Effect of Control Atmosphere Storage Model on the Quality of Chili

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Abstract. Chili (Capsicum annum L.) is perishable horticultural commodity with short shelf life. Environmental factors such as: temperature, diseases, and humidity, influence the quality of chili, hence the shelf life becomes shorter. One of the long life-saving technologies for chili freshness is by using a controlled atmosphere storage (CAS) technique. This study aimed to prolong the shelf life of chili up to two weeks by CAS method. CAS is a method of storing agricultural products where the concentrations of oxygen, carbon dioxide, nitrogen, and temperature, and the humidity of the storage space are carefully arranged. Storage typically uses low temperatures, and high RH. Storage with this controlled atmosphere has been applied to fresh fruits, vegetables, and dried commodities. For chilies with CAS, a showcase refrigerator was flowed with nitrogen gas (N2) to suppress oxygen gas concentration (O2) in storage space to close to 7%. Carbon dioxide (CO2) gas was added to a concentration of 2.5%. The conditions of oxygen and carbon dioxide gas in the showcase were maintained by continuously flowing N2 gas at a rate of 1 ml / min. The temperature and humidity of storage chambers was maintained at a temperature of 10 - 14 °C and RH in the range 90 - 95%. Observation parameters include, freshness (moisture content, texture, and color), and weight loss. CAS technology was able to maintained freshness of chili for up to 5 weeks with water content characteristics of 82 - 84%, ash content of 0.80 to 0.95%, vitamin C 237.4 - 267.16 mg / 100 g, with the texture easily broken and orange color yellowish, and weight loss reached 12.8%.

1. Introduction
National chili production continues to increase from year to year reaching 1.074.602 tons and 800.473 tons for large chili and cayenne pepper in 2014, [1]. Curly red chili also contributes reliably in increasing production. New Superior Varieties of curly chili produced by the Vegetable Research Institute Lembang have advantages, including able to adapt well to plains up to an altitude of 550 m asl. Have a harvesting age between 95–98 days after planting, the potential for production ranges from 15-21.1 tons / Ha, and has a spiciness above the average chilli [2][3]. However, this curly red chili has a short shelf life, so there is often a scarcity in the market that results in high price fluctuations when the community's needs also continue to increase [4]. Efforts to increase the fresh storage capacity of curly red chili are the main alternative to overcome various obstacles in the effort to fulfill the needs of the community which are influenced by product characteristic factors, such as color, absence of foul marks, price, minimum pesticide residues, and freshness [5].

Chili is a vegetable that is easily damaged. After being harvested, the chilli continues to undergo a process of respiration, so that to improve the life shelf the respiration process must be inhibited. Cold
storage method is one way to reduce the activity of respiration. The use of low temperatures and relatively high humidity can inhibit all biochemical reactions to a certain time limit. Storage at 2 °C in fresh chilli has been able to extend the shelf life for 4 weeks, while storage at 25 °C only lasts 2 days. Postharvest problem of chilli is also an obstacle in maintaining the quality of the attack of postharvest disease. This post-harvest disease attack has started from the fields. The most numerous and not completely overcome attacks are anthrax [6] as a result of microbial colletotrichum capsici [7], and Colletotrichum acutatum [8]. Therefore, chilli storage technology needs to be endeavored to maintain its freshness and quality.

Postharvest handling at the farmer level has not been able to answer the challenges of community needs in order to reach chilli which remains fresh in a long time span. One technology that allows for long-term storage is controlling the metabolic pattern of chilli to keep running normally and properly controlled, namely by minimizing biochemical, enzymatic and microbial degradation [9]. But the air around the product triggers the oxidative process to continue. Therefore, controlled atmospheric storage has prospects to be developed to extend the shelf life of agricultural products, especially fresh chilli. Storage by the method of controlling the atmosphere around the product, such as controlling oxygen, carbon dioxide and nitrogen, is known as controlled atmosphere storage (CAS) technology. The purpose of this study was to produce a technology for handling fresh chilli through CAS storage with a shelf life of up to 1 month, and the quality of fresh chilli was received by consumers.

2. Materials and Methods
Chili from the production centers in West Java was sorted and graded according to market demand standards (applicable SNI). The best treatment was done by preliminary research results with the capacity according to the stock market needs to guarantee its continuity. Furthermore, storage using CAS with the best oxygen and carbon dioxide concentration results in preliminary studies.

Storage with a controlled atmosphere or commonly called Controlled Atmosphere Storage (CAS) was a storage method to maintain quality and extend the shelf life of products by slowing respiration and damage reactions both chemically, biochemically and biologically. The usual procedure for controlled atmospheric storage was to reduce the concentration of oxygen (O2) by adding levels of other gases, such as nitrogen (N2) and carbon dioxide (CO2).

In trial 1 storage with a controlled atmosphere, a showcase was used as a storage place with O2-meter panels, CO2-meters, thermometers, hygrometers and humidifiers so that the conditions in the storage room could be controlled and observed, as shown in Figure 2a. Two types of chili, namely curly chili and cayenne pepper, have been tested to be stored in a showcase by placing them in plastic baskets, each containing 5 kg of fresh chili, as shown in Figure 2 (b). During storage the showcase temperature was conditioned at 10 °C, while RH ranged from 90%, with oxygen (O2) levels pressed by adding nitrogen gas (N2) to the showcase up to 7%.

The second trial of storage of CAS technology using the same method as the CAS storage 1 trial was carried out previously. Nitrogen gas (N2) was flowed into the showcase which aims to reduce the concentration of oxygen gas (O2) by adding levels of other gases, such as nitrogen (N2) and carbon dioxide (CO2).

Observations were carried out every month periodically until chili was not worth selling/ not accepted by consumers. Observation parameters included, the level of freshness (water content, texture, and color), and weight loss.

Observation of weight loss by weighing, initial weight reduced by the final weight of observation multiplied by one hundred 100% was the percentage of weight loss. Texture analysis uses texture analysis, and visually uses broken scores. Analysis of the moisture content of the oven method, the constant weight of the final weighing was deducted from the initial weight of the weighing as a percentage of water content. Analysis of vitamin C levels was done using titration method (AOAC,
2003), levels of capsaicin (dissolution of alcohol samples) and separation of capsaicin against oleoresin with 50% resolsinol [10].

3. Results and Discussion

3.1 CAS storage modification (trial 1)
In the experiment of expelling oxygen (O2) using nitrogen gas (N2) carried out on a glass jar (3 liters capacity) (Figure 1), the results showed that nitrogen gas (N2) flowed gradually will reduce oxygen (O2) in the jar. Nitrogen gas (N2) was flowed with a flow rate of 5 ml / minute, takes about 25-35 minutes to reach the condition of oxygen (O2) 5-8% in a 3-liter glass jar.

Figure 1. Storage conditions during the first 10 hours of fresh chilli storage

Addition of nitrogen gas (N2) to the showcase was carried out gradually and continuously with a flow rate of 5 ml / min. The oxygen gas (O2) level in the showcase was monitored to reach levels of around 6 - 8%, which took about 6 hours. After oxygen levels reach ≤ 8%, nitrogen gas was flowed at a flow rate of 1 ml / minute, while monitoring oxygen levels in the showcase. RH storage space was conditioned around 90-95% by using a humidifier placed at the bottom of the showcase. This humidifier will spray moisture into the storage room, so that the desired RH can be maintained. The humidity of the storage room is always monitored using RH-meters.

Figure 2. Adjustment of the showcase before entering the sample of fresh chili (a), the condition of the showcase after the sample of fresh chili is included (b)
After 22 days storage in a controlled atmosphere in the showcase, chili conditions were obtained as shown in Figure 3. The level of damage and physical condition of chili after storage are shown in Table 1.

![Figure 3. Conditions of curly chili (a) and cayenne pepper (b) after 22 days of storage](image)

The impression was still fresh as seen in curly chili and cayenne after being stored for 22 days under the conditions listed in Figure 4. This happened because of the maintenance of RH conditions which were high enough so that evaporation of water (transpiration) could be kept to a minimum and supported by a temperature of 10 °C and atmospheric conditions with gradual oxygen limitations which played a role in inhibiting the respiration rate and other physiological processes of the chili. Thus, low temperatures of 10 °C and limited oxygen and increased levels of CO2 gas can prolong the shelf life of curly and cayenne peppers as happened in tomatoes, rambutan and mango [11][12][13].

**Table 1.** The level of damage and physical condition of chili after storage for 22 days with the first CAS trial technology

| Observed parameters | Shelf 1 | Shelf 2 | Shelf 3 | Shelf 4 |
|--------------------|--------|--------|--------|--------|
| Water content      | 71.46% | 82.02% | 75.36% | 80.45% |
| Weight loss        | 15.2%  | 17.6%  | 22.4%  | 30.2%  |
| Damage level       | nd*    | nd*    | nd*    | nd*    |
| Wilt / wrinkles    | 6.4%   | 40.8%  | 32.8%  | 46%    |
| Color:             |        |        |        |        |
| L                  | 33.42  | 48.41  | 34.24  | 50.07  |
| a                  | 44.35  | 33.11  | 44.43  | 42.51  |
| b                  | 48.66  | 68.19  | 48.69  | 59.51  |
| Chroma             | 65.84  | 75.81  | 65.91  | 73.13  |
| Hue°               | 47.68  | 64.13  | 47.64  | 54.49  |
| Color**            | Red    | red    | yellowish orange | yellowish orange |
| Texture            |        |        |        |        |
| Hardness (g)       | 241.0  | 92.5   | 288.0  | 56.0   |
| Texture***         | break easily | break easily | break easily | break easily |

Note: *nd = The level of microbiological damage was not detected, **visual, ***manual by scoring

3.2 CAS storage modification (trial 2)

Re-modification was carried out based on the performance of the showcase at CAS trial 1 and post-storage chili quality. In this CAS 2 trial, modifications were made to several parts, including: placing the humidifier outside the showcase, and adding carbon dioxide (CO2) gas to the storage room. The humidifier was placed outside the showcase so that the addition of water to the humidifier was easier
and did not interfere with the ongoing storage process. Blowing water vapor into the showcase was useful for maintaining the humidity of the storage room as expected. The addition of CO2 gas aims to extend the shelf life of fresh chili. In storage that modifies the composition of the storage room air, a decrease in oxygen (O2) and an increase in carbon dioxide (CO2) resulted a decrease in the rate of respiration activity of the stored commodity. Carbon dioxide (CO2) indirectly influences synthesis ethylene. Each commodity had a different tolerance limit to the concentration of carbon dioxide (CO2). CO2 concentrations that were considered good for storage and transport were 2.5% [14]. Referring to the results of the study and adjusted to the existing CO2 sensor, the CAS trial 2 storage increases the CO2 concentration by 2.5% during storage. Chili used in CAS 2 trial was cayenne pepper harvested, sorted, weighed, then placed in plastic containers weighing 6.0 kg in each container. Then the plastic shelf containing chili was placed in the showcase in sequence. Fresh cayenne pepper was able to maintain its freshness for 35 days of storage with appearance as shown in Figure 4. The level of damage and physical condition of fresh cayenne pepper after storage are shown in Table 2.

Figure 4. Condition of chili after storage with CAS technology for 35 days Good stem (a), Good without stalk (b), and Damaged and moldy (c).

Table 2. The level of damage and physical condition of cayenne pepper after storage for 35 days with the second CAS trial technology

| Observed parameters | Cayenne pepper | Shelf 1 | Shelf 3 | Shelf 2 | Shelf 4 |
|---------------------|----------------|---------|---------|---------|---------|
| Shrink weight (%)   | 0              | 0       | 0       | 0       |
| Chili Condition:    |                |         |         |         |         |
| Good stem (%)       | 69.0           | 60.59   | 46.96   | 45.89   |
| Good stalk (%)      | 5.33           | 6.84    | 5.77    | 7.91    |
| Damaged / rotten (%)| 20.67          | 29.32   | 43.27   | 41.46   |
| Water content (%)   | 82.68          | 83.18   | 83.23   | 83.58   |
| Ash content (%)     | 0.88           | 0.86    | 0.93    | 0.90    |
| Vitamin C (mg / 100 g) | 253.62     | 267.16  | 237.44  | 252.74  |
| Antioxidant activity (%) | 56.78    | 57.51   | 58.65   | 55.43   |
| Capsaicin (ppm)     | 536.67         | 522.48  | 518.72  | 506.43  |
| Color:              |                |         |         |         |
| L                   | 54.34          | 52.69   | 50.77   | 55.77   |
| a                   | 32.61          | 33.78   | 31.65   | 32.98   |
| b                   | 65.47          | 64.67   | 66.38   | 63.74   |
| Color**             | yellowish      | yellowish| yellowish | yellowish |
| Texture:            |                |         |         |         |
| Hardness (g)        | 133.11         | 105.84  | 97.23   | 89.65   |
| Texture***          | break easily   | break easily | break easily | break easily |

Remarks: *The level of microbiological damage was not detected, **visual, ***manual by scoring

Fresh cayenne peppers were stored in a modified showcase with CAS technology for 35 days, then compared with fresh cayenne pepper packaged in perforated PE plastic @ 500 g per package stored
for 35 days. Both of these cayenne peppers were then analyzed and compared their characteristics after storage for 35 days, as shown in Table 3.

| Parameters observed       | Storage technology |
|---------------------------|--------------------|
|                           | CAS               | MAP               |
| Shrink weight (%)         | 12.8%             | 20%               |
| Water content (%)         | 83.20             | 82.18             |
| Ash content (%)           | 0.93              | 0.78              |
| Vitamin C (mg / 100 g)    | 253.62            | 237.47            |
| Antioxidant activity (%)  | 57.51             | 65.75             |
| Capsaicin (ppm)           | 522.48            | 630.87            |
| Color *:                  | yellowish orange  | yellowish orange  |
| L                         | 54.66             | 52.87             |
| a                         | 32.45             | 30.68             |
| b                         | 63.89             | 65.23             |
| Texture** : Break easily  |                   |                   |
| Hardness (g)              |                   |                   |

*Remarks : * Visual ** Manual by scoring

4. Conclusion
CAS technology was able to maintained freshness of chili for up to 5 weeks with water content characteristics of 82 - 84%, ash content of 0.80 to 0.95%, vitamin C 237.4 - 267.16 mg / 100 g, with easily broken texture and orange color yellowish, and weight loss reached 12.8%.

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