ranged from 18.20% to 19.10% in a metal bin and 18.00% to 18.50% in the sack (Table 13). A combined mean analysis of variance across storage structure indicated a significant difference at the 0.05 and 0.01 level between metal bin and sack storage structure for the studied parameters (Table 15).

A significant variation was observed in crude protein content within the storage structure and across storage structure over the storage duration. The highest crude protein content (19.10%) was recorded at sixth months of storage in the metal bin. And, the highest protein content (18.50%) was recorded at third months of storage in the sack (Table 13).

3.2.7. Thousand kernel weight

As indicated in Table 15, the storage structure has significantly influenced the thousand kernel weight of the haricot bean. The highest thousand kernel weight was recorded at the beginning of the storage in both storage structures. And, the lowest thousand kernel weight was reported at the twelfth months of storage for both storage structures. Thus, from this result, it can be inferred that the storage duration significantly influenced the thousand kernel weight of the crop regardless of the types of storage (Table 13). Even though some variation was observed among the metal bins and sacks.

Table 14. Impacts of storage structure on temperature, moisture, germination rate, and weight loss

Storage structure	Parameters			
	Temperature (℃)	Moisture (%)	Germination rate (%)	Weight Loss (%)
Metal Bin	23.32^{B}	10.28 ^{B}	66.73^{A}	4.62^{B}
Sack	25.05^{A}	10.76 ^{A}	62.67^{B}	5.00^{A}

The mean difference is significant at the 0.05 and 0.01 levels. Letter A, B shows there is a significant difference between the metal bin and sack for a given parameter.

Table 15. Impacts of storage structure on crude ash, fiber, protein, and thousand kernel weight

Storage structure	Parameters			
	Crude Ash (%)	Crude fiber (%)	Crude Protein (%)	TKW (g)
Metal Bin	3.88^{B}	7.27^{B}	18.78^{A}	172.8^{A}
Sack	4.15^{A}	9.38^{A}	18.21^{B}	172.2^{B}

The mean difference is significant at the 0.05 and 0.01 levels. Letter A, B shows there is a significant difference between the metal bin and sack for a given parameter.

The difference between metal bin and sack storage structure based on performances were showed on the results of an increment of temperature, moisture and weight loss as well as decreasing in germination rate in sacks compared with metal bin during 12 months storage. More increment in temperature, moisture and weight loss indicate more or significant postharvest losses of haricot bean in sacks. It could be concluded that in metal bins haricot beans can be stored more safely than in traditional sacks for 12 Months.

4. CONCLUSION AND RECOMMENDATION

4.1. Conclusion

On the bases of the result obtained from the current study, haricot bean stored in polythene sacks had a high weight loss/postharvest loss and low germination rate as well as an increment in temperature and moisture content. This indicates that haricot bean can be stored relatively longer period and be in a better condition in the metal bin than in polythene sacks in Rift Valley regions.

In Ethiopia, pre- and postharvest losses present one of the main problems not only in haricot bean but also in all crops. Losses can occur in cereal grains and legumes during harvesting, threshing, winnowing, drying, storage, transportation, etc. It has been estimated that about 30 to 40% of crops harvested in the developing countries seldom reach the consumer.

According to FAO and WHO (2007), postharvest losses cause not only loss of the economic value of the food produced but also the waste of scarce resources such as labor, land, and water, as well as non-renewable resources such as fertilizer and energy, all of which are used to produce, process, handle, and transport food. Solutions to reduce postharvest losses require relatively modest investment and can result in high returns compared to increasing crop production to meet the food demand (Kumar et al., 2017).

The extent to which deterioration and losses occur in the storage depends on physical and production factors, biological factors, and the storage environment. The principal biological agents of deterioration during storage are insects and mites, fungi, and rodents. The storage environment has much to do with the rate of deterioration. High temperature and humidity encourage mold formation and provide conditions for the rapid growth of the insect population. It is then worth considering storage as the main focus to analyze and reduce postharvest losses.

To avoid these losses smallholder farmers often sell their grain at a very low price soon after harvest, when the grain is abundant and cheap. Weeks and months later, needing food for their families, they are forced to buy now-scarce grain at a much higher price. Because of the above, it can be concluded that if pre- and postharvest losses are reduced, the farm income can be increased substantially without cultivating additional acres of land or increasing any additional expenditure on seed, fertilizer, irrigation, and plant protection measures to grow the crops.

4.2. Recommendations

It was observed that haricot bean is generally harvested when the leaves and pods turn yellow, by pulling up the whole plant. The crop is rarely harvested using a sickle. When a sickle is used, the harvester holds the crop and cuts it to the soil level. Once the plants are pulled up or cut, they are left in rows of small heaps in the field for further drying. This causes shattering of the pods and losses the seed during drying. To overcoming this problem appropriate drying technology should be introduced for small scale farmers.

According to the suggestions of the farmers, setting up of rural storage, provision of improving metal bin or polythene sheets with the reasonable cost is required to reduce the postharvest losses of haricot bean.

The postharvest loss of haricot bean occurs during harvesting mainly at three stages namely, during cutting of the straws due to grain shattering and incomplete cutting; during piling of the harvested straws in small amounts as harvesting continues, and during transportation of the straws to a suitable stacking or threshing site. Thus, awareness creation to the farmers regarding the loss minimization measures on those already identified stages of the harvest loss through a workshop, seminar, and training is very crucial.

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APPENDIX I

Questionnaires for the Evaluation of Haricot Bean Losses incurred through various Storage and Handling Methods of Small-Scale Farmers in Rift Valley around Adama Town.

Farmer's Name______________________________

Village_____________________________________

1. Level of Education: a) Primary School b) Secondary School c) High School d) College Graduate
2. States of the farmers: a) Privateb) Cooperativec) Union d) Other
3. What are the methods of harvesting?

   a) Machine b) Hand Pick

   c) Sickle d) Other
4. What is the ecological status of the storage area?

   a) Plain b) Mountainsc) Forest d) Sloppy
5. Type of Store:

   a) Pit d) Concrete g) Metal

   b) Wooden e) Sack h) Others

   c) Mud brick f) Basket
6. Shape of Store:

   a) Square c) Round

   b) Rectangle d) Others
7. What is the estimated life (in years) of the store? _______-
8. What is the estimated cost (in birr) of the store? ________
9. The general standard of the store construction:

   a) Good b) Average c) Poor
10. Total capacity (in quintal) of the store: _______________
11. Description of structure defects of the store (if any): _________________

    ____
12. How do you clean your store before storing your bean? ____

    ____
13. In what Month(s) is the haricot harvested? __________________________________
14. Method of threshing used:

    a) Machine c) Animals

b) Stick d) a, b, and c

15. Method of cleaning Used:

a) Machine b) Windc) Hand

16. Method of drying used:

a) Machine b) Sun c) a and b

17. How do you know when the crop is dry enough to store? ____

18. How is the crop transported from the field to threshing area? ________________ ____

19. What is the time gap between harvesting and threshing? ____________________

20. How long do you store your haricot bean? ______________________________

21. Do you store new grain on the top of old grain? ___________________________

22. For what purpose do you store the grain?

a) For food b) For sale c) For seed

23. Amount (in kg of the crop in the store used for food. ____________________

24. Amount (in kg) of the crop in the store used for seed. ____________________

25. Amount (in kg) of the crop in the store used for sale. _____________________

26. Pattern of removal of the crop from store:

a) Once a day c) Once a month

b) Once a week d) Other

27. Amount of crop (in kg) removed from the store on the pattern used: _______________

28. Do farmers sell as much as they can as soon as possible and risk buying back later in the season? If so, is this due to heavy storage loss or to shortage o capital or some other reasons?____ ____

29. What type of pests attack the crop in the store?

a) Insects d) a and b g) Other

b) Rats e) a and c

c) Mices f) b and c

30. At what time of the year are the pest attacks worst?

a) At the begging of the storage period

b) During the storage Period

c) Towards the end of storage period

d) At any time

31. How do you protect your store from insects?

a) By traditional methods

b) By Chemicals

c) By other methods

32. If the answer to question 31 is a), what type of traditional methods are used? ____

33. If the answer to question 31 is b), what type of Chemicals are used and what are the dosage?____

34. Do you control rodents? ____

35. If the answer to question 34 is "yes", what type of control methods are used?

____

36. Do you have a problem of crop spoilage doe to much moisture? __________________

37. If the answer to question 36 is "yes", which part of the store does the most spoilage occur?

a) Top b) Bottom c) Side of the wall

38. What is the total estimated crop loss (in kg) during storage? ____________________

39. What type of improvement would you like to make to the store? _________________

____

40. Do you use ventilated storage? a) Yes b) No

41. Do you use storage to store your haricot bean? a) Yes b) No

APPENDIX II

Laboratory results of physicochemical properties of twelve months stored haricot bean

Table 1. The temperature of haricot beans in metal bins and sacks (°C)

Duration (Months)	Storage Structures							
	Metal bin				Sack			
	T_1	T_2	T_3	T_{av}	T_1	T_2	T_3	T_{av}
0	22	21.5	22	21.83	22.5	22.7	22.1	22.43
3	20	21	21	20.67	23	24	23	23.33
6	24	23	22	23	24.5	25	25.5	25.4
9	26	25	24	25	26.8	26.5	26.7	26.67
12	25.8	26	26.5	26.1	27.9	27.8	27.7	27.8

Table 2. The moisture content of haricot beans in metal bins and sacks (%)

Duration (Months)	Storage Structures							
	Metal bin				Sack			
	M_1	M_2	M_3	M_{av}	M_1	M_2	M_3	M_{av}
0	9.5	9.5	9.6	9.55	9.6	9.8	9.7	9.7
3	9.7	9.9	9.5	9.7	9.9	9.8	9.9	9.86
6	10	10.2	10.3	10.16	10.5	10.6	10.7	10.6
9	10.8	10.3	10.5	10.53	11	11.2	11.5	11.23
12	11.5	11	11.9	11.46	12	12.5	12.7	12.4

Table 3. The germination rate of haricot beans in metal bins and sacks (%)

Duration (Months)	Storage Structures							
	Metal bin				Sack			
	G_1	G_2	G_3	G_{av}	G_1	G_2	G_3	G_{av}
0	98	96	97	97	98	98	97	97.67
3	85	83	84	84	82	83	81	82
6	70	72	73	71.67	65	67	66	66
9	51	53	50	51.33	48	46	44	46
12	29	31	29	29.67	23	22	20	21.67

Table 4. The weight loss of haricot beans in metal bins and sacks (%)

Duration (Months)	Storage Structures							
	Metal bin				Sack			
	W_1	W_2	W_3	W_{av}	W_1	W_2	W_3	W_{av}
0	1.42	1.43	1.5	1.45	1.5	1.52	1.7	1.57
3	2.4	2.6	2.8	2.6	2.5	2.9	2.7	2.7
6	3.5	3.7	3.9	3.7	3.9	4.1	4.2	4.07
9	5.5	5.9	5.8	5.73	6.5	6.7	6.2	6.46
12	9.6	9.5	9.8	9.63	10.5	9.8	10.3	10.5

Table 5. Impacts of SS on the proximate compositions of haricot beans

Duration (Months)	**Storage Structures**							
	Metal bin				**Sack**			
	Moisture (%)	**Ash (%)**	**Fiber (%)**	**Protein (%)**	**Moisture (%)**	**Ash (%)**	**Fiber (%)**	**Protein (%)**
0	9.55	4.1	7.09	18.9	9.7	4.05	9.2	18.32
3	9.7	4.2	7.11	19	9.86	4.4	9.4	18.5
6	10.16	2.4	7.2	19.1	10.6	4.06	9.3	18.1
9	10.53	4.3	7.7	18.2	11.23	4.11	9.4	18
12	11.46	4.4	7.6	18.7	12.4	4.12	9.6	18.11

Table 6. Impacts of storage structures on the TKW of haricot beans (g)

Storage Structure	**Storage Duration (Months)**				
	0	**3**	**6**	**9**	**12**
Metal bin	184	174	171	170	165
Sack	184	172	170	169	166

Appendex III. Haricot bean seeds after different Months of storage

Figure 1. Measurement of haricot beans TKW

Figure 2. Haricot bean seeds before storage

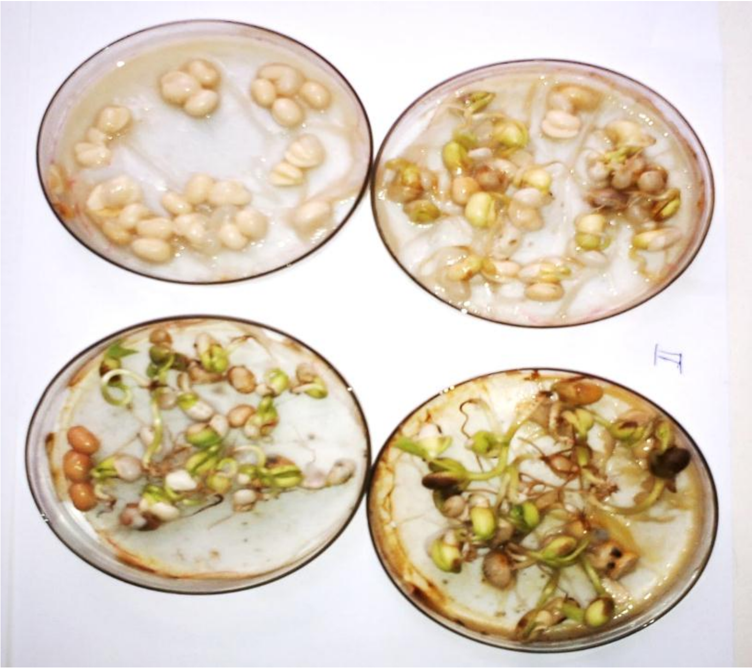

Figure 3. Haricot bean seeds after three months of storage

Figure 4. Haricot bean seeds after six months of storage

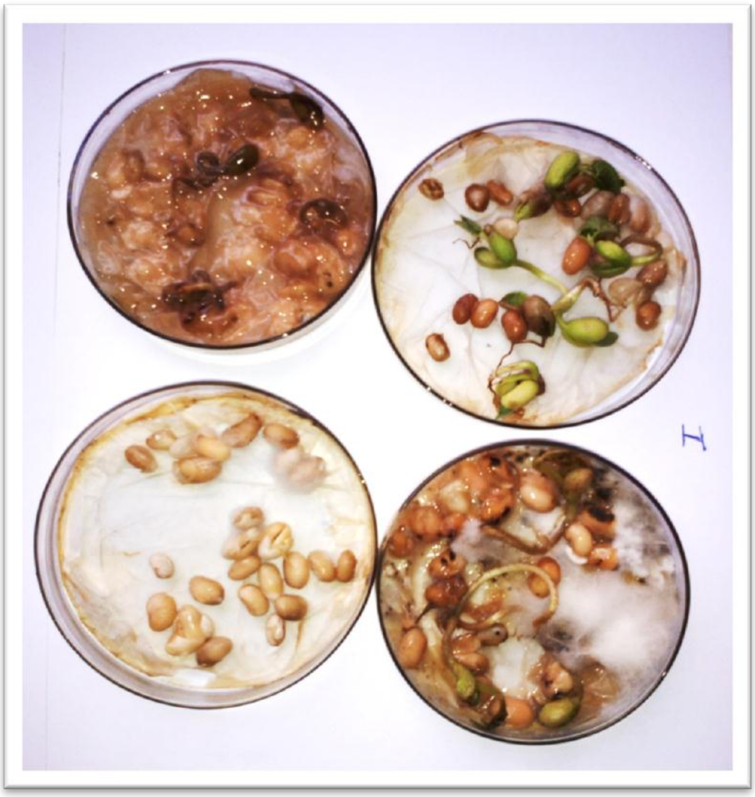

Figure 5. Haricot bean seeds after nine months of storage

Figure 6. Haricot bean seeds after twelve months of storage