ASSESSMENT OF POST HARVEST LOSS OF HEAD CABBAGE (*Brassicaoleracea* L.Var.Capitata) ALONG ITS SUPPLY CHAIN TO JIMMA MARKET AND EVALUATION OF COOLING PERFORMANCE OF THREE MODEL COLD STORAGE ROOMS

M.Sc. THESIS

BY

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MARCH 2020

JIMMA, ETHIOPIA

Assessment of Post-harvest Loss of Head Cabbage (*Brassica oleracea* L.Var.Capitata) Along Its Supply Chain to Jimma Market and Evaluation of Cooling Performance of Three Model Cold Storage Rooms

By

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M.Sc. Thesis

Submitted to the School of Graduate Studies, Jimma University, College of Agriculture and Veterinary Medicine, Department of Post harvest Management

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Food Science and Technology

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MARCH 2020

JIMMA, ETHIOPIA

DEDICATION

This thesis is dedicated to my parents, and my older brothers, Eshetu Worku and Abera Worku for all the sacrifices you made throughout my academic journey to assure I reach this far; without your encouragement and limitless support, this vision would never have become a truth.

STATEMENTS OF THE AUTHOR

I hereby declare that the thesis entitled **"Assessment of post-harvest losses of head cabbage (*Brassica oleracea* L.Var.Capitata) along its supply chain to Jimma Market and evaluation of cooling performance of three model cold storage rooms"** is an authentic record of research work done by me and the thesis has not been previously formed the basis for the award to me any degree, diploma, or certificate with similar title, of any other University and college. The users are free to use this thesis as source and duplication or multiplication of this thesis in whole or in part will be permitted by Post Harvest Management Department Head, or Dean of School of Graduate Studies of Jimma University including the author of this thesis.

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BIOGAPHICAL SKETCH

The author, Gemeda Worku Reta was born on October12, 1994inWarraJarsoworeda, and North Shoa (Salale) zone of Oromia Region. He attended his elementary school at Jarso Tuti, secondary school at Tulu Milky and preparatory school at Qarre Goha. Next to the completion of his preparatory school, he joined Jimma University College of Agriculture and veterinary medicine and graduated with B.Sc. Degree in post-harvest Management in June 2014. He engaged his own private business until he joined the graduate studies program of Jimma University College of Agriculture and Veterinary Medicine to pursue a graduate study, in Master of Science degree in Food science and technology.

AKNOWLEDGMENTS

First of all, I want to acknowledge my almighty God then my gratitude also goes to my major advisor Mr. Kumela Dibaba for his constructive opinion and guidance in all this research work. As well as my thanks are so great for my co-advisor Dr. Sirawdink Fikreyesus for his unlimited advice in conducting my thesis work. Next, my appreciation goes to the post-harvest management department in Jimma University for aids by all required laboratory materials and laboratory experts. Also, I would not like to pass without thanks to all the classmate students that they gave me limitless support; especially I want to appreciate Gizachew Merga and Hayat Hasan for their support while I was doing laboratory works.

I would also give my gratefulness to my relatives and my friends who supported and motivated me throughout my studies. My heartfelt thanks and sincere appreciation also goes to sample respondents for their inclination to scarify their time and provide unpretentious responses to questions in the schedule. Especially my gratitude is so great for Getachow Kebede who is a development agent of *Waro Kolobo* kebele for his genuinely worked with me during data collection from farmer respondents.

Finally, I would like to thanks the RELOAD project for financial support for doing my research work and giving me the opportunity of doing my research work on their constructed cold rooms.

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LIST OF ABBREVIATIONS

AA	Ascorbic acid
ANOVA	Analysis of variance
AOAC	Association of Official Analytical Chemists
CE	Cooling efficiency
CI	Chilling injury
CLP	Critical loss point
CSA	Central Statistical Agency
DWAO	*Dedo* woreda agriculture office
ECRTD	European Centre for Research Training and Development
ETB	Ethiopian Birr
FAO	Food and Agricultural Organization
FGD	Focus group discussion
JUCAVM	Jimma University College of Agriculture and Veterinary Medicine
KII	Key informant interview
LDL	Low density lipoprotein
LSD	Least significance difference
PHL	Post harvest loss
PHM	Post harvest management
RBCD	Randomized complete block design
RELOAD	Reducing loss adding value
RH	Relative humidity
SPSS	Statistical package for social science
TA	Titratable acidity
TSS	Total soluble solid
VPD	Vapor pressure deficiency

ABSTRACT

Even though head cabbage is a highly nutritious leafy vegetable, a significant proportion of postharvest loss hinders its availability and utility. Therefore this study aimed at identifying the causes and extents of postharvest losses of head cabbage along its postharvest chain and evaluation of the cooling performance of three cold storage rooms. The assessment of postharvest loss of head cabbage was carried out using FAO's 4-S methodology and data were collected from 120 farmers, 3 retailers, and 3consumers through a questionnaire, focus group discussion, key informant interview, observation, and load tracking methods then analyzed by SPSS version 16. The cooling performance of constructed cold storage rooms was evaluated by recording both outside and inside temperature and relative humidity by using testo184H1 data logger with loading and no loading of head cabbage for twelve days respectively. Physicochemical parameters of head cabbage stored in those cold storage rooms after packed in sack and plastic crate were evaluated using RCBD replicating the sample three times then analyzed by Minitab version 16. The survey results indicated that the loss of head cabbage caused due to poor pre-harvest, harvesting, and post-harvest handling practices, lack of knowledge, and socio-demographic factors of the respondents. The losses 15.4%, 18%, and 20.6% were recorded at farmers, retailers and consumers level respectively. A high loss of head cabbage was recorded at consumers' level due to poor storage and processing condition and might due to accumulative factors from production to consumption point. Therefore to reduce loss at each supply chain, proper pre-harvest and post-harvest handling practices should be applied. The experimental results depicted that the average minimum and maximum temperature difference and the average minimum and maximum relative humidity difference were calculated with ambient air were 4.7°C and 12.6°Cand 40.6% and 19.9% for medium cold room, 2.4°C and11.9°C and 33.27% and11.7%for big cold room and a little and 8.8°C and 20.8% and 6.9% for small cold room respectively during no load test. The average minimum and maximum temperature difference and the average minimum and maximum relative humidity difference were calculated with ambient air were 3.4°C and 11.6°Cand 38.7% and 24.5% for medium cold room, 2°C and10.9°C and 30.2% and 16.5% for big cold room and a little and 8°C and 15.1% and 4% for small cold room respectively during loading of head cabbage. These cold storage rooms maintained firmness, reduced weight loss, pH, ascorbic acid, total soluble solids, Titratable acidity, and prolonged storage-life compared to ambient temperature. Head cabbage packed in plastic crate and stored in the medium cold room has a good potential in maintaining the quality and long shelf life of 12 days. To minimize internal temperature from increase and minimize internal relative humidity from decrease, the rooms should be monitored properly.

Keywords: Causes of Loss, Cold Storage Room, Extent of Loss, Head Cabbage

1 INTRODUCTION

1.1 Background and Justification

The post-harvest losses of perishable (vegetable and fruits) were due to the presence of high moisture content (65-95%), insect infestation and damage during post-harvest handling techniques (Rahiel *et al*., 2018). Leafy vegetables are susceptible to high qualitative and quantitative losses after harvest because of their perishables in nature and improper postharvest handling activities (Kinyuru *et al*., 2012). Leafy vegetables are alive characterized by high metabolic activities that resulted to short storage life and loses of water through respiration and transpiration (Kader and Rolle, 2004).

In line with this, Appiah *et al*. (2012) reported that in many African countries, post harvest handling of head cabbage is enormously difficult due to it is perishable and poorly harvested, packaged and transported that lead 33.5% substantial losses during marketing practices.FAO (2005) estimated that the postharvest loss of perishable commodities in Ethiopia is as high as 50% attributed to several factors such as lack of packaging and storage facilities and poor means of transportation being the major one. Debela *et al*. (2018) also reported that the postharvest losses (40.0%) of horticultural commodities in Jimma area were mainly attributed to poor handling practices. Furthermore, Gebremariam (2014) reported head cabbage post-harvest loss assessment with in supply chain was conducted and resulted in 58.9% loss from Akaki to Addis Ababa due to storage/transportation temperature, mechanical damage during transportation, disease infection, poor quality of irrigation water, poor storage mechanisms.

Fresh fruits and vegetables are very important sources of nutrients and contribute to income enhancement of a country in general (Lambaste, 2005). The root cause of postharvest deterioration needs to be inhibited with appropriate post harvest handling practices and the main technological interventions are involving control of temperature and humidity of the atmosphere around the produce (Wills *et al*. 1989).Leafy vegetables are desired to be stored at lower temperatures since the cool environment keeps them in their fresh form with the chemical, biochemical and physiological changes are restricted to a minimum by close control of room temperature and humidity (Liberty and Echiegu, 2013).

In Ethiopia there are limited of the studies telling about the causes and extents of post-harvest loss of head cabbage at each supply chain. Postharvest losses of perishable products generally and in the head cabbage particularly in the value chain is very alarming since the causes of post harvest losses are not only losses of food, but also represent a similar waste of human effort, farm inputs, livelihoods, investments and scarce resources. Therefore the post harvest loss of perishable crops could be reduced and avoided after the causes and extents of losses are identified and policy makers and other stakeholders direct their focus towards reducing these losses by offering training and create awareness to farmers and others actors on the postharvest handling of perishable products.

Currently there is a lack of use of cold storage technology in developing countries. Most of the postharvest losses of vegetables in Ethiopia could be because of lack of adequate storage facilities that lead to high food losses and loss of market value, leaving little profit for farmers, handlers, processors or marketers, Therefore promoting the development of cold storage room from cheap and locally available materials could be good for farmers and other stakeholders to extend storage life and reduce post harvest loss of their perishable products. In view of this, this work was proposed to achieve the following objectives.

1.2 Objectives

1.2.1 General objective

To assess the post-harvest losses of head cabbage along the supply chain from *Dedo* district to Jimma market and evaluate the cooling performance of three model cold rooms

1.2.2. Specific objectives

1. To assess the causes and extent of post-harvest losses of head cabbage along the supply chain from *Dedo* district to Jimma Market
2. To evaluate the cooling performance of three cold model rooms with and without loading head cabbage
3. To determine the physicochemical properties of head cabbage packed in plastic crates and sacks, and stored in the three model cold rooms

2 LITERATURE REVIEW

2.1 Overview of fresh produce production in Ethiopia

Ethiopia is one of the countries in Africa that has huge potential for the development of different varieties of horticultural crops since this country is endowed with natural resources in different agro-ecological zones which are suitable for the cultivation of horticultural products (Hunde, 2017).

Head cabbage is one of the leafy vegetables first originated from Western Europe and Northern Mediterranean shore then it has been cultivated and used for human consumption since ancient times (Semuli, 2005). Head cabbage is rich sources in mineral and vitamins and being used as an appetizer, aides' digestion that avert constipation and protects against cancers (Samec *et al.*, 2011). Global Trade Magazine (2019) reported that 73 million tons of head cabbages were produced worldwide in 2018. CSA, 2017/18 reported that 36512.9tons of head cabbage were produced in Ethiopia in Maher season. In Dedoworeda8465.625tons of head cabbage was produced (DWAO, 2018).

2.2 Postharvest characteristics of head cabbage

Fresh produces have live characteristics that, biological processes and other factors hurt their quality and responsible for deterioration process (Kader, 2004). Postharvest losses could discourage farmers from initiating into production and marketing of fresh produce due to fear of loss of their produces since they have no proper management practice in immediate purpose during surplus production seasons(Ngcobo *et al*., 2012).

Production of fresh fruits and vegetables has its complexity due to their perishable nature characteristics and lack of knowledge as well as a shortage of capital, so horticulture industry in sub-Saharan Africa in general and in Ethiopia in particular stays at its infant stage (Hailu and Derbew, 2015). Harvested head cabbage is also susceptible to wilting and shriveling therefore, it needs to be removed from the field with ought exposing to direct sunlight as soon as possible and took to a well-ventilated shaded area during packing, transporting, storing and at all stage to consumers even at consumers hand (Kader, 2002).

2.3 Post-harvest loss of head cabbage

Postharvest loss of fresh produces is simply a measurable decrease of agro-produce in a post-harvest system that may be quantitative, qualitative and economic. This leads the loss in the monetary value of the product due to reduction in quality or quantity greatly contributes to economic losses as produces are not sold, cost increase, consumers dissatisfactory and scarcity of produce because of losses of cultivated produce (Prusky, 2011).

In Ethiopia head cabbage harvested manually, store in plastic bags or spread loosely on the ground floor and transported to nearby markets using pack animals, vehicles and on foot to the market that can bring high post-harvest loss of head cabbage (Kidane, 2016).

2.4 Causes and extent of post-harvest loss of head cabbage

The actual causes of postharvest loss in fresh produce are many and commodity-specific itself, as horticultural products are diverse in morphological structure, composition, developmental stages and general physiology (Wills *et al.*, 2007). The principal causes of post-harvest loss are poverty (lack of finance), inadequate post-harvest handlings, lack of appropriate processing technology and storage facilities, poor infrastructure as well as poor marketing systems. So for the limitation of proper storage and marketing facilities, farmers are forced to sell them produces at throwaway prices (Omolo *et al*. 2011).

Improper harvest and post-harvest practices result in losses due to spoiling of the product before reaching the market, as well as quality losses such as deterioration in appearance, taste nutritional value and all overall characteristics of produces (Devkota *et al*., 2014). Kitinoja (2010) explained that at least 20 % of the total cabbage production is lost at the farm level while 28 % is lost at the retail level due to rough handling of head cabbage heads during transit and poor storage conditions.

2.4.1 Pre-harvest factors that cause loss of head cabbage

Pre-harvest production practices are caused when the crops are still on growing; these have implications on their quality after harvest and affect the final post-harvest quality of harvested crops in one relation or many ways (Arah *et al*., 2015).

2.4.1.1 *Cultivar characteristics*

Fresh produce growers have the choice of selecting preferred cultivars before planting crops even though it may be limited by the availability of planting material depending on the accessibility in that season(Hewett, 2006).

The growers need of selecting preferred cultivars before planting crops since different cultivars differ in size, yield, color, texture, and flavor as well as storage potential market and acceptability that lead to different post-harvest characteristics of those cultivated produces (Kader, 2002). similarly to this idea `Copenhagen Market` variety preferred over `Drumhead` variety of head cabbage by growers in the Amhara region, Ethiopia, probably due to its earliness. The variety is ready for harvesting in 63-70 days after transplanting compared to Drumhead variety which requires about 105-115 days (Kidane, 2016).

2.4.1.2 *Agro-ecological conditions*

Environmental conditions during production affect the shelf life and quality of harvested fresh produces. These factors not only affect growth and development by changing the accumulation of water, dry matter and biochemical compounds but also affects the behavior of fresh produces during storage since the produces cultivated and grown in good manners can resist deterioration factors while the one that is not unable to show such condition (Hewett, 2006).

Teshome and Bobo (2019) described that, Ethiopia has significant agro-ecological variability that shapes crop production areas across the country. He recommended that, farmers grow head cabbage at Adola Rede, Southern Oromia, Ethiopia on similar agro ecology Royal and Monarch varieties for their better early maturing, maximum head yield, good head shape, firmness, marketable head size, and low incidence of loose heads.

2.4.1.3 *Mineral nutrients and water supply*

Kidane (2016) concluded that enough amount of nitrogen, phosphate and sulfur fertilizer maximizes the number of marketable leaves and total yield of cabbage heads thus withstand the chance of loss after harvest. He also recommended that head cabbage produced without implementing the recommended agronomic practices such as fertilizer rates and required water quantity can increase the incidence of damages that may enhance postharvest diseases and physiological damages which intern decrease the quality and increase postharvest losses.

2.4.2 ***Harvesting factors cause loss of head cabbage***

2.4.2.1 *Harvest at maturity condition*

Fresh produce has to be harvested when attains the appropriate stage of development based on physiological and horticultural maturity. Harvest maturity varies by the crop concerned that for example, fresh produce is ready for harvest when it has developed to the ideal condition for consumption (Ahmad and Siddiqui, 2015).

Sharma and Singh (2011) reported that harvesting of the fresh produce at their immaturity or over maturity age and the wrong time can lead to spoilage and wastages in the supply chain. So it is necessary and essential to pick the fruits or vegetables at correct maturity to facilitate proper ripening, distant transportation, and maximum storage life.

Common cabbage and Chinese cabbage heads are harvested when firm and mature that compactness of heads may be determined by hand pressure since immature harvested heads, decreases yield and shelf life (Hong and Hwang, 2016).Maturity at the time of harvesting is the crucial step that typically determines the post-harvest characteristics of fresh produces so the farmers do not have to harvest early or late harvest, their farm to avoid the cause of marketing losses of their produces (ZongQi, 2009).

2.4.2.2 *Time of harvest*

The time of the day when harvesting is done affects product quality and shelf life. If harvesting during the hotter part of the day cannot be avoided, the product should be kept shaded in the field to minimize product heat, weight loss, and wilting (Desta, 2018).

Many researches showed that harvest time of day could affect quality as harvesting at good times maintain the highest water potential, resulting in a slower rate of wilting than those with lower water potential (Jiang and Pearce, 2005). Weight loss during harvesting was higher in the unshaded cabbage heads 14.37% while 13.17% for the shaded cabbage head (Appiah *et al*., 2012).

2.4.2.3 *Harvesting method*

Most of the farmers have no awareness about the loss because of limited harvesting techniques a lot of perishable crops can be spoiled and wasted (Khan *et al*., 2007). Singh *et al*. (2009) explained that the method of harvesting is the factor that responsible for losses .Poor harvesting methods (harvesting by shaking, dropping, twisting and pulling) at the improper stage and poor care at harvest are some of the reasons that hasten postharvest losses of perishable crops after harvest (Khan *et al.*, 2007).

Methods of harvesting adopted by the smallholder farmers in Ethiopia are handpicking, cut by scissor and using unsuitable harvesting materials (Honja, 2014) which can expose the produces to different loss factors and cause loss of their perishable produces. ZongQi (2009) stated that a cabbage head can be harvested by bending it to one side and cutting it with a knife, which should be sharpened frequently to reduce effort and lessen picker fatigue.

2.4.3 *Post-harvest factors cause loss of head cabbage*

2.4.3.1 *Crops nature*

Horticultural crops contain relatively high moisture content, large in size and soft texture as compared to cereals and legumes. Their characteristics like having high metabolic activities and lose water through respiration and transpiration makes them unable to stay fresh and have short storage life (Kader and Rolle, 2004).

Appiah *et al*. (2012) explained that even if head cabbage is the hardiest of many vegetables, which is susceptible to postharvest losses due to its perishable nature. Gebremariam (2014) also described as cabbage is highly perishable and subject to rapid quality deterioration after harvest due to miss stage of maturity, water loss, unfavorable climatic condition, physical damage, contamination by pathogens and insect pests, improper handling and poor storage conditions.

2.4.3.2 *Poor temperature and relative humidity*

Temperature and relative humidity are the most important environmental variables and the driving force for water loss from the product to the environment. Vapor pressure deficiency(VPD) is increased by increasing temperature and decreasing relative humidity (Holcroft, 2015).The amount of temperature in the horticultural produce during harvesting, handling, transport, and marketing is much higher due to continuous and high rate of respiration and other related biochemical reactions of the produces (Hailu and Derbew, 2015).

Produces characteristics, likes surface injury, and maturity stage influence transpiration rate for perishable fresh produces. However, the rate of postharvest water loss is dependent primarily on the external vapor pressure deficit than commodity factors, though other environmental factors will influence the situation (Kader, 2002). According to Munhuwey *et al*. (2016) the appearance of fresh head cabbage stored at temperatures of 5 ºC and 20 ºC becomes objectionable after 12 and less than 6days, respectively. It can be kept on the retail shelf for at least 3- 5days and depending on its quality.

2.4.3.3 *Microbial action*

Barth *et al*. (2009) explained that many fruits and vegetables present nearly ideal conditions for the survival and growth of many types of microorganisms as their internal tissues are nutrient-rich, especially vegetables, have a pH near neutrality. Gebremariam (2014) stated that insect pest problems during the growing season of head cabbage can also affect postharvest quality since insect feeding hurts the appearance thus decreasing its appeal to consumers. Feeding injury on vegetables by insects can lead to surface injury, creating entry points for decay organisms and increasing the probability of postharvest diseases.

2.4.3.4 *Improper storage and handling*

When there is no storage facility and even there, if it is poor storage conditions, the resistance of fruit and vegetables to the natural disease usually declines, that leading to infection by pathogens (Tefera *et al*., 2007). In the absence of proper storage and marketing facilities, farmers are forced to sell their products at throwaway prices and sometimes farmers do not even get the two ways transportation costs back, so they would rather dump their produce near the market area than taking them back to home.

The principal causes of postharvest losses of fresh fruits and vegetables in Africa are due to poverty, inadequate postharvest handling, lack of appropriate processing technology and storage facilities, poor infrastructure as well as poor marketing systems (Buyukbay *et al*., 2011). Packaging in bulk without sorting and grading of produce are the factors responsible for the losses (Ozcan, 2007) since overloading produces heat that fastens the respiration and the produce may be rotted within few days and also the overloaded one get pressure on one another to be easily damaged.

Survey study done by Kereth *et al*. (2013) stated that in Tanzania people used packaging materials like sacks, woven bamboo baskets, and wooden crates that sacks causes produces losses due to physiological change by the metabolic reaction which in turn accelerates mechanical damage and microbial attack. Munhuwey *et al*. (2016) stated that trimming of the cabbage leaves during postharvest storage is inevitable and losses about 20% during long term storage can be expected due to moisture loss, leaf discoloration, and decay.

2.4.3.5 *Poor transportation*

Poor transportation systems for perishable products can results to high post-harvest loss since these products are more susceptible to mechanical and heat damage (Wakhol *et al*., 2015).Perishable produces need to be loaded since the produce stacked on each other inside the vehicles cause the limitation of ventilation, which usually results in rot due to high level of physiological activities of the produces (Negi and Anand, 2016). Gonzales and Acedo (2016) reported that in the traditional chain of head cabbage, wholesalers incurred a 6.8% loss due to weight loss and mechanical damage as a result of improper handling of fresh produce and poor packaging during transportation.

Table 1. Head cabbage transportation systems in Armachio district, Amhara region, Ethiopia

Transportation system	**Kerkir Bale'egziabher (N=10)**	**Chachkuna (N=12)**	**ChiraAmbezo (N=12)**	**Total (N = 32)**
On foot	0	25	20	15.6
By back of animal	50	75	60	62.5
By vehicle	30	0	0	9.4
By back of animal and vehicle	20	0	20	12.5

Source (Kidane, 2016)

2.4.3.6 *Poor market facilities*

In most African countries smallholder farmers are embarrassed for marketing their produces because of poor infrastructure, lack of market transport and inability to have predetermined agreements, the local market is not sufficient to allow smallholder farmers in remote rural areas to transform into larger-scale farming because they cannot afford to pay higher prices and also they bargain for cheap prices that they do not obtain a better return for their produce (Mdlalose, 2016). Farmers require relevant infrastructures, labor, technology, and coordination to markets their products effectively and reduce wastage or loss due to market excess with particular vegetables (Bond, 2006).Whenever head cabbage does not sell at the market, it would be lost as reasons for weight loss resulting from improper handling and poor temperature and humidity that average loss of 9.6% was incurred at retailers level (Gonzales *et al*., 2014).

2.5 Reducing post-harvest losses of head cabbage

2.5.1 Appropriate cultural practice and variety selection

The importance of agricultural practice such as the selection of planting material and cultural practices including harvesting methods and handling practice on the quality of harvested produce was (Pessu *et al*., 2011).

Appropriate pre-harvest practices such as proper spacing; weeding, fertilizing pesticide application could be conducted with great care. The reduction of postharvest losses can also be achieved by selecting cultivars that have good nutritional quality and can be stayed for a longer time without show signs of deterioration after harvest (Kitinoja *et al*., 2011). Similarly Kidane (2016) concluded the use of improved varieties like `Copenhagen Market` and other production inputs like nitrogen, phosphate and sulfur fertilizer at the rate of 102: 115:21.18Kg \hectare to increase production and productivity of any crops including head cabbage.

2.5.2 Proper harvesting and post-harvest management

In sub-Saharan Africa, postharvest losses are caused on the farm due to inappropriate cultivar selection or harvesting method (World Bank, 2010) and in transit due to poor packaging, poor temperature management, rough handling and unpaved roads since mechanical injury such as scratches, cuts, punctures, and bruises to the crop create loss. Harvesting should be carried out at appropriate stage and during the cool part of the day, which is early morning and late evening. Selection of fruits and vegetables at proper maturity at harvest, gentler handling and ethylene management can also reduce losses (Saeed and Khan, 2010). Since perishable crops are alive after harvest, that continues to respiration which results loss of nutritional value and loss of weight and processes cannot be stopped, but they can be slowed down significantly by pre-cooling before storage or distribution (Ahmad and Siddiqui, 2015).

Proper handling, good sorting, cleaning, packaging, and adequate transportation with considering the road facilities and to minimize vibration and good storage facilities are crucial to reducing post-harvest losses of fresh produces (Kitinoja and Kader, 2002). Ethiopian farmers harvested head cabbage either by cutting the stem below head using sickles or by pulling the whole plants and cutting the stems below the heads. Harvested cabbage head should be stored in clean and well-ventilated area either in a container or spread in-floor and need to be transported with properly (Kidane, 2016).

2.5.3 Market access

The majority of smallholder farmers in Africa are in subsistence production, marketing is underdeveloped and inefficient. Inadequate storage facilities are constraint to marketing large quantities of agricultural commodities produced by farmers tend to rot un-marketed produces (Kamara *et al*., 2009). Sometimes, the market is in excess with a particular vegetable and a lot of loss is experienced in line with this, prices are considerably reduced and farmers get dejected. Therefore, an efficient marketing system is very essential to avoid the losses of vegetables and get a good return from the produce (Gebremariam, 2014).

2.5.4 Training

Experienced and knowledgeable personnel are very essential for proper fresh produce supply chain starts from production to table. They should have trained to get deep knowledge of their tasks at any of the production and post-harvest handling steps to obtain quality fresh produce and protect it against contamination and deterioration (Amare, 2013). Debela *et al*. (2011) stated that there is lack of knowledge about using of packing materials. Therefore calls for public awareness campaigns must be implemented to increase their knowledge for their fresh produces of using suitable packing materials that could minimize the chance of causes of post-harvest loss.

2.5.5 Cooling of head cabbage

Freshly harvested fruits must be quickly cooled by removing field heat with a compatible cooling method since excess heat causes fruits and vegetables to have higher respiration rates, ultimately resulting in a faster deterioration of their quality (Watson *et al*., 2015). All cooling aims are to reduce deterioration, delaying senescence and lengthening the product shelf life (Kitinoja, 2013). Woldemariam and Abera (2014) reported that the average cooling efficiencies of bamboo jute and pot in pot coolers before being loaded with tomatoes were 82% and 79% and after being loaded were 67.6% and 61.6%, respectively that the physiological weight losses of stored produces were 1.03%, 1.32%, and1.42% while the shelf life were 5, 19 and 21 days for cold storage type bamboo jute, pot in pot and for ambient respectively.

2.5.5.1 *Temperature management*

The maintenance of an optimum constant temperature from the field to the store is crucial for maintaining fruit and vegetable quality (Kader, 2002). Jacxsens *et al.* (2002) stated optimum storage temperature can be varied from species to species and cultivar to cultivar. The most frequently used temperature is 4°C, considered the optimal for many vegetables. Kramchote *et al*. (2012) stated that the shelf life of head cabbage stored at 4°C, can be stored successfully for 18 days, but it deteriorated rapidly and lasts only 4 days at ambient temperature of 28°C.

2.5.5.2 *Prevention of moisture loss*

The relative humidity of the storage unit also directly influences water loss in produce. Water loss means degraded quality, saleable weight loss and reduced profit (Singh, 2011). In general, it is recommended that 90% and sometimes 98-100% RH are the optimal compromise condition for fruit and leafy vegetable storage (Kader, 2002).Appiah *et al*. (2012) stated that moisture loss resulted in weight loss and decay of head cabbage as the reason for temperature enhance the rate of transportation and possible method of reducing it by shading would help to minimize postharvest losses.

2.6 Physicochemical quality of stored head cabbage

Traditionally, various indicators have been used for determining the quality of head cabbage, texture and weight is an important quality indicator because that changes significantly depending on the length of storage period (Eum *et al*., 2013). In line with this Kramchote *et al*. (2012) explained that head cabbage at 4 and 10°C reduced weight loss and maintained the firmness and also ascorbic acid decreased slowly than head cabbage stored at 28°C).Similar study of Moreira *et al*. (2006) indicated that lettuce leaves stored at low temperature(0°C) showed no much more quality change (ascorbic acid retention), less microbiological infection and other physicochemical parameters such as soluble solids contents, water loss, and weight loss were less than the other which were stored at 8°C and 15°C.A comparable study of Esther (2013) also reported as the Coolbot cold storage room effectively lowered and maintained the temperature at 10±1°C throughout the storage period whereas the ambient room temperature fluctuated and the cold-stored produce had an extended shelf life of 35 days compared to 12 days in the ambient room.

2.7 Summary

Head cabbage is one of the leafy vegetables first originated from Western Europe and Northern Mediterranean shore then it has been cultivated thought the world and used for human consumption since ancient times. Head cabbage is rich sources in mineral, vitamins and dietary fibers and being used as an appetizer, aides' digestion that avert constipation and protects against cancers. Just like other leafy vegetables head cabbage is also highly susceptible for post harvest loss since it is alive and perishable its high metabolic activities resulted to short storage life and lose water through respiration and transpiration after harvested. Post harvest loss of head cabbage could be caused due to poor pre harvest, harvesting and post harvest handling practices.

The losses in cabbage and other crops in the value chain are very alarming since losses of food, human effort, farm inputs, livelihoods, and scarce resources. Therefore this loss can be reduced and managed after the causes and extents of loss at each supply chain are identified it could be inhibited with appropriate post harvest handling practices and the main technological interventions that involving control of temperature and humidity of the atmosphere around the produces. Training and awareness creations are crucial to all stakeholders to minimize loss of perishable produces.

3 MATERIALS AND METHODS

Part I Assessment

3.1 Study setting

This study was conducted from January 2019 to May 2019 at *Dedo* district of Jimma zone, South west Ethiopia located in south west at 12 km distance from Jimma town and 377 km from Addis Ababa, it is bordered with *Kersa* district in the north, *Omo Nada* district in east, SNNP regional state in the south and *Seka Chokersa* district in west. Its altitude lies between 880m and 2400m above sea level and the mean annual rainfall ranges between 1200mm and 2800 mm with the mean annual temperature of 20°C-25°C (National census, 2007). Physicochemical qualities determinations were conducted in JUCAVM at the post-harvest management laboratory. Head cabbage of local varieties was brought from *Waro kolobo* irrigation site after harvested at one times from one field. Head cabbage with uniform size, appearance and free from defects were used for experiments.

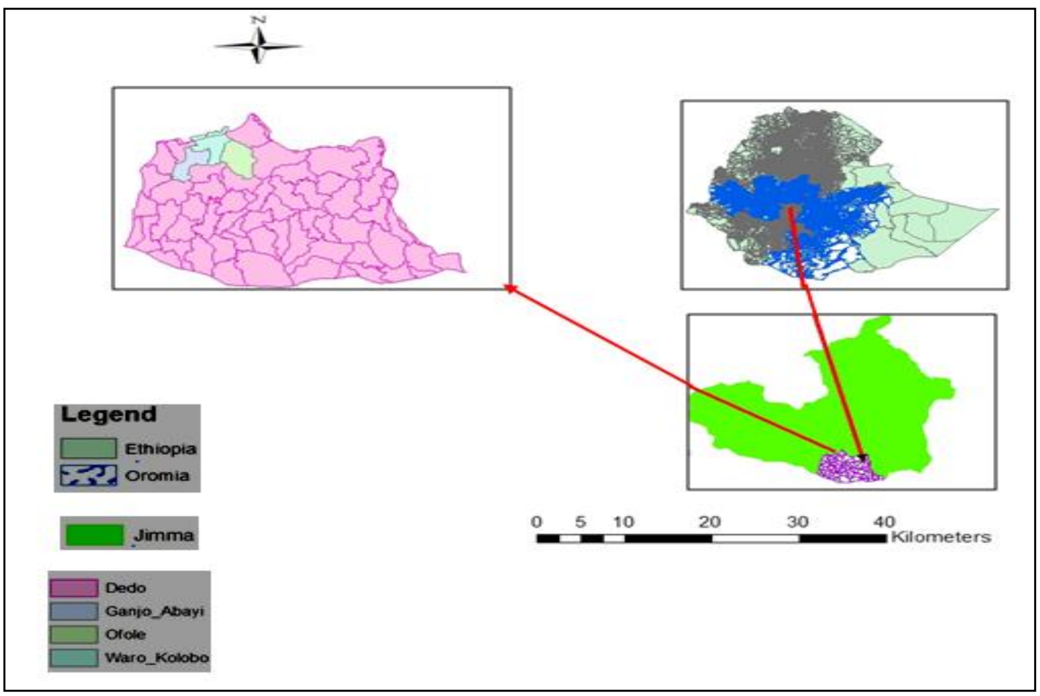


Figure 1. Map of study area

3.2 Sampling and sample size

After consulted with Jimma town rural agriculture office, *Dedo* district was selected purposively based on the fresh vegetables production potential. *Waro kolobo*, *Offole* and *Ganjo abayi* kebele were also selected purposively based on the head cabbage production potential.The sample size of respondents was determined by using formula developed by Yamane (1967).

$$n = \frac{\text{N}}{1 + \text{N}(e^2)}$$

Where: n-is the sample size, N- is the population size and e^2- is the level of precision (8%)

$$\text{n} = \frac{520}{1 + 520(0.08)^2} = 120.1479 \sim 120$$

Therefore120 respondents were randomly selected and interviewed. For sampling method, *Bisheshe* market, fruits and vegetables collection and marketing center in Jimma town, was selected purposively. *Bishishe* market is the place where *Dedo* farmers are selling their fruit and vegetable in large amount. Then three retailers who continuously buy head cabbage from *Dedo* farmers and three consumers who most of the time buy head cabbage from retailers were randomly selected from *Bisheshe* market to measure the post-harvest losses of head cabbage using actual measurement (FAO, 2016). Those selected retailers have similar head cabbage handling practices similarly the selected consumers have similar head cabbage handling practices.

3.3 Research design

The assessment of loss was conducted using FAO, 4-S methodology (FAO, 2015).

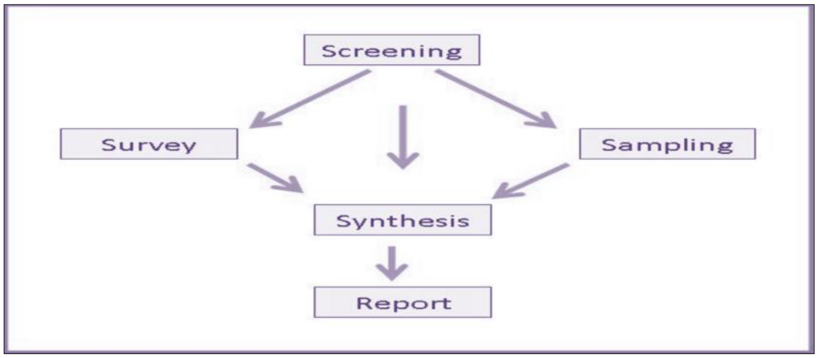


Figure 2. FAO 4-S approach loss assessment system (FAO, 2015)

The priliminary information about post harvest loss was obtained through screening methodwich is based on secondary data, documentation and reports, and expert consultations without travel to the field that helps to provides indicative data for the entire loss assessment (FAO, 2016). It also subsequently enables to make selection of the food supply chain surveying and sampling. The Survey was conducted through going right in the field, and interviews were conducted with the farmers, develpment agents, focus group discusion and key informant interviews were consulted and data about the causes and extent of post harves tloss of head cabbage at supply chain were obtanied. Depend on the survey and screening information the main head cabbage supply chain were identified and actual measurements was made to identify the critical loss point.

For sampling method, three retailers bought head cabbage from *Dedo* farmer, then from what they bought 100Kg were measured at each retailers then sold as per before, the trimmed part and unsold head cabbage were measured again and the average loss at retailers' level was calculated. Similarly, three consumers bought head cabbage from a former retailer then from what they bought, 1.4 Kg, 1.1Kg and 1.1Kg were measured at three consumers respectively. Those consumers took it to their home, at the prior to cooking the weight and the trimmed part were measured then the average loss was calculated (FAO, 2016).

3.4 Data collected

Primary data were collected through questionnaires, focus group discussion and key informant interview direct observation and actual weight measurements. Secondary data were also obtained from relevant documents, districts agricultural offices, available literature reviews from published or unpublished sources. Focus group discussion was used to learn more about opinions, practices and problems of farmers in post-harvest management of head cabbage. Therefore focus Group Discussions were held in *Waro* kolobo kebele involving eleven farmers (6 males + 5females) and in *Offole* Keble involving ten farmers (6 males + 4 females). The farmers were selected purposively based on long experience and high production potential based on the information of developmental agents. The issues of causes, extents and the impacts of postharvest loss of head cabbage were discussed by group and the information were recorded and gathered thoroughly.

Table2. Summary of participants involved in the FGD during the PHL assessment of head cabbage

Method	Respondents	Data collected	No.of experts	
			Men	Women
FGD	Farmers	Production and productivity, harvesting, pre-cooling ,storage, consumption and marketing, supply chains, transporting, gender roles in PHM, major causes of loss	12	9
KII	Expert	Production potential and consumption status, post harvest activities and techniques, causes and extent of loss in supply chain, gender roles	4	3

The KII were conducted with a selected group of key informants consisting of PHM expert from woreda and zone, crop protection expert and Development agent in attempt gender participate in relation to postharvest handling knowledge and practices (FAO, 2015). The main purpose was to generate detailed information relating to postharvest losses (causes, extents, impacts and potential solutions), validate, and build on information from group interviews and observations.

Table 3. Summary of experts involved in the KII during assessment of head cabbage

No	Experts	Information
1	Development agent from three kebeles	Production and productivity, practices and experiences of farmers on postharvest management, and estimation of losses
2	PHM experts from woreda agriculture office	Harvesting ,post harvesting practices, supply chain, loss estimation with its causes
	Crop protection expert of woreda irrigation and development office	Information revealed about pre-harvest, harvesting and postharvest practices, storage related pests, loss estimation
3	PHM experts from zone agriculture office	General post harvest handling practice, the major supply chains,tchnplogy, loss estimation and its major causes
	PHM experts from zone irrigation and development office	Informant on postharvest handling practices, major causes of loss strategies, loss estimation at zone level

Part II Experimental Part

3.5 Experimental Materials and Methods

3.5.1 Characteristics of cold rooms

Three model cold storage rooms were constructed by the joint support of RELOAD project and JUCAVM in *Dedo* district at *Waro* Kolobo kebele. The constructed cold rooms were varied with their construction materials, size and operation systems. The first (medium) cold room was made from concrete, metal sheets and bricks and its walls, roof and door insulated with coffee husk by 0.4m in thickness. It connected with solar that adjusted automatically to begin and stop ventilation in the evening and morning respectively. The second (small) cold room was made from wood, metal sheets and mud soil and all its walls, roof and door insulated with coffee husk by 0.3m in thickness. This room operated manually that its two windows opened and closed in the evening and morning respectively. The third cold room was made from wood, metal sheets and mud soil and its floor is concrete based and its walls, roof and door insulated with coffee husk by 0.3m in thickness. This room operated manually that its roof opened and closed in the evening and morning respectively. Note: The cold rooms were cooled by night ventilation and insulation principles. The thermal conductivity of coffee husk is $0.37 Wm^{-1}K^{-1}$(Meharu, 2019) since thermal conductivity is an intensive quantity of material indicates its ability to conduct heat.

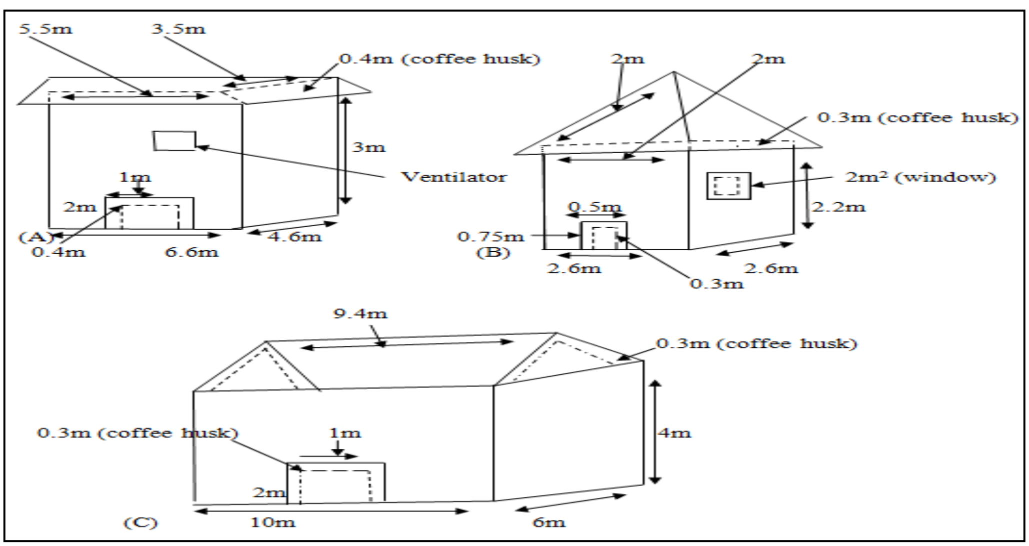


Figure3. Three model cold storage rooms constructed at *Dedo* district

3.5.2 Research design

To evaluate cooling performance of cold storage rooms, temperature and relative humidity were recorded by using **Testo Data logger**(model 184H1, Germany) in the three rooms and at ambient temperature without loading and loading head cabbage equally for twelve days. For loading head cabbage, the experiment was laid out in randomized complete block design (RCBD) with 4*2 factorial arrangements.

Table4. Factorial arrangements of an experiment

Factors	**levels**
Cold storage rooms	medium, big, and small cold rooms and ambient air
Package materials	plastic crate and sack containers
The experiment has 8 treatment combinations with 24 experimental units	

Totally three hundred eighty four head cabbages in which ninety six head cabbages were put in each cold room and ambient temperature conditions. Three head cabbage from each treatment were selected randomly for determining physic-chemical characteristics at four day intervals (Rahman *et al.,* 2013). The stored head cabbages were taken with ice box from cold storage rooms and its physicochemical qualities were evaluated. Note: Between the packages material used, the plastic crate has a good aeration characteristic than the sack container.

3.5.2 Data collected

3.5.2.1 *Temperature and relative humidity*

Both temperature and RH of inside cold rooms were recorded without loading and with loading of head cabbage by using **testo 184H1 Data** logger which was configured at one hour interval for recording. Similarly the temperature and relative humidity of ambient air temperature were recorded. Then the maximum and minimum temperature and relative humidity were collected from data logger and their differences were compared with ambient air. Without loading means that the rooms had no fresh head cabbage while with loading means that each room had 96 fresh head cabbage.

3.5.2.2 *Firmness*

Firmness of head cabbage was determined using a stable micro systems texture analyzer model (TA-XT Plus). Head cabbage were randomly selected and subjected to a puncture test at a constant speed of 10 mm/sec, moved distance 10mm using a 10 mm diameter stainless steel probe. Then maximum force (N) required to penetrate the sample to 10 mm depth was recorded and measured, on four sides of each and its average value was calculated (Susaj *et al*., 2014).

3.5.2.3 *Weight loss*

Weight loss of head cabbage was determined using the methods described by Mohammed *et al*. (2011). The initial and final weight of head cabbage was measured mass balance then the weight loss (%) was calculated using the formula:

$$\text{Weight loss } (\%) = \frac{\text{Initial weight } - \text{ final weight}}{\text{Initial Weight}} \times 100$$

3.5.2.4 *pH*

The pHof head cabbage was determined from 5ml of juice of head cabbage by using pH meter (CP500, Taiwan) (Al-Momani *et al*., 2000).The juice of head cabbage was prepared by adding 500ml of water to 300 gram of chopped head cabbage then dilution factors was used for calculation.

3.5.2.5 *Ascorbic acid*

Ascorbic acid content was determined according to AOAC (2002). Ascorbic acid from 5gram of head cabbage was extracted using Metaphosphoric acid and acetic acid solution and titrated using 2, 6-dichlorophenolindophenol. The end point was determined by volume of titer, which gives pink color with standards.

3.5.2.6 *Total soluble solid*

For TSS 2ml juice of head cabbage was measured and determined its °Brix by using refractometer (model,Dr 201-95, Germany).

3.5.2.7 *Titratable acidity*

The titratable acidity of the head cabbage was determined by taking 5ml juice of head cabbage and titrated with 0.1N (NaOH) solution (Mitcham *et al*., 1996).

The TA content was calculated, using the following equation:

$$\text{TA}\ \% = \frac{\text{ml NaOH used} \ * \ \text{N} \ * \ \text{meq}}{\text{ml of juice}} \times 100$$

Where: N = normality of NaOH,

meq = mill equivalents of malic acid which is 0.06

3.5.3 Determination of storage life

Storage life of head cabbage was determined by Garg *et al.* (2008) methods that twenty four head cabbage of each treatment was randomly selected and evaluated. During storage the head were removed at the first deterioration mark (showing visible wilting) and the removal of heads was carried out until the last head cabbage became unmarketable.

3.6 Statistical analysis

Qualitative and quantitative data from the assessment part were analyzed by simple descriptive statistics and bivariate analysis by using SPSS software version 16.Theexperimental based data were subjected to ANOVA and analyzed by using Minitab software version 16. The means significant difference were compared by using Tukey test at $\alpha = 0.05$ level.

4 RESULTS AND DISCUSSION

Part I. Assessment

4.1 Assessment of Post-harvest Loss of Head Cabbage

4.1.1 Demographic and socio-economic characteristics of households

Table5 summarizes that 82.5% of farmers were males while 17.5% were females. This implies that farming is mainly undertaken by males than females because in the study area generally most of the men are engaged in farming activities since no other job opportunity was available in which they can be engaged. Table7 below indicates that there were a significant difference ($P<0.05$) between the amount of losses and gender of the respondents at whom the highest post-harvest loss of head cabbage were recorded for male than female due to females involved in the basic postharvest activities of head cabbage-like sorting, marketing, and processing than males until it reached to consumption. During FGD it was explained that even though more male respondents participated, female respondents also participated in post-harvest practices of head cabbage. Comparable to this study, Kidane (2016) there was gender disparity in the involvement of households headed in Armachio district, Amhara region, Ethiopia. Overwhelming percentages of the respondents were male headed while fewer percentages were female headed.

Table7 explains there was a significant difference ($P<0.05$) between the number of losses of head cabbage and the educational level of the respondents. This implies that the amount of loss of head cabbage influenced by the educational level of respondents thus higher percentage loss was incurred since there was a lack of understanding and adopting fruits and vegetables post-harvest handling practices for illiterate than educated respondents. Similarly Garikai (2014) reported that farmers with higher levels of formal education (secondary and tertiary) had lower cabbage postharvest losses than those with lower education levels because of educated respondents show ability to understand and adopt new technologies. Similarly, the study of Mashau *et al*. (2012) accounted that lack of higher education could have been responsible for their failure to notice other causes of fruits and vegetables loss and education has the potential to enhance understanding and communication in post-harvest technology like preservation technology.

Table 5.Descriptive categorical demographic and socio-economic status of farmers

Variables	Categories	Frequency	Percent
Gender of participant	Male	99	82.5
	Female	21	17.5
Marital status	Single	1	0.8
	Married	97	80.8
	Widowed	20	16.7
	Divorced	2	1.7
Level of education of participant	Illiterate	75	62.5
	Primary	44	36.7
	University	1	0.8
The main occupation of the participant	Farmer	119	99.2
	Government employee	1	0.8
Have your children reached to work?	No	23	19.2
	Yes	97	80.8
Sex of children who are participated on work	Male	21	21.6
	Female	12	12.4
	Both	64	66
Place of residence of the respondent	Rural	108	90
	Semi-urban	12	10
Respondents' main source of income	Farming land	120	100
Respondents additional income	Livestock production	111	92.5
	Trade	8	6.7
	Salary	1	0.8
Who produces new income?	Husband	3	2.5
	Wife	2	1.6
	Husband and wife	38	31.7
	Family	77	64.2
Is there electricity in your area?	No	105	87.5
	Yes	15	12.5
Place where do you exchange goods?	Kebele market	1	0.8
	Dedo market	1	0.8
	Jimma market	118	98.4

Concerning occupation, 92.5% were farmers and 6.7% traders while 0.8% was a government employee in whom farmers have 9 years minimum, 30 years maximum farming experiences and 17.8 mean years farming experience. The amount of post-harvest loss of head cabbage was significantly ($P<0.05$) influenced by farmers years of farming experience (Table 7). This implies that farming experience influences the amount of post-harvest loss of head cabbage that experienced respondents can implement the knowledge of vegetable post-harvest handling technology. Similarly study of Babalola *et al*. (2010) explained that an experienced farmer population implies good knowledge and adoption of postharvest handling technology among the farmers.

In the case of respondents' dwellers, 90.0% of them lived in rural areas whereas 10.0% of them lived in a semi-urban area. In the place where respondents live was significantly ($P<0.05$) influence the amount of post-harvest loss of head cabbage (Table7). It shows that a high amount of post-harvest loss of head cabbage was recorded for rural dwellers. As observed and discussed during focus group discussion, in the rural area there was no facility of electricity to use storage technology and the road seems bad for transportation that can induce and fasten post-harvest loss of head cabbage and other perishable crops.

Table6. Descriptive continuous age and farming experiences of respondents

Variables	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Age(years)	120	28.00	50.00	41.6417	5.12335
Farming experiences (years)	120	9.00	30.00	17.8333	3.88562

The main source of income of respondents was totally from farming while additional income-generating activities 92.5% was from livestock production, 6.7% from trade and few (0.8%) from salary. The amount of post-harvest loss of head cabbage was significantly ($P<0.05$) influenced by additional income of the respondents (Table7). An additional income contributes to proper production and post-harvest handling of fruits and vegetables by reducing the unavailability of socioeconomic factors such as access to agricultural inputs, tools for harvest, packaging materials transportation and marketing conditions.

Table 7. Effects of different variables on the amount of loss of head cabbage

Variables	Categories	Amount of post-harvest loss (ton\1800 ton)				Total	x^2 (P-value)
		0.1-0.3	0.4-0.6	0.7-0.9	≥1		
Gender	Male	54(45%)	32(26.7%)	9(7.5%)	4(3.3%)	**99(83%)**	**0.024**
	Female	19(15.8%)	1(0.8%)	0	1(0.8%)	21(17%)	
Educational level	Illiterate	36(30%)	30(25%)	6(5%)	3(2.5%)	**75(63%)**	**0.027**
	Primary	36(30%)	3(2.5%)	3(2.5%)	2(1.7%)	44(36%)	
	University	1(0.83%)	0	0	0	1(0.8%)	
Farming experience	≤10	21(17.5%)	20(16.7%)	4(3.3%)	2(1.7%)	**47(39.2%)**	**0.030**
	11-20	27(22.5%)	10(8.3%)	3(2.5%)	2(1.7%)	42(35%)	
	21-30	25(20.8%)	3(2.5%)	2(1.7%)	1(0.8%)	31(25.8%)	
Respondents residence	Rural	61(50.8%)	33(27.5%)	9(7.5%)	5(4.2%)	**108(90%)**	**0.012**
	Semi-urban	12(10%)	0	0	0	12(10%)	
Respondents additional income	Livestock	64(53.3%)	33(27.5%)	9(7.5%)	5(4.2%)	**111(92.5%)**	
	Trade	8(6.7%)	0	0	0	8(6.7%)	**0.041**
	Salary	1(0.8%)	0	0	0	1(0.8%)	

Note: The insignificant variables were removed

4.1.2 Actors and product flow in the head cabbage supply chain

Most respondents sell their head cabbage to retailers and consumers while some of them sell to collectors and few of the respondents sell to wholesalers (Table 8).On the contrary, Gebremariam (2014) reported that the flow of head cabbage around the Akaki area to Addis Ababa consumers through multiple routes mostly by the wholesalers. During focus group (FGD) and key informant interview (KII), it was indicated that the major supply chain of head cabbage was through farmers, retailers and consumers even though other actors are participated in rarely similarly as indicated in the figure 4.

Table 8.Amount of head cabbage and actors involved in the supply chain

Variables	N	Minimum	Maximum	Mean	Std. Deviation
Annual average production of head cabbage (tone)	120	1.6	15	3.749	2.064
The extent of head cabbage (tone)used for consumption	119	0.1	0.6	0.296	0.096
The extent of head cabbage (tone) used to sell	120	1.4	14.8	3.455	2.044
The extent of head cabbage (quintal) sold to collectors	19	0.4	3.5	1.405	0.832
The extent of head cabbage (tone) sold to wholesalers	8	1	12.8	6.025	4.582
The extent of head cabbage (tone) sold to retailers	111	0.7	7.8	2.785	1.388
The extent of head cabbage (tone) sold to consumers	103	0.1	0.8	0.2932	0.0832

Figure 4 summarizes that most of the head cabbage was collected and transported from the production area (Dedo district) to urban retailers area by farmers.

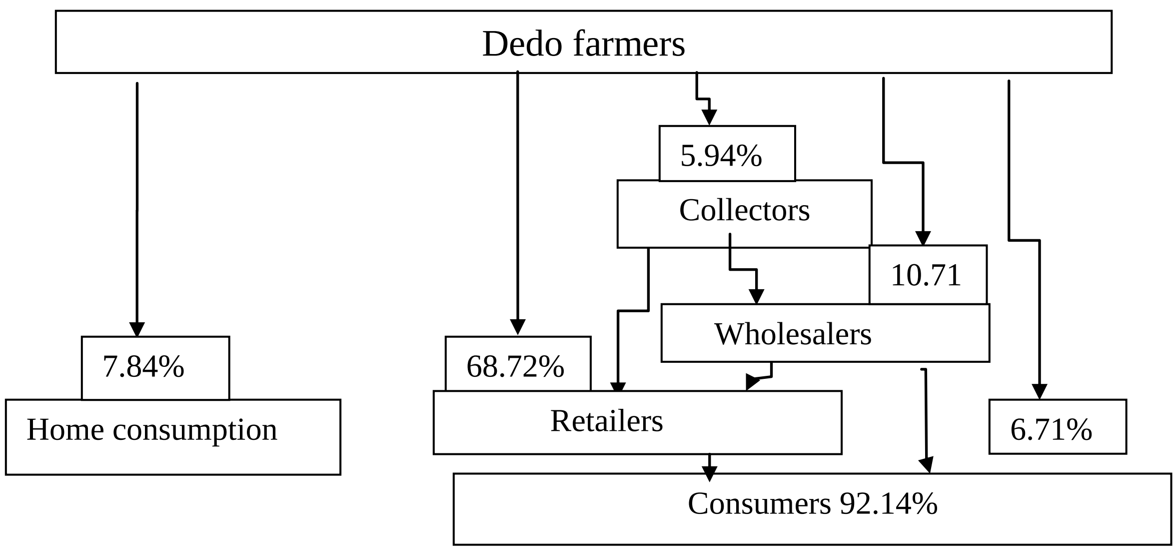


Figure4.Actors and product flow in the head cabbage supply chain

4.1.3 Head cabbage pre-harvest practices

Proper pre-harvest practices are crucial for crops to growth in good manners and withstand post harvest loss factors. The farmers used different head cabbage seed varieties according to its availability at markets so that most of them used Holland variety while few of them used France variety. During focus group discussion it was informed that Holland variety head cabbage is small in size and be matured early at two and a half months after sowing and easily being lost in the field but they prefer since it be matured early. France's variety is big and matured at least three months after sowing and they do not prefer since it late to be matured.

Regarding the types of fertilizers they used for head cabbage production, only artificial fertilizer especially dap is the only fertilizer used to cultivate head cabbage. Regarding to management practices, the farmers used insecticide and manually weeding to protect the head cabbage from insects and weeds respectively. They also depend on the irrigation water for the cultivation of head cabbage. Generally, during focus group discussion it was discussed that the respondents have poor head cabbage pre-harvest practices thus can contribute to the post-harvest loss of head cabbage.

Similarly, Arah*et al*. (2015) explained that pre-harvest production practices are the ones that may be caused when the crops are still on growing which has implications on their quality after harvest and affects the final post-harvest quality of harvested crops. Rahiel *et al*. (2018) also reported that unimproved cultivars of fruits and vegetable seeds lower the productivity and predispose the crop to most of the post-harvest losses. Again also Adarkwa (2011) concluded that postharvest loss in vegetables may be caused by several pre-harvest factors such as poor crop variety, unfavorable climate, and inadequate agricultural practices contributing to post-harvest characteristics of produce.

4.1.4 Head cabbage post-harvest practices

4.1.4.1 *Head cabbage harvesting, trimming and packaging practices*

Table 9 shows that most of the farmers (91.7%) identify the maturity of their head cabbage by touching and feeling its firmness while a few of them (8.3%) identified by its color. It was observed that immature or over mature harvested head cabbage is susceptible to damage and it could be wilted.

Similarly, Thongsavath *et al*. (2012) reported that over-maturity harvested head cabbages could lead to head cracking, and immature heads are puffy or hollow spaces and loosely arranged which makes them susceptible to damage. Hong Hwang (2016) also concluded that common cabbage and Chinese cabbage heads have to be harvested when firm and mature since compactness of heads may be determined by hand pressure.

Most of the farmers (95.8%) harvest their head cabbage in the afternoon while few (4.2%) of them harvest early in the morning (Table 9). This shows that the majority of respondents harvest cabbage in the afternoon that the product being exposed to the heat of the sun which induces weight loss and wilting. In agreement with this study, Desta (2018) discussed that harvesting time affects the quality of fresh produce and it is desirable to harvest fresh produces during the cooler parts of the day to reduce the risk of heat injury and sunburn. Similarly, Garika (2014) recommended that postharvest losses of spinach will be diminished significantly if it is harvested in the morning instead of the afternoon. Furthermore, Kereth *et al.* (2013) reported that harvesting activities should be completed during the coolest time of the day, because of high temperatures and evaporation which causes the vegetables to shrink, thus affecting the marketing quality.

In the study area, the respondents used different methods of head cabbage harvesting practice so that 60.8% of them used pulling with hand while 39.2% of them used twisting and cutting with a machete. It observed that during those harvesting practices, the produce was subjected to force that could lead to the mechanical and physical loss of head cabbage. Therefore the extent of post-harvest loss of head cabbage at harvesting level was 4.2%. Therefore during harvesting the head cabbage should not be snapped or twisted, as this method damages the head and results in inconsistent stalk length and trim since broken stalks are also more susceptible to decay (Acedo, 2010).

Table 9. Post-harvest practices of head cabbage

Variables	Categories	Frequency	Percent
Maturity identification method of head cabbage?	Touch its firmness	110	91.7
	Color	10	8.3
Mostly when you harvest head cabbage?	Early morning	5	4.2
	Afternoon	115	95.8
What harvest method you follow?	Pulling with hand	73	60.8
	Twisting and cutting	47	39.2
Which trimming practice you follow most?	Trim with hand	94	78.3
	Trim with sickle	26	21.7
Most containers used for holding head cabbage	Sacks	120	100
Which pre-cooling methods you used?	Shading	120	100
Where you pre- cool your commodities?	In field	116	96.7
	At temporary store area	4	3.3

Pre-cooling is the mechanism carried out to remove field heat of freshly harvested crops which increase respiration, transpiration, and other metabolic reactions indeed hasten post-harvest loss. All the respondents pre-cooled head cabbage under shade; 96.7% of them pre-cool it at the field and 3.3% also pre-cool at a temporary storage area for half day. They pre-cooled head cabbage by shading with pieces of shrubs, leave and put under the tree. Janet and Richard (2000) the field heat of freshly harvested crops is usually high and needed to be removed. Also, Yahaya and Mardiyya (2019) described as pre-cooling prevents premature ripening and aging of the fresh produce especially when the harvesting is done in the hot weather.

During trimming practices 78.3% of the respondents trimmed head cabbage by their hand while 22.7% trimmed by sickle. The respondents did not care about loss and the edible part might leave with the trimmed part. So that 2.5% loss of head cabbage was incurred at trimming practices. During trimming, leaves that developed yellow or brown color, became damaged, wrinkled, diseases or unappealing to be marketed were removed and the edible part also trimmed (Appiah *et al*., 2012).

In the study area, all the respondents used sack as head cabbage holding materials which may cause rotting due to lack of ventilation, severe puncture and mechanical injury hence lead to an increase in postharvest losses. So 2.08% loss of head cabbage was incurred because of poor holding materials. Similarly, Negi and Anand (2016) enlighten that in the case of produce packed in jute bags, usually stacked on each other that cause the limitation of ventilation, which usually results in produce rot due to high level of physiological activities of the produce. Again similarly Yahaya and Mardiyya (2019) stated that all the packages must be ventilated to prevent the physiological break- down of the products.

Focus group discussion (FGD) and key informant interview (KII) indicate that head cabbage harvesting, trimming and packaging practices are improper that they don't give attention to loss rather to harvest and take to home and market for selling. In addition it also discussed that these practices caused due to lack of infrastructure lead to such poor practices

Table 10. Magnitude of losses of head cabbage due to poor post-harvest practices

Variables	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
The extent of loss of head cabbage (ton) due to poor harvesting?	120	0.025	05.00	0.116	0.067
The extent of loss of head cabbage (ton) due to poor trimming?	120	0.013	0.300	0.074	0.042
The extent of loss of head cabbage (ton) due to poor container?	120	0.013	0.250	0.071	0.037
For how many days you pre-cool head cabbage?	120	0.50	0.50	0.5000	0.00000

4.1.4.2 *Head cabbage transportation and marketing practices*

Table 11 point outs that the majority (96.7%) of the respondents transported head cabbage to a temporary collection point in the afternoon while 3.3% of them did early in the morning. Most (96.7%) of the respondents transported head cabbage by animal back while 3.3% of them used human back or head.

Table 11. Head cabbage transportation and marketing practices

Variables	Categories	Frequency	Percent
Transportation method mainly used to temporary collection point?	Human back or head	4	3.3
	Animal back	116	96.7
A major time of transportation from farm to a temporary collection point?	Early morning	4	3.3
	Late afternoon	116	96.7
Most containers use to transport head cabbage to the temporary collection point?	Sacks	117	97.5
	Wooden crates	3	2.5
Mostly when you transport head cabbage to the market?	Early morning	114	96.6
	Late afternoon	4	3.4
Mostly which transportation system you use for head cabbage?	Human back or head	9	7.8
	Animals back	97	83.6
	Truck	8	6.9
	Public vehicle	2	1.7
Mostly how you load cabbage during transportation?	Overloading	114	98.3
	Throw to loading	2	1.7
Mostly how you unload cabbage after transportation?	Throw on the ground	104	89.7
	Pullover one another	12	10.3
Mostly where do you sell head cabbage?	Nearby field	7	5.8
	Urban market	113	94.2
Mostly what marketing challenges do you have?	Price fluctuation	91	75.8
	Surplus of produces	29	24.2

When transporting to temporary collection point most of the respondents used sack while few of them used wooden crates and transport it at a mean distance of 2.1Km. All these transportation practices are poor which can enhance the mechanical loss and physical loss of head cabbage. In agreement with this Gebremariam, (2014) who explained that proper and efficient transportation is very important to successfully market and maintain the quality of vegetables with minimum damage.

Table 11 shows that most farmers transported head cabbage to the market early in the morning while few of them in the afternoon and 83.6% of them transported by animal back, while7.8%,6.9% and 1.7% of them by human back or head, truck and public vehicle, respectively. Most of the respondents also overload their head cabbage while few of them load by throwing. In addition most of the respondents throw head cabbage on the ground while few of them pull over one another during unloading practices.

Table 12.Causes and extents of loss of head cabbage due to poor transportation and marketing condition

Transportation and marketing practices	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
How far farm from the temporary storage area (Km)?	120	0.1	0.4	0.208	0.062
How far the market from the store area (Km)?	120	1.0	1.5	1.148	0.151
The extent of loss of head cabbage (ton) due to poor transportation conditions?	116	0.025	0.3	0.095	0.006
The extent of loss head cabbage (ton)? due to poor marketing conditions	120	0.013	0.4	0.116	0.070
What is the price of head cabbage per ton in ETB?	120	1300.00	1500.00	1410.000	69.0877

As it observed and discussed during focus group discussion (FGD), the respondents had poor transportation practices that could induce the loss of head cabbage due to mechanical/physical damage and overheating (natural breakdown, decay and increase the rate of water loss). Also, it was observed that most of the respondents transported head cabbage on the bad (bumper) road without a suitable package at a mean distance of 11.5Km that might also lead to loss of head cabbage. Therefore 2.6% loss of head cabbage was recorded during transportation practices. Similarly, the study of Ramchandra *et al*. (2015) incurred a 1.89% loss of head cabbage during transportation practice in the Trans-Ganga Region of India resulted from inadequate transportation facilities. A similar study by Seid *et al*. (2013) also reported a 2.8% loss of head cabbage during transportation practices because of poor transportation systems.

Most of the respondents (94.2%) sold their head cabbage at the urban market (Jimma market) while a few of them sold it at a nearby field. As observed and discussed during focus group discussion, head cabbage marketing practices had some challenges, like high price fluctuation, sometimes time glutting of head cabbage at the market place, lack of suitable place for marketing. All these factors were the result of a 3.3% loss of head cabbage due to poor marketing conditions. Though it fluctuated, the minimum price of one ton of head cabbage was 1300 ETB while the maximum price was 1500 ETB and the mean price of one ton of head cabbage was 1410ETB. That means the maximum price of one kilogram of head cabbage was 1.5 ETB. Therefore the mean163.6ETB could be lost due to poor marketing condition only. The focus group discussion (FGD) and key informant interview (KII) informed that head cabbage marketing have lack of suitable marking places and prices.

Ramchandra *et al*. (2015) reported 1.92% loss of head cabbage was recorded due to an inadequate marketing system. Again also Debela *et al*. (2018) reported that postharvest losses of horticultural commodities around the Jimma area were mainly attributed due to poor transportation and the use of poor marketing structures. Also, Omolo *et al*. (2011) reported the principal causes of post-harvest loss are many such as poor marketing systems. So for the limitation of proper storage and marketing facilities, farmers are forced to sell them produces at throwaway prices.

4.1.5 Agricultural training and facilities

Table 13 shows that 97.5% of the respondents had training on land preparation while 2.5% of them had training on irrigation practices. The training of such practices was given to the respondents only by the government. The respondents had no training in post-harvest practices. During the focus group, discussion (FGD) participants revealed that there was no training regarding the post-harvest management practices given by anybody and even the respondents are unfamiliar with post-harvest handling issues. The key informant interviews (KII) also indicated that in the study area even some pre-harvest practices are there, there was no post-harvest management expert who gives training and awareness to the respondents to reduce and control post-harvest loss of their fresh produces.

Similarly, Debela *et al*. (2011) reported that in and around the Jimma area, postharvest behavior and postharvest management of fresh produces have not been given sufficient attention. Garikai (2014) also stated that training farmers aids in proper postharvest handling practices and technologies would assist in improving postharvest handling efficiency and formal postharvest handling training would experience lower post-harvest losses compared to the untrained farmers.

Table 13. Respondents training and facilities

Variables	**Categories**	**Frequency**	**Percent**
Have you training about pre-harvest?	Yes	120	100
If yes mostly on which training?	Land preparation	117	97.5
	Irrigation practices	3	2.5
Who gives you training?	Government body	120	100
Have you training about post-harvest?	No	120	100
Have your facilities on post-harvest activities?	No	120	100

4.1.6 Gender roles in post-harvest management of head cabbage

Table14 indicates that both male and female respondents participate in the post-harvest practice of head cabbage such as harvesting, pre-cooling and transporting to the temporary collection area. Most male respondents (95.5%) participated in head cabbage transporting to market while most of the female respondents (61.7%) participated in head cabbage marketing practice. In this study, it showed that both male and female respondents (60%) participated in post-harvest activities of head cabbage but more percent of male respondents participated than female respondents.

Moreover, during FGD it was explained that even though more male respondents participated, female respondents also participated in post-harvest practices of head cabbage. Similarly, Thongsavath *et al*. (2012) reported that respondents participated in head cabbage supply chain were male-dominated resulted in large post-harvest loss both in the domestic and export trade in Lao PDR, Vientiane. Conversely, Adarkwa (2011) described that a high percentage of female respondents participated in the marketing of vegetables because their major job was sale of vegetables.

Table 14. Gender participation in post-harvest practices of head cabbage

Variables	Categories	Frequency	Percent
Mostly who participates in harvesting practice?	Men	2	1.7
	Men and women	118	98.3
Mostly who participates in pre-cooling practice?	Men	2	1.7
	Men and women	118	98.3
Mostly who participate in transporting to temporary store area?	Men	9	7.5
	Men and women	111	92.5
Mostly who participate in transporting to the market?	Women	3	2.5
	Men	114	95
	Men and women	3	2.5
Mostly who participates in marketing practice?	Women	74	61.7
	Men	34	28. 3
	Men and women	12	10
Mostly who participated in post-harvest practices?	Women	3	2.5
	Men	45	37.5
	Men and women	72	60

4.1.7 Sampling method of evaluating post-harvest loss of head cabbage at retailers and consumers Level

4.1.7.1 *Post-harvest loss of head cabbage at retailers level*

The loss of head cabbage at first retailer was 15%on the second day while at a second retailer it was found that 17% of head cabbage were trimmed and rotted on the third day. At third retailer it also found that the trimmed and decayed weight loss of head cabbage was 22% on the third day. This study found that the mean total percentage loss of head cabbage at retailers' level was 18% (Figure5). The loss of head cabbage caused due to poor marketing systems such as selling in direct sunlight (no shelters, poor trimming practices and mixing marketing with other commodities. Additionally head cabbage poorly packed, loaded and unloaded and transported on the bumper road that trimmed in large amount at retailers' level.

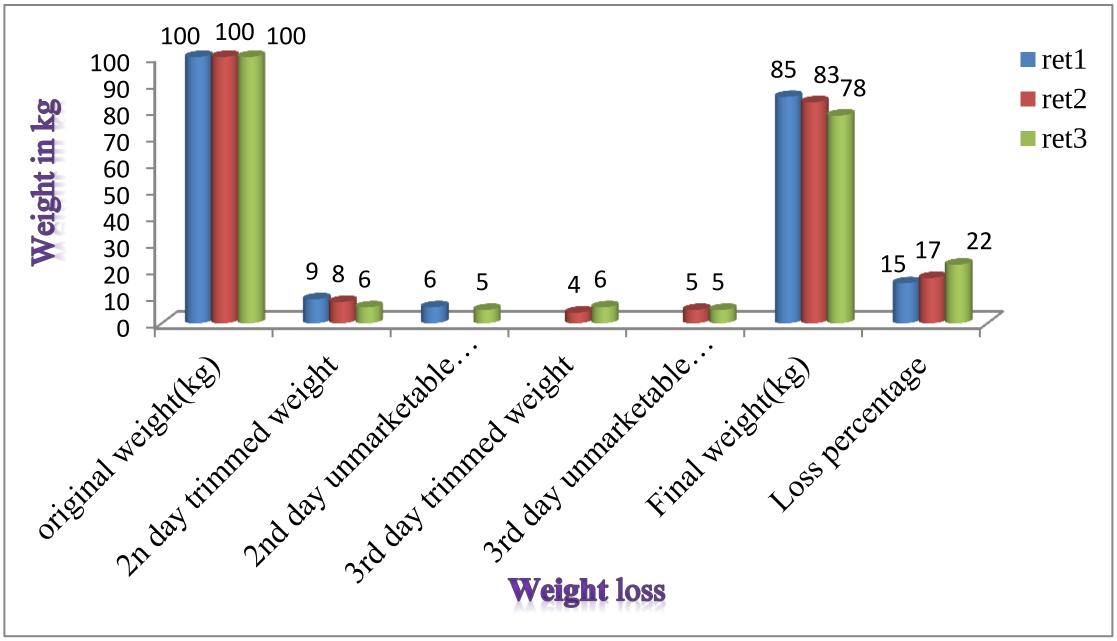


Figure 5.Quantitative loss of head cabbage at retailers' level

Similarly, Kitinoja (2010) explained that at least 28 % of the total cabbage production is lost at the retail level due to rough handling of head cabbage heads during transit and poor storage conditions. A similar study of Gonzales and Acedo (2016) also reported that 16.1% of a total loss of head cabbage was incurred at the retail stage after three days holding at ambient temperature in the traditional chain in Cebu, the Philippines as a result of improper handling of fresh produce and poor packaging during transportation.

4.1.7.2 *Post-harvest loss of head cabbage at consumers level*

Figure 6 indicates the loss of head cabbage at the consumers' level. At first consumer, it was found that about 22.8% percentage loss of head cabbage on the third day while at the second consumer the percentage loss of head cabbage on the third day was 20.9%. At the third consumer, the percentage loss of head cabbage on the second day was 18.2%. This study found 20.6% the mean total percentage loss of head cabbage at the consumers' level.

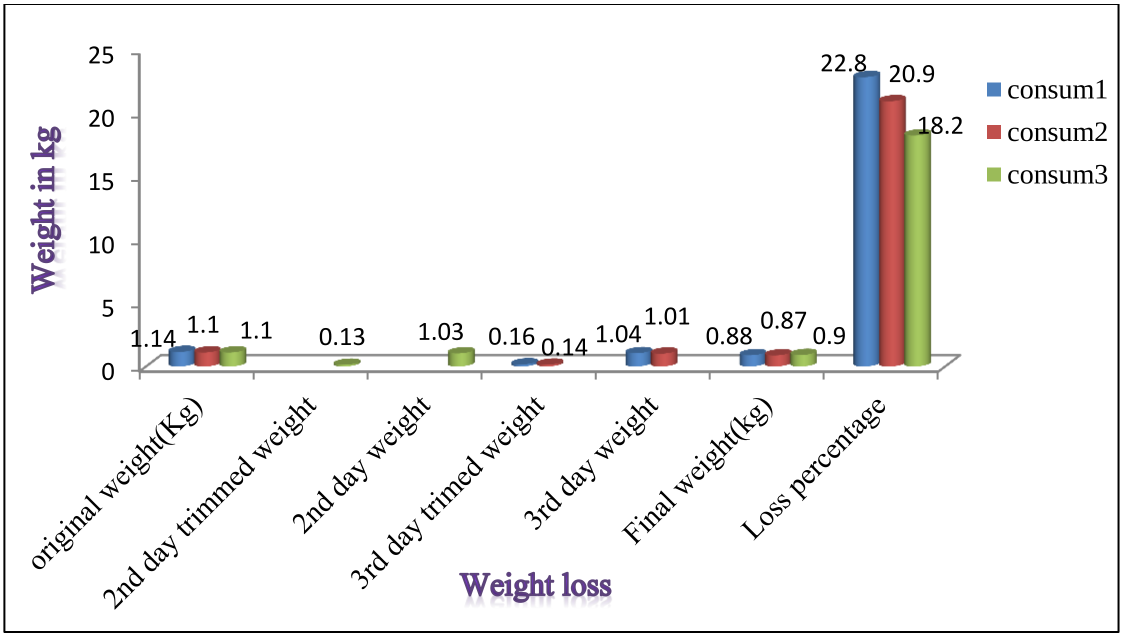


Figure 6. Quantitative loss of head cabbage at consumers' level

These losses were mainly attributed due to poor storage condition and most of the edible parts of head cabbage trimmed during processing practice at consumers' level. Additionally head cabbage being lost rapidly at consumers' level due to accumulative effects resulted from poor harvesting, packaging, and transportation and handling at market. Similarly Buzby *et al.* (2011) incurred 31% loss of head cabbage at consumer level because of overall total of factors from production to marketing system including poor handling practice at consumer levels. Kasso and Bekele (2016) also reported that in Dirre Dewa, the post harvest loss of perishables crops 20% to 50% were recorded between marketing and consumption which caused due to bad climate, disease and pest, poor harvesting and handling techniques, packaging, storage and transportation facility and market situation.

Part II experiment

4.2 Evaluation of the cooling performance of three model cold storage rooms

4.2.1 Cooling performance of cold rooms

To calculate the cooling efficiencies of cold rooms, it needs to have constant (room temperature).However the cooling medium depends on environmental temperature thus why it was difficult to calculate cooing efficiency and only temperature and relative humidity were investigated.

4.2.1.1 *Temperature and Relative Humidity during no loading*

The average minimum (4.7°C) and maximum (12.6°C) temperature difference and the average minimum(40.6%)and maximum(19.7%) relative humidity difference were calculated for medium cold room with ambient air. For big cold room the average minimum (2.4°C) and maximum (11.9°C) temperature difference and the average relative humidity minimum (33.27%) and maximum (11.7%) difference were calculated with ambient air. For small cold room the little average minimum and maximum (8.8°C) temperature difference and the average relative humidity minimum (20.8%) and maximum (6.9%) difference were calculated with ambient air during no load test (Table15). These temperature and relative humidity change were caused due to the medium cold room ventilated at night and while the roof for big and windows for small cold rooms should open and closed in the evening and in the morning respectively. A similar finding of Woldemariam and Abera (2014) reported that the average temperature 11-15°C during 'no load' test while the ambient air temperature ranged 21- 31°C and the relative humidity inside varied from 42% -75% while at outside it varied from 18% - 63%.

Table 15.Minimum and maximum temperatures and relative humidity in the cold rooms and ambient air during no loading test

	Medium room		Big room		Small room		Ambient air	
	Minimum	maximum	minimum	maximum	Minimum	maximum	minimum	maximum
Tem-peture (°C)	18.3	21.2	20.2	22	22.8	25	23	33.9
Time	Please see table 1 under annex							
RH (%)	83.5	90	76.1	82	63.6	69.4	42.8	62.5
Time	Please see table 1 under annex							

Note: The results are the average of 12 days reading

4.2.1.2 *Temperature and Relative Humidity with loading*

The average minimum (3.4°C) and maximum (11.6°C) temperature difference and the average minimum(38.7%)and maximum(24.5%) relative humidity difference were calculated for medium cold room with ambient air. For big cold room the average minimum (2°C) and maximum (10.9°C) temperature difference and the average relative humidity minimum

(30.2%) and maximum (16.5%) difference were calculated with ambient air. For small cold room the little average minimum and maximum (8°C) temperature difference and the average relative humidity minimum (15.1%) and maximum (4%) difference were calculated with ambient air during load test (Table16).These temperature increase and relative humidity decrease when loaded with head cabbage as reason of produces respiration and other metabolic activities in the each cold room. A similar finding of Tolesa and Workneh (2017) also reported that the recorded ambient temperature ranged between 13 and23 °C, while the temperature inside the cooling varied between 11 and 18 °C while ambient RH and the relative humidity of air inside the evaporative cold storage varied from 16–67.8% to 69.3–90.4%, respectively.

Table 16.Minimum and maximum temperatures and relative humidity in the cold rooms and ambient air during loading test

	Medium room		Big room		Small room	
	minimum	Maximum	minimum	maximum	minimum	Maximum
Temperature(°C)	19.6	22.3	21.0	23.03	22.7	25.9
Time	Please see table 2 under annex					
RH (%)	81.5	86.95	72.98	79	57.9	66.5
Time	Please see table 2 under annex					

Note: The results are the average of 12 days reading

4.2.2 Physicochemical quality of stored head cabbage

4.2.2.1 *Firmness*

As shown in the Table 17there were significant difference ($P<0.05$) firmness of stored head cabbage between medium and small room, medium room and ambient air, big room and ambient air due to their temperature difference during storage periods. The firmness showed a decreasing pattern with the extend of the storage period and the change being faster for head cabbages put at ambient air that can increase respiration , transpiration as well as enzymatic changes which in turn lower firmness than other cold rooms. Similarly Kramchote *et al*. (2012) who reported that firmness of cabbage heads decreased increase in storage time and temperature. Firmness was most rapid at ambient temperature as cabbage respired that hemicelluloses and pectin become more soluble, which resulted in disruption and loosening of the cell walls.

Furthermore, there was significance difference of firmness of head cabbages due to packaging materials for ambient air at the end storage period. The firmness of head cabbage stored in sack containers showed a more decreasing trend while in the plastic containers showed less loss of firmness during storage. This is due to temperature increase the metabolic and enzymatic activities responsible for starch and cell wall degradation that increase the softening of head cabbage stored in sacks than plastic containers. Faasema *et al*. (2011) reported that the firmness of sweet orange decreased during storage in the sack containers due to high respiration which soluble polysaccharides responsible for firmness.

Table 17. Effect of three cold rooms and packaging materials on the firmness (N) of stored head cabbage

Packaging Materials	**Storage rooms**	**Days after storage**			
		0	**4**	**8**	**12**
S	A	9.6 ± 0.41^{ab}	7.1 ± 0.25^{e}	6.0 ± 0.22^{e}	$\mathbf{5.1\pm0.22^{f}}$
	S	9.4 ± 0.17^{ab}	8.2 ± 0.06^{cd}	7.2 ± 0.20^{cde}	6.2 ± 0.27^{def}
	B	10.3 ± 0.34^{ab}	9.0 ± 0.06^{bc}	8.3 ± 0.33^{abc}	7.3 ± 0.14^{bcd}
	M	11.0 ± 0.36^{a}	9.3 ± 0.33^{b}	8.8 ± 0.11^{ab}	8.2 ± 0.22^{ab}
P	A	9.0 ± 0.35^{b}	7.8 ± 0.09^{de}	6.7 ± 0.20^{de}	5.7 ± 0.09^{e}
	S	10.1 ± 0.62^{ab}	8.9 ± 0.20^{bc}	7.9 ± 0.23^{bcd}	6.7 ± 0.17^{cde}
	B	10.8 ± 0.40^{ab}	9.8 ± 0.15^{ab}	9.0 ± 0.36^{ab}	8.1 ± 0.30^{abc}
	M	10.7 ± 0.35^{ab}	10.4 ± 0.32^{a}	9.5 ± 0.37^{a}	$\mathbf{9.2\pm0.63^{a}}$
	CV	4.6	6.34	8.46	9.1

Note: Means in the same column followed by the same letter(s) are not significantly different at 5% level. S: sack; P: plasticcrate; A: ambient air; S: small room; B: big room; M: medium room.

4.2.2.2 *Weight loss*

There was a significant difference ($P< 0.05$) in percentage weight loss of head cabbage during storage. The percentage weight loss showed an increasing pattern with increase in storage period even though it was greatly increased for sample stored in an ambient air due to higher temperature. The fast increase in a weight loss of head cabbage was mainly due to water loss as a result of transpiration and respiration with high temperature.

Table 18. Effect of three cold rooms and packaging materials on the weight losses (%) of stored head cabbage

Packaging Materials	Storage rooms	Days after storage			
		0	**4**	**8**	**12**
S	A	0.00	10.6 ± 0.21[a]	14.3 ± 0.11[a]	**18.1 ± 0.38[a]**
	S	0.00	9.4 ± 0.29[ab]	12.0 ± 0.36[bc]	16.0 ± 0.03[bc]
	B	0.00	8.0 ± 0.44[bc]	10.7 ± 0.16[cde]	14.5 ± 0.42[d]
	M	0.00	7.1 ± 0.39[bc]	9.6 ± 0.08[de]	12.7 ± 0.37[e]
P	A	0.00	9.5 ± 0.29[ab]	12.3 ± 0.41[b]	16.6 ± 0.31[b]
	S	0.00	8.1 ± 0.56[bc]	10.9 ± 0.27[cd]	14.8 ± 0.17[cd]
	B	0.00	7.0 ± 0.69[cd]	9.4 ± 0.24[ef]	12.0 ± 0.23[e]
	M	0.00	6.1 ± 0.28[d]	8.0 ± 0.41[f]	**10.5 ± 0.08[f]**
	CV	0.00	8.91	7. 67	7.02

Note: Means in the same column followed by the same letter(s) are not significantly different at 5% level. S: sack; P: plastic crate; A: ambient air; S: small room; B: big room; M: medium room

The weight loss might be related that at higher temperatures, vapor pressure deficit increased that can increases water loss which mainly accounts for weight losses. This study in line with the work of Kumar *et al.* (1999), who reported that storage duration and temperature have a significant effect on weight loss of fresh produces. Similarly, Kramchote *et al.* (2012) reported that cabbages held at low temperatures had the lowest weight loss throughout the storage period while there was a high percentage weight loss for head cabbage stored at ambient room conditions as a result of transpiration and respiration.

Furthermore there was significant difference percentage of weight loss between packaging materials throughout storage period except in small room. This difference was contributed due to head cabbage stored in sack increased internal temperature, in turn, increases transpiration and respiration that can increase the weight loss. Similarly, Bereda (2016) stated that high weight loss was recorded after day 3 for avocado fruits stored in traditional sack produced high temperature which enhanced transpiration and respiration.

4.2.2.3 *pH*

Among the storage temperature the maximum mean pH value (7.3) was recorded for head cabbage stored at the ambient air while minimum mean pH 6.6 value was recorded for head cabbages stored in medium cement based cold room at the end of storage day. This might be accompanied by a result of the degradation of organic acid during respiration. Similarly, Abiso *et al*. (2015) reported that the pH of the tomatoes increased with the advancement of fruit storage duration since the acidity of the fruits is decreased due to various organic acids that are consumed during respiration. Faasema *et al*. (2011) also explained that there was a general increase in the pH of the sweet orange caused by the breakup of acids with respiration during storage.

There was significant difference (P<0.05%) of pH of stored head cabbage due to packaging containers during storage periods. The maximum pH 7.3and the minimum pH value 7.0 value recorded for head cabbage packed by sacks and plastic crate at ambient air while the maximum pH 6.8and minimum6.6 value recorded for head cabbage packed by sacks and plastic crate in medium cold room respectively at the end of storage day.

Table 19. Effect of three cold rooms and packaging materials on the pH(%) of stored head cabbage

Packing Materials	**Storage rooms**	**Days after storage**			
		0	**4**	**8**	**12**
S	A	5.4 ± 0.003^{a}	7.0 ± 0.38^{a}	7.2 ± 0.3^{a}	$\mathbf{7.3 \pm 0.02^{a}}$
	S	5.3 ± 0.04^{a}	6.7 ± 0.16^{ab}	6.8 ± 0.07^{ab}	6.9 ± 0.05^{bc}
	B	5.3 ± 0.03^{a}	5.8 ± 0.22^{abc}	6.1 ± 0.34^{abc}	6.9 ± 0.01^{cd}
	M	5.3 ± 0.04^{a}	5.7 ± 0.39^{abc}	5.9 ± 0.23^{bc}	6.8 ± 0.03^{de}
P	A	5.3 ± 0.02^{a}	6.8 ± 0.44^{ab}	6.8 ± 0.03^{ab}	7.0 ± 0.01^{b}
	S	5.3±0.08a	5.8 ± 0.4^{abc}	6.2 ± 0.34^{abc}	6.8 ± 0.02^{de}
	B	5.3 ± 0.01^{a}	5.4 ± 0.12^{bc}	5.8 ± 0.26^{bc}	6.7 ± 0.03^{e}
	M	5.2 ± 0.01^{a}	5.3 ± 0.04^{c}	$53.\pm0.38^{c}$	$\mathbf{6.6 \pm 0.02^{f}}$
	CV	0.97	6.41	8.96	3.20

Note: Means in the same column followed by the same letter(s) are not significantly differentat 5% level. S: sack; P: plastic crate; A: ambient air; S: small room; B: big room; M: medium room

High pH values were recorded for produce packed in sack due to lack of aeration that promotes high temperature, in turn, rapid the rate of respiration, incase organic acids are used as substrate for respiration and decreases acidity and then increases pH values. Oppositely Bereda (2016) concluded that avocado fruits kept in cool chambers have exhibited a higher value of pH than fruits stored in the traditional sack.

4.2.2.4 *Ascorbic acid*

Storage conditions favorable to water loss are known to accelerate vitamin C loss. This study is agreeing with the study of Kramchote *et al*. (2012) who reported that cabbage stored at 4°C had the highest ascorbic acid while those stored at 28°C had the lowest content. A similar study of Mulualem, *et al*. (2014) explained that Papaya fruit stored at low temperature (16.8 °C) reduced the rate of respiration and depletion of acids, thereby showed higher AA content than those stored under ambient temperature condition.The maximum mean vitamin C (66.67%) loss was recorded for head cabbage placed in sack container and stored at ambient air condition while the minimum mean vitamin C (35.82%) loss was recorded for head cabbage placed in plastic crates at the end of storage day.

Table 20. Effect of three cold rooms and packaging materials on the ascorbic acid content (mg/100g) of stored head cabbage

Packaging Materials	**Storage rooms**	**Days after storage**			
		0	**4**	**8**	**12**
S	A	28.5 ± 0.32[a]	17.9 ± 0.26[e]	14.0 ± 0.34[e]	**9.5 ± 0.34[f]**
	S	28.5 ± 0.32[a]	19.8 ± 0.34[d]	16.0 ± 0.15[d]	11.9 ± 0.22[de]
	B	29.1 ± 0.32[a]	22.5 ± 0.26[c]	18.2 ± 0.26[c]	13.8 ± 0.22[c]
	M	28.5 ± 0.32[a]	24.7 ± 0.32[b]	20.8 ± 0.36[b]	15.6 ± 0.26[b]
P	A	28.2 ± 0.32[a]	19.2 ± 0.48[de]	15.2 ± 0.49[de]	11.1 ± 0.22[e]
	S	29.1 ± 0.31[a]	22.1 ± 0.36[c]	17.9 ± 0.46[c]	13.1 ± 0.22[cd]
	B	28.2 ± 0.32[a]	24.4 ± 0.32[b]	20.1 ± 0.38[b]	15.2 ± 0.32[b]
	M	28.2 ± 0.32[a]	26.6 ± 0.64[a]	22.6 ± 0.32[a]	**18.1 ± 0.47[a]**
	CV	2.09	7.28	7.91	9.61

Note: Means in the same column followed by the same letter(s) are not significantly different at 5% level. S: sack; P: plastic crate; A: ambient air; S: small room; B: big room; M: medium room

This could be seen that kinds of packaging containers had varied significant influence on the amount of ascorbic acid in head cabbage due to temperature difference between packaging materials during storage period. This study resembles the study of ECRTD (2015) who stated that the heat caused by respiration in cabbage in the packaging and the heat from the weather became the cause of ascorbic acid damage since ascorbic acid was unstable in hot temperature. Similarly, Kalt (2005) reported that 75-85% of losses of vitamin C in broccoli after 6 days of storage in air.

4.2.2.5 *Total soluble solid*

The total soluble solid values for stored head cabbages increased with an advancement of the storage period which could be due to hydrolysis of polysaccharides into simple sugars. Inline with this study,Viskeliene *et al*. (2017) concluded that a significant increase of soluble solids was due to an increase in reducing sugars, sucrose and total sugars in head cabbage and radish due to temperature difference.

There was a significant difference in total soluble solid between packaging containers only for ambient air during the storage period. This difference could be lowered total soluble solid content in plastic crates that can be attributed to lower transpiration and respiration that convert poly saccharide into disaccharide and simple sugar. This Study in line with Singh *et al. (*2017) who stated that lower TSS content of pear stored in different polyethylene packaging can be attributed to minimized weight loss, retard ripening and senescence processes which conversely associated with less transpiration and respiration losses

Table 21. Effect of three cold rooms and packaging materials on the total soluble solid (°Brix) of stored head cabbage

Packaging Materials	**Storage rooms**	**Days after storage**			
		0	**4**	**8**	**12**
S	A	8.3 ± 0.14^{ab}	9.0 ± 0.03^{a}	9.7 ± 0.06^{a}	**9. 9 ± 0.03^{a}**
	S	7.8 ± 0.1^{b}	8.8 ± 0.03^{ab}	8.9 ± 0.03^{bc}	9.2 ± 0.09^{bc}
	B	8.1 ± 0.1^{ab}	8.7 ± 0.03^{abc}	8.9 ± 0.03^{bcd}	9.0 ± 0.00^{cd}
	M	8.3 ± 0.09^{a}	8.6 ± 0.1^{bc}	8.7 ± 0.03^{cde}	8.9 ± 0.00^{de}
P	A	8.3 ± 0.078^{a}	8.8 ± 0.03^{ab}	9.0 ± 0.00^{b}	9.3 ± 0.09^{b}
	S	7.8 ± 0.1^{b}	8.8 ± 0.03^{abc}	8.9 ± 0.06^{bcd}	9.1 ± 0.07^{cd}
	B	8.2 ± 0.03^{ab}	8.6 ± 0.07^{c}	8.7 ± 0.06^{de}	8.9 ± 0.03^{de}
	M	8.2 ± 0.09^{ab}	8.3 ± 0.06^{d}	8.5 ± 0.03^{e}	**8.7 ± 0.00^{e}**
	CV	3.09	2.44	3.80	4.09

Note: Means in the same column followed by the same letter(s) are not significantly differentat 5% level. S: sack; P: plasticcrate; A: ambient air; S: small room; B: big room; M: medium room

4.2.2.6 *Titratable acidity*

Table 22 indicates the Titratable acidity (TA) of stored head cabbage .The Titratable acidity value of stored head cabbage was revealed a decreasing pattern throughout the storage period.

This decreased could be due to various organic acids were consumed during respiration. This study in line with the study of Faasema *et al*. (2011) who concluded that reduction in acidity might be due to the conversion of the acids into sugars and then further utilization in the metabolic process of the fruits and vegetables.

The highest decreases of Titratable acidity were recorded for head cabbages packed in sack container and stored at ambient air condition. This was attributed due to lack of aeration that contributes to high-temperature from heat generated by the product itself which consume organic acid as substrates for respiration and reduce the acidity. A similar study of Arundathi *et al*. (2019) explained that for foam nets wrapped fruits the higher acidity was prompted which might be a result of increasing the respiratory and ripening process and reduce acidity.

Table 22. Effect of three cold rooms and packaging materials on the Titratable acidity (%) of stored head cabbage

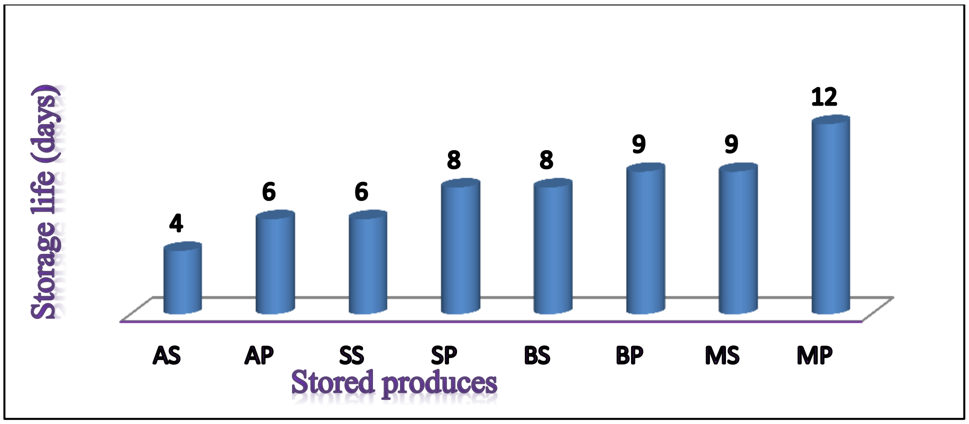
Packaging Materials	**Storage rooms**	**Days after storage**			
		0	**4**	**8**	**12**
S	A	0.9 ± 0.06^{a}	0.5 ± 0.05^{d}	0.4 ± 0.01^{d}	$\mathbf{0.3 \pm 0.02^{d}}$
	S	0.9 ± 0.04^{a}	0.6 ± 0.01^{cd}	0.5 ± 0.03^{cd}	0.4 ± 0.01^{c}
	B	0.8 ± 0.03^{a}	0.7 ± 0.03^{abc}	0.6 ± 0.02^{bc}	0.5 ± 0.04^{abc}
	M	0.9 ± 0.02^{a}	0.8 ± 0.02^{ab}	0.7 ± 0.01^{ab}	0.6 ± 0.02^{ab}
	A	0.8 ± 0.03^{a}	0.6 ± 0.02^{cd}	0.5 ± 0.03^{cd}	0.4 ± 0.01^{cd}
P	S	0.8 ± 0.04^{a}	0.7 ± 0.01^{bc}	0.6 ± 0.03^{bc}	0.5 ± 0.03^{bc}
	B	0.9 ± 0.04^{a}	0.8 ± 0.04^{ab}	0.7 ± 0.04^{ab}	0.6 ± 0.02^{ab}
	M	0.9 ± 0.02^{a}	0.9 ± 0.02^{a}	0.8 ± 0.04^{a}	$\mathbf{0.6 \pm 0.03^{a}}$
	CV	3.99	5.62	8.65	9.07

Note: Means in the same column followed by the same letter(s) are not significantly different at 5% level. S: sack; P: plastic crate; A: ambient air; S: small room; B: big room; M: medium room.

4.2.3 Storage life determination

Figure 7 shows the storage life of head cabbage stored in cold rooms and packed by plastic crates and sacks. Low-temperature storage with plastic crates increased the storage life of head cabbage. The maximum storage life of 12 days for head cabbage stored in medium cold room that has and packed by plastic crates (MP) while the minimum storage life 4days for head cabbages stored at ambient air packed by sack (AS)due to 10.1^{o}Ctemperature and 26.35%relative humidity difference between medium cold room and ambient air. This difference could retard respiration rate, metabolic activity and transpiration processes that in turn increase the life span of stored head cabbage. The ascorbic acid content that recorded under Table 20 of page 43 is best indicators of the end storage life of stored head cabbage. (Nanda *et al.* 2001) explained that ascorbic acid loss of more than 35%can be considered as an end of storage life of the stored produces.

Smilarly,Jany *et al*. (2008) also reported that head cabbage stored for 6 days in low-quality polythene at room temperature (28^{o}C) while in case of refrigeration (4^{o}C) remains up to 8 days of storage. Furthermore, Lim *et al*. (2014) concluded that low-temperature storage slows down the physiological behavior of Chinese cabbage, thereby increasing its shelf life.



Note: AS: ambient sack; AP: ambient plastic; SS: small room sack; SP: small room plastic; BS: big room sack; BP: big room plastic crate; MS: medium room sack; MP: medium room plastic

Figure 7. Effect of three cold rooms and packaging materials on the storage life of stored head cabbage

4.3 Limitations of this study

The sampling methods (continuous follow up measurements) were started from retailers up to consumers that lack continuous follow up start from farmers since it takes a lot of resources and time.

Under the experimental part the cooling performance of three cold rooms were evaluated by loading head cabbage as sample for one season due to lack of finance and time to evaluate for four season of the year with full loading of perishable crops.

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Post-harvest loss of head cabbage is considered to be a major problem for farmers and other actors' involved along its supply chain. Therefore the identification of the causes and magnitudes of postharvest loss at each supply chain is very essential to reduce and control head cabbage from deterioration, discarding, and cost increase and loss of nutritional value. The major identified causes of post harvest loss of head cabbage were poor pre-harvest factors (poor crop variety, inadequate cultural practices),harvesting factors (lack of harvesting stages and techniques) and postharvest factors (improper handling, lack of storage, poor loading and unloading practices, distance from the market). Similarly, factors such as lack of inadequate information and training were found to be a problem for farmers, marketers, and consumers.
In the head cabbage supply chain, the magnitudes of losses were 15.4%, 18% and 20.6% at farmers, retailers and consumers level respectively. The highest postharvest loss of head cabbage was found at consumers' levels due to poor storage condition and poor processing practice that most of the edible parts were trimmed. In addition this level is final levels that the aggregate effects of poor harvesting, packaging, transportation and market condition cause such high loss. To reduce the post-harvest loss of head cabbage, agricultural training and extension service should be given for farmers and other actors on proper pre harvest practice, postharvest handling, and time of harvesting, type of packaging used, transportation system and storage condition and marketing systems

The experiment part concerned about the cooling performance of cold storage rooms that the average minimum and maximum temperature difference and the average minimum and maximum relative humidity difference were calculated with ambient air were 4.7°C and 12.6°C and 40.6% and 19.9% for medium cold room, 2.4°C and11.9°C and 33.27% and11.7% for big cold room and a little and 8.8°Cand 20.8% and 6.9% for small cold room respectively during no load test. The average minimum and maximum temperature difference and the average minimum and maximum relative humidity difference were calculated with ambient air were 3.4°C and 11.6°C and 38.7% and 24.5% for medium cold room, 2°C and10.9°C and 30.2% and16.5% for big cold room and a little and 8°Cand 15.1% and 4% for small cold room respectively during loading of head cabbage. The storage life of head cabbage stored in the medium cold storage room after being placed in plastic crate and sack containers was 12 and 9 days respectively while 8 and 9 days were for head cabbage stored in the big cold storage room after being packed in plastic and sack containers respectively. The storage life of head cabbage stored in the small cold storage after being placed in plastic and sack containers was 6 and 8 days respectively while 4 and 6 days were for head cabbage stored at ambient air after being placed in plastic and sack containers respectively.

To maintain internal temperature and relative humidity, the rooms should be monitored properly that the medium cold room should be ventilated in the evening and stop in the morning while the roof of big cold room should be opened and closed in the evening and in the morning and the windows of small cold room and should be opened and closed in the evening and in the morning each day respectively.

5.2 Recommendation

During assessment part the highest critical loss point was obtained at consumers level resulted from poor storage condition and poor processing practice that most of the edible parts trimmed. Additionally the accumulative effects resulted from poor harvesting, packaging, transportation and handling at market causes high qualitative loss of head cabbage. Therefore it was advisable that consumers should give attention to good storage and processing practice. In addition to consumers, all the stakeholders should give attention and have to be trained to good agricultural practices, proper harvesting methods, suitable packaging material, proper transportation and proper storage system and good marketing systems.

During experiment part the medium cold room had lower average minimum and maximum temperature difference from ambient air while it had higher average minimum and maximum relative humidity from ambient air. The head cabbage stored in the medium cold room that put in the plastic crate had maintains the physicochemical properties extended the storage life to 12 days. It was observed that for best performance the medium cold rooms should be monitored regularly after its solar adjusted in the way that to start ventilation at night and stop in the morning respectively.

6 FUTURE LINE OF WORK

Based on the limitation of the work, the following points have been put forward for any onward research in the future:

i. In this study the identification of major causes and magnitude of post harvest loss of head cabbage was done by measuring the loss only at retailers and consumers level which is not enough. Therefore to enumerate the actual magnitude of loss of head cabbage at each supply chain, sampling method should be carried ought from the field to fork.

ii. The evaluations of cooling performance of cold rooms were carried out only for one season since limitation of time and resource. Only head cabbage was loaded and investigated. It needs to evaluate the cooling performance of cold rooms with loading other commodities from season to season.

iii. The internal temperature and relative humidity of the cold rooms could be affected with the amount of loaded produces. Therefore the full loading capacities with a cooling performance of those cold rooms need to be evaluated.

iv. If the products well cooled after harvested during temporary collection time, they withstand the loss due to improper temperature and relative humidity. Therefore other study should be done to compare the extent of post-harvest loss of head cabbage that cooled and not cooled in cold rooms in its supply chain.

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ANNEXS

I. Questionnaire

A. Demographic and Socio-economic status

1. What is your age?
2. What is your marital status? 1. Single 2.Married 3.Widowed 4.Divorced
3. What is an educational status of you and your wife/husband? 1. Illiterate 2.Primary 3.Secondary 4.Collage 5.University
4. What is an occupation of you and your wife/husband? 1. Farmer 2.Government Employee 3. NGO Employee 4.Merchant 5.Daily laborer 6.Other (specify) _______
5. Where is the place of residence of the respondent? 1. Rural 2.Semi-urban 3. Urban
6. What is the main source of income for household? 1. Farming 2.Livestock production 3. Business 4.Social grants .5 Salary 6.Other (specify) ______
7. Do you alternative income-generating activities? If yes what? 1. Livestock production 2. Poultry production 3.Both Livestock and poultry production 4.salary5. Other (specify) _____
8. Who do new income generating activity? 1. Husband 2.Wife 3.Both 4. Other (specify)
9. Where is the main place do you exchange your goods? 1. Kebele market 2.Dedo market 3.Jimma market 4.Other (specify) ___

B. Actors and Product Flow in the Head Cabbage Supply Chain

1. What is your annual average production of head cabbage (quintal)?_______
2. For what purpose do you produce head cabbage? 1. Consumption 2.Sell (marketing) 3.both
3. If you used for consumption how much of it? _______
4. If you used for marketing (sell) how much of it? _______
5. Do you sell your head cabbage to the following actors? **0. No 1.Yes Proportion**

    2. Urban consumer_______ _______
    3. Rural collectors_______ _______
    4. Wholesaler_______ _______
    5. Rural retailers_______ _______
    6. Urban retailers_______ _______
    7. Farmers cooperation_______ _______

C. Pre-harvest Practices

1. How long do you have farming experiences?______

2. Mostly which varieties of head cabbage do you cultivate? 1. France 2.Hollan 3. Other_____

3. Do you use fertilizer and which type? 1. Artificial fertilizer 2.Organic 3.Both

4. If you use artificial fertilizers, mainly which? 1 NPSB 2.Urea 3.Other (specify) ____

5. If you use organic fertilizers, mainly which? 1. Compost2 manure 3.Other (specify) ____

6. Do you use pesticide? If yes mainly which? 1. Insecticide 2.herbicide 3.fungicide 4.Other (specify) ___

7. Which water sources do you depend on? 1. Rain water 2. Irrigation water 3. Both

8. How many times you cultivate head cabbage in a year? 1. One 2.Two 3. Other (specify) __

9. Which labor force do you use? 1. Family 2. Hired

10. Do you sow seed and planting head cabbage in line? 0. No 1.Yes

11. How you control weed for head cabbage? 1. Weeding 2.Using herbicide 3. Other (specify)

D. Postharvest Practices

1. Mostly how do you identify the maturation of head cabbage? 1. Touch and feel its firmness 2.Size and shape 3.Color 4. Calendaring 5.Other (specify)_______

2. Mostly when you harvest your head cabbage? 1. Early in the morning 2. Late afternoon 3. Any time

3. What harvest methods mostly you follow? 1. Pulling with hand 2. Twisting and cutting with Machete 3.Bending and cutting with sharp knife 4.Other (specify) _______

4. Which care mostly do you have for loss during harvesting? 1. Gently harvesting 2.Shade at field 3.Use suitable container 4.Other (specify)_______

5. The extent of loss of head cabbage due to harvesting practice?_______

6. Your sorting method of head cabbage, mostly depend on? 1. Size 2. Shape 3.Compactness of head 4.Appearance 5. Other (specify)_____

7. Which trimming practice mostly you follow? 1. Trim with hand 2.Trim with sickle 3.Other (specify) ______

8. If there is loss, how much of loss due to poor trimming? _______

9. Mostly which containers you use to hold head cabbage? 1. Sacks 2.wooden box 3.plasticcrates 4. Other (specify) _______

10. If there is loss due to unsuitable container, how much of expected loss?_______

11. Which pre-cooling methods you used? 1. Room cooling 2.Hydro cooling 3.Shading 4.Other (specify) _______

12. For how long pre-cool head cabbage? _______

13. Where you pre- cool your commodities? 1. In field 2.At store area 3.Other (specify) ____

14. What transportation methods mainly you used to transport to temporary storage area? 1. Human back or head 2.Animal back 3. Truck 4. Other (specify) ______

15. What is the major time of transportation of your head cabbage from farm to temporary storage area? 1. Early morning 2.Late afternoon 3. Anytime

16. What containers mostly do you use to transport head cabbage to store area? 1. Sacks 2. Wooden crates 3.Plastic crates 4. Other (specify) ________

17. How far the farm from temporary storage area (Km)? ________

18. Mostly which storage facilities do you use? 1. Pits 2.Indoor Storage 3.Cold room 4.Other (specify) ______

19. For how long do you store this produces? ______

20. Among your storages structure which are more susceptible for spoilage of your commodities? ______

21. How much of loss of head cabbage due to lack of cooling storage? ______

22. Most of the times when you transport head cabbage to market? 1. Early morning 2.Late afternoon3. Anytime

23. Mostly which transportation system you use for head cabbage to market? 1. Human back or head 2.Animals back 3.Truk 4.Public vehicle

24. Mostly how you load head cabbage during transportation? 1. Overloading 2.Load with unfilled 3.Throw on during loading 4.Other (specify) _______

24. How far the market from the store area (Km)? ______

25. Mostly how you unload cabbage after transportation? 1. Throw on the ground 2.Pull over one another 3.Other (specify) ________

26. How much of loss of head cabbage during inappropriate transportation? ________

27. Mostly where do you sell head cabbage? 1. nearby field 2.Local market 3.Urban market 4. Other (specify) ________

28. What is the price of a tones of head cabbage?________

29. Mostly what marketing challenges do you have? 1. Price fluctuation 2.Absence of cold chain 3. Surplus of produces at market 4.Other (specify)_______

30. What do you expect the extent of loss head cabbage due to market challenge?_______

31. What do you expect the extent of loss of head cabbage due to processing?_______

E. Agriculture Training and Facilities

1. Have you training on pre harvest practices and mostly on which? 1. Land preparation 2.Soil management 3.Irrigation practices 4.Composting 5.Other (specify)_____

2. Have you training on post-harvest practices and mostly on which? 1. Harvesting practices 2. Packaging practice 3.Storage practice 4.Transportation 5.Other (specify) _______

3. Who give you training? 1. Governments 2. NGO 3.Both

4. Do you receive agricultural facilities on post-harvest practices and mostly which are? 1. Harvesting tools 2.Packaging tools 3.Provide credit facilities 4.Other (specify)______

5. Who give you agricultural facilities? 1. Government 2.NGO 3.Both

F. Gender Role in Agriculture Practices

1. Who are participating in the following post-harvesting practice? 1. Women 2.Men 3.Both

1. Harvesting practice? _______
2. Pre-cooling practice? _______
3. Transporting to temporary store area?_______
4. Storage practice? _______
5. Transporting to market? _______
6. Marketing practice? _______
7. Who is highly participated in Post-harvest practices?_______

II. Focus Group Discussion

❖ **General information on post harvest loss of head cabbage**

- Farmers No Male ___________ Female ___________
- Experts No ___________ ___________
- ➢Varieties of head cabbage grown:_________________________________
- Which head cabbage varieties has good post harvest life? ___________ ___________
- Which varieties have bad post harvest life? ___________ ___________
- Which farming method do you use? ___________ ___________

- How long farming experiences do you have? ___________ ____________ __________
- Annual Average Production (ton):________________________
- For what purpose you cultivate head cabbage? __________________
- What pre- harvest factors influence post harvest loss of head cabbage?___________
- What is the proportion of head cabbage used for home consumption?________
- What is the proportion of crop used for sell? ________________
- When you have surplus, to whom do you sell it? ___________ ___________

❖ Information on Harvesting practice

- At what day time do you harvest your head cabbage? ___________ ___________
- How do you know the maturity of cabbage whether to harvest or not? ___________
- What method of harvesting/cutting mechanism do you use? ___________ ___________
- Do you think there is high or low PHL at harvest? If yes, how much of it? ___________
- What do you think are the main reasons for the loss at harvest? ___________
- Could you tell us the proportion of decay or spoilage? _____________________
- What are the main types of losses? ___________ ___________ ___________
- What do you normally do to minimize losses at this stage? ___________ ___________
- Are you cooling your produce in field before packaging? How? ___________
- What containers or packaging materials do you use? ___________ ___________
- What practices do you do to prepare your head cabbage to store or sell? Please specify each of the following steps or add if difference: Harvesting, trimming, sorting, grading, packaging, storing (for how much), transporting to marketing then selling. ___________
- Who are participating on the above activities in more, how many?___________

❖ Question on Post harvest handling

- What handling practices do you do or have? ___________
- What packaging material do you use? ____________ ______________________
- What extent of loss do you expected during poor handling practice? ____________

❖ Question on Storage and storage structures of head cabbage

- What storage materials and storage methods do you use for head cabbage? ____________
- Do you store your head cabbage? _______________________
- How do you transport your vegetables to the storage place? ______________________

- How far is the farm from temporary collection area? ________________________ _
- Do youstore head cabbge?If yes for how many days or week?_____________
- Do you have modern storage facility? Mention specifications _____________

❖ **Questions on Transportation of head cabbage**

- How do you transport your crop from home to market? _____________
- Who is involved during transportation? _____________ ________________________
- How you load during transportation? _____________ ________________________ ________
- Mostly where do you sell your crop? Nearby markets or local etc.?_____________________
- What is the distance of the market from the farm or home? _____________
- Is there loss during transporting? If yes, how much? _____________
- For whom do you sell? What is your price kg/birr?________________________ _________
- What is the major problem in marketing of your crop? _______________________

III. Discussion with Key Informants

- do you have post harvest management (PHM) team or experts?_________________
  - What is your activity related to postharvest management? ___________________
  - What is the total number of farmers producing the head cabbage? ______
  - How much is the annual production of the head cabbage? ________________
  - For what purpose you cultivate the head cabbage? ___________________________
  - How much of the produce do you think is consumed at houselhold level? _______
  - How much of the produce do you think is going to Jimmamarket? ____________
  - What kind of support being provided to actors in the supply chain? ____________
  - What are the major supply chains the product passes until it reaachs consumers (farmers, traders, processors, consumers)? ___________________
  - Which trade route/ supply chain is assumed to be more profitable? Why? _______
  - What are the major trade routnes for this commodity in this woreda? __________
  - In which stages of the supply chain are cabbage losses more critical Why? ____
  - What do you think should be done to reduce postharvest losses in the area? _____

IV. Figure of Annex

Figure 1.Head cabbage harvesting, sorting, trimming and packaging practices

Figure 2.Head cabbage transportation and marketing practices

V. Tables of Annex

Table1.Temperatures and relative humidity in the cold storage rooms and ambient air during no loading test

For medium cold room																								
Days	1		2		3		4		5		6		7		8		9		10		11		12	
	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-
T(°C)	17.9	21.1	18.1	21	18.8	21.1	18.2	21.5	18.3	21.3	17.5	21.4	18.5	21	18.5	21.2	18.2	21.2	18.4	21	18.5	21.6	18.8	21.5
Time	8:44:29PM	1:44:29PM	12:44:AM	9:44:29 AM	12:44:29 AM	12:14:29 PM	11:59:29 PM	8:29:29 AM	12:14:29 AM	11:14:29 AM	11:29:29 PM	11:14:29 AM	12:59:29 AM	11:59:29 AM	1:14:29 AM	11:44:29	1:44:29 AM	10:59:29 AM	11:29:29 PM	10:29:29 AM	1:14:29 AM	10:59:29 AM	1:14:29 AM	11:59:29 AM
RH(%)	79.2	85.9	83.9	88.9	85.8	90.3	80	89.7	84.3	90.6	82.1	90.4	82.7	90.5	84.5	90.9	85	90.6	85	90.8	84.8	90.4	84.3	90.3
Time	1:44:29PM	8:44:29PM	6:29:29 PM	3:29:29AM	12:44:29 PM	4:59:29 AM	8:59:29 AM	3:14:29 AM	7:14:29 PM	4:29:29 AM	1:14:29 PM	3:14:29 AM	2:14:29 PM	6:14:29 AM	3:14:29 PM	4:29:29 AM	5:29:29 PM	3:59:29 AM	4:29:29 PM	3:44:29 AM	3:29:29 PM	5:14:29 AM	4:29:29 PM	4:14:29 AM
For big cold room																								
Days	1		2		3		4		5		6		7		8		9		10		11		12	
	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-
T(°C)	20.4	21.8	20.4	21.8	20.1	22.2	20.1	21.7	19.6	21.8	19.9	21.6	20	21.7	20.1	21.8	20.2	21.6	20.2	21.9	20.7	22.1	20.4	22.6
Time	12:29:14 AM	12:29:14 PM	12:44:14 AM	11:59:14 AM	11:14:14 PM	2:59:14 PM	12:59:14 AM	11:14:14 AM	11:44:14 PM	11:29:14 AM	1:59:14 AM	12:59:14 PM	11:59:14 PM	11:14:14	12:44:14 AM	2:14:14 PM	11:29:14 PM	7:14:14 AM	12:14:14 AM	12:59:14 PM	12:44:14 AM	1:14:14 PM	11:14:14 PM	11:59:14 AM
RH(%)	75	80	77	83.4	74.8	79.8	75.4	81.8	75.6	82.5	76.6	81.8	75.2	81.3	75.8	83.1	76.4	82.4	77	82.4	79	82.6	75.5	82.3
Time	3:29:14 PM	5:44:14 AM	3:44:14 PM	1:14:14 AM	1:59:14 PM	1:14:14 AM	5:29:14 PM	5:29:14 AM	11:14:14 AM	11:29:14 AM	4:44:14 PM	5:14:14 AM	3:14:14 PM	7:59:14 AM	5:59:14 PM	6:59:14 AM	6:44:14 PM	7:14:14 AM	4:14:14 PM	11:29:14 AM	4:29:14 PM	6:59:14 AM	4:44:14 PM	6:14:14 AM
For small cold room																								
Days	1		2		3		4		5		6		7		8		9		10		11		12	
	min-	max-	min-	max-	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min	max	min-	max-	min-	max-
T(°C)	21	24.6	21.6	24.7	21.9	24.5	22.8	24.6	23.3	25.2	22.8	24.8	23.4	25.3	23.5	25.2	23.8	25.1	23.5	25.3	23.4	25.5	23.4	25.5
Time	11:58:29 PM	1:13:29 PM	1:58:29 AM	11:58:29 AM	1:43:29 AM	1:28:29 PM	1:13:29 AM	1:43:29 PM	1:28:29 AM	11:13:29 AM	1:13:29 AM	1:43:29 PM	1:13:29 AM	11:43:29 AM	1:13:29 AM	11:13:29 AM	12:28:29 AM	11:13:29 AM	1:28:29 AM	11:43:29 AM	12:13:29 AM	11:28:29 AM	11:13:29 PM	1:13:29 PM
RH (%)	65.8	71.3	61	74.8	63.1	71.2	63.7	68.1	63.1	65.5	63.8	68.6	62.6	67.3	63.3	68.9	64.1	69.4	63.9	68.6	65.3	70	63.8	69
Time	2:58:29 PM	11:28:29	1:28:29	1:13:29	11:58:29	5:43:29	2:58:29	5:13:29	1:13:29	1:13:29	2:13:29	1:58:29	9:43:29	5:58:29	4:58:29	5:43:29	3:58:29	7:58:29	2:43:29	6:43:29	11:43:29	2:13:29	11:28:29	5:28:29

		PM	PM	AM	AM	AM	PM	AM	PM	AM	PM	AM	AM	AM	PM	AM	PM	AM	PM	AM	AM	AM	AM	AM

For ambient air																								
Day	1		2		3		4		5		6		7		8		9		10		11		12	
	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-	min-	max-
T(°C)	23.2	34.8	24.8	34.4	23.6	30.4	24.8	36.8	22.8	31.7	23.7	35.8	22	35.3	23.3	31.5	22.4	33.6	19.6	32.8	19.9	33.1	20.8	36.2
Time	1:36:16 AM	10:21:16	1:06:16 AM	11:06:16 AM	1:21:16 AM	2:36:16 PM	1:06:16 AM	11:21:16 AM	1:06:16 AM	11:06:16 AM	1:51:16 AM	1:21:16 PM	1:06:16 AM	11:06:16 AM	1:21:16 AM	10:06:16 AM	1:21:16 AM	11:21:16 AM	10:21:16	2:36:16 PM	1:06:16 AM	10:51:16	1:36:16 AM	11:36:16 AM
RH (%)	40.2	63	41.8	62	43.5	59	43	57	43.9	59.6	43.8	61	48.1	62.5	45.9	66	39.8	63	41.9	68.3	43.2	63.4	38.9	65.3
Time	10:21:16 AM	1:06:16 AM	11:06:16 AM	1:06:16 AM	3:21:16 PM	1:06:16 AM	2:36:16 PM	11:21:16 PM	10:36:16 AM	1:36:16 AM	11:21:16 AM	3:06:16 PM	2:36:16 PM	11:21:16 PM	3:51:16 PM	11:21:16 PM	10:36:16 AM	1:36:16 AM	3:21:16 PM	4:36:16 AM	10:51:16 AM	5:36:16 AM	4:51:16 PM	3:36:16 AM

Table 2.Temperatures and relative humidity in the cold storage rooms and ambient air during loading test

For medium cold room																								
Day	1		2		3		4		5		6		7		8		9		10		11		12	
	min-	max	min-	max	min-	max	min-	max	min	max	min	max	min	max	min-	max	min	max	min-	max	min	max	min	max
T(°C)	19.8	22.3	19.9	22.3	20	22.2	19.9	22.3	19.8	22.4	19.7	21.6	19.6	22	19.6	22.3	19.5	22.4	19.6	22.8	19.5	22.5	19.5	22.6
Time	12:44:29 AM	11:29:29 AM	1:14:29 AM	9:29:29 AM	12:14:29 AM	11:59:29 AM	12:44:29 AM	9:29:29 AM	1:59:29 AM	9:59:29 AM	2:59:29 AM	11:14:29 AM	1:59:29 AM	11:29:29 AM	11:14:29 AM	12:14:29	1:14:29 AM	11:44:29 AM	1:14:29 AM	9:14:29 AM	2:59:29 AM	9:59:29 AM	2:59:29 AM	8:14:29 AM
RH (%)	82.8	87.2	81.5	86.7	84.2	87.3	81.2	87.3	82.4	87.6	81.7	86.9	81	87.4	81	86.3	82.8	86.7	81.7	86.7	79.6	86.7	79	86.6
Time	5:44:29 PM	5:29:29 AM	3:14:29 PM	7:59:29 AM	1:29:29 PM	4:14:29 AM	2:14:29 PM	6:14:29 AM	1:44:29 PM	4:14:29 AM	4:14:29 PM	3:44:29 AM	6:29:29 PM	2:59:29 AM	7:14:29 PM	5:29:29 AM	10:44:29 AM	3:44:29 AM	4:59:29 PM	2:14:29 AM	9:59:29 AM	3:29:29 AM	10:29:29 AM	7:14:29 AM
For big cold room																								
Day	1		2		3		4		5		6		7		8		9		10		11		12	
	min-	max	min-	max	min-	max	min-	max	min	max	min-	max	min	max	min-	max	min-	max	min-	max	min	max	min-	max
T(°C)	20.9	22.5	21	23.5	21.6	23.6	21.3	23.8	21.1	22.6	20.7	22.7	20.4	22.8	20.8	22.6	20.8	23.4	20.6	22.4	20.9	24.2	20.9	22.26
Time	1:14:14 AM	1:59:14 PM	11:29:14 PM	10:14:14 AM	12:14:14 AM	11:59:14 AM	12:14:14 AM	3:14:14 PM	1:14:14 AM	11:59:14 AM	12:59:14 AM	10:59:14 AM	1:29:14 AM	11:29:14 AM	12:29:14 AM	11:59:14 AM	12:44:14 AM	2:14:14 PM	12:44:14 AM	11:14:14 AM	1:14:14 AM	11:59:14 AM	12:44:14 AM	11:29:14 AM
RH (%)	74.7	79	73.8	79.9	77	80.9	74.5	80.6	74.8	80.8	73.9	78.4	71.2	78.8	70.8	78.2	71.4	76.8	70.4	77.7	71.5	78.3	71.7	78.4

Time	4:59:14 PM	**6:14:14 AM**	2:29:14 PM	5:29:14 AM	4:29:14 PM	7:14:14 AM	3:59:14 PM	5:44:14 AM	4:44:14 PM	6:29:14 AM	5:44:14 PM	7:14:14 AM	1:29:14 PM	7:14:14 AM	2:29:14 PM	4:44:14 AM	4:29:14 PM	6:59:14 AM	4:14:14 PM	6:59:14 AM	1:59:14 PM	6:14:14 AM	10:29:14 AM	7:14:14 AM
For small cold room																								
Day	1		2		3		4		5		6		7		8		9		10		11		12	
	min-	max	min-	max	min-	max	min-	max	min	max	min-	max	min	max	min-	max	min-	max	min-	max	min	max	min-	max
T(°C)	22.2	26	23	26	22.5	25.9	22.7	26.1	23.2	25.9	23.4	25.5	21.6	25.6	23.3	25.9	23.4	26.1	22.4	26	23.3	25.9	22.3	25.5
Time	1:28:29 AM	10:43:29 AM	1:13:29 AM	11:13:29 AM	1:13:29 AM	11:28:29 AM	1:13:29 AM	11:43:29 AM	1:13:29 AM	3:58:29 AM	1:13:29 AM	10:58:29 AM	1:13:29 AM	11:58:29 AM	1:28:29 AM	11:58:29 AM	1:13:29 AM	10:58:29 AM	1:13:29 AM	11:43:29 AM	1:13:29 AM	11:58:29 AM	2:13:29 AM	2:28:29 PM
RH (%)	57.6	66.8	58.2	65.2	61.7	67.2	59.8	65.6	58.2	64.2	57.7	68	57.7	69	56.7	71	53.7	70.2	57.3	62.5	58.2	64.5	58.5	63.2
Time	4:43:29 PM	5:13:29 AM	2:13:29 PM	5:58:29 AM	10:58:29 AM	1:43:29 AM	11:58:29 AM	3:13:29 AM	3:28:29 PM	7:13:29 AM	10:43:29 AM	5:43:29 AM	1:28:29 PM	4:43:29 AM	5:28:29 PM	3:28:29 AM	11:13:29 AM	2:13:29 AM	4:28:29 PM	2:58:29 AM	7:13:29 AM	3:43:29 AM	10:58:29 AM	1:13:29 AM

Note, min- minimum; max-: maximumm