The effect of application times and temperatures of hydro-precooling on the respiration rate of cayenne pepper (*Capsicum annuum* 'bird's eye')

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Abstract. Hydro-precooling is known as one of the methods to preserve quality during the storage period of agricultural products. Punctuality of the application and temperature of precooling water has a pronounced effect on the respiration rate of agricultural products. This research was intended to study the effect of application times and temperatures of the hydro-precooling process on the respiration rate of cayenne pepper (*Capsicum annuum* 'Bird's Eye') during the storage period. Three different application times, just at harvesting, 12, and 24 hours after harvesting, and three water temperatures of 5°C, 10°C, and 15°C were studied in a completely randomized design with three replications. Chili samples were hydro-precooled by immersion method then loaded in the respirometer and stored in cold storage at the same temperature as precooling water temperatures. Oxygen and carbon dioxide changes were monitored using O₂ and CO₂ Gas Analyzer (Quantek 902D) every day for 21 days of storage period. It was found that storage time, precooling application time, water temperature, and their interaction significantly influenced the respiration rate of the samples. However, the respiratory quotient was only influenced by storage time and precooled product temperature (p<0.05). The treatment combination of precooling application just at harvesting and precooling temperature of 10°C resulted in the lowest respiration rate.

1. Introduction.
Chili (*Capsicum annuum* 'Bird's Eye') is one of agricultural product with quite high moisture content and categorized as a perishable product. Quality of this product rapidly declining especially if stored at room conditions of tropical environment as Indonesia. It is necessary for some treatments to be able to preserve the quality better before storage. It has been known that postharvest treatments are applied to delay fruit softening in order to increase storage time and shelf life, thus allowing a widespread supply of seasonal fruits to global market [1]. There are many treatments that can be used to extend and preserve the quality of agricultural products, one and the most common method is to store the products at low-temperature room. Low temperature is known to inhibit metabolic reaction inside the product's cell, obtain low respiration rate and slows down the deterioration of the product. According to Van’t Hoff law, that every 10°C temperature increases the respiration rate of agricultural products will increase two to three times faster. However, in some situations low-temperature storage room only is not enough, there are many problems appear. In such a situation, it is necessary to carry out another treatment to get the best treatment so that the product quality is maintained. One of the potential treatments that can be applied is precooling. This method is a simple treatment that has been known to have a significant impact on preserving the quality of fresh agricultural products. Basically, precooling
is a treatment that a an agricultural product is farm fresh directly refrigerating after harvest. This cooling treatment will remove the heat brought by the agricultural products from the field, as the result, it will slow down the metabolic activity of the products and it will eventually maintain better quality of the products. Usually precooling of fresh agricultural product is carried out by using cooled water or air as the medium.

Precooling by using cooled water is more effective than air and water precooling and it can also be used as the medium to clean the products. However, there still discrepancies regarding the application time of the precooling process and the final product temperature which should be applied. Products temperature and the punctuality of the application will be very important to be observed. Rapid precooling is the first operation of the cold chain to be started from the instant of harvest and considered the critical element in the modern marketing chain of fruits and vegetables [2]. While another researcher states that temperature declining (precooling) of harvested crops to reach an optimum level 1 24 hours after harvesting is the main contributing purpose of precooling methods at which the quality of crops maintained at the best point for customer satisfaction [3]. Furthermore, precooling for chili has never been done in Indonesia, the effect of precooling temperature and its application time on the respiration rate has never been reported yet. The objective of this research was to investigate the effect of precooling application time and precooled product temperature on the respiration rate of chili pepper (*Capsicum annuum* ‘Bird’s Eye’) during storage.

### 2. Material and Methods

#### 2.1 Material

In the following research, a movable precooling unit was built to facilitate in conducting the experiment. This precooling unit consisted of a box, refrigerating system, water container, a cold storage room, and a movable electric generator. Box dimension was 93x77x55cm in length, width, and thick respectively. This cooling box was divided into two compartments, one as the room for water cooling and the other for the cold storage room. The wall of this box was composed of three-layer of materials, aluminium plate for the inner wall, 5cm thick of insulator as the middle layer, and 0.5cm thick of plywood as the outer wall. A suction type refrigeration system consisted of evaporator pipes, compressor, condenser pipes, tank, and capillary pipe as the valve was also equipped. This refrigeration system was also provided with a control system to adjust the temperature inside the box as desired. This refrigeration unit was used to cold both the precooling water and the storage room of the box. An aluminium box of 45 x45 x 25cm was used to hold cooling water was positioned inside the cooling box. This part was used to hold the water which would be used as the precooling medium in the research. The precooling unit was also equipped with four roller wheels to facilitate short-distance transportation in the field, but for long-distance, it should be transported using other vehicles. To facilitate entering and removing the sample from the precooling unit, there were two doors had been made at the upper wall of the box. One door just at the upper part of cooling water container and
the others in the upper part of the cold storage room. All these doors and the upper wall of the box were also equipped with a 5cm thick insulator to minimize heat transfer from the surrounding environment.

Chili (Capsicum annual 'bird's eye') was used as the samples in the research. These chilies were directly harvested from the farmer field in Yogyakarta, Indonesia. Before used as the sample, harvested chilies were cleaned and sorted to find a good and homogeneous sample in terms of color, size, and appearances.

2.2 Methods
The procedures in the experiment were started by pouring fresh water into the water container in the precooling unit, then the generator was started to supply electric power to the refrigeration system. The box was closed tightly and after a certain period, the water would be cooled. As the water has been cooled to a predetermined desired temperature then it could be used for the process of precooling the chili samples. Selected chili samples were hydro-precooled by immersion in the cooled water container. During precooling process, temperatures of chili samples were continuously monitored using digital thermocouple Lutron BTM-4208SD with a K-type temperature sensor. After being cooled to the predetermined temperature, the samples were then wiped to remove the excess water then loaded into the respirometer and stored in cold storage at the same temperature as precooled sample temperatures. In this study, the measurement of the respiration rate used the static or closed method [4, 5]. Oxygen and carbon dioxide changes in the respirometer were monitored using O₂ and CO₂ Gas Analyzer (Quantek 902D) every day for 21 days storage period. This research was arranged in a completely randomized design, factorial 3 x 3 with three replications. The first factor was the precooling application time consisted of precooling just at harvesting or 0 hour, 12 hours, and 24 hours after harvesting. While the second factor was the temperature of the precooled product consisted of 5°C, 10°C, and 15°C. After being precooled, the samples were then stored at those same temperatures in cold storage. In the following research, it was also carried out the measurement of the chili sample which was not precooled as the comparison purpose.

2.3 Analysis
Collected data were subjected to three-way repeated measure analysis using IBM SPSS Statistics (version 25, SPSS Inc., USA) software. Sources of variation were storage time (day), the precooling treatment application time, and storage room temperature. While the mean comparisons were evaluated using Duncan's Multiple Range Test (DMRT). This analysis was applied for the data of the respiration rate and respiratory quotient.
3. Results and Discussion.

Figure 3 shows the change in oxygen concentration during storage for all evaluated samples. It can be seen that O$_2$ decreases with storage time, however, but the rate differs from one another. The similar occurrence had been observed by other researchers for different products, such as fresh-cut apple [6], cocoa beans [7], banana, guava, mango [8], and sugar palm fruit [9]. In the equal storage period, when the precooling or storage temperature increases, O$_2$ changes also increases or decreases much more rapidly. Control samples that were not precooled and stored at surround room temperature (28°C) showed a very much decrease in O$_2$ concentration during the storage period as compared to the precooled samples. Observing Figure 4 it can be see that as O$_2$ decreases, CO$_2$ concentration increases along the storage time. This was a common occurrence observed in measuring the change of O$_2$ and CO$_2$ in the static method of respirometer where the decrease of O$_2$ was followed by the increase of CO$_2$. The similar condition was observed where, as the precooling temperature increased, the production of CO$_2$ also increased, and was also obtained that the lowest increase of CO$_2$ was not for precooling at harvest time. For the same precooling temperature it shows that the lowest O$_2$ decrease or lowest CO$_2$ increasedid did not occur for precooling at harvest time, but it seemed to occur at 12 or 24 hours after harvesting especially for precooling/storage temperature of 10°C and 20°C. This may be due to the fact that during 12 hours and 24 hours after harvesting, the samples were a half one day older than chili samples at harvesting time. The older product may initiate faster respiration and its respiration rate decreased as the results of the consumption of O$_2$ and production of CO$_2$ also decreased.

![Figure 3. Oxygen concentration changes during storage at temperature (a) 5°C, (b) 10°C and (c) 15°C.](image1)

![Figure 4. Carbon dioxide concentration changes during storage at temperature 5°C, (b) 10°C and (c) 15°C.](image2)

Figure 5 shows the respiration rate expressed as the O$_2$ consumption (RO$_2$) for all the treatments. It can be seen that RO$_2$ decreases with the storage time and this in accordance with the decrease of O$_2$ concentration. In general, precooling temperature of 10°C showed the lowest respiration rate for the three precooling application times along the storage time even shorter than precooling temperature of
5°C. This effect was more clearly shown as the precooling application time increased. These findings suggest that for chili products, the slowing of the respiration rate is best found when the chilies are first cooled to 10°C followed by storing them at that temperature as well. It was reported that banana fruits pre-cooled with hydro-cooling spray at 13°C and stored in cold storage at 13°C attained the maximum shelf life [10]. While mango fruits treated with precooling at 8°C for 8 hours proved to be the most effective in view of its important several properties [11].

Statistical analysis using repeated measure ANOVA, from the test of within-subjects effects resulted that both storage time, the interaction of storage time*precooling temperature, storage time*precooling application time, and storage time precooling temperature*precooling application time were significantly affected respiration rate of the chili sample. Meanwhile, from the inter-subject test it was found that precooling temperature, precooling application time, and the interaction of these two factors also significantly affected the sample respiration (P<0.05). It has been reported that precooling is essentially the removal of heat or the temperature reduction of the perishable products as soon as possible after harvest. This process slows down the respiration rate and minimizes other deteriorating processes and thus helps maintain quality at a high level [12].

Table 1. DMRT results of the respiration rate

| Precooling Temperature | Precooling Application | RO₂ (ml/kg.h) | RO₂ (ml/kg.h) |
|------------------------|------------------------|---------------|---------------|
| 10°C                   | 0 hour after harvesting| 1.9643ᵃ       | 3.4516ᵃ       |
| 5°C                    | 24 hours after harvesting| 5.2073ᵇ       | 4.7131ᵇ       |
| 15°C                   | 12 hours after harvesting| 6.8803ᶜ       | 5.8873ᶜ       |

ᵃ) values followed with the same letter at the same column were not significant different

Figure 5. Respiration rate of RO₂ of the three precooling application times (a) at harvesting (b) 12 hours after harvesting, and (c) 24 hours after harvesting

Table 1 shows comparison of the mean using DMRT (the effect of precooling temperature and the application time of precooling on respiration rate). It was found that the 10°C precooling temperature and its application at harvest time obtained the lowest respiration rate.
Shows the value of respiratory quotient (RQ) for all treatment combinations were investigated. RQ is known as the ratio between CO$_2$ produced to O$_2$ consumed during respiration process. The values of RQ were found in the range of 0.5 to 0.9, as the comparison it was reported that broccoli stored at 13°C of room temperature obtained RQ values of 0.75 – 0.85 [13]. It was also observed that there was a trend of RQ values reduction along the storage time and gradually approaching 1. However, as mentioned above that the respiration rate decreases with increasing storage time. This suggests that during the storage time, the production of CO$_2$ from the chili sample gradually approached O$_2$ consumptions towards the normal aerobic respiration rate. This phenomenon indicated that precooling might emphasizes the respiration rate of the samples especially in the initial storage period right after precooling process causing the chili to respond with abnormal respiration rate with RQ less than one. Regarding the effect of precooled chili sample temperature or storage temperature, it was found that in general as the precooling temperature increased, the RQ value also increased for all precooling application times investigated. It was also reported that the RQ of ackee fruit arils increased with temperature, averaging 0.83, 0.98, and 0.98 at 5°C, 15°C, and 25°C, respectively [14]. This may indicate that the influence of precooling is less severe as the temperature of precooled water increases.

Statistical analysis using repeated measure ANOVA, from the inter-subject effect tests acquired that merely storage time and the interaction between storage time*precooling temperature had a significant effect on the respiratory quotient of the chili sample. Meanwhile from the inter-subject effect tests resulted that merely precooling temperature had a significant effect on the respiratory quotient of the sample (P<0.05). Further analysis of the mean comparison between treatments found that the initial precooling temperature of 5°C gained the lowest respiratory quotient and significantly different from initial precooling temperatures of 10°C and 15°C (P<0.05), whereas the two subsequent precooling temperatures had no difference.

4. Conclusion.
The general phenomenon of decreasing O$_2$ and increasing CO$_2$ during the storage were found in the measurement method of static respirometer. Statistical analysis confirmed that both storage time, storage time interaction*initial precooling temperature, storage time*precooling application time, and storage time*initial precooling temperature*precooling application time had a significant effect on the chili samples respiration rate.

Meanwhile, from the inter-subject effect test, it was found that the precooling temperature, the time of precooling application, and the interaction of these two factors also significantly affected the sample respiration rate (P<0.05). For the respiratory quotient, from the inter-subject effects test acquired that merely storage time and the interaction between storage time*precooling temperature significantly affected the results of respiration of chili samples. Meanwhile, from the inter-subject effect test, it was found that only the precooling temperature had a significant effect on sample*s respiration. It was also
observed that for chilies, the slowing of respiration rate was best found if the chilies were pre-cooled to 10°C followed by storing them at that temperature as well and the initial cooling application time was carried out right at harvest time. The effect of precooling can reduce the respiration rate of the sample, especially in the initial period of storage after the precooling process which is indicated by an abnormal respiration rate with an RQ of less than one.

5. References.
[1] Gunther CS, Marsh KB, Winz RA, Harker RF, White A and Goddard MR 2015 *J. Food Chem.* 169 5–12
[2] Elansari AM 2009 *J. Fresh Produce.* 3 49-57
[3] Rahi S, Bahrami H and Sheikdavoodi MJ 2013 *J. Life Sci Biomed.* 3 : 56-59
[4] Fonseca SC, Oliveira FAR and Brecht JK 2002 *J. Food Eng.* 52 99–119
[5] Makino Y 2013 *J. Food Sci. Technol.* 194 523–529
[6] Fagundes C, Carciofi BAM and Monteiro AR 2013 *J. Food Sci Technol Campinas.* 33 60-67
[7] Hartuti, N Bintoro, J N W Karyadi and Y Pranoto 2019 *J. Sci & Technol.* 28 509-522
[8] Rahayu D and Bintoro N 2019 Mathematical analysis and modelling of respiration rate of tropical climacteric produces during storage under various temperatures Proceeding of The 3rd International Symposium on Agricultural and Biosystem Engineering. IOP Conf. Series:Earth and Environmental Science 355-012034 Makassar Indonesia
[9] Fatharani A and N Bintoro 2019Kinetics analysis of the effect of storage room temperature andpackaging films characteristics on the rate of change of Sugar Palm Fruit (Arenga pinata) quality in A Modified Atmospheric Packaging (MAP) In : The 3rd International SymposiumonAgricultural and Biosystem Engineering. IOP Conf. Series: Earth and Environmental Science 355-012035 Makassar Indonesia
[10] Ravikumar M, Desai CS, Raghavendra HR and Pooja N 2018 *J. Chem Studi.* 6 872-878
[11] Makwana SA, Polara ND and Viradia RR. 2104. *J. Food Sci. and Tech.* 2 6-13
[12] Senthilkumar S, Vijayakumar RM and Kumar S 2015 *J. Env & Agric. Rese.* 1 24-30
[13] Tano K, Kamenan A and Arul J 2005 *J. Agronomie Africaine* 17 103-115
[14] Benkeblia N and Beaudry RM 2018 *J. Int. Food Res.* 25 119–126