FREEZING METHOD OF STRAW MUSHROOM (*Volvariella volvaceae*) USING DRY ICE

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ABSTRACT

The purpose of this study was to assess freezing method of straw mushroom (*Volvariella volvaceae*) using dry ice, which one of refrigerant with boiling point at -78.5˚C. Freezing rate of using dry ice is faster than using freezer. Ratio of 1:2 of straw mushroom with dry ice, has freezing rate of 0.27˚C/min and freezer has 0.05˚C/min. Freezing method by dry ice influenced straw mushroom tissue after thawing. Histological of straw mushroom showed that the tissue loss of fluid, resulting shrinkage and cell attachment, and greater dehydration due to differences in humidity. From the results can be concluded that freezing method of straw mushroom using dry ice has slow freezing rate, but with the assumption that smaller ice crystals formed than using freezers, based on the time needs to exceed the critical freezing zone 0-(-3.9)˚C.

Keywords: straw mushroom*, Volvariella volvaceae*, freezing, thawing, dry ice.

INTRODUCTION

Straw mushroom *(Volvariella volvaceae*) is the most cultivated mushroom commodity in Indonesia which reaches 55-60% of national production and also a highly demanded product for its nutrient content, especially protein content. Straw mushroom is very perishable commodity with high moisture and the respiration rate (Julianti, 1997), thus affecting shelf life. On room temperature, mushroom will stay undamaged up to 24 hours. Consequently, the distribution is chosen to places which only take time less than 24 hours. In fact, the consumers prefer the fresh products compared with dried, canned, or pickle mushroom, to extend the shelf life of fresh mushroom need suitable postharvest handling. Postharvest handling of fresh mushroom that is commonly used is cooling method. The refrigerator, packing with ice cubes, and packaging with dry ice usually use and could prolong the shelf life until 4-5 days (Suharjo, 2000).

Other preservation is freezing, that has advantages to provide better quality of safety, nutritional value, sensory quality, and convenience. The freezing rate influenced freezing method that rapid freezing can produce a high quality of frozen product, which will produce small ice crystals and avoiding tissue damage caused by large ice crystals. One of the cryogen that is commonly used is carbon dioxide. Liquid carbon dioxide is used for cryogenic freezing, but requires more expensive equipment, while requiring the handling of solid carbon dioxide is much simpler. Freezing by using dry ice was proved effective for saskaton berry and strawberry, therefore it necessary to apply straw mushroom freezing by using dry ice. The purpose of this study was to determine the ratio of straw mushroom with dry ice, and comparing freezing methods by using freezers and dry ice.

MATERIALS AND METHODS

500 grams of straw mushroom in egg phase packed in perforated polyethylene plastic. Dry ice will wrapped with a paper after reduced in size. Styrofoam box was used to freezing mushroom that is not firmly closed, compiled by order of dry ice, mushroom, and dry ice. This research was conducted in two stages; the first was determination of straw mushroom with dry ice ratio. The ratio

that used was 1:1 / 2, 1:1, 1:2, and 1:3. The second step was compared the freezing process by using freezers and dry ice, which fresh mushroom used as a control. The parameters that observed were temperature of center mushroom recorded by thermo hybrid until reaches -18˚C and the time, and then we will calculate the freezing rate. Histology of straw mushroom also observed to know tissue deterioration.

RESULTS AND DISCUSSION

Ratio determination of straw mushroom and dry ice

Freezing rate was influenced by the amount of dry ice, if a lot of dry ice is used, freezing rate will be faster, but if too much will be inefficient. The temperature decrease of straw mushroom can be seen at Figure 1. From that figure, ratio 1:1/2 and 1:1 did not reach -18˚C, because lacked of dry ice. At ratio 1:1/2 the temperature was raising again because all of dry ice sublimated.

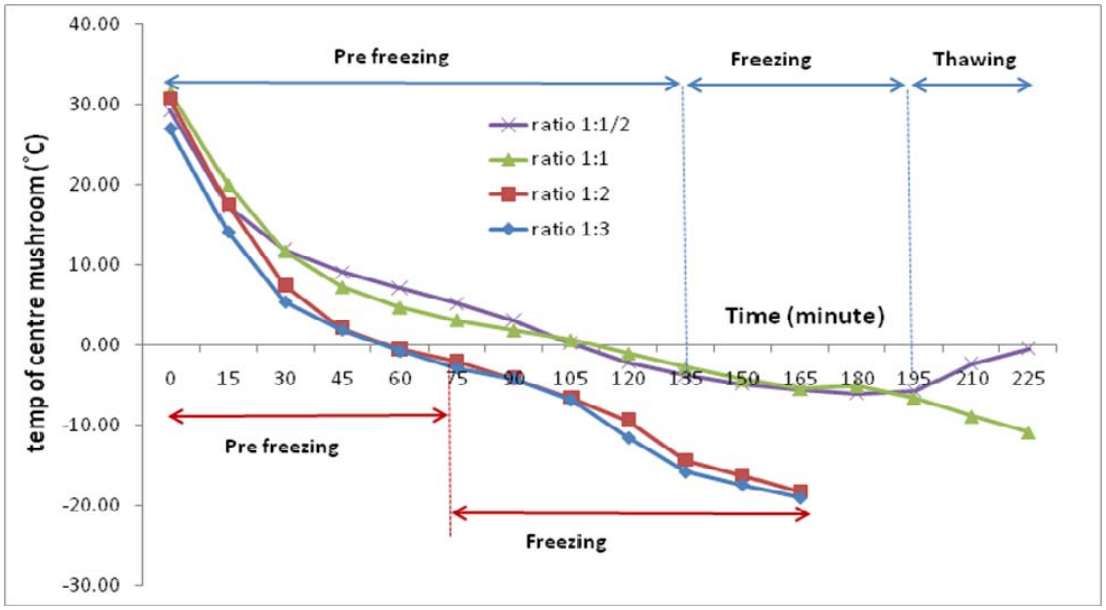


Figure 1 Temperature decrease on different ratio of straw mushroom and dry ice

Ratio 1:2 and 1:3 showed more rapid temperature decrease and reached -18˚C, because the amount of dry ice is enough to move the heat from the mushroom to reach the desired temperature. Freezing rate and consumption of dry ice used in each treatment can be seen in Table 1. Table 1 show that the ratio 1:2 has the same rate with ratio 1:3, but less consumption of dry ice. Therefore ratio 1:2 selected for the next step.

Table 1. The freezing rate and consumption of dry ice

Ratio of Straw mushroom : *Dry ice*	Temperature (ºC)	Freezing Time (minute)	Freezing Rate (ºC/minute)	dry ice consumption (grams)
1: ½	29.62	235.2	0.13	170.59
1 : 1	38.81	211.2	0.18	297.47
1 : 2	48.93	181.8	0.27	421.76
1 : 3	45.83	169.2	0.27	448.60

Comparison of freezing process by using freezer and dry ice

Freezing rate influenced product quality. A better quality of frozen product can produce by rapid freezing rate. The temperature decrease and freezing time for straw mushroom freezing by using freezer and dry ice are presented in Figure 2. The curve of temperature decrease shows that the rate of freezing on the pre freezing is almost the same for both treatments, but becomes different when through 0˚C, as shown in Table 2.

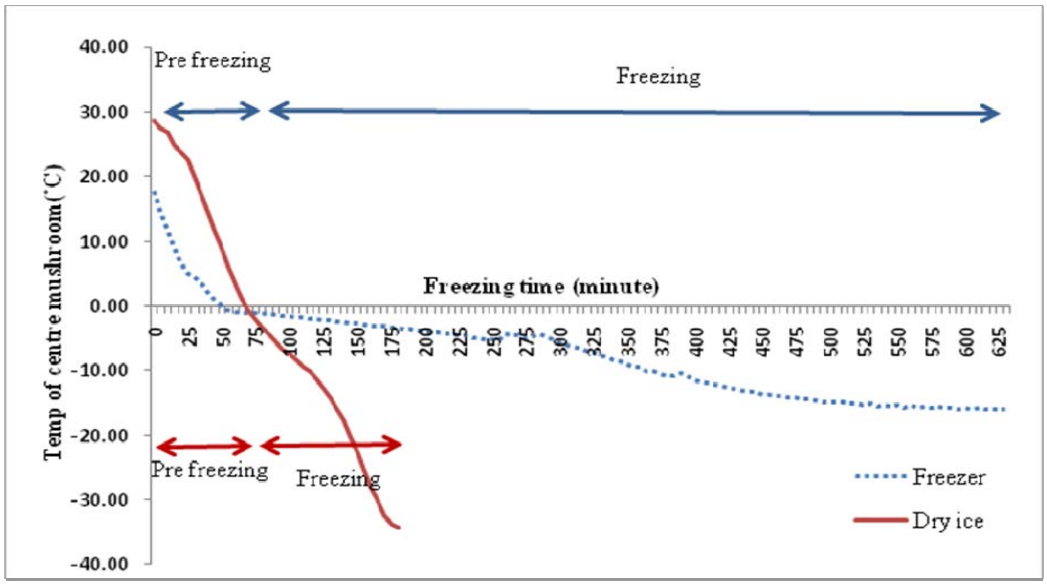


Figure 2 Temperature decrease on freezing straw mushroom by using freezer and dry ice

The freezing rate of all treatment on pre-freezing was almost the same than on freezing phase. At pre freezing, super cooling occurs on mushroom, temperature decreased rapidly until it reaches the freezing point, but the moisture content has not become ice. At freezing phase, ice crystals begin to form with the release of latent heat and the solution becomes saturated. Using dry ice could accelerate the removal of latent heat from the edible mushroom to reach the frozen state.

Table 2. Freezing rate of pre freezing and freezing for freezing by using freezer and dry ice

Treatments	Pre freezing			Freezing		
	Temp (˚C)	Time (minute)	Rate (˚C/minute)	Temp (˚C)	Time (minute)	Rate (˚C/minute)
Freezer	17,95	50	0,36	15,96	580	0,028
Dry ice	29,39	70	0,42	19,46	75	0,26

The total freezing rate of both treatments can be seen in Table 3, where the time required at this stage is determined by the rate of removal of the freezing heat, until the temperature reaches the freezing temperature of ice.

Table 3. Freezing rate by using freezer and dry ice

Treatments	Temp (˚C)	Time (minute)	Rate (˚C/minute)
Freezer	33.91	10.5	0.05
Dry ice	48.85	3.0	0.27

Alvarest (1997) states that rate of 0.5˚C/min classified as a slow freezing, and 2˚C/min classified as quick freezing. Based on the results in Table 3, it can be stated that the freezing of

straw mushroom by using freezer and dry ice classified as a slow freezing. According to Evan (2008), freezing has critical zone at temperature range 0 to -3.9˚C, which influenced the size of ice crystals produced at freezing process. When the time required to exceed the critical zone is less than 30 minutes, small ice crystals will be formed. Time required for each treatment to exceed the critical zones is presented in Table 4.

Table 4. Time required exceeding the critical zones

Treatments	Time (minute)
Freezer	155
Dry ice	20

Based on the result, there is an assumption that freezing by using dry ice can produce small ice crystals based on time it takes through the critical zone. This condition is expected to reduce the occurrence of a reduction in quality of straw mushroom.

Straw mushrooms histology

Histological was useful to study the effect of freezing and thawing treatment visually mushroom tissue after thawing. The most important thing in the observation using microscopy techniques is sample preparation; it will illustrate the influence of actual freezing. Mushroom tissues after thawing have changes as shown in Figure 5. Histological results showed that the mushroom tissues after thawing have expansion the empty space between the cells, so that the cell nuclei become closer together and there was diminution of size, whereas fresh mushroom tissues full of fluid and no space between them. This can be caused by loss of fluids in intercellular or intracellular. Loss of intercellular fluids caused tissues shrinkage and large empty intercellular spaces. Based on Chassagne, et al (2009) research, freezing treatment and thawing, can eliminate tonoplas layer that surrounds the vacuole resulting in damage to cell membranes.

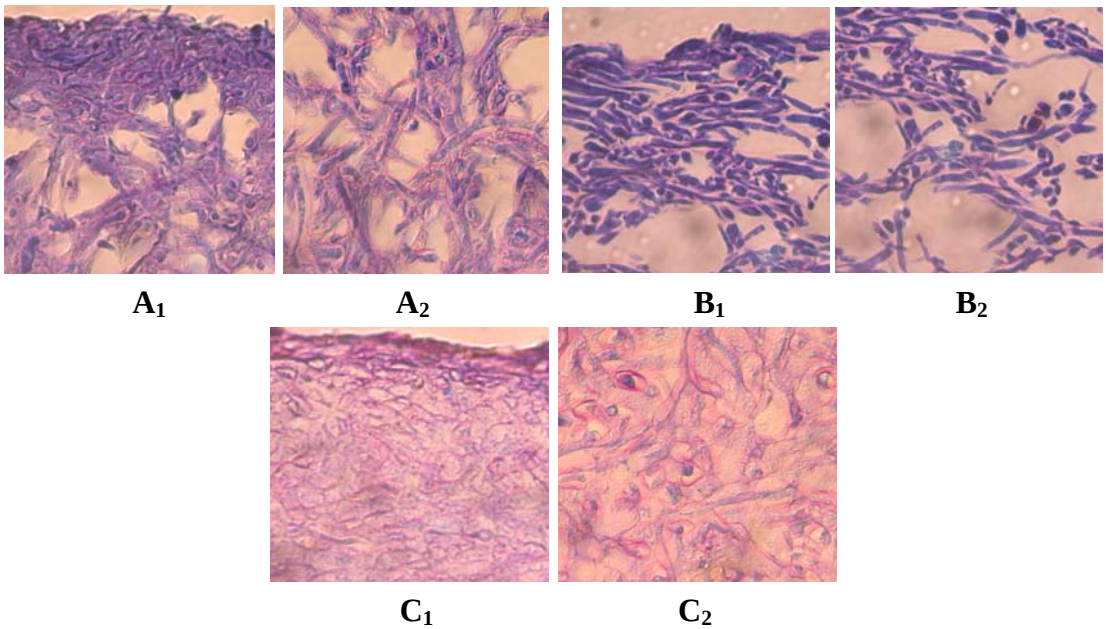


Figure 3. Histology of post-thawing straw mushroom after freezing by using (A) freezer, (B) dry ice, and (C) fresh mushroom at 20µm on (a) the edge and (2) the middle.

Mushroom tissue after thawing by using dry ice appear to lose more fluid than by using freezer, this is also supported by decreasing weight of straw mushroom after thawing, as shown in Table 5.

Table 5. Changes weights of straw mushroom after thawing

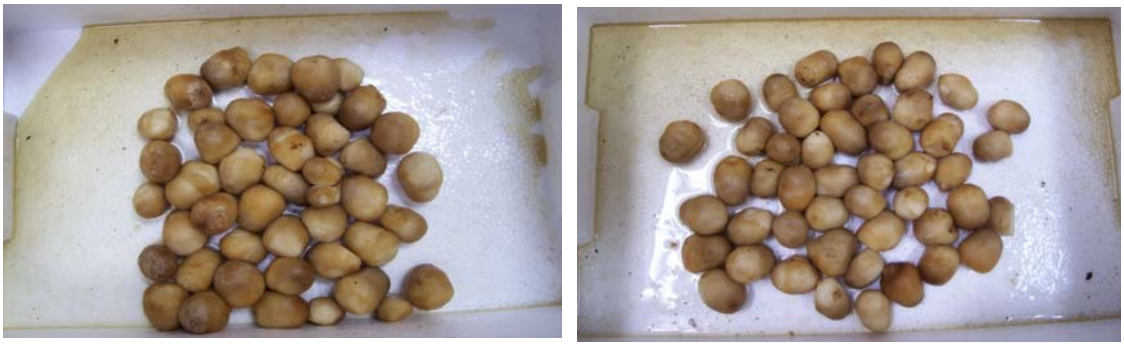
Treatments	Changes of weight (%)
Freezer	-15.76
Dry ice	-19.65

This weight reduction can caused due to dehydration during the freezing process on mushroom frozen using dry ice which occurs due to differences in air humidity (RH). Straw mushroom has high moisture, while dry ice had no moisture at all. Dehydration causes a lot of water content of the mushroom is drawn out and immediately frozen on the surface, it becomes a drip when thawed. This condition was not happened on frozen mushroom by using freezer, as shown in Figure 4.

B A

Figure 4. The Frozen straw mushroom on freezing by using (A) Freezer and (B) Dry Ice

In freezing process, ice crystals that formed in intercellular space have a vapor pressure lower than the water inside the cell, so the water is attracted by the ice crystals into intercellular space. This leads to dehydration of the cell, thus damaging the tissue. In the thawing process, cells cannot return to the original texture and shape, because the juices have come out of the cells into ice cannot be reabsorbed by the cell. The drip produced can be seen in Figure 5.



A B

Figure 5. The drip produced by straw mushroom after thawing on freezing by using (A) freezers and (B) dry ice

CONCLUSION

Dry ice can be used as an intermediary technologies to accelerate the freezing compared with the use of freezers, but still cannot replace freezer as frozen storage. The most effective ratio of straw mushroom freezing by using dry ice is 1:2 for mushroom and dry ice. The freezing rate by using dry ice is 0.27˚C / min, classified as a slow freezing, but with assumption that ice crystals formed were smaller than ice crystals formed on freezing by using freezer which has freezing rate 0.05˚C/minutes. Freezing of straw mushroom by using dry ice influenced on mushroom tissue damage due to dehydration. Therefore, for further research suggested to perform a vacuum or not perforated packaging on freezing by using dry ice to inhibit dehydration, and do some observations on mushroom shelf life in frozen state.

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