EFFECT OF TEMPERATURE AND AIR MODIFICATION IN THE SHIP'S HOLD ON THE SHELF LIFE OF THE FRUIT

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EFFECT OF TEMPERATURE AND AIR MODIFICATION IN THE SHIP'S HOLD ON THE SHELF LIFE OF THE FRUIT

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Bachelor of Engineering
(Marine Engineering)

Faculty of Marine Technology
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5 March 2021

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"I declare that this thesis entitled *Effect of Temperature and Air Modification in the Ship's Hold on the Shelf Life of the Fruit* is the result of my own research except as cited in the references. This thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree."

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ABSTRACT

As a tropical country, Indonesia produces many kinds of horticultural products, especially fruits. Apart from local marketing, the fruit produced by Indonesian farmers is also able to compete with foreign markets. In this case, a means of transportation is needed in the shipping process, one of which is a fruit transport vessel. So, we need a special storage area that can maintain the quality of the fruit. To maintain the quality of the fruit during the shipping process, there is a storage system called Controlled Atmosphere Storage (CAS), where this system tries to maintain the quality of the fruit by controlling temperature and air conditions continuously according to the desired concentration. The objective of the research to be carried out is to know the effect of temperature and atmospheric modification in a ship's cargo hold to the shelf life of fruit. In this research, several experiments were carried out using CAS prototypes to answer the research objectives. This prototype uses dry ice as a coolant, CaOH2 as a CO2 scrubber, a mixture of KMnO4 & zeolite as an ethylene scrubber, and N2 gas as an O2 scrubber. Experiments were carried out using 2 variations of fruit and 3 variations in the amount of dry ice, with fruit variations namely banana and pineapple, while variations in the amount of dry ice were 7 kg, 9 kg, and 11 kg. Based on the results of 6 experiments that have been done, it can be said that the temperature can affect the ripening process of fruit. This is because the decrease in temperature can reduce the levels of ethylene produced by fruit. Besides the temperature, the O2 and CO2 levels can also affect the fruit ripening process. This is because the increase in CO2 levels around the fruit will lower O2 levels, which causes inhibition of the respiration process in the fruit.

Keywords: CAS, Temperature, O2, CO2, Ethylene

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ABSTRAK

Sebagai negara tropis, Indonesia menghasilkan berbagai macam produk hortikultura, khususnya buah-buahan. Selain pemasaran dalam negeri, buah yang dihasilkan petani Indonesia juga mampu bersaing dengan pasar luar negeri. Dalam hal ini diperlukan alat angkut dalam proses pengirimannya, salah satunya adalah kapal pengangkut buah. Oleh karena itu, diperlukan tempat penyimpanan khusus yang dapat menjaga kualitas buah. Untuk menjaga kualitas buah selama proses pengiriman, terdapat sistem penyimpanan yang bernama *Controlled Atmosphere Storage (CAS)*, dimana sistem ini berusaha menjaga kualitas buah dengan cara mengontrol suhu dan kondisi udara secara terus menerus sesuai dengan konsentrasi yang diinginkan. Tujuan dari penelitian ini adalah untuk mengetahui pengaruh modifikasi suhu dan atmosfir di ruang muat kapal terhadap umur simpan buah. Dalam tugas akhir ini dilakukan beberapa percobaan menggunakan prototipe CAS untuk menjawab tujuan penelitian. Prototipe ini menggunakan es kering sebagai pendingin, CaOH2 sebagai CO2 *scrubber*, campuran KMnO4 & zeolite sebagai etilen *scrubber*, dan gas N2 sebagai O2 *scrubber*. Percobaan dilakukan dengan menggunakan 2 variasi buah dan 3 variasi jumlah es kering, dengan variasi buah yaitu pisang dan nanas, sedangkan variasi jumlah es kering adalah 7 kg, 9 kg, dan 11 kg. 1. Berdasarkan hasil 6 percobaan yang telah dilakukan, dapat dikatakan bahwa suhu dapat mempengaruhi proses pemasakan buah. Hal ini dikarenakan penurunan suhu dapat menurunkan kadar etilen yang dihasilkan buah. Selain suhu, kadar O2 dan CO2 juga dapat mempengaruhi proses pematangan buah. Hal ini dikarenakan peningkatan kadar CO2 di sekitar buah akan menurunkan kadar O2 yang menyebabkan terhambatnya proses respirasi pada buah.

Kata kunci: *CAS*, Suhu, O2, CO2, Etilen

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LIST OF ABBREVIATIONS

CAS	:	Controlled Atmosphere Storage
O2	:	Oxygen
CO2	:	Carbon Dioxide
KMnO4	:	Potassium Permanganate
CaOH2	:	Carbon Hydroxide
N2	:	Nitrogen

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LIST OF SYMBOLS

cm	:	Centimeter
C	:	Celcius
ppm	:	Part per million
%	:	Percent
Kg	:	Kilogram
m3	:	Meter cubic
h	:	Hours
µL	:	Micro liter

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CHAPTER 1

INTRODUCTION

1.1 Research Background

As a tropical country, Indonesia produces many kinds of horticultural products, especially fruits. According to data from BPS (Central Bureau of Statistics) in 2018 the results of fruit production in Indonesia increased from 2017-2018 with an increase in the range (1.42 - 50.99) %. Based on the largest production, there are five superior commodity fruits yearly in 2018, namely a banana of 7.26 million tonnes, mango 2.62 million tonnes, orange siam / tangerine amounted to 2.41 million tons, pineapple 1.81 million tons, and durian amounting to 1.14 million tons. Five superior commodities are produced in almost every province in Indonesia. In 2018 total export results Indonesia's annual fruit crop amounting to 87.99 thousand tons with a value of US $ 61.86 million. Mangosteen fruit exports in 2018 amounted to 38.84 thousand tons to be the largest contributor foreign exchange from annual fruits with a value of US $ 33,278,463. Most of the mangosteen fruit exported to China, Thailand, Vietnam, Malaysia and Hong Kong.

Apart from local marketing, the fruit produced by Indonesian farmers is also able to compete with foreign markets. In this case, a means of transportation is needed in the shipping process, one of which is a fruit transport vessel. So, we need a special storage area that can maintain the quality of the fruit. In principle, the storage of fruits and vegetables is carried out to control the rate of metabolic processes, such as respiration, transpiration, infection of pests and diseases and to extend shelf life. The purpose of fruit storage is to extend product usefulness, control market demand, and increase profits (Argo, 2012). Although it must go through a shipping process, the fruit that is harvested must be treated specifically so that its quality is maintained when it is on the market. It is because the fruit price is inline with the fruit quality, so if the fruit quality is high so is the fruit price.

To handle that problem, much research has already been done, and generally the use of cold storage is a method of handling used to maintain quality and extend the shelf life of fr uit that is transferred by the shipping process. The use of cold storage helps prevent the decrease of fruit quality by slowing down the ripening process. But cold storage only helps slow down the ripening process by keeping the temperature of the fruit at a low level. Besides the temperature, gas content around the fruit also affects the respiration process. So, another way to help slow down the ripening process is controlling the gas content around the fruit.

There is a tool to help keep the temperature and controlling the gas content around the fruit, is called controlled atmosphere storage (CAS). Widyaningrum said in

her study “storage by adjusting the composition of the air or controlling the concentration of oxygen and carbon dioxide is known as controlled atmosphere storage. Controlled atmosphere storage (CAS) is a storage method by controlling the concentration of oxygen and carbon dioxide continuously according to the desired concentration” (as cited in Rangkuti, 2010).

In this final project, will be done some experiment using controlled atmosphere storage (CAS) prototype which is equipped with some sensor and microcontroller to know how long the prototype can increase the shelf life of fruit. The experiment result will improve the information about the use of controlled atmosphere storage (CAS) as fruit storage at ship’s hold to help maintained the quality of fruit that transferred by ships.

1.2 Problem Statement

Based on the background that describe above, author raised the following problem, there is:

How is the effect of temperature and atmospheric modification in a ship's cargo hold to the shelf life of fruit?

1.3 Research Objectives

The objective of the research to be carried out is as follows:

To know the effect of temperature and atmospheric modification in a ship's cargo hold to the shelf life of fruit

1.4 Scope of Research

In order to clarify the topic and make the problem more specific, the scope and limitation of research are defined as follows:

a) Not doing analysis from an economic point of view

b) Not discussing the control system on the tools that are made

c) Not designing the controlled atmosphere storage system

d) Only do an experiment using laboratory scale prototype

e) Not calculating the respiration rate

1.5 Research Benefit

a) Can improve and support learning process about effect of using a controlled atmosphere storage at a ship's cargo hold

b) Can help farmers in the process of delivering fruit, so that fruit quality is maintained.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In general, this chapter provides a set of summaries for all related materials contained in various references. The material presented is made from the latest references of related studies and basics theories. The related studies and basic theory are sourced from scientific papers, journals, books, final project report, and internet. All of materials in this chapter expected to support the process of working on this final project.

2.2 Related Studies

2.2.1 Effect of Storage with Controlled Atmosphere on Quality of Rambutan Fruit 'Binjai'

(Julianti et al, 2013). Effect of Storage with Controlled Atmosphere on Quality of Rambutan Fruit 'Binjai'. Research. University of North Sumatera.

The objective of the research was to determine optimum O2 and CO2 concentration for rambutan Binjai storage at 10 0C. Changes in quality, weight loss, moisture content, total soluble solid, total sugar, titratable acidity, vitamin C, red value of skin color, hardness and sensory characteristics in rambutan var. Binjai fruits held for 20 days at 10 0C in air or controlled atmosphere (1-3% O2 2-4% CO2; 1-3% O2 5-7% CO2; 1-3% O2 8-10% CO2,; 4-6% O2 2-4% CO2; 4-6% O2 5-7% CO2; and 4-6% O2 8-10% CO2) were evaluated. Various atmosphere had significantly different effects on weight lost, total sugar, total souble solid, titratable acidity, red value of color, hardness and sensory value (taste, color, and flavor) of rambutan 'Binjai' fruits in 10 0C of storage. The best quality of rambutan 'Binjai' fruits was found at controlled atmosphere of 4-6% O2: 2-4% CO2 for up to 20 days of storage at 10 0C.

2.2.2 The Technique of Measuring the Rate of Respiration of Horticultural Products Under Controlled Atmospheric Conditions

(Hasbullah, 2007). The Technique of Measuring the Rate of Respiration of Horticultural Products Under Controlled Atmospheric Conditions. Research. Bogor Institute of Agriculture.

Respiration rate data on various gas compositions are needed in the design of horticultural fresh storage, both modified atmosphere (MA) and controlled atmosphere (CA) storage systems. This paper discusses techniques for measuring respiration rates in controlled atmospheric conditions using the closed system method to obtain respiration

rate data at various gas compositions (02 and C02). The measurement results show that the respiration rate in mangoes is influenced by the composition of the gas, where the rate of respiration increases with increasing concentration of 02 and decreasing concentration of CO2. Mathematical models based on the principle of enzymatic reactions are good enough to formulate the rate of respiration as a function of the concentrations of 02 and C02.

2.2.3 Manipulation Atmosphere Against CO2 and O2 Gas Concentration to Increase the Shelf Life of Fruits in Dry Ice Cooled Box

(Sari, 2016). Manipulation Atmosphere Against CO2 and O2 Gas Concentration to Increase the Shelf Life of Fruits in Dry Ice Cooled Box. Bachelor Thesis. Sepuluh Nopember Institute of Technology.

Indonesia is a country with 35% of the tropical's world fruit commodity which one banana. Physically, this fruit can only survive for 3-4 days in a temperature 28-30˚C. This fruit will quickly rot if there is no atmosphere treatment for banana life time. By utilizing dry ice as the cooling medium. In this experiment the use of dry ice 50gr / kg banana. Used bananas mass variation are 3 kg and 1.5 kg. The equipments used they are: Styrofoam box, thermocouple, gas detector, sealant, hygrometer, and bananas. First, banana have initial cooling 20 ° C before being put in a box. Observation and measurement of O2 and CO2 gas concentration is done at a temperature range of 14 ° C-27 ° C. From the experimental results known that bananas using dry ice looked more fresh than those not using dry ice after engineering the atmosphere One of the changes which the concentration of CO2 gas from 21% to 8,3% in this experiment. Profits have 9x the price of the ordinary with this method

2.2.4 The Effect of Air Composition on the Quality of Siam Brastagi Orange (Citrus nobilis LOUR var Microcarpa) During Room Temperature Storage

(Nainggolan et al, 2016). The Effect of Air Composition on the Quality of Siam Brastagi Orange (Citrus nobilis LOUR var Microcarpa) During Room Temperature Storage. Bachelor Thesis. University of North Sumatera.

This research was conducted to discover the effect of atmosphere composition during storage at room temperature on the quality of Berastagi tangerines. The research was conducted by applying a complete randomly design with two factors, i e atmosphere composition of A1 = concentrations of O2 3-7%, concentrations of CO2 1-3%, A2 = concentrations of O2 8-12%, concentrations of CO2 1-3%, A3 = concentrations of O2 3-7%, concentrations of CO2 4-6%, A4 = concentrations of O2 8-12%, concentrations of CO2 4-6%, and A5 = Control (open air). Length of storage were L1 = 5 days, L2 = 10 days, and L3 = 15 days. The Parameters obsserved were water content, mass loss, vitamin C content, total soluble solids, total acid, hardness, organoleptic of color, smell, taste, and texture. The results of the research showed that atmosphere composition had highly

significant effect the water content, mass loss, vitamin C content, total soluble solids, total acid, hardness, organoleptic of color, smell, taste, and texture. The length of storage had highly significant effect on the water content, mass loss, vitamin C content, total soluble solids, total acid, hardness, organoleptic of color, smell, taste, and texture. The longer of the length of the storage , the lower the water content, the vitamin C content, and the total acid, but the higher the mass loss was. The interaction only affected the water content and the total acid. The air composition of O2 3-7%, and CO2 1-3% could maintain the quality of Berastagi tangerine for 15 days.

2.3 Basic Theory

All of basic concept, theory, and information that related with final project will be explained in this section. The concepts or theories described in this section are used as a guide for solving the research problems and carrying out research tasks arranged in the research methodology. The explanation are consist of ship's cargo hold, factors that affecting the shelf life of fruit, controlled atmosphere storage (CAS), cold storage, and dry ice.

2.3.1 Ship's Cargo Hold

Ships have been conventionally linked to trade and hence carrying platforms for different types of cargo. Cargo carried on ships can be general, breakbulk, or liquid bulk, and can be packed in barges, containers, drums, or etc. The different types of cargo lead to different types of ship, it's because they have their own treatment needs to keep their condition and quality. So because of that each ship's cargo hold is designed pertaining to a specific purpose and need.

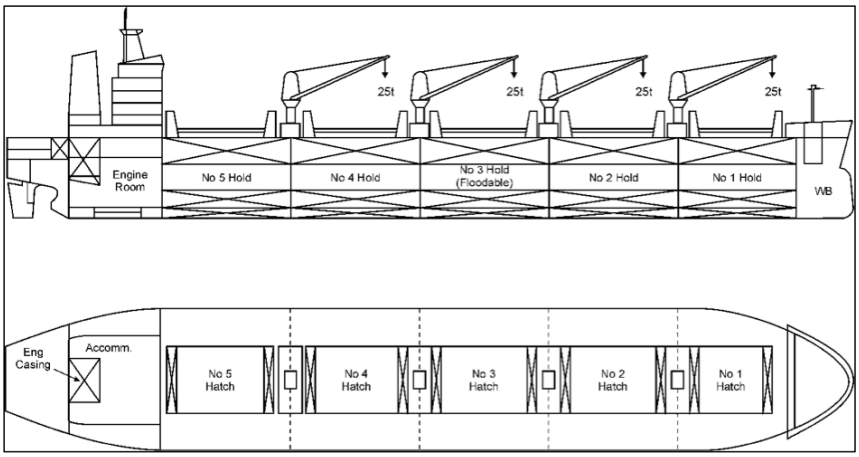


Figure 2.1 Ship's overview
(www.marineinsight.com)

The cargo hold is a room below the deck that is used as a ship's cargo storage area. Cargo goods must be properly handled, so that they will not be damaged and will not rot. The cargo hold must also be watertight, which ensures that the goods inside the hold must be guaranteed not to touch water.

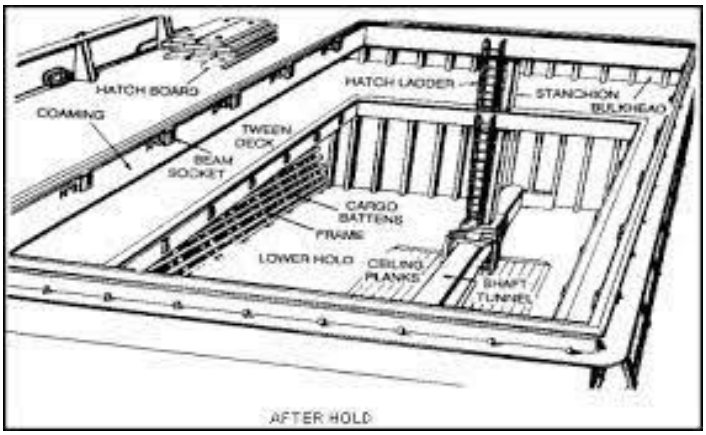


Figure 2.2 Ship’s cargo hold
(www.pfri.uniri.hr)

2.3.2 Factors Affecting the Shelf Life of Fruits

One of horticulture commodities that have high demand is kinds of fruits. And to fulfill that number of demand, the supplier must deliver the fruits in several ways. One of the delivery ways is delivered by ship. Fruits are food products that don't use a preservative, and have a high nutrition value. So, because they don't use a preservative, they have a low shelf life. The shelf life of fruits is affected by two factors, there are respiration and transpiration.

2.3.2.1 Respiration

Respiration is a biological metabolic process using oxygen in the breakdown of complex compounds (such as carbohydrates, proteins and fats) to produce CO2, water and a number of electrons. In general, after harvesting, agricultural products still carry out respiration and other metabolic processes until they are damaged and life processes stop (Syarief and Irawati, 1988).

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 673\ \text{kcal}$$

Figure 2.3 Respiration formula
(Rokhani, 2011)

The factors that affect respiration can be divided into two, namely internal factors (from within the material itself) such as the level of organ development, the chemical

composition of the tissue, the size of the product, the presence of a natural coating on the surface of the skin, and the type of tissue. External factors (from outside or the environment around the material itself) such as temperature, use of ethylene, availability of oxygen, carbon dioxide, presence of growth-regulating compounds, and the presence of injury to the fruit (Muchtadi, 1992).

The rate of respiration can be defined as the weight of CO2 produced per unit weight of the fruit or vegetable per unit time (i.e., mg of CO2/kg/h). The respiration rate may also be expressed in mL of CO2/kg/h or the quantity of O2 taken up rather than CO2 given out (Rao,2015). Depending on the type of product, the respiration rate varies, but is predominantly affected by the temperature and gas content of the product.

a. Temperature

As previously mentioned, one that affects the rate of respiration is temperature. Due to its drastic impact on biological reaction rates including respiration, temperature is the most important environmental factor in the postharvest life of horticultural products. The respiration rates of certain fruits at various temperatures are given in figure below.

Table 2.1 Respiration rate at various temperature *(Hardenberg et al, 1986*)

	Temperature (°C)					
Commodity	**0**	**4–5**	**10**	**15–16**	**20–21**	**25–27**
Apples, summer	3–6	5–11	14–20	18–21	20–41	25–27
Bananas, green	–	–	–	21–23	33–35	–
Bananas, ripening	–	–	21–39	25–75	33–142	50–245
Beans, Lima	10–30	20–36	–	100–125	133–142	50–245
Broccoli	19–21	32–37	75–87	161–186	278–320	–
Cabbage	4–6	9–12	17–19	20–32	28–49	49–63
Cauliflower	16–19	19–22	32–36	43–49	75–86	84–140
Grapefruit	–	–	7–9	10–18	13–26	19
Grapefruit	–	–	11	10–23	19–25	20–28
Lemons	–	–	11	10–23	19–25	20–28
Limes	–	–	–	6–10	7–10	15–45
Oranges	2–5	4–7	6–9	13–24	22–34	25–40
Cucumbers	–	–	23–29	24–33	14–48	19–55
Garlic	4–14	9–33	9–10	14–29	13–25	–
Grapes, vinifera	1–2	3–6	8	10–12	–	25–30
Mangoes	–	10–12	–	45	75–151	120
Watermelons	–	3–4	6–9	–	17–25	–
Mushrooms	28–44	71	100	–	264–316	–
Onions, dry	3	3–4	7–8	10–11	14–19	27–29
Onions, green	10–32	17–39	36–62	66–115	78–178	98–210
Okra	–	52–59	86–95	138–153	248–274	138–362
Papayas	4–6	–	–	15–32	–	39–58
Pears, shelled	47–75	79–98	–	–	349–556	–
Pineapple	–	2	4–7	10–16	19–29	28–43
Potatoes, mature	–	3–9	7–10	6–12	8–16	–
Sweet corn, with husk	30–51	43–83	104–120	151–175	268–311	282–435
Sweet potatoes, cured	–	–	14	20–24	–	–
Tomatoes, mature green	–	5–8	12–18	16–28	28–41	35–51
Tomatoes, ripe	–	–	13–16	24–29	24–44	30–42

From the figure we can see the respiration rate of fruits and vegetables expressed as the rate of carbon dioxide produced (mg/kg/h) at various temperatures. The respiration rates increase following the increase of temperatures. As an example, the respiration rates of Oranges are 2-5(mg/kg/h) at temperature 0°C, and when the temperature increases to 4-5°C the respiration rates increase to 4-7(mg/kg/h). These cases dramatically illustrate the need to reduce the temperature of fresh fruits and vegetables as soon as possible after harvesting in order to maximize shelf life.

b. Oxygen (O2) and Carbon Dioxide (CO2) Concentration

Besides temperature, gas content around the commodity also has a huge effect on the rate of respiration. There are several types of gas around the commodity, like O2, CO2, N, and etc. But in respiration there are two types of gas which are very related and affect it, there are oxygen (O2) and carbon dioxide (CO2). In the respiration process that was already mentioned previously, it needs some O2 from ambient air to oxidize C6H12O6 compound and as the result it produces some CO2 then releases it. So because of that the concentration of both gas (O2 and CO2) greatly affect the rate of respiration.

From the respiration equation, it would indicate that the respiration rate and storage life would be extended if the CO2 in the ambient atmosphere was increased or the O2 decreased. Reduction of the O2 concentration to less than 10% provides a tool for controlling the respiration rate and slowing down senescence, although an adequate O2 concentration must be available to maintain aerobic respiration. Elevated CO2 levels can inhibit, promote, or have no effect on C2H4 production by fruits. However, CO2 has been shown to be a competitive inhibitor of C2H4 action, delaying fruit ripening by displacing C2H4 from its receptor site (Rao, 2015).

Table 2.2 Optimum gas composition for fruits and vegetables
(Kader & Saltveit, 1989)

Komoditas	Suhu °C	Komposisi gas (%)	
		O_2	CO_2
Apel	0 – 5	1 – 3	1 – 5
Adpokat	5 – 13	2 – 5	3 – 10
Pisang	12 – 15	2 – 5	2 – 5
Mangga	10 – 15	3 – 5	5 – 10
Pepaya	10 – 15	3 – 5	5 – 10
Buncis	5 – 10	2 – 3	4 – 7
Mentimun	8 – 12	3 – 5	0
Brokoli	0 – 5	1 – 2	5 – 10
Tomat hijau	12 – 20	3 – 5	0 – 3
matang	8 – 12	3 – 5	0 – 5

From the figure we can see the optimum gas composition for fruits and vegetables at certains temperature conditions.

c. Ethylene

Ethylene (C2H4) is an unsaturated hydrocarbon compound that is a gas at room temperature. Ethylene can be produced by living plant tissue at certain times. Ethylene plays an important role in the postharvest physiology of horticultural products. Ethylene will be advantageous when improving fruit and vegetable quality through accelerated and uniform ripening prior to marketing, however ethylene has a detrimental effect by increasing the senescence rate. Ethylene can remove the green color of raw fruit and leaf vegetables, accelerate fruit ripening during post-harvest handling and storage, and shorten shelf life and affect the quality of fruit, flowers and vegetables after harvest (Winarno and Wirakartakusumah, 1981).

Ethylene is a substance that naturally plays a role very important in postharvest physiological processes, including accelerating senesen and decreasing shelf life, triggering climacteric respiration, speed up and uniform cooking (Kader, 1985; Kays, 1997). Ethylene regulating fruit ripening by coordinating expression of the genes responsible in various processes including rate increase respiration, autocatalytic ethylene production, degradation chlorophyll, carotenoid synthesis, conversion of starch to sugar, and increased activity of enzymes cell wall breaker (Winarno, 1992).

The figure below shows that the capacity to produce C2H4 varies greatly among fruits, with those fruits exhibiting moderate-to-very-high production rates being generally classified as climacteric fruits. Vegetables also produce C2H4 although data are comparatively scarce. The potent effects of ethylene on plant growth, development, and senescence mean that this gas, which is commonly found in the environment, can greatly reduce the storage life of perishable commodities sensitive to it (Rao, 2015).

Table 2.3 Classification of fruits according to their maximum ethylene production rate
(Ryall & Lipton,1979)

Ethylene Production Rate µL/kg/h at 20°C	Fruits
Very low: 0.01–0.1	Cherry, citrus, grape, pomegranate, strawberry
Low: 0.1–1.0	Blueberry, kiwifruit, peppers, persimmon, pineapple, raspberry
Moderate: 1.0–10.0	Banana, fig, honeydew melons, mango, tomato
High: 10.0–100.0	Apple, apricot, avocado, plum, cantaloupe, nectarine, papaya, peach, pear
Very high: > 100.0	Cherimoya, mammy apple, passion fruit, sapota

µL/kg/h × 0.91 = mL/ton/h

2.3.2.2 Transpiration

Transpiration is the removal of water from the network of vegetable products. Transpiration rate is influenced by internal factors (morphology / anatomy, surface to volume ratio, physical damage, harvesting age) and external factors (temperature, RH, air movement and atmospheric pressure). According to Sastry, et al in Sucahyo (1999), water loss in fruits occurs due to transpiration factors, where the rate of transpiration will be influenced by commodity factors and environmental factors.

The transpiration rate of the fruit depends on the type and degree of maturity, this has to do with the thickness, structure of the skin, epidermal cells and wax coating. The effect of decreased transpiration during storage at low temperatures will be smaller than at high temperatures (Pantastico, 1986).

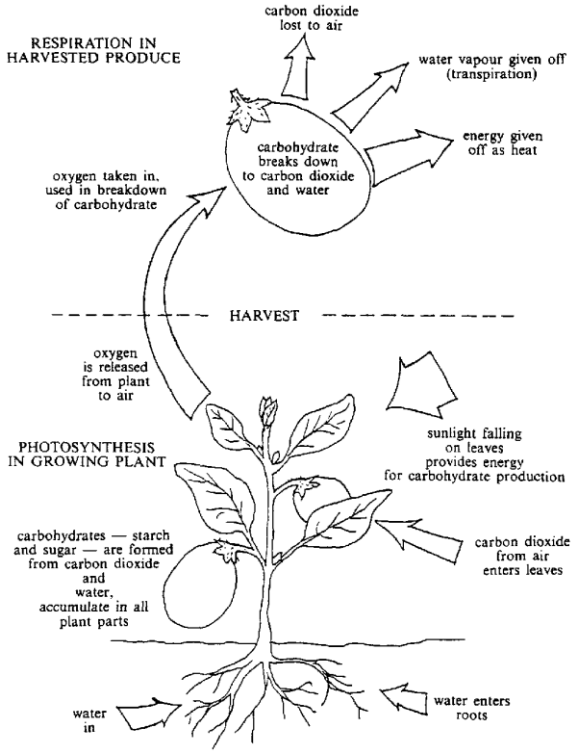


Figure 2.4 Transpiration
(www.fao.org)

2.3.3 Controlled Atmosphere Storage

The method of storing fresh horticulture is considered to be effective if it is capable of reducing the rate of ripening process and preventing spoilage and other storage at the same time, so that freshness can be preserved at a level appropriate to consumers. There are several ways to increase the shelf life of horticulture commodities, one of them

is storage that can control and modify the atmosphere in it. This technology is called controlled atmosphere storage (CAS).

The controlled atmosphere storage (CAS) process is the most important innovation in fruit and vegetable storage since the introduction of mechanical refrigeration. To reduce fruit losses during refrigerated storage, it is important to maximize all the potentialities of this method in order to suppress the vital activity of phytopathogenic microorganisms that are always present on the fruit surfaces, to retard the processes connected with most harvest ripening of fruits, and to delay the senescence and collapse of fruit tissues. But in most cases, maintaining a definite regime of temperature and humidity alone is not sufficient for prolonging the period for which fruits can be preserved and reducing fruit losses. A definite gas composition of the atmosphere, strictly differentiated for each type of fruit and for different varieties of the same fruit, is also necessary (Rao, 2015).

Controlled atmosphere storage (CAS) is a fruit and vegetable storage technique that can maintain the quality of fruit / vegetables by providing different air conditions to normal air conditions, especially the proportions of O2 and CO2. O2 and CO2 concentrations are controlled by reducing O2 concentrations and increasing CO2 concentrations to increase product shelf life (Wills et al., 1982). The first studies regarding fruit preservations in gaseous medium were carried out in an atmosphere consisting of more CO2 and less O2 than normally present in air. Carbon dioxide played the dominant role, which is why the method is also called the “carbon dioxide preservation method.” It was found that CO2 concentration in the regime not only reduces the vital activities of the fruit but also provides strong antiseptic nature (Rao, 2015).

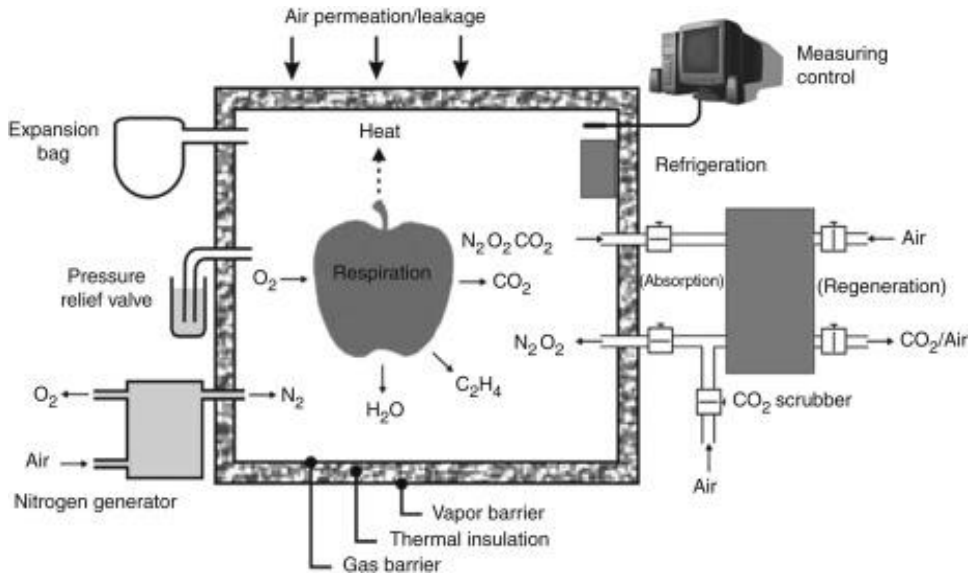


Figure 2.5 Controlled atmosphere storage illustration
(www.sciencedirect.com)

Many investigations have shown that the basic advantages of fruit preservation in a controlled atmosphere are as follows.

a. The so-called low-temperature diseases are prevented during refrigeration.
b. Infestation of fruits by other physiological diseases frequently encountered when fruits are preserved in refrigerators in conventional fruit storages is reduced.
c. The taste and aroma fruits are better preserved.
d. The consistency of fruits is maintained for longer periods.
e. The fruit losses in the controlled atmosphere are reduced by half to one third, while the period of preservation is significantly higher than when kept in an uncontrolled atmosphere (Rao, 2015).

2.3.4 Cold Storage

Cold storage is a room or warehouse that is specifically built to use certain temperature conditions and is used to store different types of products in order to preserve freshness, especially perishable products. It cannot be denied that cold storage is very much needed, one example is almost every household has a cold storage to help them maintain the freshness of their food. Just like in a household, the ship's cargo hold also requires the use of cold storage. In this case the difference is that the ship's cargo hold requires a larger cold storage.

A ship’s cargo hold must have a cold storage with the purpose to maintain the quality of the cargo carried by the ship until it reaches its destination. Cargo likes horticulture commodities, fish, and meat are types of cargo that must be kept fresh by cooling it. The length of the voyage of the ship includes cold storage in the cargo hold of cargo carriers, which is easily damaged or rotted.

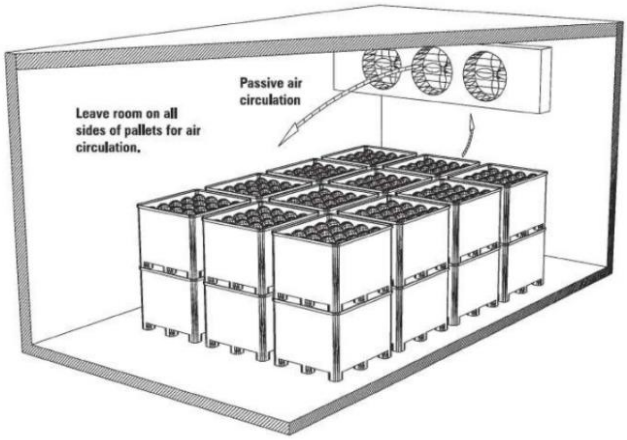


Figure 2.6 Cold Storage
(Kumar, 2011)

2.3.5 Dry Ice

Dry ice is frozen carbon dioxide, it is the solid phase of carbon dioxide (CO2). Dry ice has a very good sublimation feature. It transforms directly into carbon dioxide gas rather than a liquid when it breaks down. Carbon dioxide gas is always present in the environment, but in low concentrations. It is colorless and odorless. The freezing point of carbon dioxide is -109.3 ° F or -78.5 ° C, so dry ice won't last long at room temperature (Anwar, 2017). This dry ice is mostly used as a cooling agent. Its benefits include lower temperatures than water ice, and no residue left. It is useful in preserving frozen foods where mechanical refrigeration is not available. So in this Controlled Atmosphere Storage (CAS) experiment, the dry ice will be used as a coolant and CO2 source.

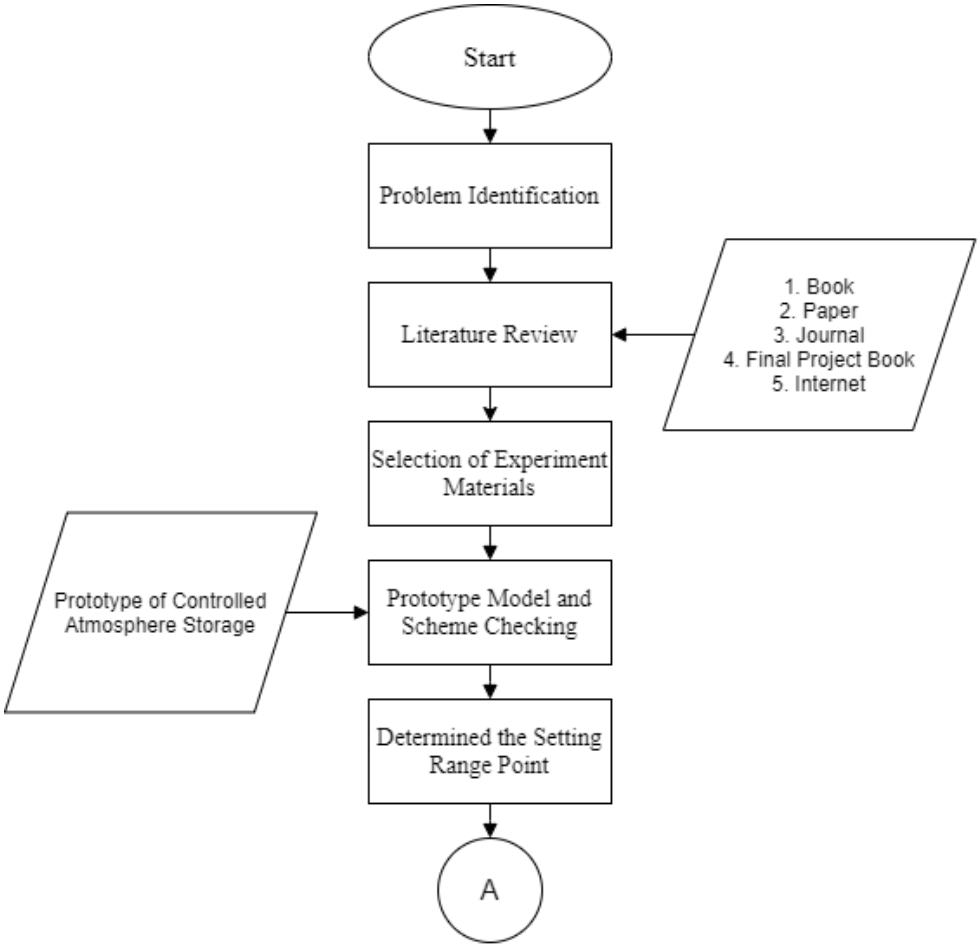
CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

In general, this chapter describes the method and pattern in carrying out the final project that will be used in answering research problems and achieve the research objectives. The flowchart of the research will clearly describe. And also, the steps detail from problem identification until conclusion and suggestion will be explain.

3.2 Research Flowchart



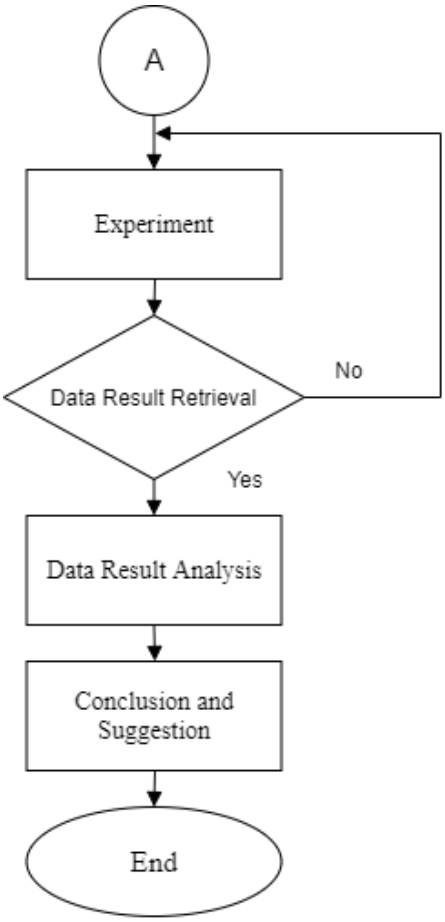


Figure 3.1 Research Flow Chart

3.3 Problem Identification

This stage is the first step in the final project research. It initiated by identifying and make a problem formulation regarding the research to be done based on the problem that found in background. Then compiled the problem limitation in this research is to narrow down the problem to be discussed. Also formulating research objective and determined the research benefit must done in this step. This is done to facilitate processing and completion of writing this thesis.

3.4 Literature Review

In this stage, the author provides supporting information and basic theories that will be discussed as well as knowledge foundation related to the topic research. In this final project research, the author conducted a literature study on *Ship's Cargo Hold, Factors Affecting the Shelf Life of Fruits, Controlled Atmosphere Storage (CAS), Cold*

Storage, and Dry Ice which the author obtained from books, journals, papers, final project book dan the internet.

3.5 Selection of Experiment Materials

At this stage, the materials that will be used during the experiment will be selected. The selection of this material aims to find which material is most relevant to use in the experiment and of course the selection is reviewed based on economic factors, ease of access, flexibility, and compatibility with the system that has been made. The selected materials are in the form of various types of fruit, materials for absorbing CO2 in the CO2 scrubber, materials for absorbing ethylene in the ethylene scrubber, materials for reducing the O2 content, and ingredients for cooling. And also, at this stage the amount of each material that has been selected is determined.

3.6 Prototype Model and Scheme Checking

As mentioned in the problem boundary in chapter 1 that this study did not design or manufacture Controlled Atmosphere Storage prototypes, so in this study the experiment was carried out using existing CAS prototypes. At this stage, you will check the model of the CAS prototype that will be used and also understand how the scheme of the prototype works.

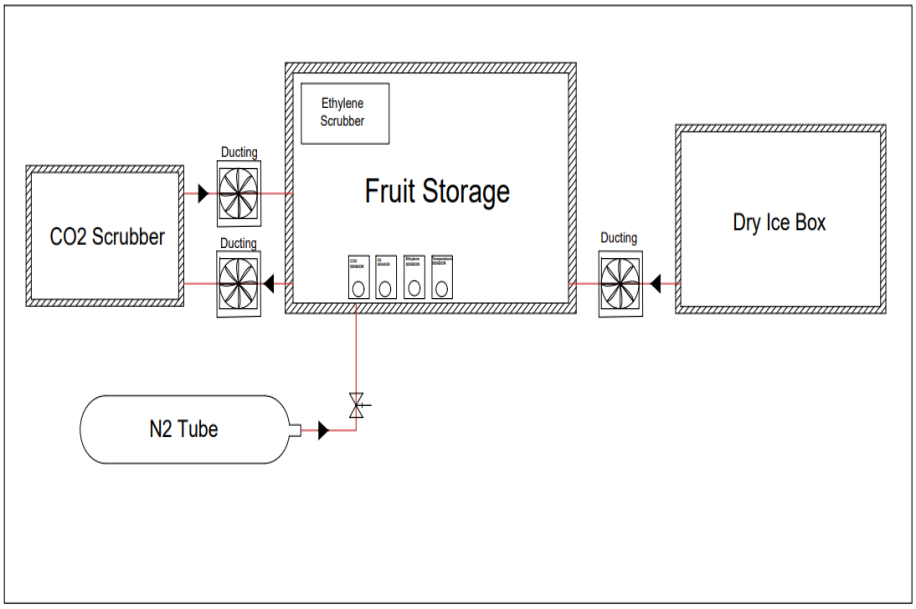


Figure 3.2 CAS Prototype Model and Scheme
(Author, 2021)

The picture above is a schematic of how the CAS prototype works. The figure shows that the system in the CAS prototype has 4 main components, there are a large main box as a storage box for storing fruit, a medium-sized secondary box as a refrigerant box for a place of dry ice, a small secondary box as a CO2 scrubber box, and a gas tube as a container for N2 gas. In accordance with this picture, the working scheme of the CAS prototype are:

a) When the temperature sensor detects that the temperature in the storage box exceeds the desired temperature range, the fan that connects the storage box to the refrigerant box will turn on and move cold air from the refrigerant box into the storage box, and when the sensor detects that the temperature in the storage box is within the desired range then the fan will turn off.
b) When the CO2 sensor detects that the CO2 content in the storage box exceeds the desired CO2 range, the fan that connects the storage box to the CO2 scrubber box will turn on and move the air from the storage box into the CO2 scrubber box in the form of a CO2 scrubber to be circulated and returned to the storage box. So that the CO2 content in the air at the storage box can decrease. And when the sensor detects that the CO2 content in the storage box is within the desired range, the fan will turn off.
c) When the O2 sensor detects that the O2 content in the storage box exceeds the desired O2 range, the valve that connects the storage box to the gas tube will turn on and drain N2 from the gas tube into the storage box with the aim of reducing the O2 content in the storage box. and when the sensor detects that the O2 content in the storage box is within the desired range, the valve will shut off.

3.7 Determined the Setting Range Point

The experiment to be carried out in this study requires a range of temperature and O2 & CO2 content to create the best atmosphere for storing fruit. Each type of fruit has its own range to maximize their shelf life, we cannot use the range of one fruit for another. So, at this stage the range for temperature and content of O2 & CO2 will be determined for each fruit variant to be used in the experiment, this determination will refer to the literature in literacy studies. The range of temperature and O2 & CO2 content will be used as a setting point as a reference when the experiment is carried out.

3.8 Experiment

In this stage, will be done an experiment using the prototype of Controlled Atmosphere Storage (CAS). According to the literature review there are several factors that affect the fruit respiration likes temperature, CO2 and O2 concentration, and ethylene level. So, in the prototype there are some dry ice as the refrigerant and CO2 source, CaOH2 as the CO2 scrubber to decrease the CO2 level, N2 tube as the N2 source, and mixture of zeolit and KMnO4 as the ethylene scrubber to reduce the ethylene level.

Firstly we put some fruits in the CAS and also a number of dry ice, N2 in N2 tube, CaOH2 in CO2 scrubber, and mixture zeolit and KMnO4 in ethylene scrubber. Then there are some sensor and microcontroller in the prototype, so when sensor detect that the level of temperature, CO2, or O2 is out of the desired range then the microcontroller will trigger the dry ice vane, CO2 scrubber, or N2 tube to work until the temperature, CO2, or O2 reach the desired range. The experiment will done several times, with some variation in fruit type and amount of dry ice.

3.9 Data Result Retrieval

This stage is carried out to obtain information about the data needed to do data analysis. In this stage will be taking and collecting data from the experiments with its various that already done. The data that will be collect is how long the CAS can keep the temperature and modification atmosphere still in the desired range with some amount of dry ice, active charcoal, and mixture of zeolit and KMnO4.

3.10 Data Result Analysis

In this stage will follow up the data that are collected from the experiments. The data will be analysis to get more explanation about the experiment. Then the data will made into a graphic and observed the effect of variation in the experiment. From the analysis can be find which variation of the experiment that have longest time to keep the level of temperature, CO2, and O2 still in desired range.

3.11 Conclusion and Suggestion

This stage is the last stage of the final project. In this stage, all result of the experiment, analysis, and validation will be explained. There also some conclusion and suggestion according to the experiment, so that the future similar research can improve the deficiency of this project.

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CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In the Results and Discussion chapter, the research results and findings obtained are described and discussed in detail. The results of the study refer to the expected results obtained using the method planned in the research methodology. Meanwhile, the research findings refer to other results beyond the expectation obtained from the research carried out. These findings can be in the form of new information, data or phenomena that are important in nature, improving and enriching knowledge development in the field or other related fields.

4.2 Experiment Setting Range Point

In conducting the experiment, a range of temperature, humidity, and O2 & CO2 content of each fruit variant is needed, to be used as a setting point. So, during the experiment, this setting point will be used as a guide for the atmospheric conditions that are trying to be achieved. This range is obtained based on ASHRAE Handbooks and some literature in previous studies, and its adjusted to the current research conditions and experiments. According to the book, the best atmosphere (O2 & CO2) range for storing fruit is set at percent, but the CO2 sensor in the CAS prototype can only detect CO2 levels in ppm units. Therefore, it is necessary to do calculations to convert the setting point of co2 that used to use percent units into ppm units. In the end, the setting point that will be used as a guide are the temperature with units celsius, O2 with percent units, and CO2 with ppm units. The following are the setting points that will be used as a guide in the experiment:

Table 4.1 Experiment Setting Point *(Author, 2021)*

Setting Point					
Comodities	Temperature (°C)	Atmosphere			
		O2 (%)	O2 (ppm)	CO2 (%)	CO2 (ppm)
Banana	11-15	2-5	28.6 - 71.5	2-5	39.6 - 99
Pineapple	7-13	2-5	28.6 - 71.5	5-10	99 - 198

4.2.1 Converting CO2 Units

Because the CO2 sensor in the CAS prototype is only capable of detecting CO2 levels in ppm units, it is necessary to calculate the unit from percent to ppm. Here's how to calculate to convert its unit.

Known :

1 ppm	=	1	mg/L
Total Volume of Storage Box	=	131	L
ρ CO_2	=	1.98	g/L

Calculation :

For	=	2%	of CO_2 content
Gas Volume in Storage	=	% of CO_2 x Total Volume of Storage Box	
	=	2% x 131 L	
	=	2.62	L
Mass of Gas	=	V. ρ	
	=	2.62 L x 1.98 g/L	
	=	5.1876	g
	=	5187.6	mg
CO_2 Content in ppm :	=	CO_2 Mass/Total Volume	
	=	5187.6 mg / 131 L	
	=	39.6	mg/L
	=	39.6	ppm

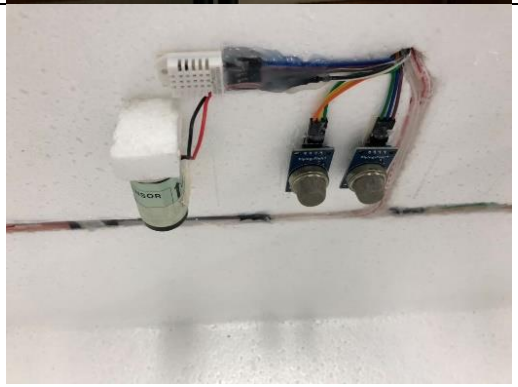
So, based on the results of these calculations can be seen that 2% of CO_2 equals to 39.6 ppm of CO_2. Therefore, if the CO_2 content in the storage box is 2%, the CO_2 sensor in the CAS prototype will show a CO_2 level of 39.6 ppm. The calculations carried out above are only intended to convert the lower limit units of the CO_2 range on bananas only. Therefore, it is necessary to do a similar calculation to convert the upper limit unit of the CO_2 range on bananas and also the CO_2 range units on pineapples.

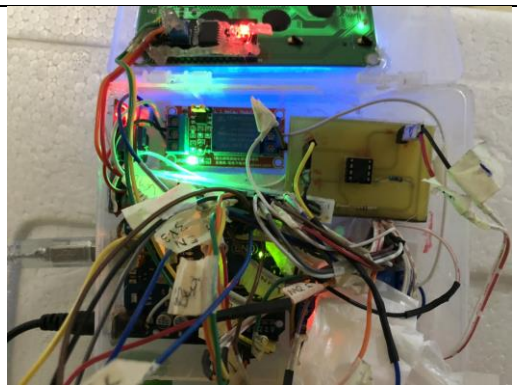
4.3 Prototype and Materials for Experiment

4.3.1 Prototype

As already mentioned, in this research will be doing some experiments to find out the effect of using CAS to the shelf life of the fruits. So, the experiments will use the laboratory scale of CAS prototype. This prototype consists of 3 main parts, there are the storage box, CO_2 scrubber box, and refrigerant box.

Table 4.2 Components of CAS Prototype *(Author, 2021)*

Storage Box			
No	**Component**	**Figure**	**Explanation**
1.	Styrofoam (70x50x40) cm		This styrofoam is design as the storage box of the fruits
2.	Sensors		There are several sensors inside the box to determine the level of temperature, CO2, O2, and ethylene. - Temperature Sensor (xxxx) - CO2 Sensor (xxxx) - O2 Sensor (xxxx) - Ethylene Sensor (xxxx)
3.	Instrument Box		It is some little box outside the storage box, this box is filled by instruments and cables to support the sensor and actuator inside the storage box, and also as the centre of data program of this prototype.

			
4.	N2 Tube		This tube have the purpose to storage the N2 gas that will flow in to the storage box
5.	Valve & Hose		This components have a function as tools to transferred the N2 gas from the tube to storage box

6.	Fruit Basket		It function as the fruits container inside the storage box
Refrigerant Box			
No	**Component**	**Figure**	**Explanation**
1.	Styrofoam (51x37.5x35) cm		This styrofoam is design as the storage of dry ice
2.	Acrylic		This is used as a ducting to connect the refrigerant box to storage box

3.	Fan (12V, 0.15A)		This is used to flow the air from refrigerant box to storage box
CO2 Scrubber Box			
No	**Component**	**Figure**	**Explanation**
1.	Styrofoam (38.5x30x33.5) cm		This styrofoam is design to store the CaOH as the CO2 scrubber
2.	Carton Rack		This is used as a rack to put the CaOH inside CO2 scrubber box

3.	Acrylic		This is used as a ducting to connect the storage box to CO2 scrubber box
4.	Fan (12V, 0.15A)		This is used to flow the air from storage box to CO2 scrubber box

So, the table above show the parts and components of CAS prototype that will be use in experiments. And here is the figure that show the overview of the prototype.

Figure 4.1 CAS Prototype
(Author, 2021)

4.3.2 Materials

In addition to the prototype, the materials that will be used in the experiment are also needs to prepare. With the existence of several variations in the experiment, supporting materials for these variations are also needed. So, the table below will show what materials are needed during the experiment.

Table 4.3 Materials for Experiment *(Author, 2021)*

No	Materials	Figure	Number	Explanation
1.	Dry Ice		7 Kg 9 Kg 10 Kg	The dry ice is use to be the refrigerant or cooling source in this experiment. There are 3 variants of mass that will use as variation at the experiment.

2.	CaOH2		50 Gram	CaOH2 is use to be the scrubber for CO2. So, it will be put in CO2 scrubber box during the experiment

3.	Mixture of KMnO4 & Zeolit		18 Gram	This mixture is use to be the scrubber for ethylene, so this CAS can minimize the ethylene level around the fruits

4.	N2 Gas		1 m3	N2 gas is use as additional gas that can decrease the O2 level, and will flow in to the storage box when the O2 level inside the box is higher than the setting point
5.	Bananas		4 Kg	Bananas are one of fruit variants that will be the object at the experiment

6.	Pineapples		4 Kg	Pineapples are one of fruit variants that will be the object at the experiment

So, that are the materials to be use in the experiments for this research. Every number of materials that show at the table above its use only for a single experiment. As known in this research there will be several experiments, so in every experiment will use that number of materials.

4.4 Steps of Experiment

These are the steps of the experiment:

1) Prepare the experimental materials
2) Make sure the CAS prototype is in a condition ready for use
3) Put the materials that have been prepared according to their place:
   - Put the fruit in the basket in the storage box
   - Put CaOH2 on the CO2 scrubber box
   - Put dry ice in the refrigerant box
   - Place the ethylene scrubber (mixture of KMnO4 & Zeolit) under the fruit basket
4) Close the box tightly
5) Open the valve regulator on tube N2 and make sure the flow rate on the regulator is 1 l/ m
6) Start running the prototype
7) Record the initial atmosphere of the fruit storage
8) Observe and record any changes in temperature, humidity levels, ethylene gas levels and O2 and CO2 content
9) Stop the experiment when the dry ice in the refrigerant box has run out. And clean / tidy up the prototype again from the materials that have been used
10) Repeat Steps 3-9 with the specified dry ice variations
11) Repeat Steps 3-10 with a variety of fruit types that have been determined

4.5 Experiment Results

Experiments have been carried out six times with 2 types of variables varied. These variables are the type of fruit and mass of dry ice used. Variations in the types of fruit used in this experiment are bananas and pineapples. And the mass variations of dry ice that are proposed are 7 kg, 9 kg, and 11 kg. Then these are the results of the experiment.

4.5.1 Experiment Results on Bananas

Banana has been experimented 3 times with variations in the mass of dry ice used. The experiment was carried out using 4 kg of bananas, 1 m3 of N2 gas, 50 grams of CaOH2, and 18 grams mixture of KMnO4 & Zeolit. The results of the banana experiments are as follows.

Table 4.4 Experiment Variant of Bananas *(Author, 2021)*

Type of Comodities	Number of					Running Time (Hours)
	Comodities (Kg)	Dry Ice (Kg)	N2 (m3)	CaOH2 (gram)	Mixture of KMnO4 & Zeolit (gram)	
Bananas	4	7	1	50	18	36
		9				48
		11				58

The following are figures that are an overview when experimenting, both when the initial condition before the experiment is run and also when the experiment is running. Can also be seen how the laying position and condition of experiment materials at the beginning and at the end of experimentation.

Figure 4.2 Figures at the Beginning of Banana Experiment (1)
(Author, 2021)

Figure 4.3 Figures at the Beginning of Banana Experiment (2)
(Author, 2021)

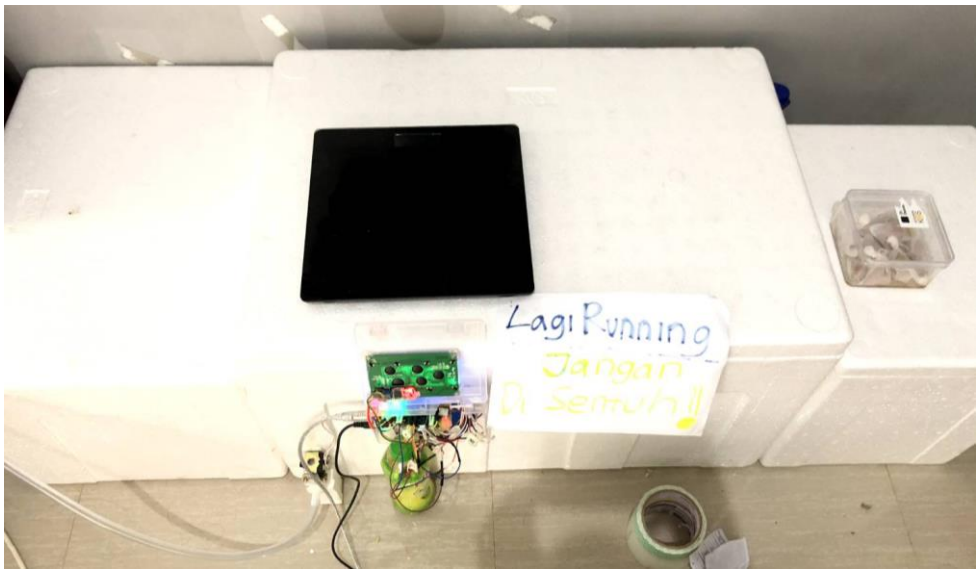


Figure 4.4 Figures of Banana Experiment When Running
(Author, 2021)

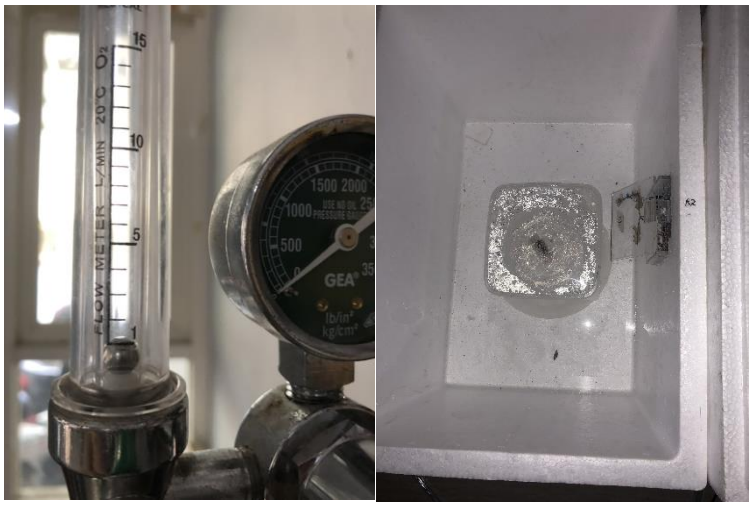


Figure 4.5 Figures at the End of Banana Experiment (1)
(Author, 2021)

Figure 4.6 Figures at the End of Banana Experiment (2)
(Author, 2021)

A. The Result on Bananas First Experiments

These are the experiment result on bananas using 7 Kg of dry ice:

Table 4.5 Experiment Result on Bananas First Experiments
(Author, 2021)

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
1	11:53:22 AM	29.7	3.25	17.2	62
2	11:53:52 AM	29.4	3.17	16.4	62
3	11:54:22 AM	29.1	3.07	15.9	61
4	11:54:52 AM	29	3.03	16.0	64
5	11:55:22 AM	28.8	3.07	15.7	63
No. Data	**Time**	**Temperature (°C)**	**Etylene (ppm)**	**O2 (%)**	**CO2 (ppm)**
438	3:31:38 PM	21.1	3.13	13.2	62
439	3:32:08 PM	21.1	2.85	12.8	64
440	3:32:38 PM	21.1	2.9	12.6	61
441	3:33:08 PM	21	3.13	13.5	63
442	3:33:38 PM	21.1	2.89	12.7	61

In the banana first experiment is using 7 kg of dry ice, the experiment lasted for about 36 hours and data retrieval was taken every 30 seconds. From the table of results above, it can be seen that the initial conditions in this experiment were 29.7 C for temperature, 3.25 ppm for ethylene levels, 17.2% for O2 levels, and 62 ppm for CO2 levels. And from 5 times the data taken at the beginning of the experiment can be seen that temperature conditions and O2 levels always decrease, ethylene levels tend to fall, and CO2 levels tend to be constant. This is because the temperature, O2 levels, and ethylene levels are still above the desired setting point, while for CO2 levels have entered the desired setting range points.

From the table of results above, it can also be seen the condition when this experiment reaches the lowest temperature point, namely when the data collection to 441 or about 4.5 hours after this experiment begins. In the data taken to 441 conditions in this experiment was 21 C for temperature, 3.13 ppm for ethylene levels, 13.5% for O2 levels, and 63 ppm for CO2 levels. In this condition it can be said that the temperature and O2 levels are still not reached in the desired points, while for co2 levels have entered at the desired point.

a. Temperature

These are the results on the temperature during this experiment:

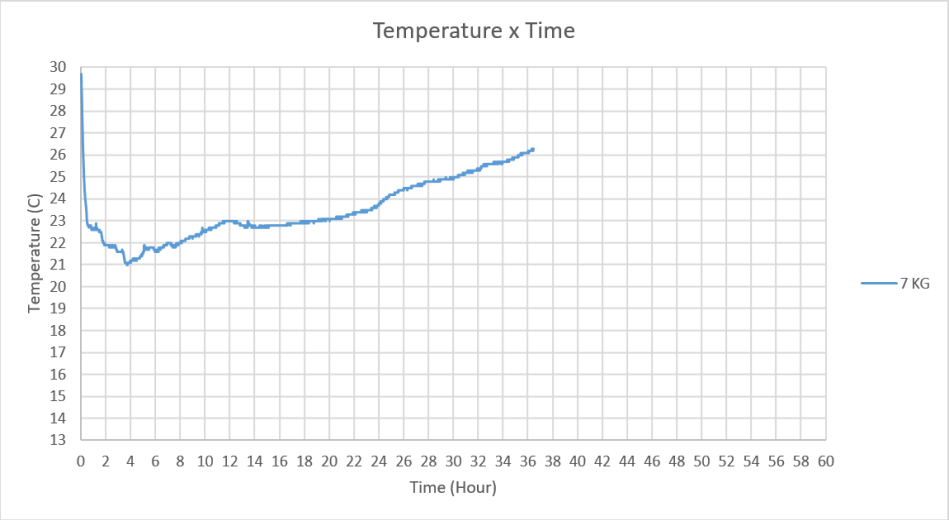


Figure 4.7 Graph of Temperature Against Time at Bananas First Experiment *(Author, 2021)*

As mentioned earlier, this experiment lasted for 36 hours and the graph above shows the temperature changes that occurred during this experiment. It can be seen in the first hour since the experiment began, the temperature has dropped dramatically and can reach the lowest temperature of 21 C in about 3.5 hours since the experiment began. Once it reaches its lowest temperature point, it begins to rise constantly and slowly until the end of the experiment. At the end of this experiment, the temperature showed around the number 26 C. From the chart above it can be concluded that by using 7 kg of dry ice is only able to lower the temperature to the point of 21 C, with the required time of about 3.5 hours.

b. Ethylene

These are the results on the ethylene during this experiment:

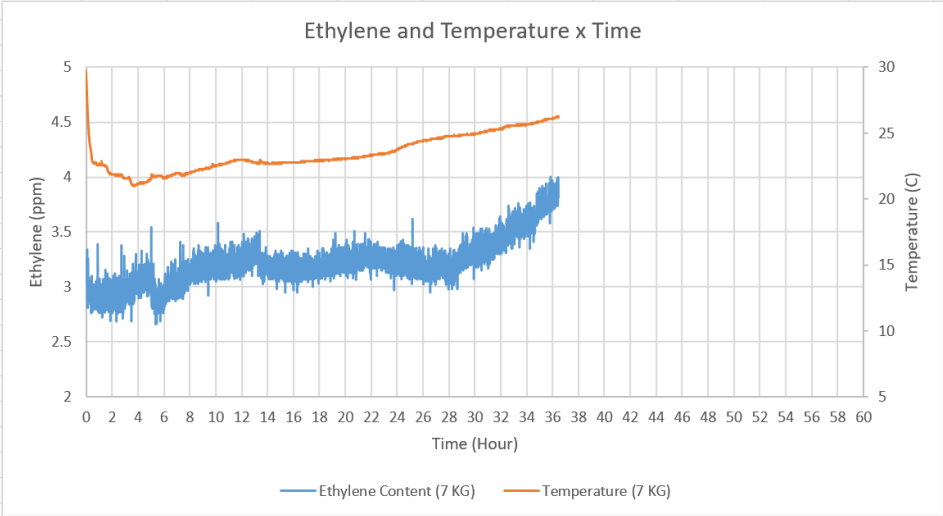


Figure 4.8 Graph of Ethylene Levels Against Temperature and Time at Bananas First Experiment *(Author, 2021)*

Previously it has been mentioned that this experiment uses ethylene scrubber to minimize ethylene levels, with the number of scrubbers used is 18 grams. In the table above can be seen ethylene levels during the experiment using 7 kg of dry ice lasted. Ethylene levels in this experiment are in the range of 2.7 ppm – 4 ppm. At the beginning of the experiment, ethylene levels tend to rise and fall steadily and got a fairly drastic decrease around the fifth hour since the experiment began. And also around the fifth hour since the experiment began, ethylene levels reached its lowest point of 2.7, after which ethylene levels increased significantly until the eighth hour of the experiment. At the 28th hour, ethylene levels tend to rise steadily and eventually reach their highest point at the end of the experiment.

When looking at the data in the graph above, it can be said that in this experiment the temperature has an influence on ethylene levels, and it can also be said that the graph formed based on ethylene levels has a similar shape to the form of the graph produced by the temperature. When seen also ethylene levels tend to fall when the temperature decreases and tends to rise when the temperature increases, this is because the temperature can affect the fruit in producing ethylene so that the lower the temperature around the fruit, the level of ethylene produced will be lower. In the end it can be concluded that by using 18 grams of ethylene scrubber and 7 kg of dry ice the lowest ethylene content that can be achieved is 2.7 ppm only, and the effective time of the ethylene scrubber works only 28 hours because after that ethylene levels continue to increase constantly.

c. CO2 Content

These are the results on the CO2 content during this experiment:

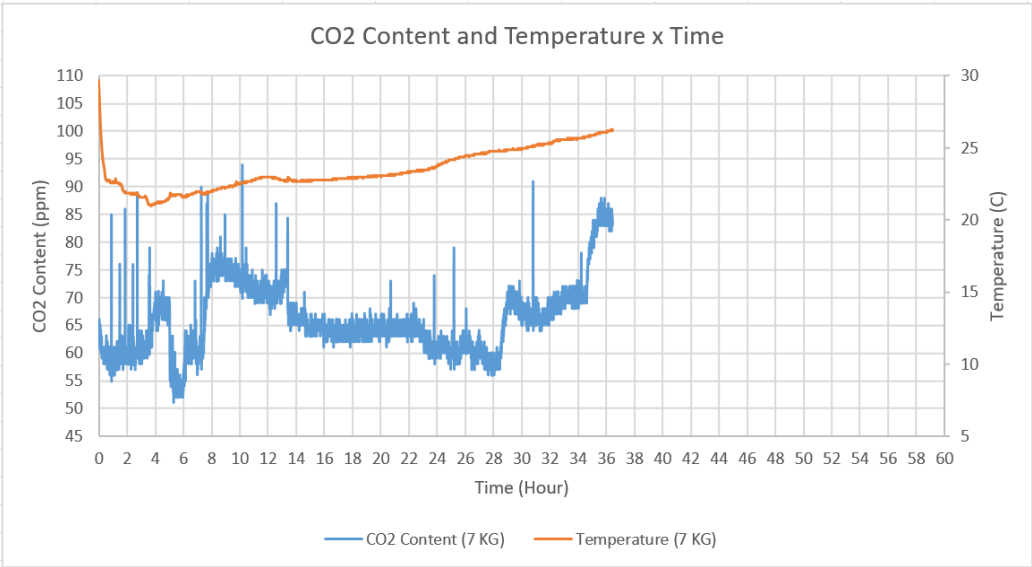


Figure 4.9 Graph of CO2 Levels Against Temperature and Time at Bananas First Experiment *(Author, 2021)*

Previously it has been mentioned that this experiment uses CO2 scrubber to minimize CO2 levels, with the number of scrubbers used is 50 grams. In the table above can be seen CO2 levels during the experiment using 7 kg of dry ice lasted. From the data above it can be said that the CO2 levels in this experiment are already at the desired range point setting, so that the performance of the CO2 scrubber does not play an active role. Although always within the range, CO2 levels also experienced ups and downs during the experiment, ups and downs that were quite drastic and significant occurred at the 4th – 9th hour of the experiment and at the 28th hour – the end of the experiment. In the graph above, when looking at temperature data and CO2 levels data, it can be seen that if the temperature decreases, CO2 levels will tend to rise. This happens at the beginning of the experiment lasts until the 5th hour of the experiment.

d. O2 Content

These are the results on the O2 content during this experiment:

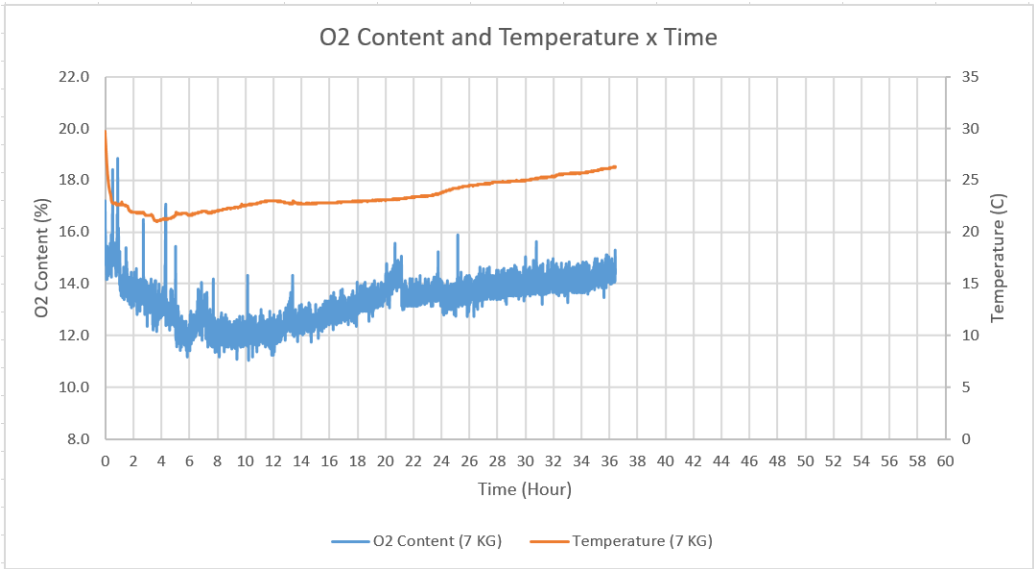


Figure 4.10 Graph of O2 Levels Against Temperature and Time at Bananas First Experiment *(Author, 2021)*

Previously it has been mentioned that this experiment uses N2 gas to minimize O2 levels, with the amount of gas used is 1 m3 and the flow rate applied is 1 l / m. In the table above can be seen O2 levels during the experiment using 7 kg of dry ice lasted. O2 levels in this experiment are in the range of 11% - 19%. It can be said that 1 m3 of N2 gas and 7 kg of dry ice can only lower O2 levels by 11% and it takes as little as 10 hours to reach that point. After reaching its lowest point at the 10th hour of the experiment, O2 levels tend to rise slowly and constantly until the end of the experiment. In the graph above, when looking at the data of O2 levels and temperature levels, it can be seen that if the temperature decreases then O2 levels will tend to decrease as well and vice versa. This is because when the temperature is lower, the CO2 levels in the CAS prototype will increase, which causes O2 levels to decrease.

B. The Result on Bananas Second Experiments

These are the experiment result on bananas using 9 Kg of dry ice:

Table 4.6 Experiment Result on Bananas Second Experiments
(Author, 2021)

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
1	11:38:06 AM	28.5	4.9	12.81	66
2	11:38:36 AM	28.5	4.92	13.86	78
3	11:39:06 AM	28.3	4.79	13.40	74
4	11:39:36 AM	28	4.92	12.36	71
5	11:40:06 AM	27.7	4.82	13.14	70
No. Data	**Time**	**Temperature (°C)**	**Etylene (ppm)**	**O2 (%)**	**CO2 (ppm)**
1823	2:48:06 AM	17.1	2.85	5.23	63
1824	2:48:36 AM	17.1	2.84	5.36	61
1825	2:49:06 AM	17.1	2.79	5.16	63
1826	2:49:36 AM	17	2.79	4.97	62
1827	2:50:06 AM	17.1	2.8	5.16	62

In the banana second experiments is using 9 kg of dry ice, the experiment lasted for about 48 hours and the data retrieval was taken every 30 seconds. From the table of results above can be seen that the initial conditions in this experiment is 28.5 C for temperature, 4.9 ppm for ethylene levels, 12.81% for O2 levels, and 66 ppm for CO2 levels. And from 5 times the data taken at the beginning of the experiment can be seen that temperature conditions always decrease, ethylene levels and O2 levels tend to fall, and CO2 levels tend to be constant. This is because the temperature, O2 levels, and ethylene levels are still above the desired setting point, while for co2 levels have entered the desired setting range points.

From the table of results above, it can also be seen the condition when this experiment reaches the lowest temperature point, namely when the data retrieval to 1826 or about 15 hours after this experiment began. In the 1826 data collection, the conditions in this experiment were 17 C for temperature, 2.79 ppm for ethylene levels, 4.97% for O2 levels, and 62 ppm for CO2 levels. In this condition it can be said that the temperature is still not reached the desired setting point, while for CO2 levels and O2 levels have entered at the desired setting point.

a. Temperature

These are the results on the temperature during this experiment:

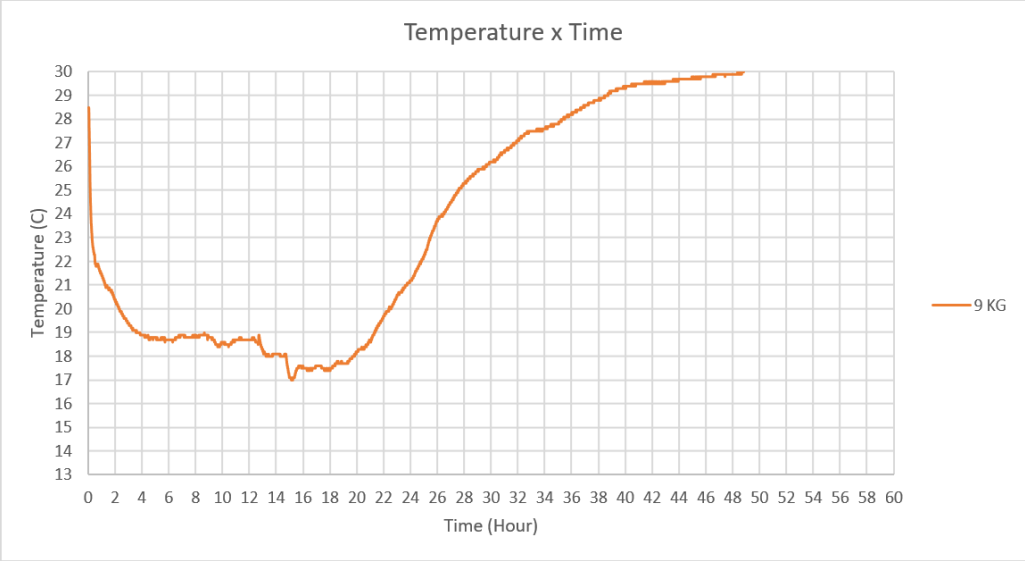


Figure 4.11 Graph of Temperature Against Time at Bananas Second Experiment *(Author, 2021)*

As mentioned earlier, this experiment lasted for 48 hours and the graph above shows the temperature changes that occurred during this experiment. It can be seen in the first 1.5 hours since the experiment began, the temperature has dropped dramatically and can reach the lowest temperature of 17 C in about 15 hours since the experiment began. After reaching the lowest temperature point, the temperature begins to rise constantly and slowly until the 20th hour. In the 20th to 28th hours, the temperature increases quite rapidly, then afterwards the temperature begins to rise constantly and slowly until the end of the experiment. At the end of this experiment, the temperature showed around the number 30 C. From the chart above it can be concluded that by using 9 kg of dry ice can only lower the temperature to the point of 17 C, with the required time of about 15 hours.

b. Ethylene

These are the results on the ethylene during this experiment:

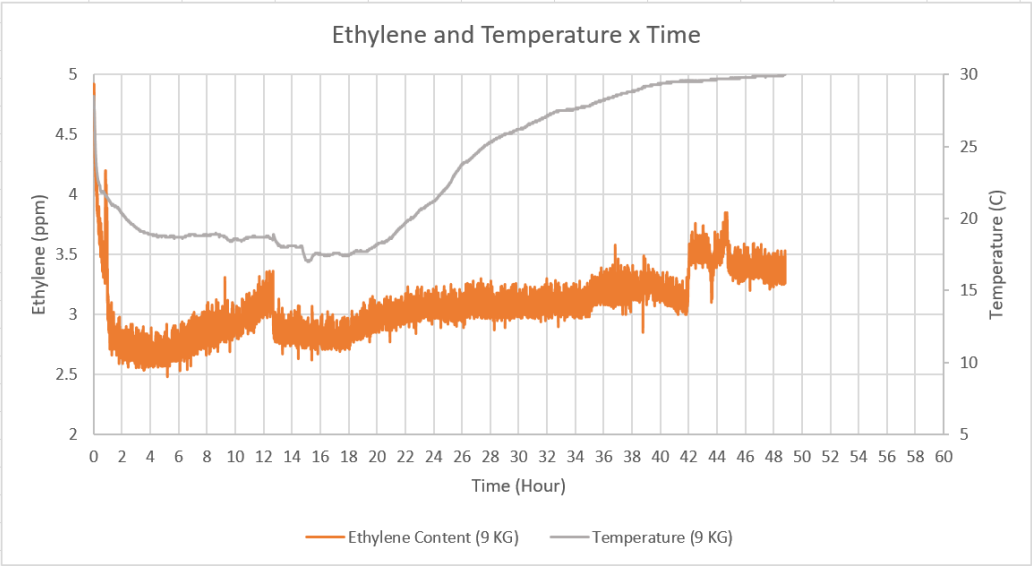


Figure 4.12 Graph of Ethylene Levels Against Temperature and Time at Bananas Second Experiment *(Author, 2021)*

Just like before, that this experiment uses ethylene scrubber with an amount of 18 grams. In the table above can be seen ethylene levels during the experiment using 9 kg of dry ice lasted. Ethylene levels in this experiment are in the range of 2.45 ppm – 3.8 ppm. In the initial two hours of the experiment, ethylene levels dropped dramatically, and after that it continued to rise. After got a constant increase, ethylene levels dropped dramatically around the 13th hour, and then tended to increase slowly until the end of the experiment. In this experiment the lowest ethylene levels were at the point of 2.45 ppm which occurred at about the fifth hour of the experiment.

When looking at the data in the graph above, it can be said that the data on the graph shows something similar to the graph in the experiment using 7 kg of dry ice, namely that the graph formed based on ethylene levels has a similar shape to the form of the graph produced by the temperature. And also when viewed, just like the experiment results with 7 kg of dry ice, ethylene levels tend to follow the conditions of the temperature, this is because the temperature can affect the fruit in producing ethylene so that the lower the temperature around the fruit, the level of ethylene produced will be lower. In the end it can be concluded that by using 18 grams of ethylene scrubber and 9 kg of dry ice the lowest ethylene content that can be achieved is 2.45 ppm.

c. CO2 Content

These are the results on the CO2 content during this experiment:

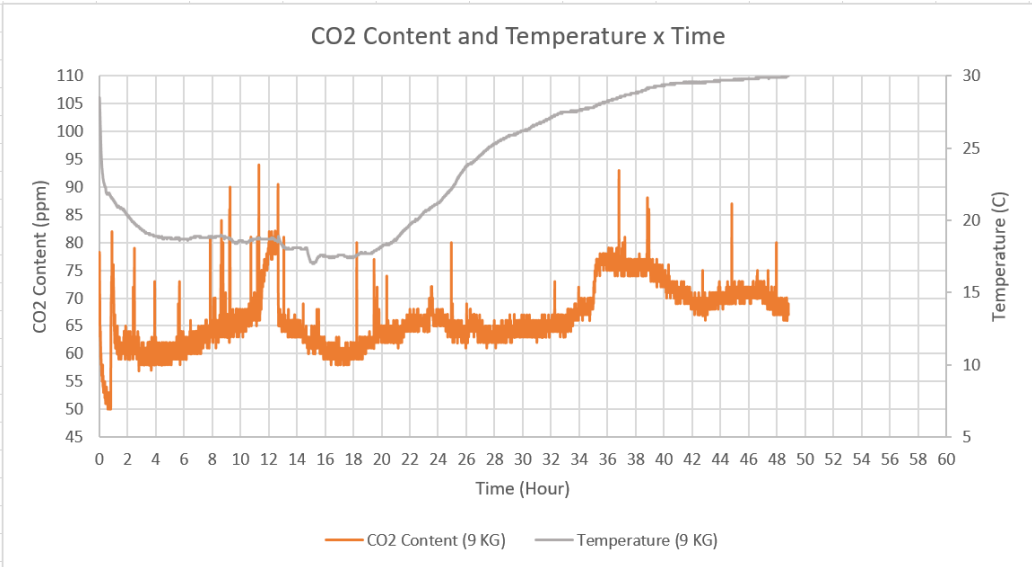


Figure 4.13 Graph of CO2 Levels Against Temperature and Time at Bananas Second Experiment *(Author, 2021)*

Just like before, that this experiment uses CO2 scrubber with an amount of 50 grams. In the table above can be seen CO2 levels during the experiment using 9 kg of dry ice lasted. Just like the experiment using 7 kg of dry ice, from the graph above it can be said that the CO2 levels in this experiment are already in the desired range point setting. In this experiment, CO2 levels also experienced ups and downs even though they were still in the range. When compared to temperatures, CO2 levels tend to increase as temperatures tend to drop, and vice versa. The lowest CO2 level in this experiment was 50 ppm and occurred around the first hour of the experiment, while the highest CO2 level was 94.5 ppm and occurred around the 11th hour of the experiment.

d. O2 Content

These are the results on the O2 content during this experiment:

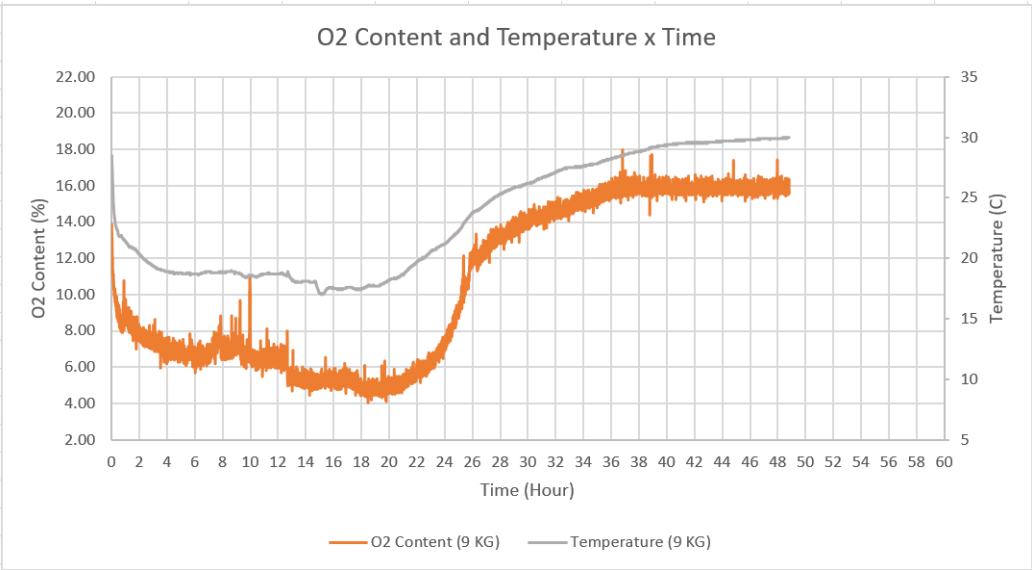


Figure 4.14 Graph of O2 Levels Against Temperature and Time at Bananas Second Experiment *(Author, 2021)*

Just like before, that this experiment uses N2 gas with an amount of 1 m3 and the flow rate applied is 1 l / m. In the table above can be seen O2 levels during the experiment using 9 kg of dry ice lasted. O2 levels in this experiment are in the range of 4% - 18%, which means that in this experiment there is a time when O2 levels are above the best O2 range. N2 gas has an active role to lower O2 levels in order to enter the setting range point. Can be seen at the beginning of the experiment took place, it took about 13 hours for N2 gas to lower O2 levels into the desired range. And N2 gas is only able to keep O2 levels in the range for about 8 hours, after which O2 levels increase rapidly. Just like the previous experiment, O2 levels decreased as temperatures dropped.

C. The Result on Bananas Third Experiments

These are the experiment result on bananas using 11 Kg of dry ice:

Table 4.7 Experiment Result on Bananas Third Experiments
(Author, 2021)

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
1	8:02:58 AM	26.9	3.99	13.7	124
2	8:03:28 AM	26.8	4.13	15.0	138
3	8:03:58 AM	26.6	3.94	13.7	133
4	8:04:28 AM	26.3	3.97	14.1	131
5	8:04:58 AM	26.1	3.87	13.3	130
No. Data	**Time**	**Temperature (°C)**	**Etylene (ppm)**	**O2 (%)**	**CO2 (ppm)**
1966	9:40:22 AM	14.7	2.61	3.6	151
1967	9:40:52 AM	14.7	2.67	3.7	151
1968	9:41:22 AM	14.7	2.69	3.7	150
1969	9:41:52 AM	14.7	2.61	3.5	151
1970	9:42:22 AM	14.6	2.67	3.6	151

In the banana third experiments is using 11 kg of dry ice, the experiment lasted for about 58 hours and data retrieval was taken every 30 seconds. From the table of results above can be seen that the initial conditions in this experiment are 26.9 C for temperature, 3.99 ppm for ethylene levels, 15% for O2 levels, and 124 ppm for CO2 levels. And from 5 times the data taken at the beginning of the experiment can be seen that temperature conditions, ethylene levels, O2 levels, and CO2 levels tend to fall. This is because the temperature, O2 levels, CO2 levels, and ethylene levels are still above the desired setting points.

From the table of results above, it can also be seen the condition when this experiment reaches the lowest temperature point, namely when the data retrieval to 1970 or about 16 hours after this experiment began. In the 1970 data collection, the conditions in this experiment were 14.6 C for temperature, 2.67 ppm for ethylene levels, 3.6% for O2 levels, and 151 ppm for CO2 levels. In this condition it can be said that the temperature and O2 levels have entered at the desired point, while for co2 levels still do not enter at the desired point.

a. Temperature

These are the results on the temperature during this experiment:

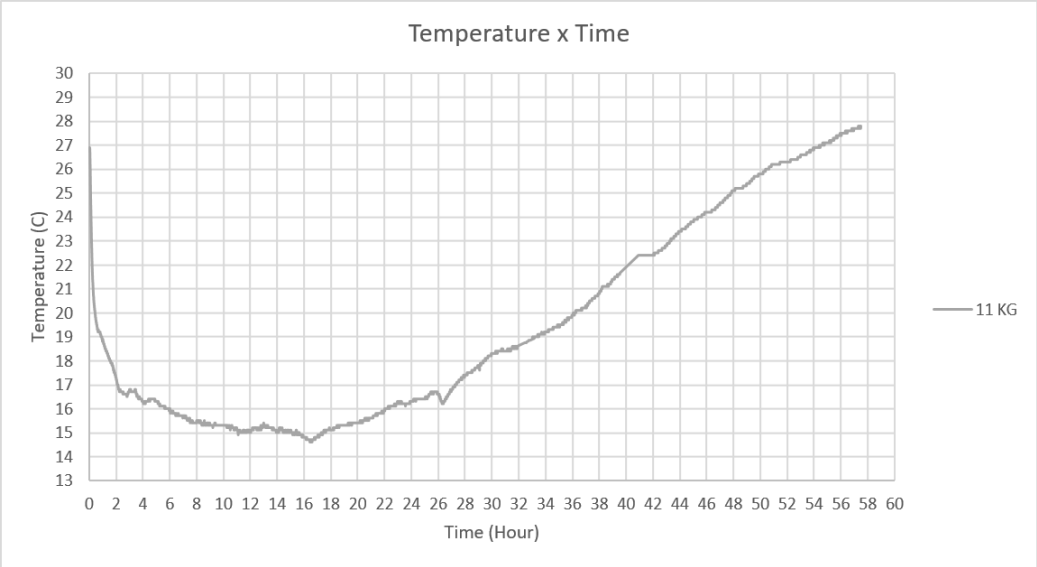


Figure 4.15 Graph of Temperature Against Time at Bananas Third Experiment *(Author, 2021)*

As mentioned earlier, this experiment lasted for 58 hours and the graph above shows the temperature changes that occurred during this experiment. It can be seen in the first 2 hours since the experiment began, the temperature dropped drastically and after that the temperature dropped slowly and constantly until it reached the lowest temperature of 14.6 C at the 17th hour of the experiment. Once it reaches its lowest temperature point, it begins to rise constantly and slowly until the end of the experiment. At the end of this experiment, the temperature showed around the number 28 C. From the chart above it can be concluded that by using 11 kg of dry ice is able to lower the temperature to the point of 14.6 C, with the required time of about 17 hours.

b. Ethylene

These are the results on the ethylene during this experiment:

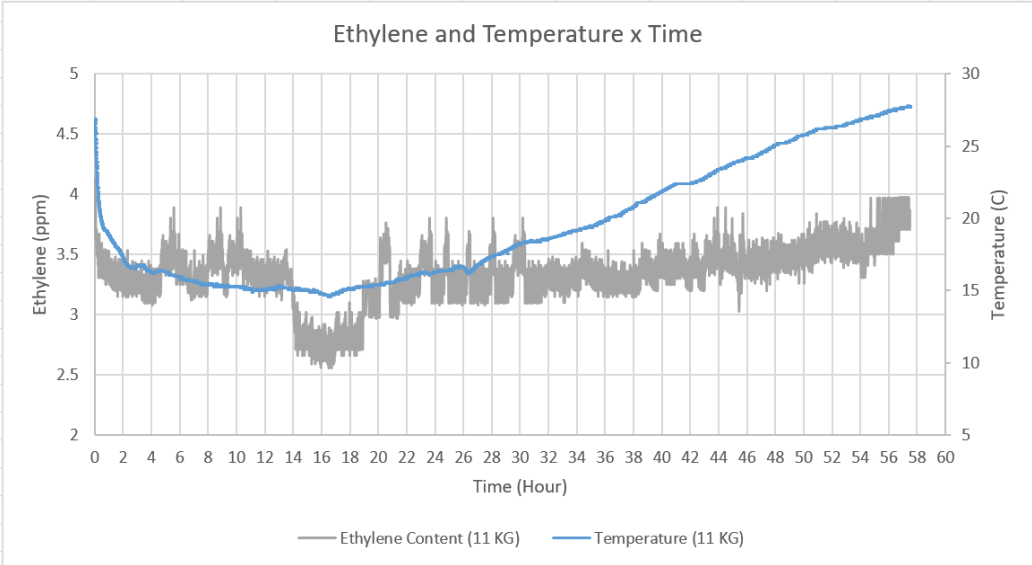


Figure 4.16 Graph of Ethylene Levels Against Temperature and Time at Bananas Third Experiment *(Author, 2021)*

Just like in first and second experiments, that the ethylene scrubber used is 18 grams. In the table above can be seen ethylene levels during the experiment using 11 kg of dry ice lasted. Ethylene levels in this experiment are in the range of 2.6 ppm – 3.9 ppm. In the initial four hours of the experiment, ethylene levels tended to decrease constantly. After that, at the 4th - 18th hour experiment, ethylene levels experienced significant ups and downs until finally at the 18th hour ethylene levels decreased quite drastically and reached the lowest point at about the 16th hour of the experiment. The lowest point that can be reached in this experiment is 2.6 ppm. Starting from the 32nd hour, ethylene levels tend to experience a steady and constant increase until the end of the experiment.

The data in the graph above tends to be similar to the ethylene graph in the experiment using 7 kg and 9 kg of dry ice, which can be said that the temperature has an influence on ethylene levels. It can be concluded that using 18 grams of ethylene scrubber and 11 kg of dry ice the lowest ethylene content that can be achieved is about 2.6 ppm.

c. CO2 Content

These are the results on the CO2 content during this experiment:

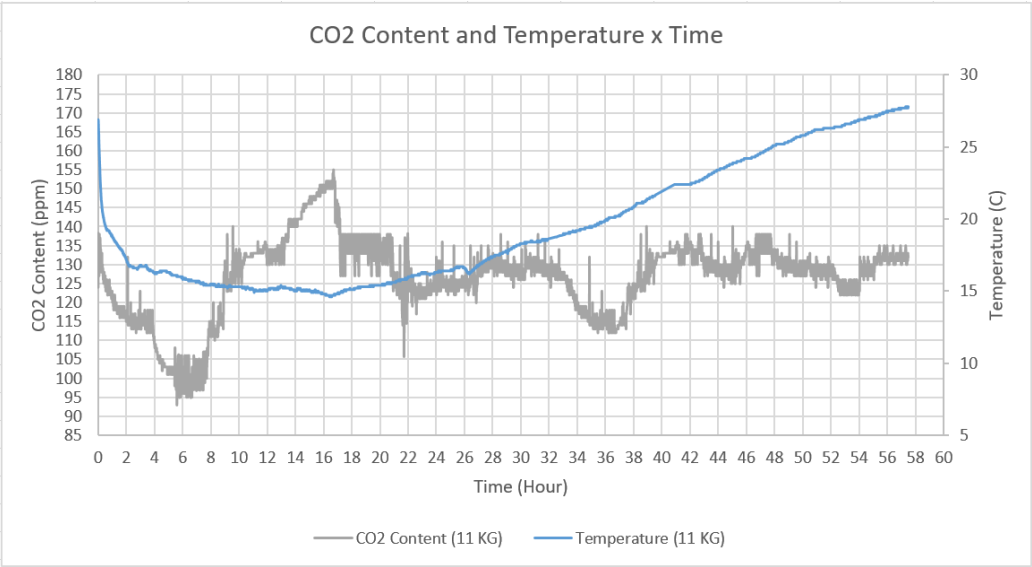


Figure 4.17 Graph of CO2 Levels Against Temperature and Time at Bananas Third Experiment *(Author, 2021)*

Just like in first and second experiments, that the CO2 scrubber used is 50 grams. In the table above can be seen CO2 levels during the experiment using 11 kg of dry ice lasted. In this experiment, O2 levels showed levels of about 94 ppm – 155 ppm, which means that in this experiment there was a time when CO2 levels were above the best CO2 levels range. CO2 scrubber has an active role to lower CO2 levels in order to enter the setting range point. Can be seen at the beginning of the experiment took place, it took about 6 hours for CO2 scrubber able to lower CO2 levels into the desired range. And CO2 scrubbers are only able to keep CO2 levels in the range for about 3 hours, after which CO2 levels increase rapidly. Just like the previous experiment, CO2 levels increase as temperatures drop. The highest CO2 level in this experiment was 155 ppm at about the 16th hour of the experiment and the lowest level was 94 ppm at about the 5th hour of the experiment.

4.5.2 Experiment Results on Pineapples

Pineapple has been experimented 3 times with variations in the mass of dry ice used. The experiment was carried out using 4 kg of pineapples, 1 m3 of N2 gas, 50 grams of CaOH2, and 18 grams mixture of KMnO4 & Zeolit. The results of the pineapple experiments are as follows.

Table 4.8 Experiment Variant of Pineapples *(Author, 2021)*

Type of Comodities	Number of					Running Time (Hours)
	Comodities (Kg)	Dry Ice (Kg)	N2 (m3)	CaOH2 (gram)	Mixture of KMnO4 & Zeolit (gram)	
Pineapples	4	7	1	50	18	36
		9				48
		11				58

The following are figures that are an overview when experimenting, both when the initial condition before the experiment is run and also when the experiment is running. Can also be seen how the laying position and condition of experiment materials at the beginning and at the end of experimentation.

Figure 4.18 Figures at the Beginning of Pineapple Experiment (1)
(Author, 2021)

Figure 4.19 Figures at the Beginning of Pineapple Experiment (2)
(Author, 2021)

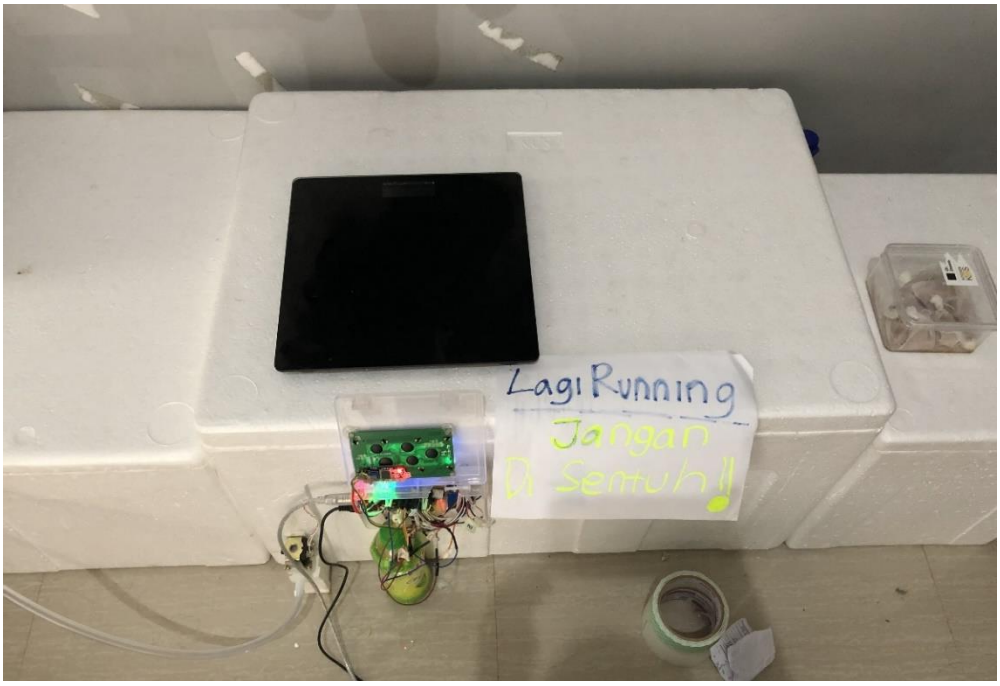


Figure 4.20 Figures of Pineapple Experiment When Running
(Author, 2021)

Figure 4.21 Figures at the End of Pineapple Experiment (1)
(Author, 2021)

Figure 4.22 Figures at the End of Pineapple Experiment (2)
(Author, 2021)

A. The Result on Pineapples First Experiments

These are the experiment result on pineapples using 7 Kg of dry ice:

Table 4.9 Experiment Result on Pineapples First Experiments
(Author, 2021)

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
1	9:53:10 AM	29.1	3.13	13.0	96
2	9:53:40 AM	29	3.15	12.9	103
3	9:54:10 AM	28.8	3.18	12.9	104
4	9:54:40 AM	28.6	3.07	12.4	102
5	9:55:10 AM	28.5	3.1	12.4	98
No. Data	**Time**	**Temperature (°C)**	**Etylene (ppm)**	**O2 (%)**	**CO2 (ppm)**
1026	6:25:21 PM	22.7	3.2	11.4	95
1027	6:25:51 PM	22.7	3.07	10.7	94
1028	6:26:20 PM	22.7	3.17	11.0	96
1029	6:26:50 PM	22.6	3.2	11.0	95
1030	6:27:20 PM	22.7	3.21	11.2	95

In the pineapples first experiments is using 7 kg of dry ice, the experiment lasted for about 36 hours and data retrieval was taken every 30 seconds. From the table of results above, it can be seen that the initial conditions in this experiment were 29.1 C for temperature, 3.13 ppm for ethylene levels, 13% for O2 levels, and 96 ppm for CO2 levels. And from 5 times the data taken at the beginning of the experiment can be seen that temperature conditions and O2 levels always decrease, ethylene levels tend to fall, and CO2 levels tend to be constant. This is because the temperature, O2 levels, and ethylene levels are still above the desired setting point, while for CO2 levels have entered the desired setting range points.

From the table of results above, it can also be seen the condition when this experiment reaches the lowest temperature point, namely when the data collection to 1029 or about 8.5 hours after this experiment begins. In the data taken to 1029 conditions in this experiment was 22.6 C for temperature, 3.2 ppm for ethylene levels, 11% for O2 levels, and 95 ppm for CO2 levels. In this condition it can be said that the temperature, O2 levels, and CO2 levels are still not reached in the desired points.

a. Temperature

These are the results on the temperature during this experiment:

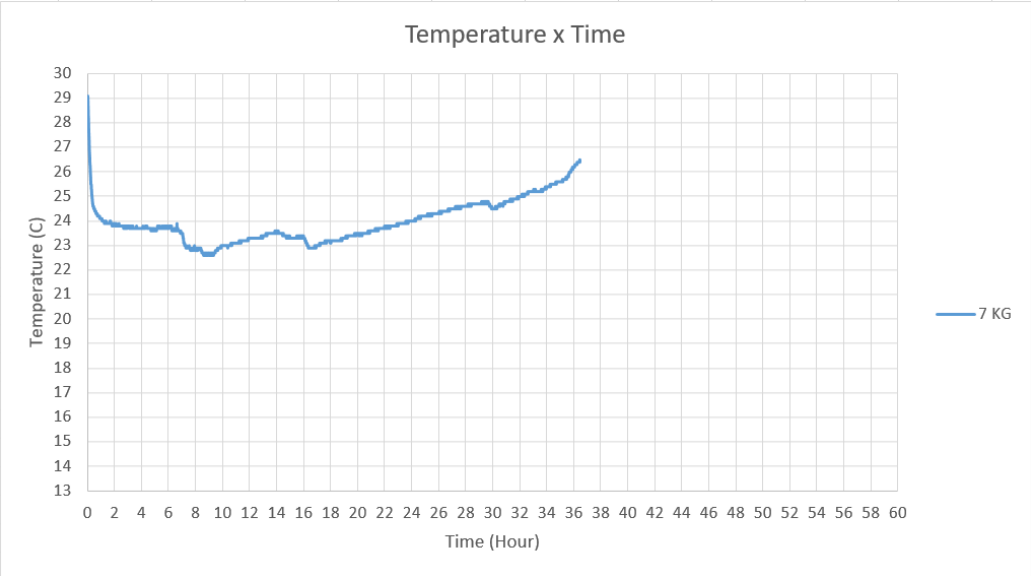


Figure 4.23 Graph of Temperature Against Time at Pineapples First Experiment *(Author, 2021)*

As mentioned earlier, this experiment lasted for 36 hours and the graph above shows the temperature changes that occurred during this experiment. It can be seen in the first hour since the experiment began, the temperature has dropped dramatically and can reach the lowest temperature of 22.6 C in about 8.5 hours since the experiment began. Once it reaches its lowest temperature point, it begins to rise constantly and slowly until the end of the experiment. At the end of this experiment, the temperature showed around the number 26.5 C. From the chart above it can be concluded that by using 7 kg of dry ice is only able to lower the temperature to the point of 22.6 C, with the required time of about 8.5 hours.

b. Ethylene

These are the results on the ethylene during this experiment:

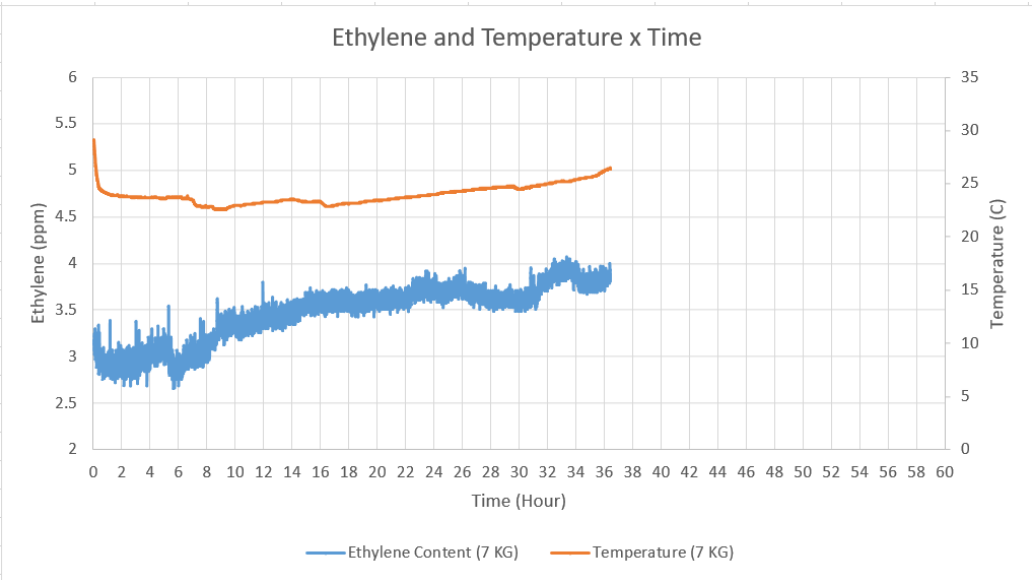


Figure 4.24 Graph of Ethylene Levels Against Temperature and Time at Pineapples First Experiment *(Author, 2021)*

Previously it has been mentioned that this experiment uses ethylene scrubber to minimize ethylene levels, with the number of scrubbers used is 18 grams. In the table above can be seen ethylene levels during the experiment using 7 kg of dry ice lasted. Ethylene levels in this experiment are in the range of 2.6 ppm – 4.1 ppm. At the beginning of the experiment, ethylene levels tend to rise and fall steadily and got a fairly drastic decrease around the fifth hour since the experiment began. And around the sixth hour since the experiment began, ethylene levels reached its lowest point of 2.6. Once it reaches its lowest temperature point, it begins to rise constantly and slowly until the end of the experiment.

When looking at the data in the graph above, it can be said that in this experiment the temperature has an influence on ethylene levels, and it can also be said that the graph formed based on ethylene levels has a similar shape to the form of the graph produced by the temperature. When seen also ethylene levels tend to fall when the temperature decreases and tends to rise when the temperature increases, this is because the temperature can affect the fruit in producing ethylene so that the lower the temperature around the fruit, the level of ethylene produced will be lower. In the end it can be concluded that by using 18 grams of ethylene scrubber and 7 kg of dry ice the lowest ethylene content that can be achieved is 2.6 ppm

only, and the effective time of the ethylene scrubber works only 6 hours because after that ethylene levels continue to increase constantly.

c. CO2 Content

These are the results on the CO2 content during this experiment:

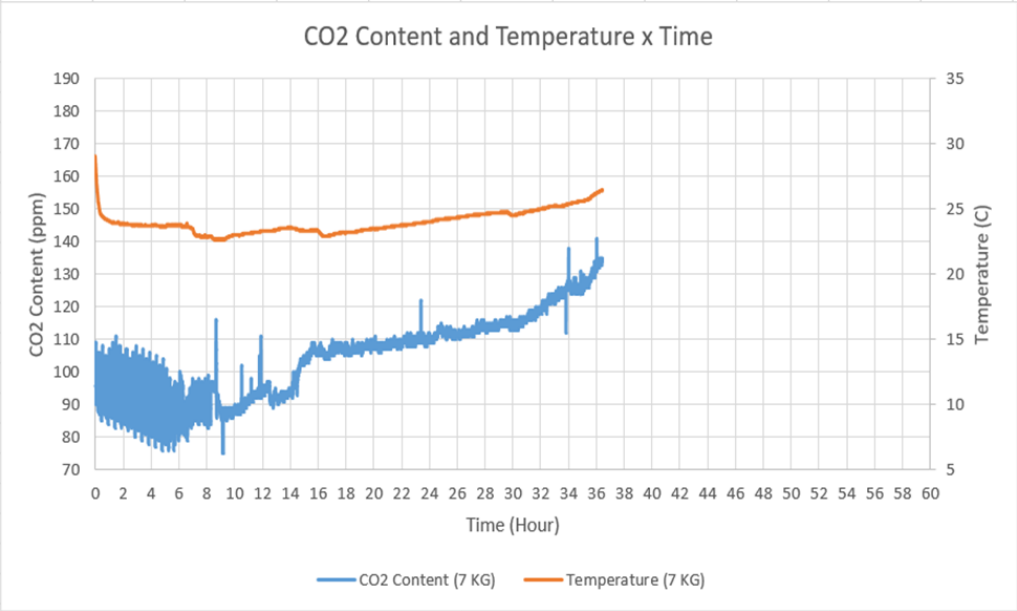


Figure 4.25 Graph of CO2 Levels Against Temperature and Time at Pineapples First Experiment *(Author, 2021)*

Previously it has been mentioned that this experiment uses CO2 scrubber to minimize CO2 levels, with the number of scrubbers used is 50 grams. In the table above can be seen CO2 levels during the experiment using 7 kg of dry ice lasted. From the graph above it can be said that the CO2 levels in this experiment are already in the desired range point setting. In this experiment, CO2 levels also experienced ups and downs even though they were still in the range. When compared to temperatures, CO2 levels tend to increase as temperatures tend to drop, and vice versa. The lowest CO2 level in this experiment was 75 ppm and occurred around the ninth hour of the experiment, while the highest CO2 level was 142 ppm and occurred around the 36th hour of the experiment**.**

d. O2 Content

These are the results on the O2 content during this experiment:

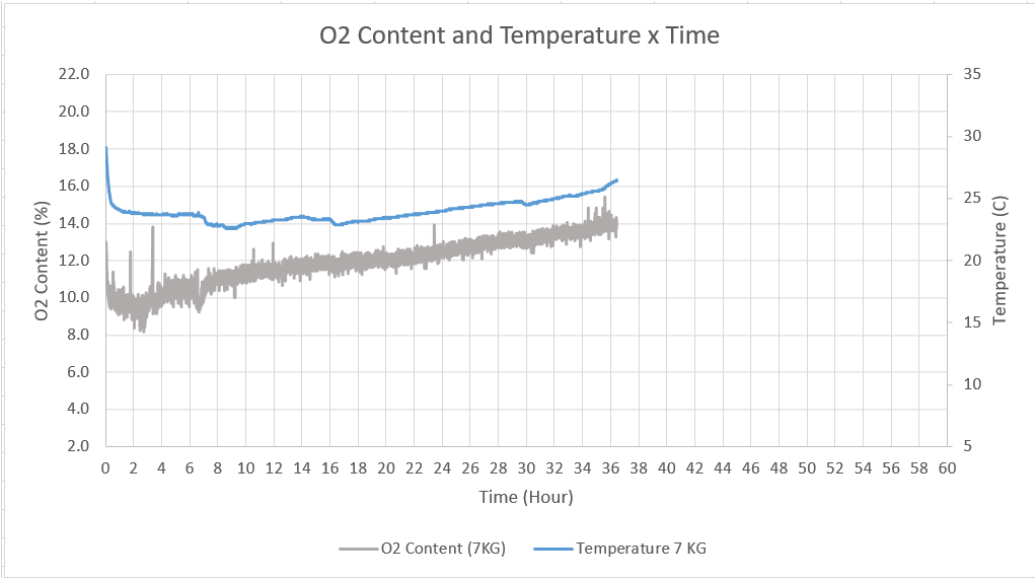


Figure 4.26 Graph of O2 Levels Against Temperature and Time at Pineapples First Experiment *(Author, 2021)*

Previously it has been mentioned that this experiment uses N2 gas to minimize O2 levels, with the amount of gas used is 1 m3 and the flow rate applied is 1 l / m. In the table above can be seen O2 levels during the experiment using 7 kg of dry ice lasted. O2 levels in this experiment are in the range of 8.2% - 15.5%. It can be said that 1 m3 of N2 gas and 7 kg of dry ice can only lower O2 levels by 8.2% and it takes as little as 3 hours to reach that point. After reaching its lowest point at the 3rd hour of the experiment, O2 levels tend to rise slowly and constantly until the end of the experiment. In the graph above, when looking at the data of O2 levels and temperature levels, it can be seen that if the temperature decreases then O2 levels will tend to decrease as well and vice versa. This is because when the temperature is lower, the CO2 levels in the CAS prototype will increase, which causes O2 levels to decrease.

B. The Result on Pineapples Second Experiments

These are the experiment result on pineapples using 9 Kg of dry ice:

Table 4.10 Experiment Result on Pineapples Second Experiments
(Author, 2021)

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
1	8:14:30 AM	28.1	3.26	14.0	119
2	8:15:00 AM	28	3.49	14.9	139
3	8:15:30 AM	27.9	3.53	14.6	139
4	8:16:00 AM	27.6	3.49	13.5	139
5	8:16:30 AM	27.3	3.58	13.2	139
No. Data	**Time**	**Temperature (°C)**	**Etylene (ppm)**	**O2 (%)**	**CO2 (ppm)**
996	4:31:28 PM	19.7	3.2	10.4	121
997	4:31:58 PM	19.7	3.3	10.4	121
998	4:32:27 PM	19.7	3.38	11.0	121
999	4:32:57 PM	19.6	3.33	10.8	122
1000	4:33:27 PM	19.6	3.23	10.4	120

In the pineapple second experiments is using 9 kg of dry ice, the experiment lasted for about 48 hours and the data retrieval was taken every 30 seconds. From the table of results above can be seen that the initial conditions in this experiment is 28.1 C for temperature, 3.26 ppm for ethylene levels, 14% for O2 levels, and 119 ppm for CO2 levels. And from 5 times the data taken at the beginning of the experiment can be seen that temperature conditions and O2 level always decrease, ethylene levels and CO2 levels tend to be constant. This is because the temperature and O2 levels are still above the desired setting point, while for CO2 levels have entered the desired setting range points.

From the table of results above, it can also be seen the condition when this experiment reaches the lowest temperature point, namely when the data retrieval to 999 or about 8 hours after this experiment began. In the 999 data collection, the conditions in this experiment were 19.6 C for temperature, 3.33 ppm for ethylene levels, 10.8% for O2 levels, and 122 ppm for CO2 levels. In this condition it can be said that the temperature and O2 level are still not reached the desired setting point, while for CO2 levels have entered at the desired setting point.

a. Temperature

These are the results on the temperature during this experiment:

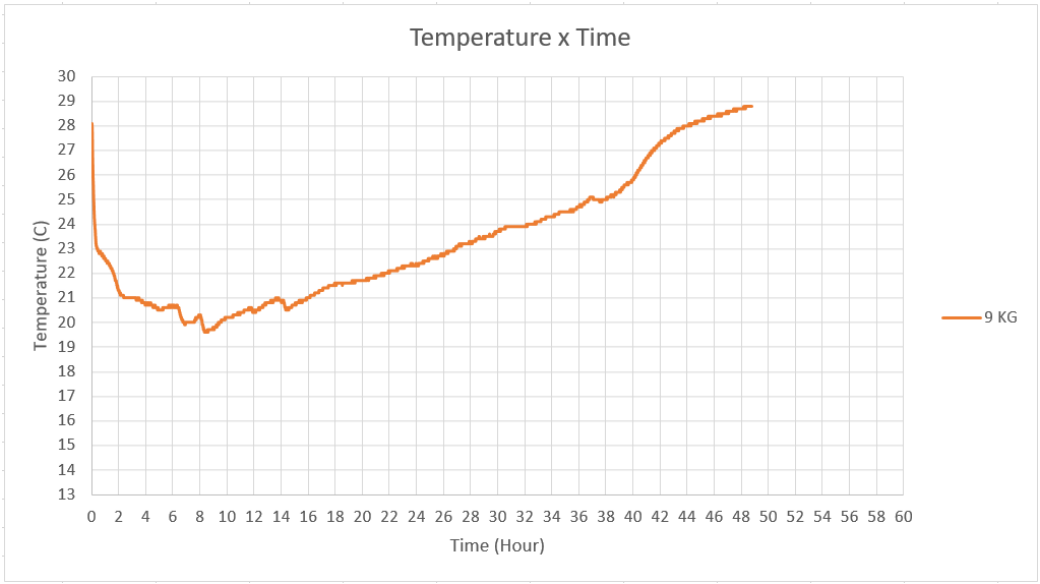


Figure 4.27 Graph of Temperature Against Time at Pineapples Second Experiment *(Author, 2021)*

As mentioned earlier, this experiment lasted for 48 hours and the graph above shows the temperature changes that occurred during this experiment. It can be seen in the first 2 hours since the experiment began, the temperature has dropped dramatically and can reach the lowest temperature of 19.6 C in about 8 hours since the experiment began. After reaching the lowest temperature point, the temperature rise constantly and slowly until the end of the experiment. At the end of this experiment, the temperature showed around the number 29 C. From the chart above it can be concluded that by using 9 kg of dry ice can only lower the temperature to the point of 19.6 C, with the required time of about 8 hours.

b. Ethylene

These are the results on the ethylene during this experiment:

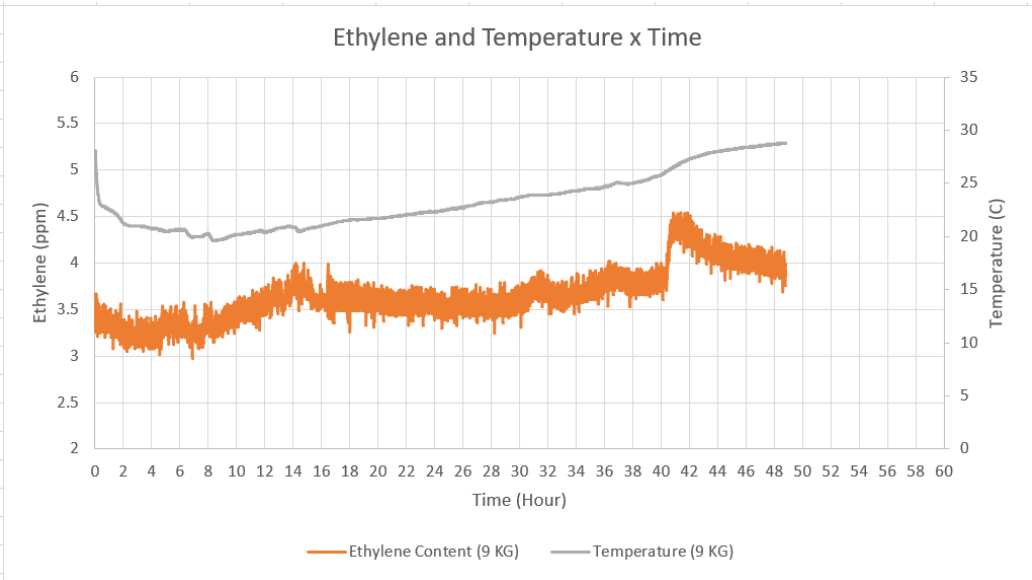


Figure 4.28 Graph of Ethylene Levels Against Temperature and Time at Pineapples Second Experiment *(Author, 2021)*

Just like before, that this experiment uses ethylene scrubber with an amount of 18 grams. In the table above can be seen ethylene levels during the experiment using 9 kg of dry ice lasted. Ethylene levels in this experiment are in the range of 2.95 ppm – 5.55 ppm. In the initial four hours of the experiment, ethylene levels decrease constantly, and after that it continued to rise. After got a constant increase, ethylene levels dropped dramatically around the 7th hour, and then tended to increase slowly until the end of the experiment. In this experiment the lowest ethylene levels were at the point of 2.95 ppm which occurred at about the seventh hour of the experiment.

When looking at the data in the graph above, it can be said that the data on the graph shows something similar to the graph in the experiment using 7 kg of dry ice, namely that the graph formed based on ethylene levels has a similar shape to the form of the graph produced by the temperature. And also when viewed, just like the experiment results with 7 kg of dry ice, ethylene levels tend to follow the conditions of the temperature, this is because the temperature can affect the fruit in producing ethylene so that the lower the temperature around the fruit, the level of ethylene produced will be lower. In the end it can be concluded that by using 18 grams of ethylene scrubber and 9 kg of dry ice the lowest ethylene content that can be achieved is 2.95 ppm.

c. CO2 Content

These are the results on the CO2 content during this experiment:

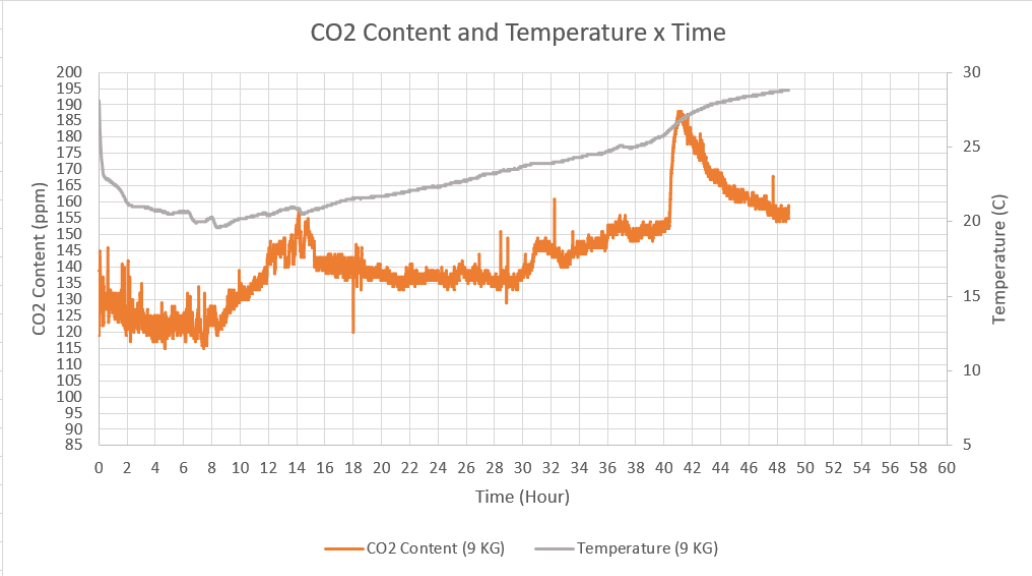


Figure 4.29 Graph of CO2 Levels Against Temperature and Time at Pineapples Second Experiment *(Author, 2021)*

Just like before, that this experiment uses CO2 scrubber with an amount of 50 grams. In the table above can be seen CO2 levels during the experiment using 9 kg of dry ice lasted. Just like the experiment using 7 kg of dry ice, from the graph above it can be said that the CO2 levels in this experiment are already in the desired range point setting. In this experiment, CO2 levels also experienced ups and downs even though they were still in the range. When compared to temperatures, CO2 levels tend to increase as temperatures tend to drop, and vice versa. The lowest CO2 level in this experiment was 114 ppm and occurred around the fourth hour of the experiment, while the highest CO2 level was 189 ppm and occurred around the 41st hour of the experiment**.**

d. O2 Content

These are the results on the O2 content during this experiment:

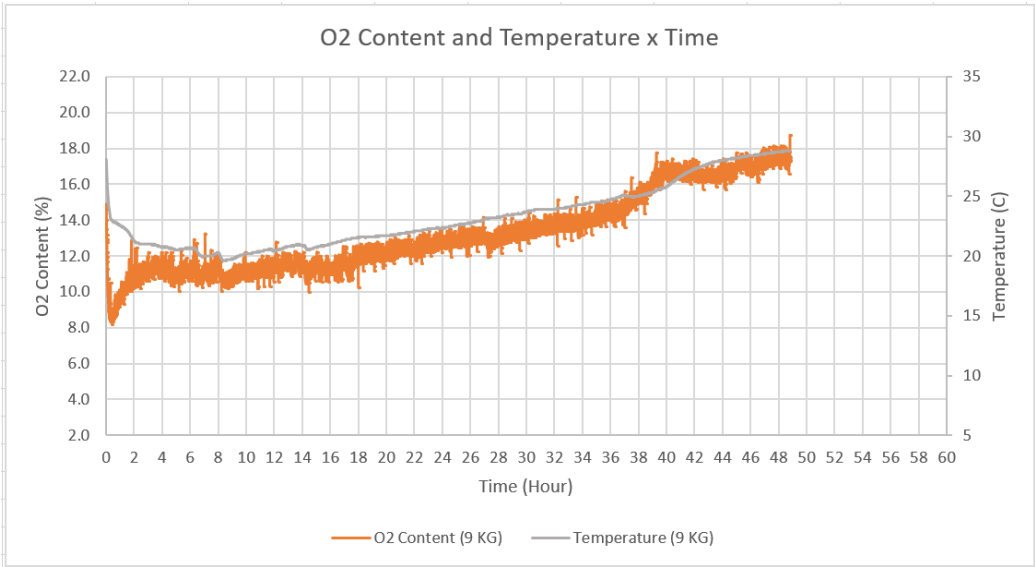


Figure 4.30 Graph of O2 Levels Against Temperature and Time at Pineapples Second Experiment *(Author, 2021)*

Just like before, that this experiment uses N2 gas with an amount of 1 m3 and the flow rate applied is 1 l / m. In the table above can be seen O2 levels during the experiment using 9 kg of dry ice lasted. O2 levels in this experiment are in the range of 8% - 19%, which means that in this experiment the O2 level couldn't reach the desire range. N2 gas has an active role to lower O2 levels in order to enter the setting range point. Can be seen at the beginning of the experiment took place, it took about less than hours for N2 gas to lower O2 levels into the lowest point, but that point is still above the desired range. After reached the lowest point, O2 levels increase rapidly until the end of experiment. Just like the previous experiment, O2 levels decreased as temperatures dropped.

C. The Result on Pineapples Third Experiments

These are the experiment result on pineapples using 11 Kg of dry ice:

Table 4.11 Experiment Result on Pineapples Third Experiments
(Author, 2021)

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
1	8:20:25 PM	25.5	4.02	12.7	155
2	8:20:55 PM	25.3	3.95	12.1	153
3	8:21:25 PM	25.1	3.89	11.6	151
4	8:21:55 PM	24.9	3.97	12.1	152
5	8:22:25 PM	24.8	3.82	11.7	153
No. Data	**Time**	**Temperature (°C)**	**Etylene (ppm)**	**O2 (%)**	**CO2 (ppm)**
886	3:42:36 AM	18	3.31	4.8	106
887	3:43:06 AM	18	3.48	5.3	107
888	3:43:36 AM	18	3.46	4.9	109
889	3:44:06 AM	17.9	3.43	5.2	107
890	3:44:36 AM	17.9	3.33	4.9	107

In the pineapples third experiments is using 11 kg of dry ice, the experiment lasted for about 58 hours and data retrieval was taken every 30 seconds. From the table of results above can be seen that the initial conditions in this experiment are 25.5 C for temperature, 4.02 ppm for ethylene levels, 12.7% for O2 levels, and 155 ppm for CO2 levels. And from 5 times the data taken at the beginning of the experiment can be seen that temperature conditions, ethylene levels, and O2 levels are tends to fall, whereas CO2 levels is tend to be constant. This is because the temperature, O2 levels, and ethylene levels are still above the desired setting points.

From the table of results above, it can also be seen the condition when this experiment reaches the lowest temperature point, namely when the data retrieval to 889 or about 7 hours after this experiment began. In the 889 data collection, the conditions in this experiment were 17.9 C for temperature, 3.43 ppm for ethylene levels, 5.2% for O2 levels, and 107 ppm for CO2 levels. In this condition it can be said that the temperature and O2 level are still not reached the desired setting point, while for CO2 levels have entered at the desired setting point.

a. Temperature

These are the results on the temperature during this experiment:

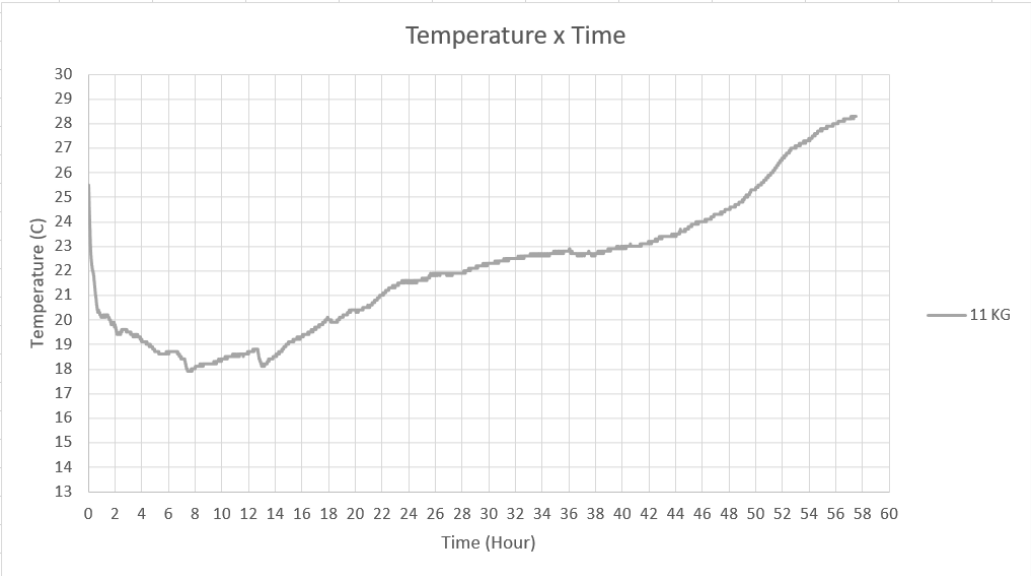


Figure 4.31 Graph of Temperature Against Time at Pineapples Third Experiment *(Author, 2021)*

As mentioned earlier, this experiment lasted for 58 hours and the graph above shows the temperature changes that occurred during this experiment. It can be seen in the first 2 hours since the experiment began, the temperature dropped drastically and after that the temperature dropped slowly and constantly until it reached the lowest temperature of 17.9 C at the 7th hour of the experiment. Once it reaches its lowest temperature point, it begins to rise constantly and slowly until the end of the experiment. At the end of this experiment, the temperature showed around the number 28.5 C. From the chart above it can be concluded that by using 11 kg of dry ice is able to lower the temperature to the point of 17.9 C, with the required time of about 7 hours.

b. Ethylene

These are the results on the ethylene during this experiment:

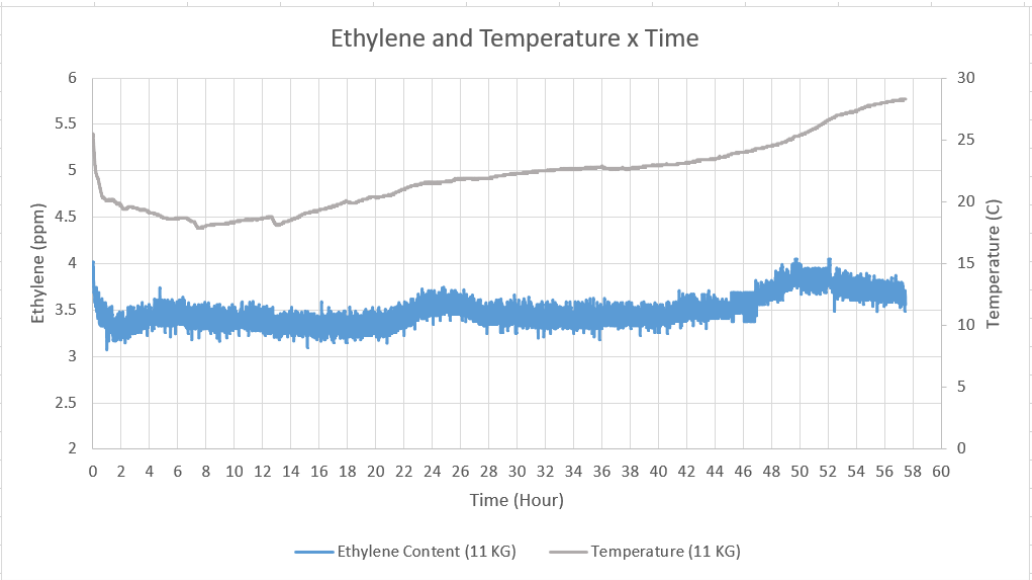


Figure 4.32 Graph of Ethylene Levels Against Temperature and Time at Pineapples Third Experiment *(Author, 2021)*

Just like in first and second experiments, that the ethylene scrubber used is 18 grams. In the table above can be seen ethylene levels during the experiment using 11 kg of dry ice lasted. Ethylene levels in this experiment are in the range of 3.1 ppm – 4.1 ppm. In the initial two hours of the experiment, ethylene levels tended to decrease constantly. After that, at the 2nd - 5th hour experiment, ethylene levels increasing constantly until finally ethylene levels back to decreased at the 5th hour. The lowest point that can be reached in this experiment is 3.1 ppm. Starting from the 28th hour, ethylene levels tend to experience a steady and constant increase until the end of the experiment.

The data in the graph above tends to be similar to the ethylene graph in the experiment using 7 kg and 9 kg of dry ice, which can be said that the temperature has an influence on ethylene levels. It can be concluded that using 18 grams of ethylene scrubber and 11 kg of dry ice the lowest ethylene content that can be achieved is about 3.1 ppm.

c. CO2 Content

These are the results on the CO2 content during this experiment:

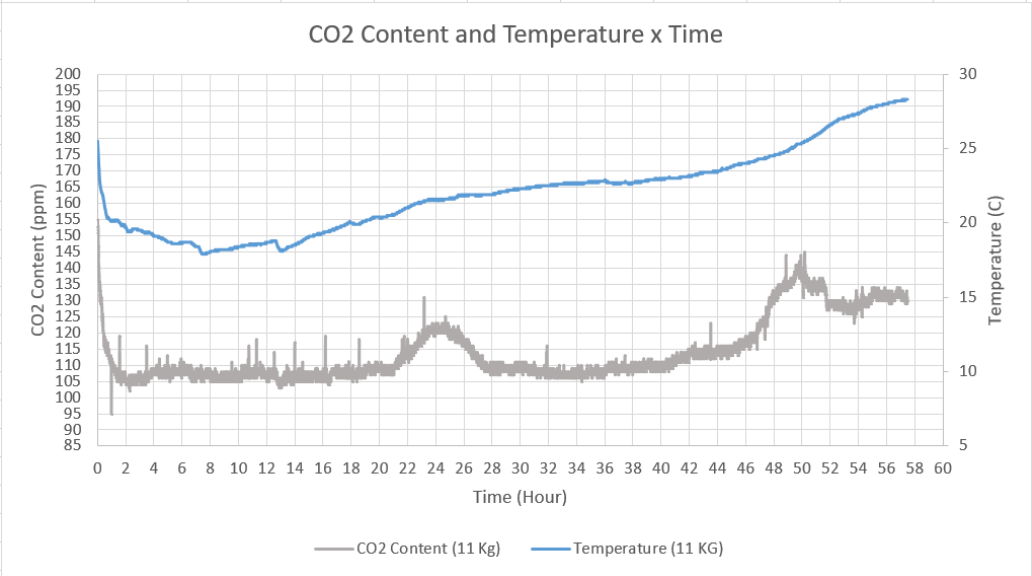


Figure 4.33 Graph of CO2 Levels Against Temperature and Time at Pineapples Third Experiment *(Author, 2021)*

Just like in first and second experiments, that the CO2 scrubber used is 50 grams. In the table above can be seen CO2 levels during the experiment using 11 kg of dry ice lasted. In this experiment, O2 levels showed levels of about 103 ppm – 145 ppm. From the data above it can be said that the CO2 levels in this experiment are already at the desired range point setting, so that the performance of the CO2 scrubber does not play an active role. Although always within the range, CO2 levels also experienced ups and downs during the experiment, ups and downs that were quite drastic and significant occurred at the 21th – 28th hour of the experiment and at the 46th hour – the end of the experiment. The highest CO2 level in this experiment was 145 ppm at about the 50th hour of the experiment and the lowest level was 103 ppm at about the second hour of the experiment.

d. O2 Content

These are the results on the O2 content during this experiment:

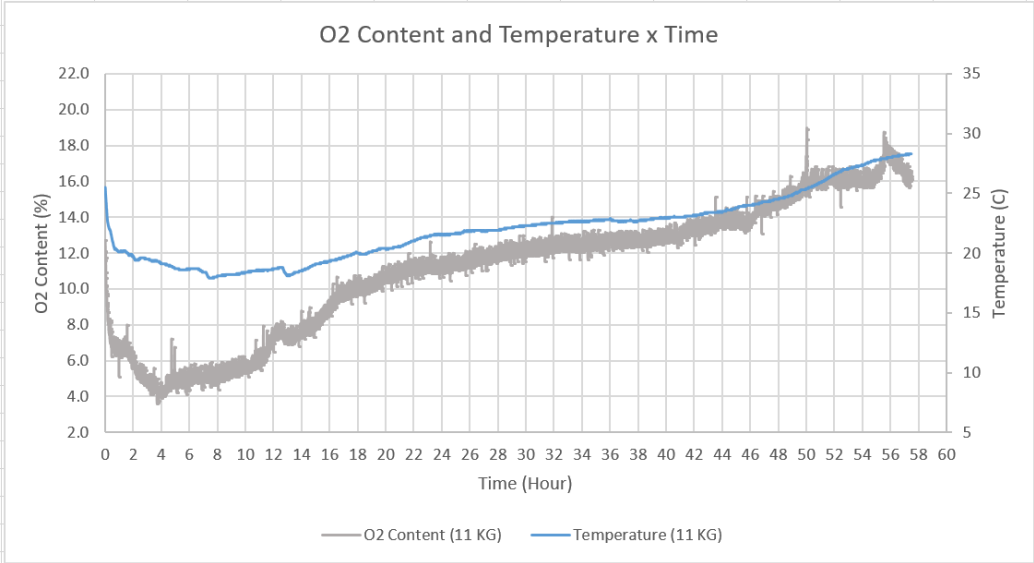


Figure 4.34 Graph of O2 Levels Against Temperature and Time at Pineapples Third Experiment *(Author, 2021)*

Just like before, that this experiment uses N2 gas with an amount of 1 m3 and the flow rate applied is 1 l / m. In the table above can be seen O2 levels during the experiment using 11 kg of dry ice lasted. O2 levels in this experiment are in the range of 3.5% - 19%, which means that in this experiment there is a time when O2 levels are above the best O2 range. N2 gas has an active role to lower O2 levels in order to enter the setting range point. Can be seen at the beginning of the experiment took place, it took about 2nd hours for N2 gas to lower O2 levels into the desired range. And N2 gas is only able to keep O2 levels in the range for about 6 hours, after which O2 levels increase rapidly. Just like the previous experiment, O2 levels decreased as temperatures dropped.

4.6 Analysis Experiment Data Result

4.6.1 Analysis Experiment Data Result on Bananas

As mentioned earlier, that in bananas experimented three times with variations on the mass of dry ice that is 7 kg, 9kg, and 11 kg. And the three experiments lasted for 36 hours for 7 kg of dry ice mass, 48 hours for 9 kg of dry ice mass, and 58 hours for 11 kg of dry ice mass. The following will be discussed about comparison and analysis of experiment data based on temperature, ethylene levels, and CO2 levels.

A. Temperature

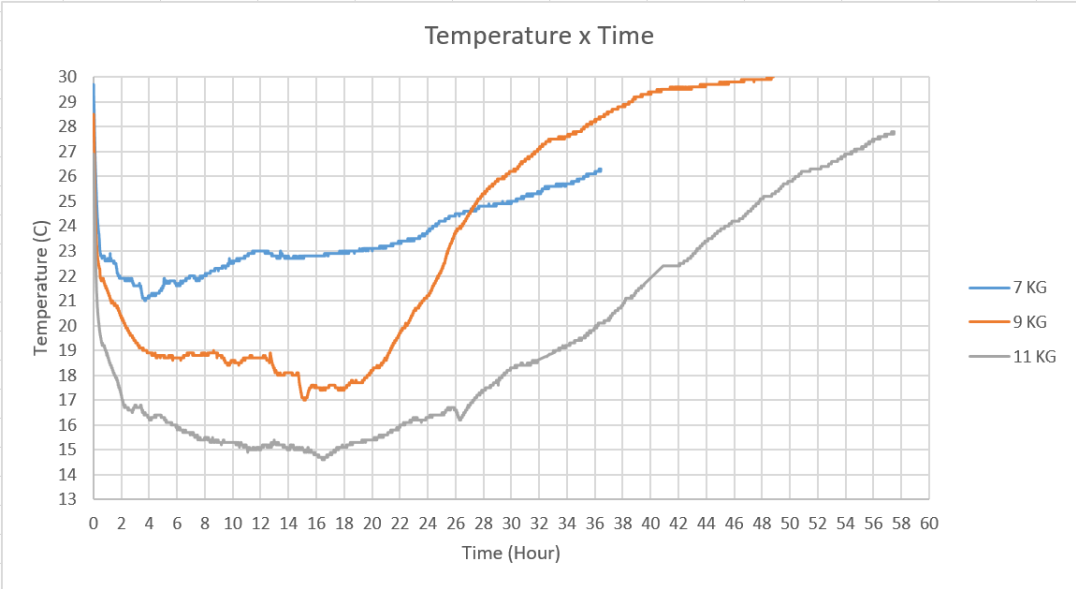


Figure 4.35 Comparison Graph of Temperature at the Three Bananas Experiment Against Time *(Author, 2021)*

Based on the comparison chart above, it can be seen that the more dry ice is used, the temperature will drop faster and lower, and it will take longer for the ice to run out. In the use of dry ice, the increasing number also affects the lowest temperature that can be reached by this CAS prototype. This is evidenced in the graph above, namely the use of dry ice mass of 7 kg has the lowest temperature that can be achieved is 21 C, the use of dry ice mass of 9 kg has the lowest temperature that can be achieved is 17 C, while the use of dry ice mass is 11 kg. has the lowest temperature that can be achieved is 14.6 C.

From the table above it can also be seen that with the use of dry ice as much as 7 kg and 9 kg, it has not been able to reach the best temperature range desired for storage of bananas which is 11-15 C. Whereas with the use of dry ice as much as

11 kg has been able to reach the best temperature range and it takes about 14 hours to reach that range. The use of 11 kg dry ice can withstand the temperature in the desired temperature range for 4 hours. So the effective length of time that can be generated if this CAS prototype uses 11 kg of dry ice is 18 hours.

B. Ethylene

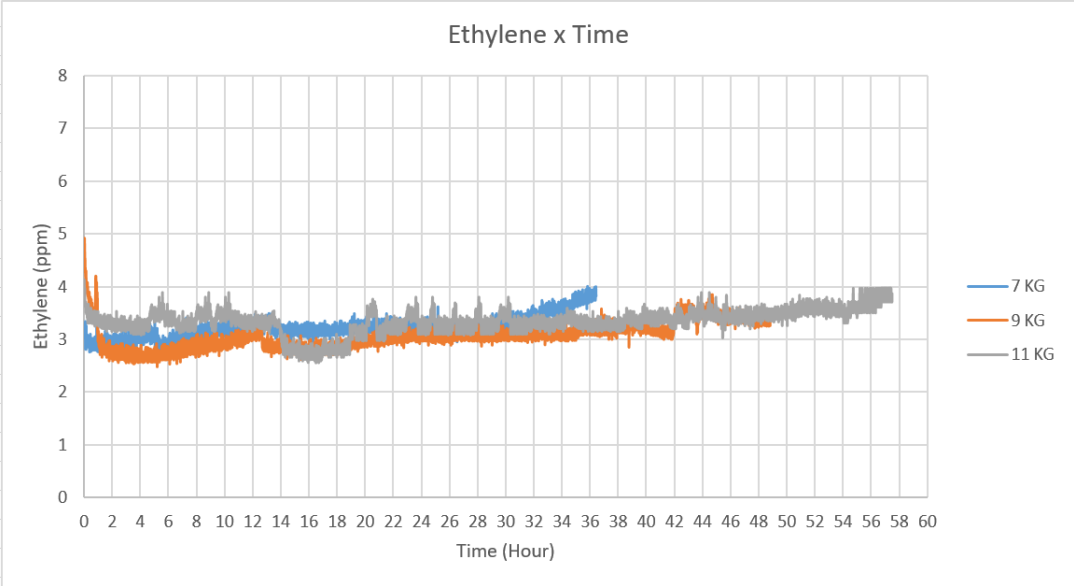


Figure 4.36 Comparison Graph of Ethylene Levels at the Three Bananas Experiment Against Time *(Author, 2021)*

The graph above is a comparison graph of ethylene levels in the three bananas experiments. In this experiment, ethylene levels (one of the factors that influence fruit ripening) are reduced to minimize in number by using ethylene scrubber, and ethylene scrubber used in these three experiments has the same amount of 18 grams. Of the three experiments conducted, it has a close enough ethylene content during the experiment which is about 2.8 ppm – 3.8 ppm. From the three experiments, it can be seen that 18 grams of ethylene scrubber can only lower ethylene levels to 2.8 ppm only. It can also be seen in the table above that the temperature also affects ethylene levels, this is indicated by the time when ethylene levels decrease or reach their lowest point similar to the time when the temperature in the experiment reaches its lowest point. It can be concluded that decreased temperature can cause ethylene levels to decrease as well, and the use of 18 grams of ethylene scrubber can help lower ethylene levels in this CAS prototype.

According to ASHRAE Handbook, the ethylene production rate in bananas 10 µL/(Kg.h). In this experiments, the number of bananas that used are 4 kg, so it

can said that the ethylene production rate are 40 µL/(4 Kg.h) or 9.5 ppm/h. It can be seen in graph above that in the three pineapples experiments the ethylene scrubber and the temperature can maintain the ethylene production rate in pineapples. So that the ethylene production rate during the experiment average is less than 9.5 ppm/h.

C. CO2

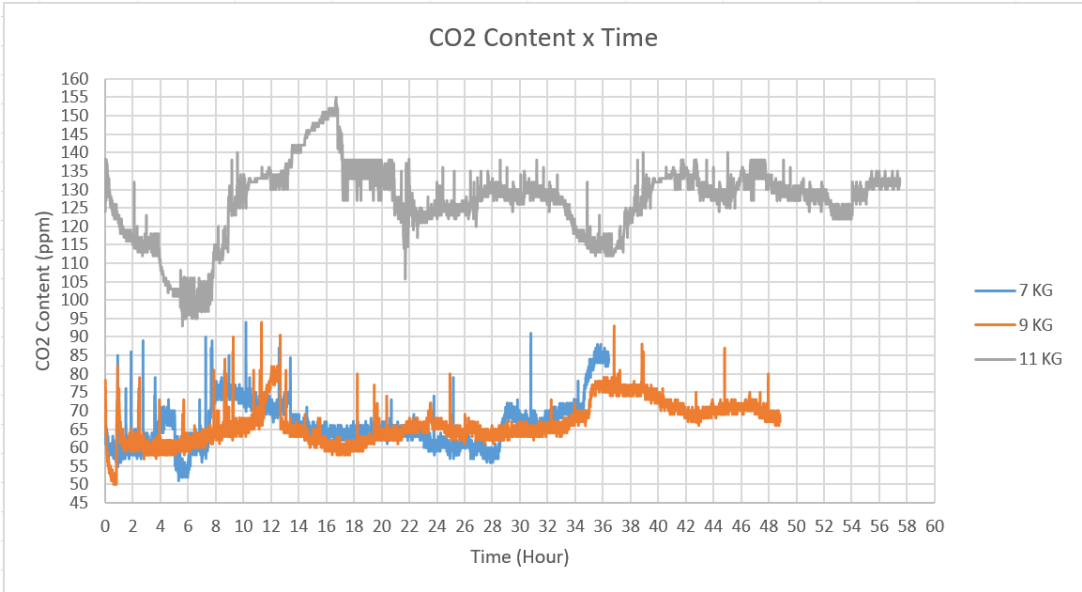


Figure 4.37 Comparison Graph of CO2 Levels at the Three Bananas Experiment Against Time *(Author, 2021)*

The graph above is a comparison graph of CO2 levels in the mass variation of dry ice used in experiments. In this experiment, CO2 levels are attempted to achieve the best range of CO2 levels to store bananas, and also if the CO2 levels have reached the desired range then it needs to be maintained in that range. If we look at the table above, in the experiment using 7 kg and 9 kg of dry ice ethylene levels showed a level of about 49 ppm - 94 ppm which the content has entered into the range of the best CO2 levels (39.6 - 99 ppm) to deviate bananas. Whereas when experiments using 11 kg of dry ice, O2 levels showed levels of about 94 ppm - 155 ppm, which means in this experiment there was a time when CO2 levels were above the range of the best CO2 levels.

In all three experiments, CO2 scrubber was used as an effort to reduce CO2 levels when it exceeded the desired CO2 range. The amount of CO2 scrubber used in these three experiments is the same as 50 grams. In experiments using 7 kg and 9 kg, CO2 scrubber does not play too much role because the CO2 levels are in accordance with the desired range. While in experiments with 11 kg of dry ice, CO2 scrubber plays

an active role to lower CO2 levels that are quite far above the desired range, the result is CO2 scrubber able to lower CO2 levels to enter the range but only able to keep it about 3 hours.

In the table above can also be seen that the more dry ice used, the CO2 levels will increase. In all three experiments it was also shown that the time when CO2 levels increase or reach their highest point is similar to the time when the temperature reaches its lowest point. Both of these are caused because the coolant source used in this CAS prototype is dry ice which is frozen CO2.

4.6.2 Analysis Experiment Data Result on Pineapples

As mentioned earlier, that in pineapples experimented three times with variations on the mass of dry ice that is 7 kg, 9kg, and 11 kg. And the three experiments lasted for 36 hours for 7 kg of dry ice mass, 48 hours for 9 kg of dry ice mass, and 58 hours for 11 kg of dry ice mass. The following will be discussed about comparison and analysis of experiment data based on temperature, ethylene levels, CO2 levels, and O2 levels.

A. Temperature

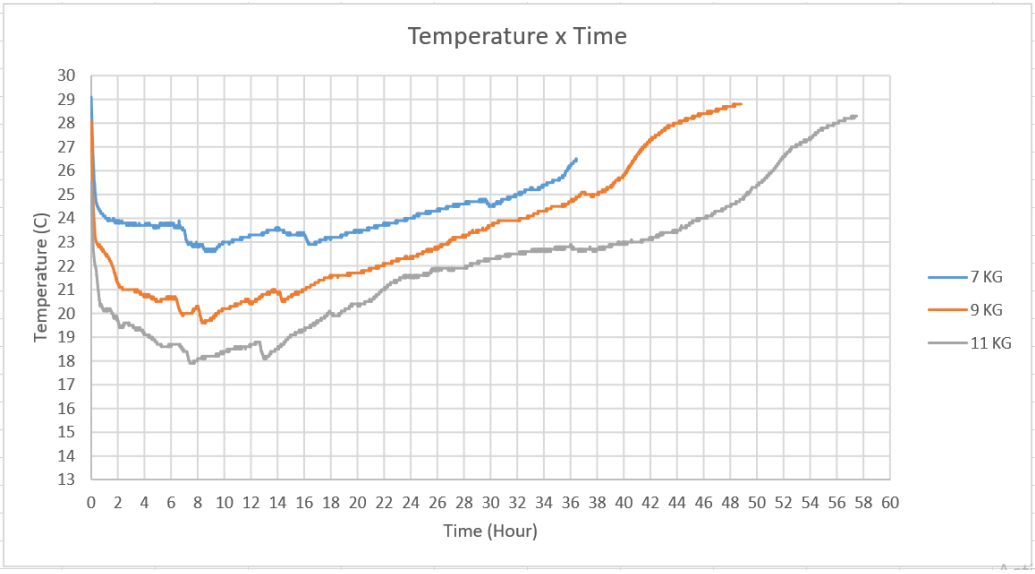


Figure 4.38 Comparison Graph of Temperature at the Three Pineapples Experiment Against Time *(Author, 2021)*

Based on the comparison chart above, same like banana comparison chart, it can be seen that the more dry ice is used, the temperature will drop faster and lower, and it will take longer for the ice to run out. In the use of dry ice, the increasing number also affects the lowest temperature that can be reached by this CAS prototype. This is evidenced in the graph above, namely the use of dry ice mass

of 7 kg has the lowest temperature that can be achieved is 22.6 C, the use of dry ice mass of 9 kg has the lowest temperature that can be achieved is 19.6 C, while the use of dry ice mass is 11 kg. has the lowest temperature that can be achieved is 17.9 C. From the table above it can also be seen that all of three experiment still not been able to reach the best temperature range desired for storage of pineapples which is 7-13 C.

B. Ethylene

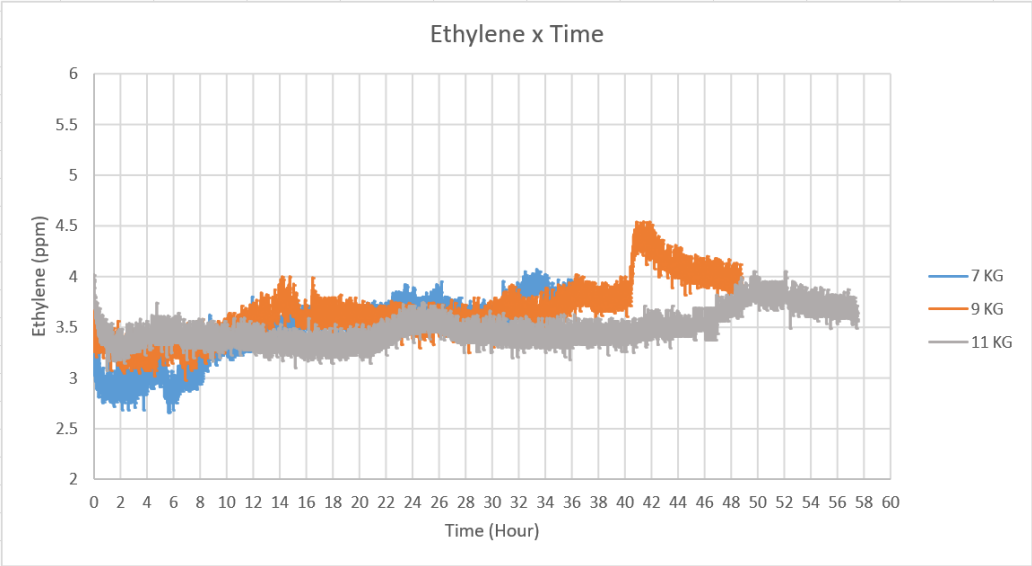


Figure 4.39 Comparison Graph of Ethylene Levels at the Three Pineapples Experiment Against Time *(Author, 2021)*

The graph above is a comparison graph of ethylene levels in the three pineapples experiments. In this experiment, ethylene levels (one of the factors that influence fruit ripening) are reduced to minimize in number by using ethylene scrubber, and ethylene scrubber used in these three experiments has the same amount of 18 grams. Of the three experiments conducted, it has a close enough ethylene content during the experiment which is about 2.6 ppm – 4.6 ppm. From the three experiments, it can be seen that 18 grams of ethylene scrubber can only lower ethylene levels to 2.6 ppm only. It can also be seen in the graph above that the temperature also affects ethylene levels, this is indicated by the time when ethylene levels decrease or reach their lowest point similar to the time when the temperature in the experiment reaches its lowest point. It can be concluded that decreased temperature can cause ethylene levels to decrease as well, and the use of 18 grams of ethylene scrubber can help lower ethylene levels in this CAS prototype.

According to ASHRAE Handbook, the ethylene production rate in pineapples 1 µL/(Kg.h). In this experiments, the number of pineapples that used are 4 kg, so it can said that the ethylene production rate are 4 µL/(4 Kg.h) or 0.7 ppm/h. It can be seen in graph above that in the three pineapples experiments the ethylene scrubber and the temperature can maintain the ethylene production rate in pineapples. So that the ethylene production rate during the experiment average is less than 0.7 ppm/h.

C. CO2

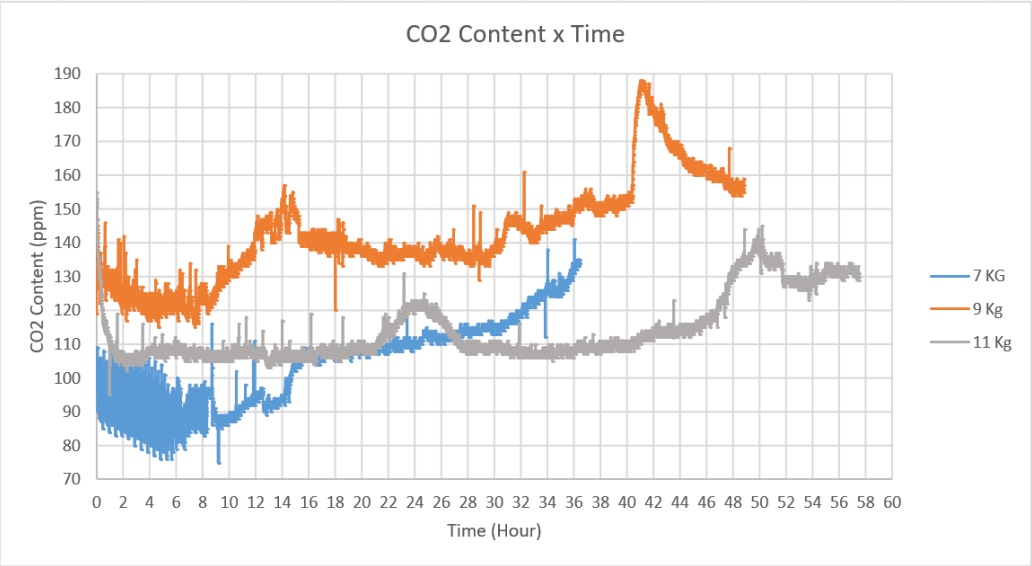


Figure 4.40 Comparison Graph of CO2 Levels at the Three Pineapples Experiment Against Time *(Author, 2021)*

The graph above is a comparison graph of CO2 levels in the three pineapples experiments. In this experiment, CO2 levels are attempted to achieve the best range of CO2 levels to store pineapples, and also if the CO2 levels have reached the desired range then it needs to be maintained in that range. If we look at the table above, in the second and third experiments ethylene levels showed a level of about 105 ppm - 189 ppm which the content has entered into the range of the best CO2 levels (99 - 198 ppm) to deviate pineapples. Whereas in the first experiments, O2 levels showed levels of about 75 ppm - 141 ppm, which means in this experiment there was a time when CO2 levels were below the range of the best CO2 levels.

In the table above can also be seen that the more of dry ice used, the CO2 levels will increase. In all three experiments it was also shown that the time when CO2 levels increase or reach their highest point is similar to the time when the

temperature reaches its lowest point. Both of these are caused because the coolant source used in this CAS prototype is dry ice which is frozen CO2.

D. O2

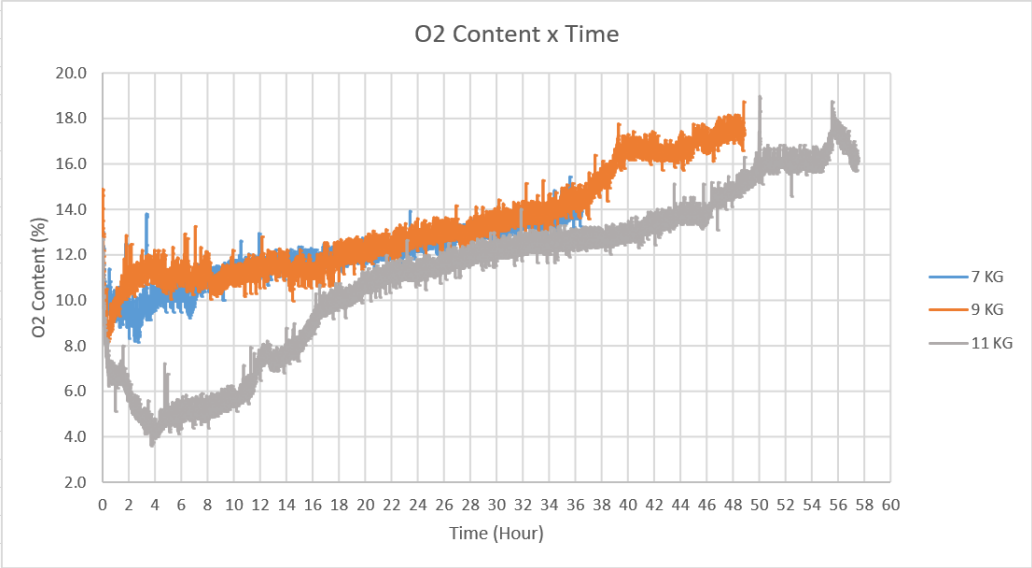


Figure 4.41 Comparison Graph of O2 Levels at the Three Pineapples Experiment Against Time *(Author, 2021)*

The graph above is a comparison graph of O2 levels in the three pineapples experiments. In this experiments, efforts were made to ensure that the O2 levels reached the best range of O2 levels for storing pineapples, and also if the O2 levels have reached the desired range, it needs to be maintained in that range. If we look at the table above, in the first and second experiments, the levels of ethylene showed levels of around 8% - 18.5%, where these levels have not entered the best O2 level range (2 - 5%) to deviate pineapple. Meanwhile, in the third experiment, the ethylene content showed levels of around 3.5% - 18%, which means that in this experiment there was a time when the O2 level was above the best range of CO2 levels.

In these three experiments, N2 gas was used as an effort to reduce O2 levels if they exceeded the desired O2 range. The amount of N2 gas used in these three experiments is the same, namely 1 m3. In the three experiments conducted, only in the third experiment the O2 levels were able to reach the desired range. From this it can be concluded that a decrease in temperature and an increase in CO2 levels affect the levels of O2, and the use of 1 m3 of N2 gas can help reduce O2 levels.

4.6.3 Analysis Display of Experiment Fruits

Before the experiment was carried out, a number of fruits had been prepared which would later be freely placed at room temperature and air conditions during the experiment. This aims to see the differences in the appearance or display between the fruit used for the experiment with the fruit that is placed freely. The following is a display of the comparison.

(a) Display of bananas using CAS

(b) Display of bananas without using CAS

(a) Display of pineapples using CAS

(b) Display of pineapples without using CAS

Figure 4.42 Comparison Display of Fruits that using and without using CAS
(Author, 2021)

It can be seen at the figure above, the display of bananas and pineapples that place freely in room temperature and air conditions first entered the ripening stage compared to the fruit placed on the CAS prototype with the temperature and air conditions being controlled. So, it can be said that storing fruits with temperature and air modifications can help slow the ripening of the fruits, thereby can extending the shelf life of the fruits.

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CHAPTER 5

CONCLUSION

5.1 Overview of the Research

In this research, several experiments have been carried out to determine the effect of temperature and air modification on the shelf life of the fruit, which is expected to be a solution to prolonging life and maintaining the quality of the fruit that delivered using sea transportation such as ships. Therefore, the experiment was carried out using a CAS prototype and carried out several experiments. Experiments were carried out using 2 variations of fruit and 3 variations in the amount of dry ice, with fruit variations namely banana and pineapple, while variations in the amount of dry ice were 7 kg, 9 kg, and 11 kg. So that the total experiment carried out in this research was 6 experiments.

5.2 Conclusion

Based on the results of experiments that have been carried out in controlled atmosphere storage protoype, the following conclusions are obtained:

1. Based on the results of 6 experiments that have been done, it can be said that the temperature can affect the ripening process of fruit. This is because the decrease in temperature can reduce the levels of ethylene produced by fruit. Can be seen in one of the results of the experiment, namely when the temperature that was originally 26.9 C dropped to 14.6 C caused ethylene levels in the fruit to drop from the original 3.99 ppm to 2.67 ppm.
2. Based on the results of 6 experiments that have been done, it can be said that O2 and CO2 levels can affect the fruit ripening process. This is because the increase in CO2 levels around the fruit will lower O2 levels, which causes inhibition of the respiration process in the fruit. Can be seen in one of the results of the experiment, namely when CO2 levels that were initially 124 ppm rose to 151 ppm caused O2 levels around the fruit to fall which initially 13.7% to 3.6%.
3. Controlling temperature conditions, O2 & CO2 levels, and ethylene levels are very helpful in extending the shelf life of fruit. It can be said that if CAS system can always maintain temperature and air conditions in accordance with the setting point, it can extend the shelf life of fruit 1-4 weeks for bananas, and 2-4 weeks for pineapples.

5.3 Recommendation

For the sake of carrying out better research in the future, the following suggestions can be used as a consideration:

1. Because in this experiment only use two types of tropical fruits, namely bananas and pineapples, it is highly recommended that in the future research can be done using other types of tropical fruits.
2. In this study, experiments were conducted using CAS prototypes that utilize dry ice as coolant. In the future, similar experiments can be carried out using CAS prototypes with other cooling sources.
3. A deep economic analysis is needed to determine the effectiveness of CAS usage for fruit storage.

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APPENDIX

1. The following is the data result on bananas first experiments:

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
1	11:53:22 AM	29.7	3.25	17.2	62
2	11:53:52 AM	29.4	3.17	16.4	62
3	11:54:22 AM	29.1	3.07	15.9	61
4	11:54:52 AM	29	3.03	16.0	64
5	11:55:22 AM	28.8	3.07	15.7	63
6	11:55:52 AM	28.6	3.07	15.2	66
7	11:56:22 AM	28.4	3.12	15.4	61
8	11:56:52 AM	28.2	3.05	14.9	62
9	11:57:22 AM	27.9	3.08	14.7	64
10	11:57:52 AM	27.7	3.03	14.8	64
11	11:58:22 AM	27.5	3.15	15.2	62
12	11:58:52 AM	27.3	3.33	15.0	63
13	11:59:22 AM	27.1	2.82	14.2	65
14	11:59:52 AM	26.9	3.02	14.4	61
15	12:00:22 PM	26.7	3.15	14.6	61
16	12:00:52 PM	26.5	3.12	15.0	62
17	12:01:22 PM	26.4	2.95	14.6	63
18	12:01:52 PM	26.2	2.82	14.2	64
19	12:02:22 PM	26.1	3.25	15.4	61
20	12:02:52 PM	25.9	3.1	14.9	60
21	12:03:22 PM	25.8	3	14.7	63
22	12:03:52 PM	25.6	3	14.6	61
23	12:04:22 PM	25.5	2.98	14.6	62
24	12:04:52 PM	25.4	3.03	14.7	60
25	12:05:22 PM	25.3	2.95	14.8	63
26	12:05:52 PM	25.1	2.89	14.3	60
27	12:06:22 PM	25	2.92	14.6	61
28	12:06:52 PM	24.9	2.87	14.3	59
29	12:07:22 PM	24.8	3.08	15.0	60
30	12:07:51 PM	24.7	3.03	15.0	59
31	12:08:21 PM	24.6	2.9	14.4	60
32	12:08:51 PM	24.5	2.94	14.8	60
33	12:09:21 PM	24.4	2.87	14.4	60
34	12:09:51 PM	24.3	2.95	14.6	60
35	12:10:21 PM	24.3	2.97	14.8	61
36	12:10:51 PM	24.2	2.95	14.5	60
37	12:11:21 PM	24.1	2.9	14.6	60
38	12:11:51 PM	24.1	3.05	15.3	59
39	12:12:21 PM	24	2.97	14.8	59

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
428	3:26:38 PM	21.1	2.97	13.1	60
429	3:27:08 PM	21.1	3.03	14.1	74
430	3:27:38 PM	21.1	2.92	12.9	64
431	3:28:08 PM	21.1	2.9	13.0	64
432	3:28:38 PM	21.1	2.84	12.6	63
433	3:29:08 PM	21.1	2.89	12.5	60
434	3:29:38 PM	21.1	3.21	14.1	79
435	3:30:08 PM	21.1	2.97	12.7	63
436	3:30:38 PM	21.1	2.92	13.5	72
437	3:31:08 PM	21.1	2.85	12.4	61
438	3:31:38 PM	21.1	3.13	13.2	62
439	3:32:08 PM	21.1	2.85	12.8	64
440	3:32:38 PM	21.1	2.9	12.6	61
441	3:33:08 PM	21	3.13	13.5	63
442	3:33:38 PM	21.1	2.89	12.7	61
443	3:34:08 PM	21.1	2.95	12.2	64
444	3:34:38 PM	21.1	3	12.7	61
445	3:35:08 PM	21.1	2.92	12.6	62
446	3:35:38 PM	21	3	12.7	63
447	3:36:08 PM	21	3.02	12.9	63
448	3:36:38 PM	21.1	2.87	12.6	61
449	3:37:08 PM	21	2.95	12.5	63
450	3:37:38 PM	21.1	2.92	12.5	62
451	3:38:08 PM	21.1	2.92	12.4	61
452	3:38:38 PM	21.1	2.95	12.9	62
453	3:39:08 PM	21.1	3.08	13.3	61
454	3:39:37 PM	21.1	3.02	12.6	62
455	3:40:07 PM	21.1	2.98	12.9	66
456	3:40:37 PM	21.1	3.13	13.6	66
457	3:41:07 PM	21.1	3.02	13.2	67
458	3:41:37 PM	21.1	3.07	13.1	66
459	3:42:07 PM	21.1	2.97	12.6	64
460	3:42:37 PM	21.1	3.23	13.7	66
461	3:43:07 PM	21.1	3.12	13.5	65
462	3:43:37 PM	21.1	3.05	12.9	67
463	3:44:07 PM	21.1	3.3	14.0	67
464	3:44:37 PM	21.1	2.98	12.7	66
465	3:45:07 PM	21.1	2.97	12.8	66
466	3:45:37 PM	21.1	3.12	13.5	67

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
4334	11:57:30 PM	26.2	3.76	14.1	85
4335	11:58:00 PM	26.2	3.9	14.9	87
4336	11:58:30 PM	26.2	3.8	14.4	84
4337	11:59:00 PM	26.2	3.76	14.2	84
4338	11:59:30 PM	26.2	3.72	14.0	84
4339	12:00:00 AM	26.2	3.76	14.2	84
4340	12:00:30 AM	26.2	3.85	14.8	86
4341	12:01:00 AM	26.2	3.85	14.6	83
4342	12:01:30 AM	26.2	3.9	15.0	83
4343	12:02:00 AM	26.2	3.92	14.6	83
4344	12:02:30 AM	26.2	3.92	14.6	82
4345	12:02:59 AM	26.2	3.79	14.4	84
4346	12:03:29 AM	26.2	3.8	14.5	85
4347	12:03:59 AM	26.2	3.8	14.4	84
4348	12:04:29 AM	26.2	3.79	14.5	86
4349	12:04:59 AM	26.2	3.74	14.1	83
4350	12:05:29 AM	26.2	3.74	14.2	83
4351	12:05:59 AM	26.2	3.77	14.1	84
4352	12:06:29 AM	26.2	3.95	14.7	84
4353	12:06:59 AM	26.2	3.85	14.6	86
4354	12:07:29 AM	26.2	3.79	14.4	84
4355	12:07:59 AM	26.2	3.8	14.2	84
4356	12:08:29 AM	26.3	3.9	14.7	85
4357	12:08:59 AM	26.2	3.84	14.3	85
4358	12:09:29 AM	26.2	3.79	14.1	83
4359	12:09:59 AM	26.3	3.87	14.8	85
4360	12:10:29 AM	26.2	3.99	14.1	85
4361	12:10:59 AM	26.3	3.85	14.4	84
4362	12:11:29 AM	26.2	3.85	14.2	82
4363	12:11:59 AM	26.2	3.8	14.4	84
4364	12:12:29 AM	26.3	3.79	14.2	86
4365	12:12:59 AM	26.2	3.74	14.1	85
4366	12:13:29 AM	26.2	3.77	14.2	84
4367	12:13:59 AM	26.2	3.8	14.3	83
4368	12:14:29 AM	26.3	3.82	14.3	85
4369	12:14:59 AM	26.2	3.82	14.1	83
4370	12:15:29 AM	26.2	4	15.3	84
4371	12:15:59 AM	26.3	3.85	14.4	84
4372	12:16:29 AM	26.3	3.82	14.6	84

2. The following is the data result on bananas second experiments:

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
1	11:38:06 AM	28.5	4.9	12.81	66
2	11:38:36 AM	28.5	4.92	13.86	78
3	11:39:06 AM	28.3	4.79	13.40	74
4	11:39:36 AM	28	4.92	12.36	71
5	11:40:06 AM	27.7	4.82	13.14	70
6	11:40:36 AM	27.5	4.66	12.62	65
7	11:41:06 AM	27.2	4.53	11.96	65
8	11:41:36 AM	26.9	4.54	12.09	63
9	11:42:06 AM	26.6	4.51	12.09	63
10	11:42:36 AM	26.3	4.31	11.38	64
11	11:43:06 AM	26	4.36	11.38	62
12	11:43:36 AM	25.7	4.26	11.31	61
13	11:44:06 AM	25.4	4.28	11.11	59
14	11:44:36 AM	25.2	4.2	11.11	59
15	11:45:06 AM	24.9	4.23	11.11	60
16	11:45:36 AM	24.7	4.15	10.79	58
17	11:46:06 AM	24.5	4.3	11.11	58
18	11:46:36 AM	24.4	4.17	10.53	58
19	11:47:06 AM	24.2	4.12	10.72	58
20	11:47:36 AM	24.1	4.1	10.26	57
21	11:48:06 AM	23.9	4.03	10.26	56
22	11:48:36 AM	23.8	4.05	10.33	56
23	11:49:06 AM	23.6	4.03	10.33	56
24	11:49:36 AM	23.6	3.99	9.94	56
25	11:50:06 AM	23.5	4	10.20	55
26	11:50:36 AM	23.4	4	10.00	57
27	11:51:06 AM	23.3	3.95	9.94	57
28	11:51:35 AM	23.2	3.87	9.81	56
29	11:52:05 AM	23.2	4.08	10.33	58
30	11:52:35 AM	23.1	3.87	9.81	56
31	11:53:05 AM	23	3.84	9.61	56
32	11:53:35 AM	22.9	4	10.13	54
33	11:54:05 AM	22.9	3.82	9.55	56
34	11:54:35 AM	22.8	3.9	9.87	55
35	11:55:05 AM	22.8	3.85	9.81	55
36	11:55:35 AM	22.7	3.84	9.48	53
37	11:56:05 AM	22.7	3.82	9.55	55
38	11:56:35 AM	22.6	3.77	9.35	53
39	11:57:05 AM	22.6	3.77	9.41	55

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
1806	2:39:37 AM	17.1	2.74	4.84	61
1807	2:40:07 AM	17.1	2.82	5.10	62
1808	2:40:37 AM	17.1	2.87	5.36	64
1809	2:41:07 AM	17.1	2.82	5.23	61
1810	2:41:36 AM	17.1	2.92	5.62	62
1811	2:42:06 AM	17.1	2.95	5.75	63
1812	2:42:36 AM	17.1	2.95	5.56	62
1813	2:43:06 AM	17	2.8	5.03	62
1814	2:43:36 AM	17	2.84	5.43	62
1815	2:44:06 AM	17	2.74	5.10	63
1816	2:44:36 AM	17.1	2.9	5.49	61
1817	2:45:06 AM	17.1	2.97	5.88	63
1818	2:45:36 AM	17.1	2.76	4.90	62
1819	2:46:06 AM	17.1	2.79	5.10	61
1820	2:46:36 AM	17	2.8	5.36	60
1821	2:47:06 AM	17.1	2.8	5.36	62
1822	2:47:36 AM	17.1	2.77	5.03	61
1823	2:48:06 AM	17.1	2.85	5.23	63
1824	2:48:36 AM	17.1	2.84	5.36	61
1825	2:49:06 AM	17.1	2.79	5.16	63
1826	2:49:36 AM	17	2.79	4.97	62
1827	2:50:06 AM	17.1	2.8	5.16	62
1828	2:50:36 AM	17.1	2.76	5.23	65
1829	2:51:06 AM	17.1	2.77	5.23	63
1830	2:51:36 AM	17.1	2.9	5.56	61
1831	2:52:06 AM	17.1	2.87	5.49	62
1832	2:52:36 AM	17.1	2.89	5.36	61
1833	2:53:06 AM	17.1	2.8	5.10	61
1834	2:53:36 AM	17.1	2.76	5.16	60
1835	2:54:06 AM	17.1	2.82	5.23	63
1836	2:54:36 AM	17.1	2.74	4.97	62
1837	2:55:06 AM	17.1	2.76	5.10	62
1838	2:55:36 AM	17.1	2.9	5.49	62
1839	2:56:06 AM	17.1	2.71	4.97	61
1840	2:56:35 AM	17.1	2.72	5.10	61
1841	2:57:05 AM	17.1	2.92	5.62	62
1842	2:57:35 AM	17.1	2.74	5.03	62
1843	2:58:05 AM	17.2	2.74	4.97	62
1844	2:58:35 AM	17.2	2.76	5.10	64

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
5820	12:04:26 PM	29.9	3.31	15.76	67
5821	12:04:56 PM	30	3.31	15.56	67
5822	12:05:26 PM	29.9	3.28	15.69	67
5823	12:05:56 PM	29.9	3.41	16.08	68
5824	12:06:26 PM	29.9	3.33	15.63	67
5825	12:06:56 PM	29.9	3.53	16.41	69
5826	12:07:26 PM	29.9	3.3	15.56	67
5827	12:07:56 PM	29.9	3.36	16.02	70
5828	12:08:26 PM	29.9	3.3	15.69	67
5829	12:08:56 PM	30	3.25	15.43	66
5830	12:09:26 PM	29.9	3.35	15.76	68
5831	12:09:56 PM	29.9	3.28	15.63	67
5832	12:10:26 PM	30	3.28	15.56	67
5833	12:10:56 PM	29.9	3.31	15.82	69
5834	12:11:26 PM	29.9	3.26	15.56	67
5835	12:11:56 PM	30	3.44	16.15	68
5836	12:12:26 PM	29.9	3.44	16.02	69
5837	12:12:56 PM	29.9	3.48	16.41	69
5838	12:13:26 PM	30	3.39	16.02	68
5839	12:13:56 PM	30	3.33	15.56	67
5840	12:14:26 PM	29.9	3.3	15.56	67
5841	12:14:56 PM	30	3.38	16.08	67
5842	12:15:26 PM	30	3.43	16.02	67
5843	12:15:56 PM	30	3.41	16.15	70
5844	12:16:26 PM	30	3.31	15.69	69
5845	12:16:56 PM	30	3.3	15.56	67
5846	12:17:25 PM	30	3.31	15.69	69
5847	12:17:55 PM	30	3.25	15.49	66
5848	12:18:25 PM	30	3.26	15.56	67
5849	12:18:55 PM	30	3.48	15.82	68
5850	12:19:25 PM	30	3.35	15.82	67
5851	12:19:55 PM	30	3.36	15.69	68
5852	12:20:25 PM	30	3.33	15.63	67
5853	12:20:55 PM	30	3.36	15.95	69
5854	12:21:25 PM	30	3.44	16.15	68
5855	12:21:55 PM	30	3.28	15.56	67
5856	12:22:25 PM	30	3.38	16.08	67
5857	12:22:55 PM	30	3.53	16.34	69
5858	12:23:26 PM	30	3.26	15.56	67

3. The following is the data result on bananas third experiments:

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
1	8:02:58 AM	26.9	3.99	13.7	124
2	8:03:28 AM	26.8	4.13	15.0	138
3	8:03:58 AM	26.6	3.94	13.7	133
4	8:04:28 AM	26.3	3.97	14.1	131
5	8:04:58 AM	26.1	3.87	13.3	130
6	8:05:28 AM	25.9	3.71	12.7	129
7	8:05:58 AM	25.5	3.97	13.3	127
8	8:06:28 AM	25.2	3.74	12.6	127
9	8:06:58 AM	24.9	3.67	12.1	137
10	8:07:28 AM	24.6	3.72	15.3	136
11	8:07:58 AM	24.4	3.62	11.8	138
12	8:08:28 AM	24.2	3.62	11.5	137
13	8:08:58 AM	23.9	3.61	11.6	137
14	8:09:28 AM	23.7	3.67	11.5	136
15	8:09:58 AM	23.5	3.71	12.0	134
16	8:10:28 AM	23.2	3.62	11.6	135
17	8:10:58 AM	23	3.51	11.2	137
18	8:11:28 AM	22.8	3.54	11.2	136
19	8:11:57 AM	22.6	3.66	11.2	135
20	8:12:27 AM	22.4	3.58	11.0	134
21	8:12:57 AM	22.2	3.49	10.5	133
22	8:13:27 AM	22.1	3.48	10.7	134
23	8:13:57 AM	21.9	3.49	10.7	134
24	8:14:27 AM	21.8	3.62	11.0	131
25	8:14:57 AM	21.6	3.48	10.7	130
26	8:15:27 AM	21.5	3.51	10.2	128
27	8:15:57 AM	21.3	3.46	10.3	129
28	8:16:27 AM	21.3	3.41	10.1	129
29	8:16:57 AM	21.2	3.51	10.3	130
30	8:17:27 AM	21.1	3.44	10.2	129
31	8:17:57 AM	21	3.53	10.1	130
32	8:18:27 AM	20.9	3.31	9.6	130
33	8:18:57 AM	20.8	3.41	10.1	133
34	8:19:27 AM	20.7	3.48	10.1	129
35	8:19:57 AM	20.7	3.51	9.9	130
36	8:20:27 AM	20.6	3.53	10.2	128
37	8:20:57 AM	20.5	3.67	10.7	130
38	8:21:27 AM	20.5	3.66	10.0	128
39	8:21:57 AM	20.4	3.54	10.3	128

4. The following is the data result on pineapples first experiments:

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
1	9:53:10 AM	29.1	3.13	13.0	96
2	9:53:40 AM	29	3.15	12.9	103
3	9:54:10 AM	28.8	3.18	12.9	104
4	9:54:40 AM	28.6	3.07	12.4	102
5	9:55:10 AM	28.5	3.1	12.4	98
6	9:55:40 AM	28.3	3.23	12.3	100
7	9:56:10 AM	28.2	3.03	11.6	97
8	9:56:40 AM	28	3.25	11.4	109
9	9:57:10 AM	27.8	3.17	11.4	103
10	9:57:40 AM	27.7	3.02	11.4	90
11	9:58:10 AM	27.5	3.3	11.1	100
12	9:58:40 AM	27.4	3.13	11.0	97
13	9:59:10 AM	27.2	2.97	10.6	93
14	9:59:40 AM	27	3.07	10.7	93
15	10:00:10 AM	26.9	3.12	10.5	98
16	10:00:40 AM	26.8	3.08	10.3	104
17	10:01:10 AM	26.7	3.03	10.4	98
18	10:01:40 AM	26.6	3.12	10.9	98
19	10:02:10 AM	26.5	2.97	10.1	90
20	10:02:40 AM	26.3	3.15	10.1	103
21	10:03:10 AM	26.3	3.05	10.1	99
22	10:03:40 AM	26.2	3.17	10.5	100
23	10:04:10 AM	26.1	3.07	10.1	96
24	10:04:40 AM	26	2.95	10.1	91
25	10:05:10 AM	25.9	2.89	9.8	89
26	10:05:40 AM	25.8	2.98	9.9	88
27	10:06:10 AM	25.7	2.98	9.9	90
28	10:06:40 AM	25.5	2.89	9.7	88
29	10:07:10 AM	25.5	3	9.7	88
30	10:07:40 AM	25.5	3.25	9.6	98
31	10:08:10 AM	25.5	3.17	9.7	100
32	10:08:40 AM	25.4	3.07	10.3	106
33	10:09:10 AM	25.3	3.03	9.7	99
34	10:09:40 AM	25.3	3.07	9.5	100
35	10:10:10 AM	25.2	3.07	10.0	97
36	10:10:40 AM	25.1	3.12	9.5	99
37	10:11:10 AM	25.1	3.05	9.5	106
38	10:11:40 AM	25	3.08	9.7	105
39	10:12:09 AM	25	3.03	9.5	87
40	10:12:39 AM	24.9	3.15	10.4	102
41	10:13:09 AM	24.9	3.33	9.8	94
42	10:13:39 AM	24.8	2.82	10.6	95
43	10:14:09 AM	24.8	3.02	10.0	90
44	10:14:39 AM	24.7	3.15	9.9	100
45	10:15:09 AM	24.7	3.12	9.7	101

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
1006	6:15:21 PM	22.8	3.21	11.2	96
1007	6:15:51 PM	22.8	3.25	11.4	96
1008	6:16:21 PM	22.8	3.1	10.7	96
1009	6:16:51 PM	22.8	3.18	10.9	95
1010	6:17:21 PM	22.8	3.2	11.2	97
1011	6:17:51 PM	22.8	3.25	11.4	95
1012	6:18:21 PM	22.8	3.15	10.8	95
1013	6:18:51 PM	22.8	3.26	11.4	96
1014	6:19:21 PM	22.7	3.3	11.3	96
1015	6:19:51 PM	22.7	3.21	11.2	96
1016	6:20:21 PM	22.7	3.15	10.4	97
1017	6:20:51 PM	22.7	3.08	10.7	95
1018	6:21:21 PM	22.7	3.12	10.7	96
1019	6:21:51 PM	22.7	3.15	10.9	96
1020	6:22:21 PM	22.7	3.13	10.9	96
1021	6:22:51 PM	22.7	3.12	10.8	95
1022	6:23:21 PM	22.7	3.25	11.4	95
1023	6:23:51 PM	22.7	3.26	11.4	95
1024	6:24:21 PM	22.7	3.13	10.9	96
1025	6:24:51 PM	22.7	3.08	10.9	96
1026	6:25:21 PM	22.7	3.2	11.4	95
1027	6:25:51 PM	22.7	3.07	10.7	94
1028	6:26:20 PM	22.7	3.17	11.0	96
1029	6:26:50 PM	22.6	3.2	11.0	95
1030	6:27:20 PM	22.7	3.21	11.2	95
1031	6:27:50 PM	22.7	3.2	10.9	95
1032	6:28:20 PM	22.6	3.21	11.0	96
1033	6:28:50 PM	22.7	3.21	11.3	95
1034	6:29:20 PM	22.6	3.13	10.9	95
1035	6:29:50 PM	22.7	3.2	11.0	97
1036	6:30:20 PM	22.6	3.13	10.9	94
1037	6:30:50 PM	22.7	3.2	11.0	97
1038	6:31:20 PM	22.6	3.13	10.8	96
1039	6:31:50 PM	22.6	3.15	10.8	97
1040	6:32:20 PM	22.6	3.15	10.5	97
1041	6:32:50 PM	22.7	3.3	11.5	96
1042	6:33:20 PM	22.7	3.25	10.9	95
1043	6:33:50 PM	22.6	3.31	10.9	101
1044	6:34:20 PM	22.6	3.51	11.2	116
1045	6:34:50 PM	22.7	3.39	11.0	107
1046	6:35:20 PM	22.7	3.62	11.5	103
1047	6:35:50 PM	22.6	3.59	11.4	94
1048	6:36:20 PM	22.6	3.48	11.1	88
1049	6:36:50 PM	22.6	3.31	10.7	86
1050	6:37:20 PM	22.6	3.46	11.2	87

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
4327	9:54:07 PM	26.3	3.87	14.1	132
4328	9:54:37 PM	26.3	3.79	13.7	132
4329	9:55:07 PM	26.3	3.82	13.9	132
4330	9:55:37 PM	26.3	3.87	13.9	133
4331	9:56:07 PM	26.3	3.77	13.7	133
4332	9:56:37 PM	26.3	3.76	13.7	132
4333	9:57:06 PM	26.3	3.95	14.2	132
4334	9:57:36 PM	26.3	3.8	13.8	133
4335	9:58:06 PM	26.3	3.79	13.7	132
4336	9:58:36 PM	26.3	3.9	14.1	134
4337	9:59:06 PM	26.3	3.87	14.0	132
4338	9:59:36 PM	26.3	3.9	14.1	134
4339	10:00:06 PM	26.3	3.85	13.6	134
4340	10:00:36 PM	26.3	3.82	14.0	134
4341	10:01:06 PM	26.3	3.87	13.7	134
4342	10:01:36 PM	26.3	3.79	13.9	133
4343	10:02:06 PM	26.3	3.87	14.1	134
4344	10:02:36 PM	26.3	3.76	13.6	134
4345	10:03:06 PM	26.3	3.9	14.1	134
4346	10:03:36 PM	26.3	3.77	13.6	132
4347	10:04:06 PM	26.4	3.87	14.2	134
4348	10:04:36 PM	26.4	3.84	13.9	133
4349	10:05:06 PM	26.4	3.79	13.7	133
4350	10:05:36 PM	26.4	3.87	14.0	134
4351	10:06:06 PM	26.4	3.92	14.0	134
4352	10:06:36 PM	26.4	3.9	14.1	135
4353	10:07:06 PM	26.4	3.84	13.9	135
4354	10:07:36 PM	26.4	3.82	13.7	133
4355	10:08:06 PM	26.4	3.79	13.7	133
4356	10:08:36 PM	26.4	3.84	13.9	133
4357	10:09:06 PM	26.4	3.92	14.2	134
4358	10:09:36 PM	26.4	3.92	14.1	134
4359	10:10:06 PM	26.4	3.8	13.9	134
4360	10:10:36 PM	26.4	3.9	14.1	133
4361	10:11:06 PM	26.4	3.85	14.0	133
4362	10:11:36 PM	26.4	3.79	13.8	135
4363	10:12:06 PM	26.4	3.87	14.1	134
4364	10:12:35 PM	26.4	3.82	13.3	134
4365	10:13:05 PM	26.4	3.79	13.8	133
4366	10:13:35 PM	26.4	3.92	14.2	134
4367	10:14:05 PM	26.4	4	14.3	135
4368	10:14:35 PM	26.4	3.84	13.7	133
4369	10:15:05 PM	26.4	3.84	13.9	134
4370	10:15:35 PM	26.5	3.94	14.2	134
4371	10:16:05 PM	26.4	3.89	13.9	135

5. The following is the data result on pineapples first experiments:

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
1	8:14:30 AM	28.1	3.26	14.0	119
2	8:15:00 AM	28	3.49	14.9	139
3	8:15:30 AM	27.9	3.53	14.6	139
4	8:16:00 AM	27.6	3.49	13.5	139
5	8:16:30 AM	27.3	3.58	13.2	139
6	8:17:00 AM	27	3.64	12.9	145
7	8:17:30 AM	26.7	3.67	12.8	145
8	8:18:00 AM	26.5	3.66	12.2	143
9	8:18:30 AM	26.2	3.64	11.9	143
10	8:19:00 AM	26	3.66	11.7	142
11	8:19:30 AM	25.8	3.62	11.3	139
12	8:19:59 AM	25.7	3.54	10.8	139
13	8:20:29 AM	25.5	3.49	10.7	137
14	8:20:59 AM	25.3	3.49	10.3	135
15	8:21:29 AM	25.2	3.48	10.1	136
16	8:21:59 AM	25	3.41	9.7	131
17	8:22:29 AM	24.9	3.61	10.3	131
18	8:22:59 AM	24.8	3.48	10.4	131
19	8:23:29 AM	24.6	3.58	10.0	129
20	8:23:59 AM	24.5	3.46	9.5	129
21	8:24:29 AM	24.3	3.21	8.9	128
22	8:24:59 AM	24.2	3.44	9.3	127
23	8:25:29 AM	24.2	3.44	9.3	130
24	8:25:59 AM	24.1	3.36	9.5	130
25	8:26:29 AM	24	3.36	8.8	129
26	8:26:59 AM	24	3.33	8.7	126
27	8:27:29 AM	23.9	3.3	8.5	126
28	8:27:59 AM	23.8	3.56	9.3	127
29	8:28:29 AM	23.8	3.3	8.5	127
30	8:28:59 AM	23.7	3.48	8.9	129
31	8:29:29 AM	23.6	3.53	9.4	122
32	8:29:59 AM	23.5	3.28	8.4	125
33	8:30:29 AM	23.5	3.49	9.0	127
34	8:30:59 AM	23.4	3.36	8.7	128
35	8:31:29 AM	23.3	3.49	9.1	127
36	8:31:59 AM	23.2	3.36	8.7	126
37	8:32:29 AM	23.2	3.53	10.5	137
38	8:32:59 AM	23.2	3.31	8.5	124
39	8:33:29 AM	23.1	3.31	8.3	122
40	8:33:59 AM	23.1	3.33	8.5	125
41	8:34:29 AM	23.1	3.25	8.5	123
42	8:34:58 AM	23.1	3.35	8.7	134
43	8:35:28 AM	23.1	3.35	8.7	131
44	8:35:58 AM	23	3.48	8.9	132
45	8:36:28 AM	23	3.33	8.4	128

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
978	4:22:28 PM	20	3.31	11.0	125
979	4:22:58 PM	20	3.41	11.1	125
980	4:23:28 PM	19.9	3.41	11.0	125
981	4:23:58 PM	19.9	3.3	10.7	127
982	4:24:28 PM	19.9	3.3	10.7	125
983	4:24:58 PM	19.9	3.58	11.7	127
984	4:25:28 PM	19.9	3.31	10.8	126
985	4:25:58 PM	19.9	3.41	11.2	128
986	4:26:28 PM	19.9	3.46	11.2	127
987	4:26:58 PM	19.8	3.44	11.2	126
988	4:27:28 PM	19.8	3.36	10.0	127
989	4:27:58 PM	19.8	3.49	11.2	124
990	4:28:28 PM	19.7	3.31	10.8	124
991	4:28:58 PM	19.8	3.33	10.8	126
992	4:29:28 PM	19.7	3.23	10.5	123
993	4:29:58 PM	19.7	3.38	11.1	125
994	4:30:28 PM	19.7	3.28	10.6	122
995	4:30:58 PM	19.7	3.25	10.6	124
996	4:31:28 PM	19.7	3.2	10.4	121
997	4:31:58 PM	19.7	3.3	10.4	121
998	4:32:27 PM	19.7	3.38	11.0	121
999	4:32:57 PM	19.6	3.33	10.8	122
1000	4:33:27 PM	19.6	3.23	10.4	120
1001	4:33:57 PM	19.6	3.25	10.4	119
1002	4:34:27 PM	19.6	3.26	10.6	120
1003	4:34:57 PM	19.6	3.38	10.9	124
1004	4:35:27 PM	19.6	3.15	10.3	122
1005	4:35:57 PM	19.6	3.33	10.8	122
1006	4:36:27 PM	19.6	3.26	10.4	120
1007	4:36:57 PM	19.6	3.23	10.3	119
1008	4:37:27 PM	19.6	3.21	10.4	122
1009	4:37:57 PM	19.6	3.31	10.7	121
1010	4:38:27 PM	19.6	3.15	10.3	123
1011	4:38:57 PM	19.6	3.36	10.8	120
1012	4:39:27 PM	19.6	3.39	11.0	122
1013	4:39:57 PM	19.6	3.38	10.8	121
1014	4:40:27 PM	19.6	3.3	10.4	120
1015	4:40:57 PM	19.6	3.31	10.8	122
1016	4:41:27 PM	19.6	3.28	10.5	122
1017	4:41:57 PM	19.6	3.43	11.0	122
1018	4:42:27 PM	19.6	3.3	10.6	121
1019	4:42:57 PM	19.6	3.33	10.8	121
1020	4:43:27 PM	19.6	3.39	10.8	122
1021	4:43:57 PM	19.6	3.2	10.2	121
1022	4:44:27 PM	19.6	3.39	11.0	122

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
5814	8:38:43 AM	28.8	3.9	17.3	157
5815	8:39:13 AM	28.8	3.89	17.1	155
5816	8:39:43 AM	28.8	3.89	17.2	155
5817	8:40:13 AM	28.8	3.94	16.9	158
5818	8:40:43 AM	28.8	3.97	17.4	157
5819	8:41:13 AM	28.8	3.94	17.6	157
5820	8:41:43 AM	28.8	3.84	17.1	155
5821	8:42:13 AM	28.8	4.07	18.0	157
5822	8:42:43 AM	28.8	3.89	17.2	157
5823	8:43:13 AM	28.8	3.9	17.2	157
5824	8:43:43 AM	28.8	3.92	17.6	158
5825	8:44:13 AM	28.8	3.89	17.2	158
5826	8:44:43 AM	28.8	3.84	17.3	156
5827	8:45:13 AM	28.8	3.9	17.5	156
5828	8:45:43 AM	28.8	3.84	17.2	156
5829	8:46:13 AM	28.8	3.9	17.2	156
5830	8:46:43 AM	28.8	3.84	17.0	155
5831	8:47:13 AM	28.8	3.89	17.2	155
5832	8:47:43 AM	28.8	3.9	17.4	157
5833	8:48:13 AM	28.8	3.69	16.8	158
5834	8:48:43 AM	28.8	4	17.6	154
5835	8:49:13 AM	28.8	3.87	17.2	158
5836	8:49:43 AM	28.8	3.84	17.0	157
5837	8:50:13 AM	28.8	3.85	17.0	155
5838	8:50:43 AM	28.8	3.87	17.2	156
5839	8:51:13 AM	28.8	4.08	17.8	155
5840	8:51:43 AM	28.8	3.9	17.3	157
5841	8:52:13 AM	28.8	3.85	17.1	155
5842	8:52:43 AM	28.8	3.89	17.2	156
5843	8:53:13 AM	28.8	4.12	17.9	156
5844	8:53:43 AM	28.8	3.97	17.4	155
5845	8:54:13 AM	28.8	4.03	17.6	155
5846	8:54:43 AM	28.8	3.97	17.7	156
5847	8:55:13 AM	28.8	3.89	17.3	155
5848	8:55:42 AM	28.8	3.92	17.6	156
5849	8:56:12 AM	28.8	3.94	16.6	156
5850	8:56:42 AM	28.8	4	17.6	155
5851	8:57:12 AM	28.8	3.99	17.8	158
5852	8:57:42 AM	28.8	3.9	17.4	155
5853	8:58:12 AM	28.8	3.76	17.2	157
5854	8:58:42 AM	28.8	3.99	17.6	156
5855	8:59:12 AM	28.8	3.9	17.4	155
5856	8:59:42 AM	28.8	3.92	17.5	155
5857	9:00:12 AM	28.8	3.9	17.3	157
5858	9:00:42 AM	28.8	3.87	18.7	159

6. The following is the data result on pineapples first experiments:

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
1	8:20:25 PM	25.5	4.02	12.7	155
2	8:20:55 PM	25.3	3.95	12.1	153
3	8:21:25 PM	25.1	3.89	11.6	151
4	8:21:55 PM	24.9	3.97	12.1	152
5	8:22:25 PM	24.8	3.82	11.7	153
6	8:22:55 PM	24.6	3.8	10.9	147
7	8:23:25 PM	24.5	3.79	10.6	147
8	8:23:55 PM	24.3	3.69	10.2	144
9	8:24:25 PM	24.2	3.76	10.2	140
10	8:24:55 PM	24	3.69	9.9	141
11	8:25:25 PM	23.8	3.72	9.8	140
12	8:25:55 PM	23.7	3.67	9.6	138
13	8:26:24 PM	23.6	3.74	9.8	136
14	8:26:54 PM	23.4	3.74	9.6	138
15	8:27:24 PM	23.3	3.59	9.0	136
16	8:27:54 PM	23.1	3.62	9.2	136
17	8:28:24 PM	23	3.66	9.1	136
18	8:28:54 PM	22.9	3.66	9.2	135
19	8:29:24 PM	22.8	3.59	8.8	133
20	8:29:54 PM	22.7	3.61	8.7	133
21	8:30:24 PM	22.6	3.59	8.7	135
22	8:30:54 PM	22.6	3.56	8.3	132
23	8:31:24 PM	22.5	3.54	8.2	130
24	8:31:54 PM	22.5	3.62	8.7	133
25	8:32:24 PM	22.4	3.56	8.1	131
26	8:32:54 PM	22.4	3.54	8.1	132
27	8:33:24 PM	22.3	3.58	8.3	129
28	8:33:54 PM	22.3	3.56	8.1	129
29	8:34:24 PM	22.2	3.64	8.3	129
30	8:34:54 PM	22.2	3.74	8.2	130
31	8:35:24 PM	22.2	3.49	7.7	129
32	8:35:54 PM	22.1	3.49	7.7	129
33	8:36:24 PM	22.1	3.64	7.5	131
34	8:36:54 PM	22.1	3.54	7.8	129
35	8:37:24 PM	22	3.53	7.5	128
36	8:37:54 PM	22	3.51	7.6	129
37	8:38:24 PM	22	3.56	7.7	128
38	8:38:54 PM	22	3.58	7.8	127
39	8:39:24 PM	22	3.58	7.6	125
40	8:39:54 PM	22	3.43	7.2	124
41	8:40:24 PM	21.9	3.48	7.4	126
42	8:40:54 PM	21.9	3.46	7.1	124
43	8:41:24 PM	21.9	3.41	7.0	123
44	8:41:53 PM	21.9	3.44	7.1	122
45	8:42:23 PM	21.8	3.42	7.2	125

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
867	3:33:07 AM	18.3	3.31	4.9	108
868	3:33:36 AM	18.3	3.43	5.3	107
869	3:34:06 AM	18.3	3.38	5.0	108
870	3:34:36 AM	18.2	3.3	4.8	107
871	3:35:06 AM	18.2	3.54	5.6	107
872	3:35:36 AM	18.2	3.39	5.1	107
873	3:36:06 AM	18.2	3.48	5.3	106
874	3:36:36 AM	18.2	3.36	5.1	108
875	3:37:06 AM	18.1	3.49	5.4	107
876	3:37:36 AM	18.1	3.36	5.0	107
877	3:38:06 AM	18.1	3.49	5.6	107
878	3:38:36 AM	18.1	3.36	5.1	107
879	3:39:06 AM	18	3.35	4.9	107
880	3:39:36 AM	18	3.35	4.8	107
881	3:40:06 AM	18	3.33	4.9	110
882	3:40:36 AM	18	3.49	5.5	105
883	3:41:06 AM	18	3.35	5.3	108
884	3:41:36 AM	18	3.39	5.2	108
885	3:42:06 AM	18	3.43	5.1	107
886	3:42:36 AM	18	3.31	4.8	106
887	3:43:06 AM	18	3.48	5.3	107
888	3:43:36 AM	18	3.46	4.9	109
889	3:44:06 AM	17.9	3.43	5.2	107
890	3:44:36 AM	17.9	3.33	4.9	107
891	3:45:06 AM	17.9	3.41	5.4	106
892	3:45:36 AM	17.9	3.39	5.2	107
893	3:46:06 AM	17.9	3.49	5.4	106
894	3:46:36 AM	17.9	3.38	5.0	106
895	3:47:06 AM	17.9	3.39	5.1	108
896	3:47:36 AM	17.9	3.46	5.4	107
897	3:48:06 AM	17.9	3.56	5.8	107
898	3:48:36 AM	17.9	3.41	4.9	106
899	3:49:06 AM	17.9	3.46	5.3	106
900	3:49:36 AM	17.9	3.2	4.5	108
901	3:50:06 AM	17.9	3.36	5.2	108
902	3:50:36 AM	17.9	3.3	5.0	107
903	3:51:06 AM	17.9	3.3	4.8	105
904	3:51:36 AM	17.9	3.36	5.0	107
905	3:52:06 AM	17.9	3.38	5.1	108
906	3:52:36 AM	17.9	3.35	4.8	106
907	3:53:06 AM	17.9	3.3	4.9	106
908	3:53:36 AM	17.9	3.38	5.4	107
909	3:54:06 AM	17.9	3.39	5.1	107
910	3:54:36 AM	17.9	3.44	5.9	107
911	3:55:06 AM	17.9	3.41	5.0	107

No. Data	Time	Temperature (°C)	Etylene (ppm)	O2 (%)	CO2 (ppm)
6856	5:25:42 AM	28.3	3.72	21.1	131
6857	5:26:11 AM	28.2	3.54	20.9	133
6858	5:26:41 AM	28.3	3.62	21.1	131
6859	5:27:11 AM	28.2	3.56	20.7	131
6860	5:27:41 AM	28.3	3.62	21.1	132
6861	5:28:11 AM	28.3	3.62	21.0	131
6862	5:28:41 AM	28.3	3.69	21.3	131
6863	5:29:11 AM	28.3	3.72	21.5	131
6864	5:29:41 AM	28.3	3.8	22.0	132
6865	5:30:11 AM	28.3	3.66	21.2	130
6866	5:30:41 AM	28.3	3.59	21.0	131
6867	5:31:11 AM	28.3	3.66	21.2	131
6868	5:31:41 AM	28.3	3.72	21.5	131
6869	5:32:11 AM	28.3	3.59	21.1	131
6870	5:32:41 AM	28.3	3.56	20.9	130
6871	5:33:11 AM	28.3	3.69	21.5	130
6872	5:33:41 AM	28.3	3.72	21.6	131
6873	5:34:11 AM	28.3	3.79	21.9	131
6874	5:34:41 AM	28.3	3.72	21.4	131
6875	5:35:11 AM	28.3	3.64	21.3	132
6876	5:35:41 AM	28.3	3.58	21.1	130
6877	5:36:11 AM	28.2	3.76	21.7	130
6878	5:36:41 AM	28.3	3.69	20.7	132
6879	5:37:11 AM	28.3	3.67	21.5	131
6880	5:37:41 AM	28.3	3.69	21.4	130
6881	5:38:11 AM	28.3	3.61	21.1	129
6882	5:38:41 AM	28.3	3.64	21.2	130
6883	5:39:11 AM	28.3	3.59	21.3	132
6884	5:39:41 AM	28.3	3.69	21.5	132
6885	5:40:11 AM	28.3	3.62	21.3	130
6886	5:40:41 AM	28.3	3.58	21.1	130
6887	5:41:11 AM	28.3	3.62	21.1	130
6888	5:41:41 AM	28.3	3.69	20.7	131
6889	5:42:11 AM	28.3	3.58	21.1	131
6890	5:42:41 AM	28.3	3.71	21.3	131
6891	5:43:11 AM	28.3	3.62	21.3	130
6892	5:43:41 AM	28.3	3.49	21.0	133
6893	5:44:11 AM	28.3	3.62	21.3	130
6894	5:44:41 AM	28.3	3.64	21.5	130
6895	5:45:11 AM	28.3	3.71	21.6	130
6896	5:45:41 AM	28.3	3.66	21.3	129
6897	5:46:11 AM	28.3	3.64	21.3	131
6898	5:46:41 AM	28.3	3.56	21.1	130
6899	5:47:11 AM	28.3	3.58	21.1	130