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Reducing Post Harvest Loss of Maize by Manufacturing and Introducing of Air Tight Silos Grain Storage in Selected Areas of Tigray, Ethiopia

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

The economy of Ethiopians depends chiefly on agriculture. The major staple grains are the most important field crops and the chief element in the diet of most Ethiopians. Maize is the largest and most productive crop in Ethiopia. In 2007/08, maize production was 4.2 million tons, 40 percent higher than teff, 56 percent higher than sorghum, and 75 percent higher than wheat production. Postharvest losses are major problem in enhancement of maize production. The main controlling mechanism to avoid these losses is using appropriate grain storage. As FAO introduced stated household metal silo is a key post-harvest technology in the fight against hunger and for food security. The house hold air tight metal silos generally hold between 100 and 3 000 kilos. The objective of this activity is to minimize post-harvest losses of maize grains by introducing this airtight silos in selected wordea's of the region.

Different air tight silos were manufactured according the SDC Manual for Manufacturing Metal Silos for Grain Storage in MAMRERC workshop. Preliminary test was conducted to check air leakage and strength of welding of the silo. Farmers were selected based on the willingness and resource they have. Weight loss, relative humidity, temperature, moisture content, count breakage from 1000kernel and insects occurred and farmer's perception was collected in compiring with tradition silo and plastic bag.

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From these the air tight silo has low weight loss form 125gm initially and after recorded for six months the weight reduces to 122.6, 114.35, and 112.25gms respectivly. The moisture of maize grain decrease from 13% have different in the three containers 26.48, 28.72 and 27 and difference of -0.52, 1.72, and 0 and average Relative humidity's are 7.96, 4.96, and 3.96 for metal silo, traditional Gottera and plastic bag respectively. The counted and damaged from 1000 kernels are high in plastic bag and traditional silo. the farmers perception in relative advantage and characteristic of the silo are good.

Keywords: Air tight silo; plastic bag; storage; Gottera; weight loss; relative humidity; moisture content and temperature.

1. INTRODUCTION

1.1 Background and Justification

Two-thirds of the people in eastern and southern Africa live in rural areas where they make a living from agriculture, often from degraded and marginal lands, with little opportunity to diversify incomes through additional employment in non-farming activities [1]. Ethiopia is primarily an agricultural country and its economy depends on the agriculture sector [2] Just when crop cultivation started in Ethiopia has not been determined, but its long history is also reflected in the high agricultural biodiversity, including endemic crops, the best known of which is the cereal teff (Eragrostis tef). The high diversity in crop species and genetic diversity within crops is a reflection of the environmental and cultural diversity of Ethiopia [3,4].

Ethiopia's major staple grains are the most important field crops and the chief element in the diet of most Ethiopians. The principal grains are teff, wheat, barley, corn, sorghum, and millet. The first three are primarily cool-weather crops cultivated at altitudes generally above I,500 meters. Teff, indigenous to Ethiopia, furnishes the flour for injera, unleavened bread that is the principal form in which grain is consumed in the highlands and in urban centers throughout the country. Barley is grown mostly between 2,000 and 3,500 meters (Thomas. et al, 1991) [5].

Postharvest loss, the quantitative and qualitative loss of food value in food crops until they reach the consumer, is a leading cause of food insecurity in sub-Saharan Africa (SSA) [6]. In Eastern and Southern Africa alone, postharvest loss (PHL) of grain can be valued at US$1.6 billion/year, or about 13.56% of the total value of grain production in the region, and could potentially reach nearly US$4 billion/year in SSA out of an estimated annual value of US$27 billion [7].

Maize is the largest and most productive crop in Ethiopia. In 2007/08, maize production was 4.2 million tons, 40 percent higher than teff, 56 percent higher than sorghum, and 75 percent higher than wheat production. With an average yield of 1.74 tons per hectare (equal to 3.2 million tons grown over 1.8 million hectares) from 1995 to 2008, maize has been the leading cereal crop in Ethiopia since the mid-1990s in terms of both crop yield and production [8].

Sorghum, millet, and corn are cultivated mostly in warmer areas at lower altitudes along the country's western, southwestern, and eastern peripheries. Sorghum and millet, which are drought resistant, grow well at low elevations where rainfall is less reliable. Corn is grown chiefly between elevations of I,500 and 2,200 meters and requires large amounts of rainfall to ensure good harvests (Thomas et al, 1991) [9]. These three grains constitute the staple foods of a good part of the population and are major items in the diet of the most peoples in the region and country.

Most farmers in our region are most notably the low-income, Post-harvest losses (PHL), which can and do occur all along the chain from farm to fork resulting in higher prices and lost revenue which reduces real income for producers and consumers and especially the poor, since such a high percentage of their disposable income is devoted to staple foods. It is now increasingly realized that reducing PHL along food chains can, in certain cases, provide a more cost-effective and environmentally sustainable means of promoting food and nutrition security than investments focusing on increasing production.

In developing countries, lack of appropriate grain storage technologies leads up to 20-30% losses, particularly due to postharvest pests and insects. As a result, smallholder farmers end up selling their grain soon after harvest, only to buy it back at an expensive price just a few months after harvest, falling in a poverty trap. The potential impact on poverty reduction and greater livelihood security will not be realized if farmers are unable to store grains and sell surplus production at attractive prices [10,11].

Postharvest losses, also have an impact on environmental degradation and climate change as land, water, human labor and non- renewable resources such as fertilizer and energy are used to produce, process, handle and transport food that no one consumes. Apart from causing quantitative losses, pests in stored grain are also linked to a flay toxin contamination and poisoning.

However, an increase in land productivity without corresponding increases in storage, processing and preparation of nutritious foods from the excess harvest may worsen postharvest losses at a greater magnitude than 40% [10] Christopher 2017. Therefore, there is debate whether or not agricultural intensification will improve or worsen food insecurity and poverty of households who lack the capacity to preserve excess production; majority of smallholder are in this category.

A possible higher cost of intensification and less revenue caused by higher postharvest losses may further aggravate poverty. Hence, improving the capacity of smallholders' to process and store farm outputs and also produce nutrient-dense foods for household consumption is a precondition for reducing poverty, hunger and malnutrition among intensifying farming communities.

As FAO 2008 stated household metal silo is a key post-harvest technology in the fight against hunger and for food security. It is a simple structure that allows grains to be kept for long periods and prevents attack from pests such as rodents, insects and birds. If the grains have been properly dried (<14 percent moisture in the case of cereals and <10 percent in the case of pulses and oilseeds) and the household metal silo is kept under cover, there are no problems of moisture condensation in its inside. Household metal silos generally hold between 100 and 3 000 kilos. A household metal silo with a capacity of 1 000 kilos can conserve the grain needed to feed a family of five for one year.

The air tight silos were introduced as part of effective grain storage project in different countries; Kenya, Malawi in 2012 which is being scaled up by the International Maize and Wheat Improvement center. And our center aims to identifying best practices and innovative arrangements for increasing agricultural productivity in ways that improve income and nutrition of farm households through introducing this silo.

This research focuses on adding value to farmers through knowledge and institutional innovations that increase food and nutritional security of the poor and vulnerable groups farmers in selected sites first and the whole region as well as country. The approach included developing the value chains for priority crops within a diverse farming system by enhancing the rural agro-processing and storing system sector and building the capacity of farmers, mostly women, to produce nutritious food for home consumption and for the market. to do this our center like to manufacture air tight silo in different werdas of our region.

Fig. 1. Air tight silos [12]

1.2 Objectives

1.2.1 General objectives

- To minimize post-harvest losses of grains (maize and sorghum) by introducing this airtight silos in selected wordea's of the region

1.2.2 Specific objective

- To manufacture and introduce of air tight silo to selected farmers
- To participatory evaluate air tight silo in maize and sorghum

2. MATERIALS AND METHODS

2.1 Data Type and Data Collection

The data were collected between January and June, 2018 in the district of (*Laelay adyabo*) north western of Tigray region. The major commodity observed was maize and the major data are:

- Quantitative (weight loss, moisture content loss, difference in temperature and number of damaged kernels from selected sample of 100 gm) and;
- Qualitative (physical observations, existing of pest or other damages, color change, internal temperature in the air tight silo).

The data's was collected using hygro meter and digital moisture tester for temperature and relative humidity, digital weighing balance for weight of 1000 kernels and reduction of weght. Structured data recording sheet was prepared to collect the data's three times a day.

2.2 Manufacturing of Silos

Different sized air tight silos were manufactured based on Swiss Agency for Development and Co-operation / SDC Manual for Manufacturing Metal Silos for Grain Storage published in 2008 detail design and calculations. Four different sized silos (two, four, six and eight quintal) were manufactured in Mekelle Agricultural Mechanization and Rural Energy Research Center (MAMREREC) work shop. The size of the silos based on the resource of farmers, four type of silos in each site was manufactured and distributed to the selected farmers as show in Table 1.

Table 1. Different size and cost of air tight silos [13] and MAMREREC, 2018

s/n	Description	Capacity	Estimation cost in (birr)
01	Silo (dia. 60.1cm, height 1.00m)	200k.g	990birr
02	Silo(dia.79.5cm, height 1.14m)	400k.g	1630birr
03	Silo (dia.87.1cm, height 1.44m)	600k.g	2270birr
04	Silo(dia 87.1cm, height 1.82m)	888k.g	2910birr

Fig. 2. Manufacturing of different sized air tight silos manufactured in MAMREREC, 2018

Fig. 3. Giving training to selected farmers and Developmental Agents (DAs) in T/adyabo and L/adyabo destricts, 2018

- Primary test was done in MAMREREC work shop to check if there are leakages of air in and out and strength of welding using candle light and charcoal fumigation system.
- 16 farmers was selected from the woreda's and training was given to them and 4DAs in each selected tabias

2.3 Sampling Size

The experiment had three Treatment set in each selected farmers in L/adyabo district of maize as shown in the table below. The treatments stay for six months in each areas. Have collected farmers perception, on over all characterstics or nature of the air tight silo using selected technical parameters.

Sample	Treatment
A	A1
	A2
	A3

Where A Adi dearo maize with A1,A2,A3 are traditional storage made from cow dang, plastic bag and Air tight silo.

3. RESULTS AND DISCUSSION

From the selected treatments and collected data's; the analysis has been conducted for six months on maize. The experiment was conducted in *L/adyabo, adi kokeb tabia* in Air tight silo, Traditional silo *'gottera'* and plastic bag. The major criteras to be measured in this task was weight loss, Mosture content difference of maize grain, relative humidity (RH) and temperature diference (Temp °C), number of and percentage damged maize kernels from 1000kernel, and existing of pests in the given period of time.

3.1 Weight Loss

From the fixed container taken of samples selected in each treatment minimum weight loss recorded in air tight silo due to the silo protects from unwanted heat and conserves moisture of the grain. The fixed container weighs 125gm initially and after recorded for four months the weight reduces to 122.6, 114.35, and 112.25gms for air tight silo, traditional silo, and plastic bag respectively in maize. And the observed weight in a given period of time is recorded as shown in the table below in three treatments for maize and two treatments in sorghum. the major causes of weight loss in maize grain are changing in MC%, change in relative humidity and temperature as shown in section 3.9 of Table 4 person correlation.

3.2 Moisture Content Loss of Maize Grain

Maize storing in air tight silo have low decreasing of MC%, but high in plastic bag and tradaational silo. In the six months the reduction of MC% was as indicated in Fig. 5. There is fluctuation of MC% in different weeks but in most cases there is uniformly reduction in the storages. The MC% of the samples was recorded using digital moisture tester and initially the stored maize grains had 13% moisture content; and after 25 weeks the moisture decrease to 11.73, 8.5 and 7.3% in air tight silo, traditional silo and plastic bag respectively.

During the field experiment, we observed high moisture condensation under the lids of some metal silos, Increase in maize grain MC% during storage could negatively affect grain quality and seed viability [14]. Cellular respiration of grain and insects within the container to use some of the stored glucose and available oxygen metabolically would lead to the production of CO2, water and energy (Adenosine triphosphate, or ATP) [15]. So reducing of MC% causes to quality and weight loss of maize. The improved storage/air tight silo is aproprate technology to store maize grain, because of low in loss of moisture.

3.3 Relative Humidiy and Temperature Difference

As shown in Table 2 The temperature difference (Temp in °C) and relaive humidity (Rh in %) in the storages in comparation with room temperature was recorded with help of hygrometer. The three treatments are storages without pestsides during the whole storring period.

The room temperature of L/adyabo, Adi kokeb site was 27°C and average temperature of air tight silo, Tradational silo '*gottera*' and plastic bag were 26.48, 28.72 and 27 and difference of -0.52, 1.72, and 0 respectivly for respectively through out the whole experiment season. So air tight silo minimize temperature by 0.52 from room temperature and traditional silo have negative impact on temperature. The higher average temperatures suggest that the heat was most likely generated by high insect populations inside the container and there are tendencies to form insects in traditional silo.

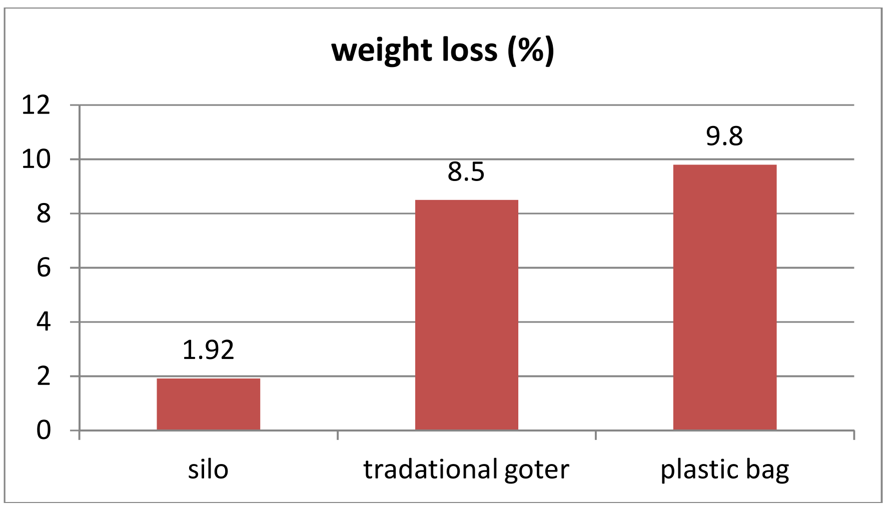

Fig. 4. Weight loss in % age from 125 gm fixed container in six months

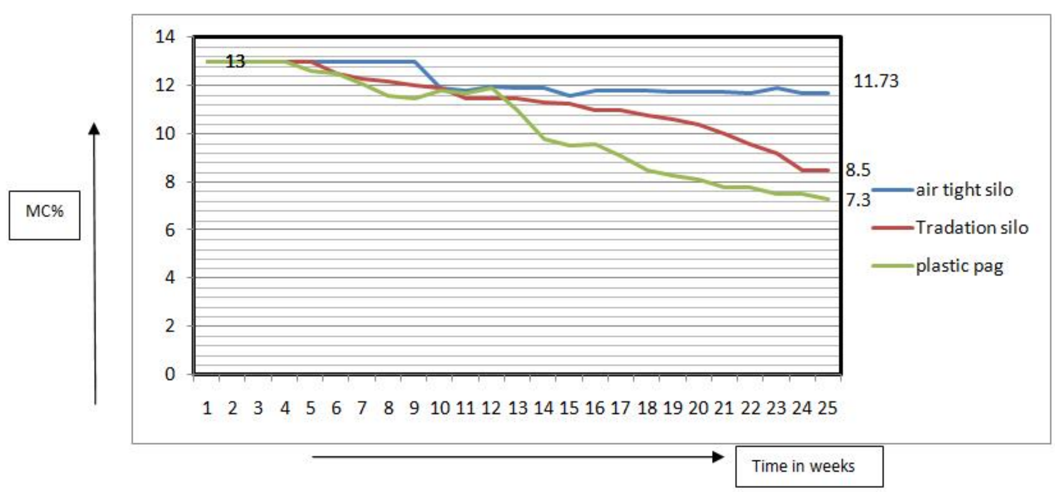

Fig. 5. Moisture content variation in the given period of time

The relative humidity in six months the average Relative humidity's of the containers are 7.96, 4.96, and 3.96 for metal silo, traditional Gottera and plastic bag respectively. The data recorded in three times per day during data collection (morning, noon and after noon).

As Chiappini et al. [16] and Baoua et al. [17], stated the Sahelian agroecology with relatively higher temperatures (e.g., 28-39°C) and low humidity (e.g. < 20%) may increase the oxygen demand and desiccation of insect pests such as *T. castaneum* leading to high mortality, the environmental conditions found at the at all the experimental storages in L/adyabo seem to be less harsh for the spoilage and insects.

3.4 Number of Damaged from 100gm Kernels

During the data recording time 100 gm sample of kernels were taken randomly to count number of damaged grains in each commodity. And from this research have get more damages in traditional silo 'gottora' and plastic bag; the causes were due to eaten by rat, termite and pests. The degree of damage and damaged kernel numbers are summarized in the Fig. 6. The broken kernels doesn't mean lost (out of use) untile they have not spoil or forming unwanted odurs and color change. They used for own food consumption but reduce market price.

3.5 Physical Observation

From the selected treatments have been observed some of the grains forms molds like and change colors. But most of them have not change physically

3.6 Existing of Pests and Other Damages

Of the observed pests and other are; pests in three samples one in air tight silo and two in traditional silo, damaged by termites in two samples of plastic bag, three samples were damaged by rat in traditional silo and plastic bag, and two samples damaged by unknown flying insects or rodents like. Pantenius [18] estimated 0.2%–11.8% weight loss due to insect infestation in maize after 6 months of storage in traditional granaries in Togo. Metal silo was the most effective option in controlling pest infestation, metal silo was equally effective in controlling pest infestation even without any insecticide use [19].

3.7 Farmers Perception

From the selected 15 farmers we have collected their perception one how to use, the advantages they get from the silo in comparing with the two types of local storages. Have been collected data's based on questioner developed; the questioner including advantage and disadvantage, cost in comparing with traditional storages, comfort, place need for the silo set, in term of health, durability, availability of construction material. The detail analysis was as shown in the Table 3.

3.8 Pearson Correlation of the Storages

The correlation between weight loss % in relation with change in relative humidity (±0.057) and temperature (± -0.021) have no significulnt difference with different storing time but high significant difference in the storing technologies (±0.344), Moisture content (±-0.399), damaged weight and damaged counted from 1000 kernels in 95 and 99% confidence interval as shown in the Table 4 below. The moisture content of the graine have high significant difference with respect to Relative humidity (±-0.454), change in temperature (±0.470), and type of technology (±-0.460). damamged weight percentage of maize grain also have high significant difference with respect to Relative humidity (±-0.307), change in temperature (±-0.304), and type of technology (±-0.375). damaged counted from 1000 kernels have high significant difference with respect to Relative humidity (±-0.319), change in temperature (±-0.378), and type of technology (±-0.459).

Table 2. Relative humidity and temperature inside and outside the conteiners in six months

Type of technology	Temp in	Temp out	Temp change	Rhin	Rhout	Rhchange
silo	26.48	27	-0.52	32.96	25	7.96
tradational goter	28.72	27	1.72	29.96	25	4.96
plastic bag	27	27	0	28.96	25	3.96

Table 3. Summery of farmer's perception analysis from interview

Parameters	Number of respondents	Response		Percent (%)
		Yes	No	
Highly divisible/easily triable	15	13	2	93.33
Strongly observable results	15	14	1	100.00
A short response lag time	15	15		86.67
Low complexity	15	13	2	-
Low cost	15		15	86.67
Low risk of failure of the trial	15	13	2	93.33
Well implemented trial	15	14	1	86.67
Innovation similar to normal practice	15	13	2	100.00
Strong linkage between the landholder's practices (and thus innovation) and the problem being addressed.	15	15		100.00
Gender neutral	15	15		86.67

Table 4. Person correlation of the storing technologies under different treatments

Pearson correlation	weight loss in Kg	MC in %	change in RH	change in Temp oC	damaged weight in %	Damage counted from 1000 kernel/ %/	type of technology
weight loss in Kg	1	-.399**	.057	-.021	.373**	.352**	.344**
Sig dif		.000	.629	.861	.001	.002	.003
moisture content in %	-.399**	1	-.454**	.470**	-.854**	-.883**	-.460**
Sig dif	.000		.000	.000	.000	.000	.000
change in relative humidity	.057	-.454**	1	-.664**	.307**	.319**	.000
Sig dif	.629	.000		.000	.007	.005	1.000
change in temperature in oC	-.021	.470**	-.664**	1	-.304**	-.378**	.000
Sig dif	.861	.000	.000		.008	.001	1.000
damaged weight in %	.373**	-.854**	.307**	-.304**	1	.925**	.375**
Sig dif	.001	.000	.007	.008		.000	.001
damage counted from 1000 kernel/ %/	.352**	-.883**	.319**	-.378**	.925**	1	.459**
Sig dif	.002	.000	.005	.001	.000		.000
type of technology	.344**	-.460**	.000	.000	.375**	.459**	1
Sig dif	.003	.000	1.000	1.000	.001	.000	

***. Correlation is significant at the 0.01 level (2-tailed) *. Correlation is significant at the 0.05 level (2-tailed)*

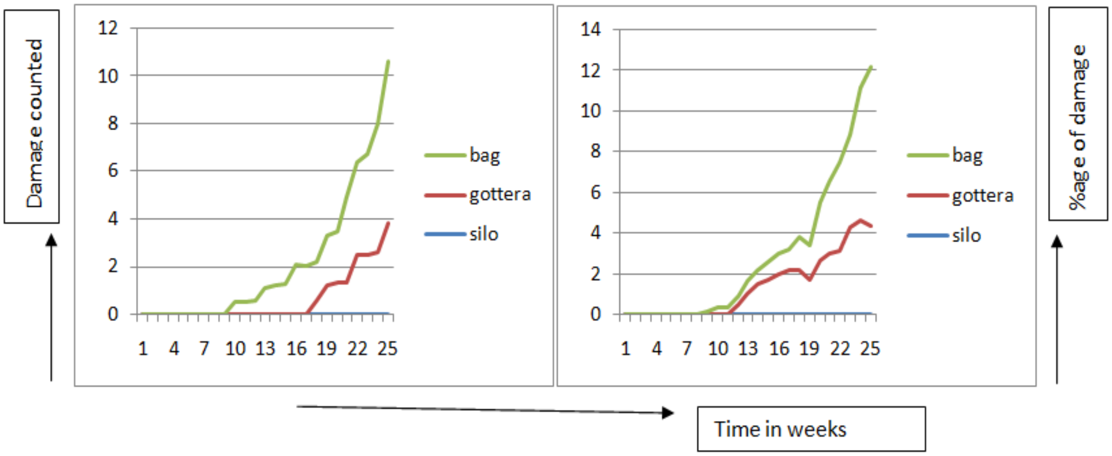

Fig. 6. Damage counted from 1000 kernels and %age damage kernels counted

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

This research concludes that the air tight silo is good technology for small holder's farmers to protect their product or grains from pests, rats, color change due to environmental impacts, to conserve moisture loss, and regulates temperature.

And this air tight silo have advantages in; From these the air tight silo has low weight loss in comparing with traditional silo and plastic bag 125gm initially and after recorded for six months the weight reduces to 122.6, 114.35, and 112.25gms respectivly. The moisture of maize grain from 13% decrease to 11.73, 8.5 and 7.3% in the three containers respectively. Relative humidity and temperature have different in the three containers 26.48, 28.72 and 27 and difference of -0.52, 1.72, and 0 and average Relative humidity's are 7.96, 4.96, and 3.96 for metal silo, traditional Gottera and plastic bag respectively. The counted and damaged from 1000 kernels are high in plastic bag and traditional silo. the farmers perception in relative advantage and characteristic of the silo are good.

Air tight silo have good advantage in controlling weight loss, preserving Relative humidity and optimizing Temperature in comparing with traditional gutter and plastic bag. The kernels of maize have low broken and low weight loss in air tight silo. The grain in traditional Gotera and plastic bag have lost due to pests and rats but in case of silo it was protected. The air tight silo is easily manufacturing by local manufacturers, easily adoptable and high advantage. The containers have high significance difference in all parameters.

4.2 Recommendation

The recommendation from this research is:

- Due to air tight silo is a good technology to preserve grains for six months in comparing with traditional silo and plastic bag it should have to scaling up to small scale farmers potential produce maize and other grains.
- Prepairing detail training to local manufacturers on how to manufacture air tight silo and making farmers easily availability of the material in their district and kebele.
- Additional cost benefit analyisis, relative advantage and other socioeconomic issues of air tight silo with respect to traditional silo and plastic should analysis in the demonstrating the technology.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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