

Post Harvest Corn Handling for Improving Quality and Competitiveness

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Abstract. The awareness and knowledge of postharvest losses at the farm level is still very low, so it is necessary to conduct research to determine the application of postharvest technology at the farm level. The research was conducted from January to December 2017 in Minahasa, North Minahasa and South Minahasa districts. The results of the study showed that each stage of postharvest treatment varied from 5% of conventional and 1.92% of introduced technology. The use of postharvest BB shelling tools with an operating time of 9 minutes/100 kg with an operational cost of 187,800 IDR/ha, results in a loss of yield of about 0.8%, peeled corn sheller with an operating time of 10.25 minutes/100 kg and an operating cost of 213,400 IDR/ha lost yield of 0.95%, compared to traditional shelling tools with an operating time of 130 minutes/100 kg and operational costs of 1,354,100 IDR/ha, yield loss of 0.2% lower but high labor costs. The use of a dryer with a capacity of 3 - 4 tons with a drying time of 12-17 hours can save the labor cost of 2 working days (200,000 IDR) when compared to a sun dryer, the yield loss is 0.1-0.2%. Dry shelled maize, rice, and corn bran stored for 3 months have not experienced a significant change in moisture content, with the control treatment, the use of zeolite, activated charcoal, quicklime, turmeric powder and fragrant lemongrass powder. The use of activated charcoal and zeolites can inhibit changes in moisture content and the growth of *Sitophilus zeamais*.

1 Introduction

Corn commodity has a very strategic role, both in the food security system and as the driving wheel of the national economy. In the next five years the demand for corn for the food, feed, and other industrial needs is projected to continue to increase along with population growth.

Indonesia's population growth rate per year is 1.49 percent and the population is projected to increase by around 3.5 million people each year. In addition, the increase in corn demand is also driven by an increase in community income which has an impact on increasing purchasing power, especially for meeting the need for chicken meat [19]. Corn demand continues to increase directly proportional to population growth, as a result of increased food needs, consumption of animal protein and energy [41].

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Therefore, the Government is trying hard to increase its production through the expansion of planting corn through the Gema Palagung program with a target within the period 2005 – 2015, there will be an additional harvest area of 456,810 ha and the Special Efforts Program [19].

The increase in corn production cannot be separated from its post-harvest activities. Post-harvest corn activities include harvesting, transportation, drying, threshing and storage [2]. The amount of losses in post-harvest corn activities (not included in storage activities) varies from 1.2 - 5.2% of losses due to scattered and 5-10% due to quality losses. Based on data from the Post Harvest Directorate (2013), the magnitude of the post-harvest shrinkage corn base rate is 5.20%.

Harvest and drying times affect the number of corn kernels that are not suitable for human consumption, with a loss of 3.6-11.2% [15]. The rate of loss or yield loss due to rodents worldwide is estimated to be at least 30% [21] Furthermore; [48] yield losses by rodents of up to 35% of grain stored; It is almost similar to the conclusion drawn by [23] that rodents significantly contribute to yield losses, namely about 1.3 million tonnes of food loss each year.

The harvested area of corn in North Sulawesi Province in 2014 was 80,8127,475 ha with a production of 488,362 tons. If the post-harvest losses are 5.20%, the yield loss will be 2,539 tons of corn. This figure is quite large and could reduce the self-sufficiency target for corn in North Sulawesi. This means that the post-harvest stage plays an important role in reducing yield losses. In connection with the increasing demand for maize, post-harvest handling techniques must be implemented properly, so that the maize produced is of high quality, and has an impact on a relatively high selling price [2]. The use of post-harvest equipment is a must in terms of reducing yield losses and improving quality and shortening work time [39].

Through the study post-harvest corn handling in North Sulawesi, it is expected to be able to analyze the system and process of post-harvest corn that has existed in North Sulawesi, can reduce yield losses and produce good quality corn, as well as get relatively high selling prices. The introduction of post-harvest equipment is expected to overcome labor constraints in corn farming, suppress yield loss and improve quality in order to increase corn farm income.

2 Materials and Methods

The assessment activities were carried out in the corn center areas in North Sulawesi, namely Minahasa, North Minahasa and South Minahasa districts. The storage study was conducted at the BPTP Laboratory. The assessment is carried out from January 2017 to December 2017.

The assessment materials are in the form of corn plants, packaging materials and other supporting materials. The equipment used were corn harvesting tools, threshing tools, dryers, dry shelled corn storage equipment and tools used in packaging and other assistive devices.

2.1 Research stages:

- a. Secondary data collection in related institutions in the form of area, harvest, production and productivity of corn as well as the level of corn consumption and market prices
- b. Primary data collection; Data is collected in the form of postharvest stages that have been carried out, the technology used, the equipment used. Data was collected at the farmer group level and the BPP level through structured interviews and questionnaire.

For data collection yield losses on each component: harvesting, threshing, drying, storage and packaging. Data collection in the field by taking random samples and interviews. Interviews were conducted in groups and individual community members who have expertise and social status such as community leaders, and other community members who have knowledge of corn farming and corn agro-industry activities through "open ended" interview techniques.

- c. Identify the needs of farming tools by paying attention to agronomic aspects: cultivation techniques, cropping patterns, climate patterns of distribution of types of activities in a year, distribution of the number of workers per hectare needed, distribution of available labor and its capacity and volume of work to be worked on. Economic aspects: investment in labor costs and materials needed. Technical aspects: type and capacity of agricultural machinery to be used, estimated rest periods, estimated service life, after sales service support, farm credit availability and other financing systems.
- d. The study was conducted in one of the farmer groups that can be applied after harvesting equipment. The treatment applied was the response of the sheller and dryer to some types of corn varieties and the variation of operating time. The suitability test of agricultural machinery includes: functional test, verification, and adaptation test on a large scale so that the machineries are technically, economically and socially feasible.
- e. Storage of corn kernels, corn rice and rice bran using zeolite absorbent material, Calcium oxide, activated charcoal, citronella powder and turmeric powder with a composition of 20% of the weight of the material. 1 kg of material is packed using 0.08 mm Polyethylene. The material is then stored at room temperature. Observations were made on the water content and the presence of *Sitophilus zeamais* beetles at 0 months, 3 and 6 months of storage.

2.2 Data collection

2.2.1 Secondary data

Secondary data collected included socio-cultural aspects of the community at the study site in general, bio-physical condition, potential yield of maize, level of knowledge about postharvest handling and the availability of agricultural machine tools.

2.2.2 Primary Data

- a. Socio-economic and cultural data obtained from structured and semi-structural interviews. The data obtained in the form of quantitative data on socio-economic aspects: labor costs, investment, materials needed while the cultural aspects: planting, harvesting and post-harvest systems. The number of agricultural machine tools needed is calculated based on the physical volume of work available minus the volume of work that can be completed with available labor and machinery [2] with the following equation:

$$UT = \frac{Ls - Lg}{Cap}$$

- UT : Agricultural machine tools needed for an activity in the region
- Ls : Work Volume
- Lg : Volume of work that can be worked on by human resources
- Cap : Capacity per unit of agricultural machine tool needed

- b. Physical and biophysical data at the time of direct observation in the field (field observation): type of harvest and post-harvest equipment, type and capacity of machineries, estimated time of use, age of machineries, availability of the financing system. Technical test data for the equipment introduced include: minimum field capacity, minimum field efficiency, fuel consumption, noise, vibration and maximum shrinkage. Data loss yields are taken at each stage: Harvest losses, shrinkage losses, drying losses [6]. Moisture content [6] Estimation of shelf life by the Arrhenius method.

3 Results and Discussion

3.1 Corn Potential in North Sulawesi

In Table 1, land area and corn production in North Sulawesi and 3 study location districts are Minahasa, North Minahasa and South Minahasa with an area of 27,533 Ha or around 34.1% of the corn land area in North Sulawesi with a total production of 102791 tons (34.21 %) and only contributes 1.5% of Indonesia's maize production. Corn ranks third after wheat and rice in cereal production worldwide [45] therefore it is an important crop in terms of food security.

Table 1. Land Area, Production and Productivity of Maize in North Sulawesi Province 2016

No.	District/City	Harvested Area(Ha)	Production (ton)	Productivity (quintal/ha)
1	Bolaang Mongondow	38,394	140,470	36.6
2	Minahasa	15,463	57,030	36.9
3	Sangihe Islands	58	225	38.8
4	Talaud Islands	112	432	38.6
5	South Minahasa	7,368	28,015	38.0
6	North Minahasa	4,702	17,746	37.7
7	North Bolaang Mongondow	3,798	14,500	38.2
8	Siau, Tagulandang, Biaro	56	215	38.4
9	Southeast Minahasa	4,760	18,158	38.2
10	South Bolaang Mongondow	285	1,101	38.6
11	East Bolaang Mongondow	1,597	6,138	38.4
12	Manado	374	1,437	38.4
13	Bitung	428	1,646	38.5
14	Tomohon	2,745	10,514	38.3
15	Kotamobago	744	2,863	38.5
	North Sulawesi	80,885	300,490	37.2

Corn contributes to energy consumption per capita and income especially in developing countries. [40] consider it a commercial crop and also a staple food for several countries. Currently, world corn production is around 10.14 billion MT [45]. The United States is the world's leading producer of maize with more than 30% following China 21%, Brazil 7.9% and Indonesia is ranked 7th in the world (2017) accounting for around 7% of the world's overall grain production.

The selling price of corn in North Sulawesi does not use applicable quality standards, causing farmers to not pay attention to the quality of corn produced at harvest. Because corn is one of the food and feed commodities with high levels of aflatoxin contamination, the HACCP approach is needed to control aflatoxin contamination [22]. To produce quality

corn, it is necessary to know the quality standards issued by the Indonesian National Standard (SNI) for both food and feed. The quality requirements of maize are free from pests and diseases, free of foul odors, acids or other odors, free of chemicals such as insecticides and fungicides, and have normal temperatures.

Corn quality standards according to SNI are divided into four quality classes. Quality I maximum water content is (14%) maximum damage is (2%), colored items, broken grains and maximum impurities content (1%) and maximum aflatoxin (5 mg / kg) [13].

[38] A decrease in grain quality can also occur due to the growth of fungi that can produce aflatoxin in high water content. So that a better drying facility is needed than relying on sun-drying during pre and post harvest. Most grain damage is due to a combination of external functions

3.2 Equipment Allocation and Tool Performance

Equipment requirements in each region can be calculated based on land area and corn production using the formula $UT = Ls-Lg / Cap$. By using this formula, the need for tools in each location can be calculated. Minahasa with a production of around 57,030 tons with an allocation of 88 units of corn sheller, each tool only works 76,018 kg / day. Minahasa with 57,030 tons of corn production, only 76 units of corn shellers are needed. Likewise, North Minahasa with a production of 17,746 tons, ideally only needs around 23 units, while South Minahasa with a production of 28,015 tons requires 37 units (Table 2). Thus, there are still many tools that work below the existing capacity. The need for a vertical dryer or flat bed dryer with a dryer capacity of 3-6 tons / day. Therefore, Minahasa requires 26 units, South Minahasa 13 units and North Minahasa 8 units. For more details, see Table 2.

Table 2. Estimated Corn sheller and Vertical Dryer requirements based on corn production

No	District /City	Harvested Area(Ha)	Production (ton)	Existing Tools		Requirement	
				Corn Sheller/ Corn Combine Harvester	Flat Bed Dryer/ Vertical Dryer	Corn Sheller/ Corn Combine Harvester	Flat Bed Dryer/ Vertical Dryer
1	Minahasa	15,463	57,030	90	7	76	26
2	North Minahasa	4,702	17,746	85	3	23	8
3	South Minahasa	7,368	28,015	85	6	37	13

In Table 2 it can be seen that the corn sheller is sufficient to even exceed the requirements, while the dryer is only fulfilled around 14%. If yield losses can be reduced by the use of a 1.9% shell and dryer machine then the additional income obtained from yield losses in the three study areas is 1.2-1.3 billion dollar.

In some areas, sales are made after harvest, this method can harm farmers because the price is low. According to [17] with respect to the law of supply and demand, if demand decreases and supply remains unchanged, it leads to lower prices [24, 14, 49, 1, 36, 11, 37, 42]. Price variations encourage farmers to save, 1% price variation is equivalent to saving 8.4 kg. Therefore, households can increase profits by storing corn until market prices improve [18].

The use of agricultural tools is a must in order to reduce yield losses. Matthews [38] asserts that losses can occur when grain is scattered or leaked, or in the bio-decay process in which the grains become rotten after fungal attack or are physically consumed by pests such as insects, rodents or birds. It involves biotic and abiotic factors which contribute very

high to the damage to the physical value of corn kernels, resulting in low selling prices. The decline in grain quality can also occur due to the growth of fungi that can produce aflatoxin in high water content. So a better drying facility is needed than relying on sun-drying during pre and post-harvest to achieve the safety of corn kernels. Most of the damage to grain is caused by a combination of various external functions.

3.3 Postharvest Shrinkage

Efforts to increase corn production must be in line with post-harvest handling because the rate of yield loss is quite high. According to post-harvest corn handling includes harvesting, shelling, drying, transporting and storing. [34, 43] reported that the shrinkage of corn yield in post-harvest activities (excluding storage) ranged from 1.2 to 5.2%. From the results of the Focus Group Discussion (FGD) and the results of the postharvest handling corn at the farm level can be seen in Table 3.

Table 3. Existing Post-harvest Technology and Crop Loss (TA. 2017)

Description	Existing	Introducing Technology	Yield Loss (%)
Harvest	Hands, when harvesting generally sees physically: corn stalk, brown color, dry leaves.	Hands, when harvesting see physically (leaves have started to dry out, brown color) and harvest age according to existing varieties 100-120 days	Shattered at harvest 0.05 - 0.1 Sheller delay 0.5-1%
Sheller	Hands Traditional wood shelled rubber-coated tire	Corn sheller	Scattered, wasted, broken by tools 0.5 - 2%
Drying	Dried by the sun using a mat Smoke with coir or corncobs 2-3 days 15% moisture content	Vertikal dryer Flat bed Dryer 8-12 hours 11% moisture content	Shattered storage time in sacks eaten by chicken 0.2 - 0.4
Transportation	Cow Wheelbarrow Motorcycle	Motorcycle Car	Scattered because the packaging leaked 0.01-0.02
Storage	Shed with mat and use plastic sacks (cob and shelled)	Plastic bag 0.08 mm polyethylene plastic Silo	Scattered while storing Pest and Disease 0,1-0,2%
Packaging	Plastic sacks	Thick plastic sacks	Scattered when packing 0,05 – 0,1
Marketing	Picked up at home by the traders KA 15% price IDR 2500/kg	Picked up at the farmer with a standard price IDR 3000 / kg KA. 13%	
Total yield loss	Overall yield loss according to farmers calculations is 5%. Production of 5 tons / ha yields a loss of 250 kg (IDR 625000 / ha)	Estimated decrease of 1% can save products of 50 kg / ha or IDR 125,000 / ha	1,92 % x 5 ton (96 kg/ ha = IDR 240.000/ ha)

In Table 3, the highest yield shrinkage occurs in the shelling process that is 0.5 -2%. But it is still lower than that reported by Ananto et al [2] which is 4.0%. Overall postharvest losses are 1.92% lower than the results of the study reported by Director General of Food Crops [19]. Likewise, the quality loss is 2-3% lower than reported by Aqil [7] which is 4%

and Director General of Food Crops [19] is 5-10%. To get quality corn kernels, the important things to consider in shelling processing are the water content of the seeds, the shape and construction of the tooth of the sheller, the distance of the tooth tip of the sheller and the rotation speed of the cylinder [43].

In general, corn storage at the farmer group level does not meet the quality requirements, besides the water content is still quite high, the storage facilities are inadequate. Storage facilities are needed to maintain the quality of corn kernels and overcome excess production during the main harvest [7].

In Table 3, the yield loss due to storage and packaging is 0.1-, 02%. Loss of yield due to inadequate storage facilities as reported by Singleton [46] stated that the amount of corn kernels lost to storage due to rodents would be sufficient to feed 7 million people for a year at a rate of 0.5 kg / day / person with a projected value of 141.7 million USD which is 11.1 USD for every 100 kg. The use of triple bags (PICS bags) was reported to reduce grain losses by 90% [16]. Apart from improved storage facilities, farmers should be well informed about safe moisture levels of grain. Balancing humidity and temperature is key to maintaining grain quality and the best price. So it is highly recommended that after harvest, it is immediately dried at a safer humidity level of 10–13% for cereals and 7–8% for oil [50]. Post-harvest losses occur along the value chain, namely harvest handling and storage (37%), processing (7%), distribution and marketing (13%), consumption 5% (Lipinski et al., 2013). In most developing countries, storage pests cause large economic losses [10].

3.4 Technical Test of Postharvest Equipment at farmers group Level

The technical test tool which is a help from the Post-harvest Center are the peeled corn sheller, traditional sheller, gas heat source dryer and sun dryer. The calculation results can be seen in Table 4.

Table 4. Observation results on the use of shellers and dryers in North Sulawesi in 2017

Type of tool	Labor (person)	Operating time (minutes / 100 kg)	Save labor (OH)	Lost Results
Post-harvest Sheller Tool	2	9,02 minutes	10 OH	0,4 - 0,8%
Peeler Sheller	2	10.25 minutes	8 OH	0,5 - 0,95%
Traditional Sheller	1	130 minutes	-	0,1 - 0,2%
Dryer	2	12 hours/3 ton	6 OH	0,1 - 0,2%
Sun Drying	1	3-4 days	-	0,1 - 0,2%

In Table 4, it can be seen that the use of a sheller can save labor of 11.43 OH for the corn sheller and 11.17 OH for the peeled corn or around IDR 1,143,000 and IDR 1,117,000, when compared to traditional sheller which is IDR 1,354,100. The advantage of a non-peeled sheller machine tool is more efficient in terms of time, the rate of damage to seeds is low (<1%) because the corn grubby can function as a cushion in the shelling process. Its capacity reaches 3.6 tons of shelled / hour for feed and 1 ton of shelled / hour for seeds with a cleanliness level of 99% [47]. The use of flat bed dryers can save up to IDR 142,000, at a cost of IDR 658,000, when compared to using a sun dryer with a labor cost of IDR 800,000. If corn production is below 3 tons, the use of tools is not recommended because farmers will experience losses with high production costs. This is the reason why farmers do not use dryers if their corn production is small.

Accelerating the drying process without increasing the temperature with a heat pump system is also cheaper to operate than traditional natural gas fueled systems and produces high quality [12]. Furthermore Aulakh [8] concluded that corn cobs with seed moisture

content of 30-33% can be dried faster at 50 ° C. Choosing a combination of high and low temperature degrees can reduce drying time compared to drying low temperatures. The best combination for drying is at 50 °C for 20 hours retains 90% sprouts. This combination saves drying time by about 21%.

The use of dryers should be used in groups to avoid wasting production costs and efficient use of tools. The use of postharvest equipment can reduce the use of labor which can reduce production costs, also reduce yield losses and can improve the quality of dry shelled corn. According to Saenong and Mas'ud, [44] the use of sheller can alleviate and accelerate the shelling process economically and efficiently, with an efficiency level of up to 95%.

3.5 Corn Storage

The results of corn storage in the form of seed, corn rice and corn bran can be seen in Figure 1.

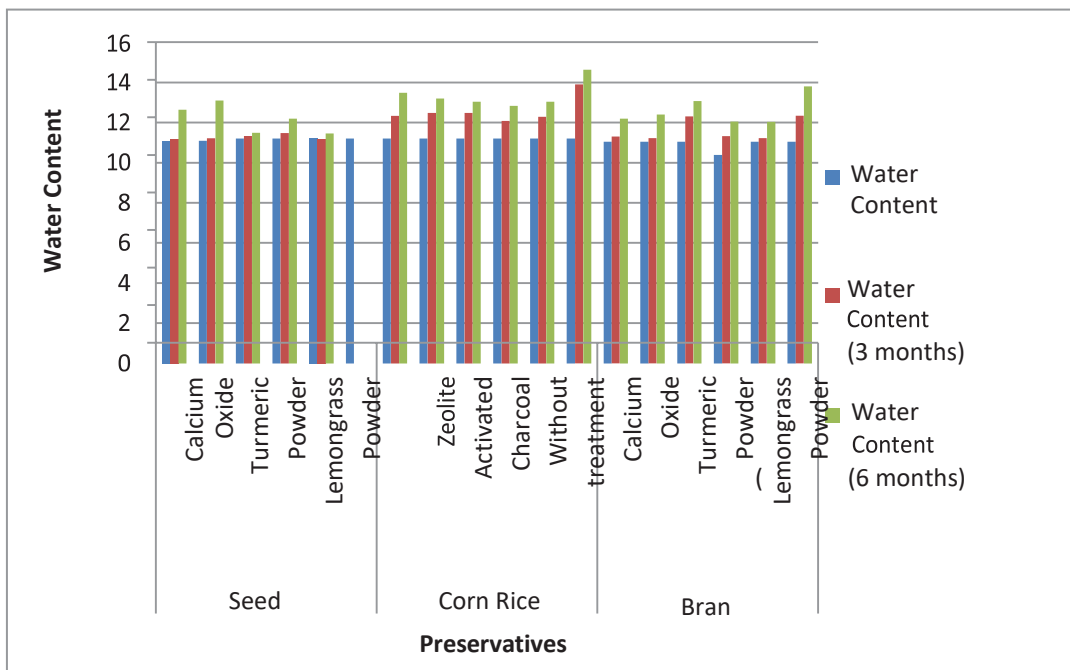


Fig.1. Effect of treatment on water content during storage

Over the last few decades, various synthetic pesticides have been applied to protect stored grain and other agricultural products from insect attack, but their massive use has had so many detrimental effects on the environment and the poisoning of non-target organisms Dhaliwal and Gurdeep. However, these chemicals are declared to be ecologically unsafe because they last longer in the environment and enter the food chain. It has been reported [31], that certain insect pests have acquired resistance to most insecticides. To overcome the bad effects of synthetic pesticides, the best alternative is to use local natural ingredients. Based on some literature and farmer information, in this study several natural ingredients that contain polyphenols are used which can repel pests and maintain moisture content because they are applied in powder and particle form [47].

In Figure 1, it can be seen that the water content increases with the length of storage time. Storage at 3 months has not shown a significant effect on water content. At 6 months

of storage, there was a significant increase in water content. This is thought to be due to the unstable heat of the storage room which causes humidity, so that water vapor is absorbed into the stored material. Storage of corn grains in closed areas leads to the formation of carbon dioxide and reduction of oxygen, due to permanent respiration. Grains are hygroscopic, they absorb and emit moisture, so they have a significant effect on grain quality and storage capacity which can increase the moisture content of the grains. To avoid this reduction in grain moisture content and storage stability is provided at 12% humidity. [3, 4, 29, 5].

Reported by Kokom [32] periodic monitoring is carried out to determine temperature fluctuations, gas composition between grains, insect infestations, and grain quality parameters. Environmental temperature has been shown to create a temperature gradient in the upper layer and migration of moisture occurs towards the peak of grain bulk. The moisture content of corn kernels stored in airtight plastic bags remained practically the same during storage, compared to levels in polypropylene packaging. Polypropylene can be used for storing corn, protecting it from insect attack without the need to use insecticides [33]. However, for all treatments, *Sitophilus Spp* pest was not found. Saenong and Mas'ud [44] reported that at 12% water content of seeds can inhibit the development of powder beetles. The development of powder beetle population will develop at water levels above 12% and will develop rapidly at 15% or more. The safe water content for storing shelled corn is below 14%. At these water levels, mold is difficult to grow and does not cause spores. Under closed storage conditions, insects and fungi combine the power to deplete oxygen from airtight stored corn to create an atmosphere unfavorable for their own survival. Corn grain moisture content is considered safe at 12% during storage. , attributed to insects not being able to develop properly [25]. It has been reported by Basavaraja [9] in India - Karnataka that the losses due to traditional drying are assessed to be 0.80 kg / 0.1 tonnes of rice and 0.66 kg / 0.1 tonnes of wheat

The use of absorbent materials such as calcium oxide, activated charcoal and zeolite can absorb excessive water content so that it does not change the water content in the stored material. Citronella powder and turmeric containing essential oils and polyphenol components that can inhibit the growth of pests as well as function as absorbents because it is applied in powder form. During storage, warehouse pests that often damage corn are *S. Zeamais*. Some research found that the weight of corn kernels stored for 6 months has decreased by 17% and the level of damage has reached 85% due to *S. Zeamais* attacks [44]. The same thing was reported by FAO [23] as the yield loss reached 9.6 - 20.2%.

The decrease in weight of corn kernels due to pests is very drastic. According to Saenong and Mas'ud [44] *S. Zeamays* pests can be controlled by using plant-based substances such as *A. Nandus* lemongrass but their effectiveness as a pesticide is relatively short. Fragrant root and lemongrass with a dose of 5-20% can suppress the population of the pest powder *Sitophilus spp* on corn seeds for 9 weeks, also can reduce the weight loss of seeds and but does not affect the ability to grow. During storage other than *Sitophilus zeamais*, pests that often attack grain are *Rhizopertha dominica* and *Tribolium castaneum* [20]. It was also reported by that the application of black pepper to corn kernels (1 g / 100 seeds) was effective in controlling *S. Zeamais* with a mortality rate reaching 80%.

4 Conclusion

Each post-harvest handling stage loses varying results. The loss of conventional methods is around 5%, introduction technology (Technological Innovation) is around 1.92%. The use of sheller and dryer can save labor 20-50% compared with manual sheller and sun dryer it also can reduce yield losses of 1.9% -3%. Dry shelled corn, corn rice and corn bran stored for 3 months have not experienced significant changes in water content either in control

(without treatment) or the use of zeolites, activated charcoal, calcium oxide, turmeric powder and lemongrass powder. Up until 6 months of storage, *Sitophilus Zeamais* has not been found.

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