THE EFFECT OF HYDRO COOLING TIME, STORAGE TEMPERATURE AND STORAGE DURATION ON SABA BANANA

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DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF BACHELOR OF AGRICULTURAL SCIENCE WITH HONOURS

PERPUSTAKAAN
UNIVERSITI MALAYSIA SABAH

HORTICULTURE AND LANDSCAPING PROGRAMME
FACULTY OF SUSTAINABLE AGRICULTURE
UNIVERSITY MALAYSIA SABAH
2016

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JUDUL: EFFECT OF HYDRO COOLING TIME, STORAGE TEMPERATURE AND STORAGE DURATION ON SABA BANANA.

IJAZAH: DEGREE OF BACHELOR OF AGRICULTURAL SCIENCE WITH HONOURS (HORTICULTURE AND LANDSCAPING)

SAYA: JAGATHISWARRI SUPRAMANIAM **SESI PENGAJIAN:** 2012 – 2016

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ACKNOWLEDGEMENTS

First of all, I am very grateful to God Almighty for His grace and blessings for me to complete this thesis. I would like to take this opportunity to thank my supervisor Dr. Jupikely James Silip and my co-supervisor Madam Salumiah for guiding me throughout the journey of completing this thesis despite their tight schedules.

Besides that, I would like to thank my parents, Mr. Supramaniam Appalasamy and Mrs. Ramalammah Ramanaidu who have been my strength all the time for me to be success in my studies. I also would like to thank my sisters and my aunt for supporting and be there for me all the time.

Furthermore, I would like to thank my friends and lecturers who have been very helpful throughout completing this thesis.

Last but not least, I would like to dedicate this thesis for my family members especially to my parents.

Thank you.

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ABSTRACT

This study was conducted in Postharvest Lab of Faculty Sustainable Agriculture. The objective of this study was to determine the effect of hydro cooling time, storage temperature and storage duration on Saba banana. The hypothesis that has been tested in this experiment was there is significant difference in the effect of hydro cooling time (CT), storage temperature (ST) and storage duration (SD) on Saba banana. The treatments used in this experiment were different hydro cooling times (0, ½, 7/8); then Saba banana was stored at cold temperature (13±2°C), room temperature (26±2°C) and outside temperature (30±2°C) after hydro cooling for 3 weeks duration. The parameters that have been recorded in this study were weight loss, pulp firmness, skin colour, visual appearance, pH, total soluble solid and titratable acidity. The experimental design that was used for this study was Completely Randomised Design (CRD) with a factorial arrangement of treatments (3CT x 3ST x 4 SD), with three replications and two fruits per treatment per replication. The results were analysed using SAS Version 9.1. Analysis of variance (ANOVA) was used to get the variance among the treatments, storage temperatures and storage duration. LSD was performed to determine difference on the mean values. The results indicate that the cooling time has significantly affected the weight loss, pulp firmness, skin colour L*, skin colour C*, pH, total soluble solid and titratable acidity but it did not affect significantly on skin colour h° and visual appearance. Meanwhile the storage temperature affects significantly all the parameter except skin colour h° and all the parameters have significantly affected at all storage durations. Treatment combinations of cooling time and storage temperature were found to have significant interaction effects on visual appearance and titratable acidity only. The treatment combinations between cooling time and storage duration were found to have significant effect on weight loss, total soluble solid and titratable acidity. The treatment combination between storage temperature and storage duration were found to have significant effects on all the postharvest qualities except for the pH. The treatment combinations between cooling time, storage temperature and storage duration were found to have significant effect on skin colour L*, skin colour C*, visual appearance and titratable acidity. In conclusion, there is no any precooling time that can be suggested for the farmers to be used in their farm because precooling increases the weight loss and reduces visual appearance.

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KESAN MASA PENYEJUKAN AIR SEJUK, SUHU DAN TEMPOH PENYIMPANAN TERHADAP PISANG SABA

ABSTRAK

*Kajian ini telah dijalankan di Makmal Lepas Tuai di Fakulti Pertanian Lestari. Objektif kajian ini adalah untuk menentukan kesan masa penyejukan air, suhu dan tempoh penyimpanan terhadap pisang Saba. Hipotesis yang telah diuji dalam eksperimen ini ialah terdapat perbezaan yang signifikan dalam kesan masa penyejukan air (CT), suhu penyimpanan (ST) dan tempoh penyimpanan (SD) pisang Saba. Rawatan yang digunakan dalam eksperimen ini adalah masa penyejukkan menggunakan air sejuk yang berbeza (0, ½, 7/8), kemudian pisang Saba disimpan pada suhu sejuk (13±2°C), suhu bilik (26±2°C) dan suhu di luar (30±2°C) selepas penyejukan air sejuk untuk tempoh 3 minggu. Parameter yang telah direkodkan dalam kajian ini adalah kehilangan berat buah, kekerasan isi buah, warna kulit, rupa visual, pH, jumlah pepejal larut dan keasidan tertitrat (TA). Reka bentuk eksperiment yang digunakan untuk kajian ini adalah reka bentuk rawak lengkap dengan susunan faktorial rawatan (3CT x 3 ST x 4 SD), dengan tiga replikasi dan dua buah digunakan untuk setiap replikasi. Keputusan yang diperolehi telah dianalisa menggunakan perisian SAS versi 9.1. Semua data yang diperolehi dari eksperimen telah tertakluk kepada analisis varians (ANAVA) antara masa penyejukan air (CT), suhu penyimpanan (ST) dan tempoh penyimpanan (SD). Untuk yang terdapat interaksi yang signifikasi, ujian LSD telah digunakan untuk mengesan perbezaan antara rawatan. Keputusan menunjukkan bahawa masa penyejukan mempunyai kesan signifikan terhadap kehilangan berat buah, kekerasan isi, warna kulit L *, warna kulit C *, pH, jumlah pepejal larut dan asid tertitrat. Masa penyejukkan tidak memberi kesan ketara pada warna kulit h° dan rupa visual. Manakala suhu penyimpanan memberi kesan signifikan terhadap semua parameter kecuali warna kulit h° dan tempoh penyimpanan mempunyai kesan signifikan terhadap semua paramater. Gabungan rawatan masa penyejukan dan suhu penyimpanan didapati mempunyai kesan interaksi yang bererti pada rupa visual dan asid tertitrat. Gabungan rawatan antara masa penyejukan dan tempoh penyimpanan didapati mempunyai kesan yang bererti ke atas penurunan berat buah, jumlah keasidan yang kukuh dan tertitrat larut. Gabungan rawatan antara suhu dan tempoh penyimpanan didapati mempunyai kesan yang besar ke atas semua kualiti lepas tuai kecuali pH. Gabungan rawatan antara masa penyejukan, suhu dan tempoh simpanan didapati mempunyai kesan yang ketara pada warna kulit L *, kulit warna C *, rupa visual dan asid tertitrat. Kesimpulannya, tiada masa prapenyejukan yang boleh dicadangkan untuk para petani untuk digunakan di ladang mereka kerana prapenyejukan meningkatkan kehilangan berat buah dan mengurangkan rupa visual buah.*

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LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

%	Percent
°Brix	Degree Brix
°C	Degree Celcius
ANOVA	Analysis of Variance
C*	Chroma
CRD	Completely Randomised Design
CT	Cooling Time
h°	Hue
kg	Kilogram
kgF	Kilogram Force
L*	Lightness
LSD	Least Significant Difference
mg	Milligram
mL	Millilitre
NaOH	Sodium Hydroxide
SD	Storage Duration
ST	Storage Temperature
TA	Titratable Acidity
TSS	Total Soluble Solid

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CHAPTER 1

INTRODUCTION

1.1 Background

Banana is a well-known tropical fruit which belongs to Musaceae family. It is ranked the fourth after rice, wheat and maize as important staple food in the world (Hossain, 2014; Diedhiou *et al.*, 2014). Banana is the commonly grown crop and usually fruit is the part which consumed the most due to their taste and nutrient rich characteristics. It is rich in carbohydrate, calcium, potassium, antioxidants and other micronutrients. Banana is an economic staple food for many countries. Banana is highly perishable fruit and it is can be easily damaged due to high water content which is a factor that contributing for it to be susceptible towards the fungal infections. However, it produces high amount of ethylene due to its climacteric physiological characteristics which cause the prompt change in physiological and chemical changes in the fruit including aroma, colour, texture, respiration rate, chemical composition and senescence. The ripening is enhanced by the presence of high amount of oxygen usage, ethylene production, chlorophyll degradation, breakdown of starch, and relocation of nutrients between the pulp and other parts (Mohapatra *et al.*, 2010).

Hydro cooling is one of the precooling techniques which can be used to reduce the temperature of the harvested commodities. Due to the harvesting stress, the field heat will be generated and cause the fruit to experience overheating. High temperature can cause the acceleration of biochemical activities and will result in fruit tissue damage and cause spoilage (Mohapatra *et al.*, 2010). The field heat can be removed fast by hydro cooling through the direct contact of the fruit with the chilled water. This process has excellent heat conduction. Reducing the internal temperature of fruit will inhibit the metabolic activity in the fruit; the ripening rate will be decreased, reducing the water loss, helps to preserve fruit quality and lengthen the shelf life of produce (Shahi *et al.*, 2012). Hydro cooling can be done by rinsing; spraying or dipping the

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banana bunches in cold water for an effective heat removal (Piriyaphansakul and Kanlayanarat, 2010).

Temperature is an important factor to be considered in order to store the commodities for longer term. This is because high temperature will increase the metabolic activity and respiration rate of the fruit and it increase the ripening process of the fruit and consequently lead to spoilage of fruits. According to Kader (2013) and Bhande *et al.* (2008) the rise in temperature of 5-10°C will increase the respiration rate two to three fold and will shorten the shelf life fruits. As for extending the shelf life of fruit it is crucial to maintaining an optimum temperature. As for banana, the optimum temperature for storage is about 13-14°C and for ripening is 20°C (Mohapatra *et al.*, 2010).

1.2 Justification

Banana is highly perishable fruit which degrades rapidly with the presence of ethylene and higher temperature. Thus, good postharvest handling practices required in order to maintain the qualities of banana to extend the shelf life. The main factor to be managed in order to extend the shelf life of fruit is the fruit temperature. Fruit temperature is the one of the core reason for the fruit degradation. Thus, precooling has to be done once harvested to reduce the internal temperature of the fruit and store the fruit at the desirable storage temperature in order to maintain its quality and extends the shelf life. This study is about the effect of hydro cooling time, storage temperature and storage duration on qualities and shelf life of Saba banana. By this, it may help farmers to choose a suitable precooling time and a desire storage temperature to store their banana for a longer period.

1.3 Objectives

The objective of this study is to determine the effect of hydro cooling time, storage temperature and storage duration on Saba banana.

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1.4 Hypothesis

H_0: There is no significant difference in the effect of hydro cooling time, storage temperature and storage duration on Saba banana.

H_A: There is significant difference in the effect of hydro cooling time, storage temperature and storage duration on Saba banana.

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CHAPTER 2

LITERATURE REVIEW

2.1 Origin and Botany of Banana

Banana is a major tropical fruit which is one of the oldest cultivated plants in the world. Botanically, banana is classified as berry which belongs to Musaceae family. It is believed that banana originated from Tropical Asia, it has become across the board throughout the tropical and subtropical regions.

Banana is climacteric fruit which is a seedless, a parthenocarpic berry which develops without pollination and fertilization (Armstrong, 2001). The banana plant is a large perennial herb develops a false trunk or pseudostem composed of leaf sheaths, from the centre of which there emerges the apical flower and fruit spike. The banana fruit are very well known for the richness of potassium and of their high carbohydrate content which is mainly glucose. Banana fruit is highly nutritious which contains vitamin B6 which is crucial in haem synthesis in haemoglobin and helps to fight infections (Yakub, 2015). They are being harvested all year round. The banana spike is known as bunch. A bunch consists of a series of hands. The individual fruits of banana are called fingers. Saba banana is usually in shorter size and it is highly angular and stubby. It has thick skin and it turned yellow when ripens while the pulp is in creamy white colour with fine-textured and fully developed core which occasionally has seeds.

According to Valmayor *et al.* (1990) Saba banana is well known cultivar used for commercial production in the Philippines but less in other ASEAN countries. The banana is known with its different name according to the country. In the Philippines, it is known as Saba banana, in Malaysia Pisang Nipah, in Indonesia Pisang Kepok and Kluai Hin in Thailand. Commonly, the weight of one bunch ranges from 14 to 22kg which has 10-16 hands with 16-20 fingers in each hand. The fingers of Saba

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banana are stout, short and angular with a thick skin which turns to yellow when it is ripen. The average finger diameter ranges from 3.5-4.5cm and the length is about 10-15cm. The pulp of the fruit is fine textured with well-developed core and has creamy white colour. The Saba banana is usually cooked before consumption although the flesh becomes sweet upon ripening.

Most edible banana originated mainly from two species in the section of Musa, *Musa acuminata* and *Musa balbisiana*. The cultivars are either hybrids among subspecies of *Musa acuminata* or between *Musa acuminata* and *Musa balbisiana*. These hybrids can be diploid, triploid or tetraploids.

Figure 2.1 Saba banana

Source: http://www.floridahillnursery.com/banana-tree-plants-c-3/musa-saba-banana-tree-the-giant-p-456

2.2 Banana Production

2.2.1 World

Bananas and plantains (*Musa* spp.), the fourth most important food crop in the world, are a vegetative propagated crop with great economic importance in tropical and sub-tropical countries. There are 150 countries growing banana worldwide, with an overall production of 56.4 million metric tonnes with a cultivated area of 3.8 million hectares (Khatri *et al.*, 2009; Chai *et al.*, 2004; Gubbuk *et al.*, 2004). According to Gondolini

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(2014) banana is the world's most exported fresh fruit which worth more than US$ 7 billion per year. In year of 2012 to 2013, the total acreage of banana was 5007520 hectares with the production of 103632349 metric tonnes and the productivity was 20.7 metric tonnes per hectare (Yakub, 2015).

2.2.2 Malaysia

According to Hassan (2004), banana is cultivated in Malaysia as one of the important fruit crops. Banana has been ranked fourth in export revenue and second in term of production area in Malaysia. He has mentioned that the emphasis has been given to this crop under the National Agricultural Policy besides other fruits. So, the crop will remain as an important industry in Malaysia. However, the total production of banana has decreased due to the high labour cost; marketing issues and increasing threat of Fusarium wilt diseases (Chai *et al.*, 2004).

The total cultivated area of banana for the past several years is about 29 000 ha with an annual production valued about US$ 24 million at about 294 000 metric tonnes (Malik *et al.*, 2013). The cultivation practices in Malaysia comprises from large plantation for export to smallholding banana producer for local consumption which is produced by monoculture or mixed clones. The cultivation knowledge and input level varies from farm size and farm owner participation (active or not) which affects the quality and fruit yield (Siti Hawa Jamaluddin, 2000). The three main states producing bananas majorly are Johor, Pahang and Sarawak. Most of them are smallholders and growing banana as mixed crop, mono crop and do intercropping with the perennial industrial crops like oil palm and rubber (Mokhtarudin and William, 2013).

2.3 Types of Banana

Bananas are mainly divided into two types including dessert banana and cooking banana. Dessert bananas are the banana which can be consumed raw without cooking while cooking banana is the banana that need to be cooked before consumption. Dessert bananas are usually sweet, soft and flavoursome while cooking banana is mealy and starchy. In Malaysia, the example of dessert bananas are Berangan, Mas, Cavendish and Rastali and example of cooking banana are Pisang Nangka, Pisang Raja, Pisang Lang, Pisang Relong, Pisang Tanduk, Pisang Saba and Pisang Awak (Mokhtarudin and William, 2013). Saba banana or cardava can be eaten raw or cooked. Cardava can be processed into catsup (banana sauce), vinegar, wine, banana

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chips, and the microwavable Saba. Through time, cardaba has been an important element in the Filipino cuisine as it is also included in some of Filipino favourite dishes such as pochero (Pork/Beef Stew with Saba) and estofado.

2.4 Nutritional Value of Banana

In general, banana is known as one of the most nutritious fruits. It is the world's number one leading fruit due to the fact that it contains many natural nutrients such as iron, carbohydrate, protein, potassium and vitamin A and C. Banana has the health benefits that help to keep body well nourished, prevent anaemia and reduces stress.

Table 2.1 The nutritional content of 100g edible portion of banana (eaten fresh).

Nutritional	**Nutritional value(mg/100g)**
Energy (kJ)	368.00
Protein	1.10
Fat	0.20
Carbohydrate	22.00
Calcium	7.00
Phosphorus	27.00
Iron	0.90
Vitamin A	0.03
Vitamin B (Thiamine)	0.04
Vitamin C	10.00

Source: Robinson, 1996.

2.5 Precooling Technology

Precooling is cooling of freshly harvested produce for quality protection prior shipping, processing or staring. It prolongs the shelf life of the produce by decreasing the growth rate of microorganisms and the rate of physiological changes such as water loss, ethylene production, respiration and enzymatic processes (ISCI, 2015). Precooling was firstly introduced by Powel and his co-workers in US Department of Agriculture (USDA) in year 1904 (Senthilkumar *et al.*, 2015; Silip, 2014; Brosnan and Sun, 2001; Ryall and Pentzer, 1982).

There are few precooling definitions which include removal of field heat in produce after harvesting in order to reduce the metabolism rate and reduces the possibility of spoilage prior for transporting or storing (Silip, 2014; Brosnan and Sun,

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2001), fast reduction of product temperature (Silip, 2014; Brosnan and Sun, 2001) and lower the produce temperature as soon as possible after harvesting (Silip, 2014; Brosnan and Sun, 2001). Overheating of the fruit can occur due to field heat generated due to the harvest stress. It can cause the damage of the plant tissue and increasing the biochemical activities which can lead to fruit spoilage (Mohapatra *et al.*, 2010).

Rapid precooling reduces loss of moisture, suppresses the development of microorganisms that cause rot and reduces rate of respiration and enzymatic action. It prevents wilting by reducing water loss, decreases the ethylene production and reduces the impact on ethylene-sensitive produce by ethylene (ISCI, 2015). Hence, a proper precooling has to be done to the produce in order to maintain pre-harvest quality and freshness and decrease the deterioration (ASHRAE, 2010; Becker and Fricke, 2002).

Precooling operations need movement of cooling medium and better volume of refrigeration than storage room to hold produce at a consistent temperature. Precooling process require special equipment because it is totally different from refrigerated storage system (Fricke, 2006). There are few techniques to carry out precooling of produce, including hydro cooling, room cooling, vacuum cooling, forced-air cooling, cryogenic and package icing (Senthilkumar *et al.*, 2015; Silip, 2014; Mittal *et al.*, 2014; ASHRAE,2010; Silip and Hajar, 2007). These techniques use various mediums and modes in their function. Hydro cooling using cold water, room cooling and forced-air cooling uses cold air, vacuum cooling uses evaporation of water, cryogenic cooling uses liquid nitrogen and package icing has direct contact with ice (Senthilkumar *et al.*, 2015).

These strategies quickly exchange heat from the produce to a cooling medium, for example, ice, air, or water. Cooling times from a few minutes to more than 24 hours may be needed (ASHRAE, 2010). The cooling method to be used is determined by factors such as type of produce, packaging type, convenience, cost, availability of equipment, utilisation of existing equipment, and effectiveness of the technique to precool the produce (Mittal *et al.*, 2014).

Precooling necessities and techniques greatly determined by the physiology of product in relation to maturity and ambient temperature during harvesting (Silip, 2014; ASHRAE, 2010). For an example, the profoundly perishable products like cantaloupes and vine-ripened tomato must be cooled as soon as possible after harvest but the less

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perishable produce like white potatoes and sweet potatoes may require curing at high temperature. However, they still need some cooling when the ambient temperature during harvesting is high (ASHRAE, 2010).

2.5.1 Hydro Cooling

Hydro cooling is one of the precooling techniques where the product will be sprayed with or immersed in a container of chilled water (Silip, 2014; Becker and Fricke, 2002). The cold water is known to have better heat conduction because it removes the field heat from the produce quickly and efficiently compared to other precooling methods (Piriyaphansakul and Kanlayanarat, 2010).

Hydro cooling requires better refrigeration capacity compared to the requirement needed to keep a product at consistent temperature (Silip and Hajar, 2007; Becker and Fricker, 2002; Brosnan and Sun, 2001). The produce which are commonly hydro cooled include peaches, tart cherries, radishes, snow peas, celery, cantaloupes, sweet corn, snap beans and asparagus while sometimes hydro cooled produce are cucumbers, peppers, melons and early crop potatoes (Becker and Fricke, 2002). Many researchers have recommended the hydro cooling as one of the precooling technique of produces especially those which must be washed before sent to retailers (Silip, 2014). Commonly, hydro cooled produces are wet tolerable and not be spoiled by falling water and disinfectants in the water (UNIDO, 2001).

Conventional hydro cooling makes produce to undergo cooling either in container or in cartons. The conventional hydro cooler construction usually based on the size of specific models. The increase in size of models is because to provide extra space for entry and exit of transport equipment. The bigger cooling area provides better hydro cooling capacity. The hydro coolers requires large amount of water for immersing the produce. For an active cooling area, the water flow rate required is 20 gallon/minute/feet (Silip, 2014).

The efficiency of hydro cooling is reduced as the water gains the heat from surrounding. The heat sources from the surrounding include air, radiations from hot surfaces, conduction from the surroundings and solar loads. The efficiency of hydro cooling can be enhanced when it is protected from the heat resources. Besides the heat, the energy of hydro cooler can be lost when the hydro cooler operates at less

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than full capacity or occasionally and when more water is being used than required (ASHRAE, 2010).

According to ASHRAE (2010) and Fricke (2006) to increase the hydro cooler efficiency, some factors have to be considered when designing and operating the equipment. The factors to be considered are:

- Perform the hydro cooler at maximum capacity
- Protect the hydro cooler from the wind and direct sunlight by insulating all the refrigerated surfaces
- Utilize an appropriately sized water reservoir to reduce energy wastage. This is because the energy is wasted when oversized water tank is being used and hydro cooled water is disposed after using. Besides, it may be hard to maintain constant hydro cooling water temperature and flow rate with an undersized water reservoir.
- The conveyor of hydro cooler is cushioned using plastic strips on both the inlet and outlet to minimise the gain of infiltration heat.
- Consider utilizing thermal storage, in which chilled water or ice is made and stored during period of low energy demand and is therefore utilized alongside mechanical refrigeration to chill hydro cooling water periods of high energy demand. Thermal storage minimise the size of the obliged refrigeration equipment and reduces energy costs.

According to Senthilkumar *et al.* (2015) there are few types of designs of hydro cooler available. They were used in commercial operations. For each hydro cooler, the cooling rates and efficiencies are varies. Each individual techniques are differs from each other by the cooling method and how do the produce placed in the cooler.

The types of hydro cooler available include immersion type, flood or conventional type, truck hydro cooler and batch type (Senthilkumar *et al.*, 2015; Brosnan and Sun, 2003).

The immersion type cooler uses a combination of immersion and flood cooling. The hydro coolers are shallow, large and rectangular tanks that hold moving chilled water. An inclined conveyor gradually lifts the loose produces that are immersed into tank of chilled water and moves it through an overhead shower. The duration for the produce to be in water is differs with its initial condition and the required final

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