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低溫物流系統冷凍貨櫃溫度管理之研究

The Study of Temperature Management of Reefer Container in Low Temperature Logistics System

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摘要

為尋找防止冷凍貨物鮮度不佳及貨損的最適物流條件，本文首先比較不同凍結溫度對鯖鰺預冷貯存之影響，鯖鰺貨物分別置於以-25℃預冷及-20℃預冷之凍結設備，實施急速冷凍，並定時測定其溫度。結果顯示，以-25℃送風式凍結法於凍結17小時，貨物中心溫度可以到達-19℃，而以-20℃送風式凍結法中心溫度為-15.1℃，而並無顯著的下降，距離指定運送溫度有 3.9℃之溫差。當貨物表面溫度到達-19℃所須之時間，-20℃送風式凍結法為 7 小時、-25℃送風式凍結法為 5 小時。其次，比較不同積載方式對鯖鰺貨物之影響，鯖鰺貨物分別以水平積載、垂直積載及超高積載方式置於以-19℃之冷凍模擬櫃，實施急速冷凍，並定時測溫。結果顯示，水平、垂直積載櫃內溫差沒有超過3℃，而超高積載方式則有超過3℃。接著，比較不同斷電期間對鯖鰺鮮度之影響，短期間斷電以蘇澳運送至基隆時間 2 至 3 小時，對冷凍鯖鰺影響有限，但人為因素延遲交櫃，而造成較長期間如隔日交櫃而斷電18小時以上，對冷凍鯖鰺貨物就有影響。結果顯示，以運送協議許可斷電 8 小時，貨物表面溫度上升至-15.6℃左右，中心溫度為-16.1℃，而櫃溫上升至-14.6℃。如以斷電18小時，貨物表面溫度上升至-11.8℃左右，中心溫度為-12.5℃，櫃內溫度為-9.5℃。

關鍵詞：冷凍貨櫃，低溫物流系統，溫度管理

ABSTRACT

To preserve freshness and to prevent damage of frozen cargo, the condition on logistical process is optimized. The effects of -25°C air blast and -20°C air blast freezing methods on the pre-cooling stowage of mackerel and scad are also investigated. After 17 hours of freezing by -25°C air blast, the temperature of the frozen products reaches -19°C,

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whereas by -20°C air blast, the temperature of the products reaches -15.1°C (a 3.9°C temperature difference from the required transportation temperature). The effects of horizontal, vertical, and over load stowage on mackerel and scad are also studied. After freezing by -19°C air blast, the temperature difference between horizontal and vertical stowage is < 3°C, and the temperature difference for over load stowage is > 3°C. After eight hours of no power in the reefer container, the surface body temperature of the fish rises to -15.6°C and central body temperature to -16.1°C; after 18 hours of no power, surface body temperature rises to -11.8°C and central body temperature to -12.5°C with container temperature reaching -9.5°C.

Keywords: Reefer Container, Low Temperature Logistics System, Temperature Management

I Introduction

Seafood product is one of man's most important meat products, but the quickest to spoil and most difficult to preserve. Fresh fish usually needs to be frozen or refrigerated for preservation. Freezing is suitable for the preservation of deep sea catch while refrigeration is usually used for the preservation of fish caught in coastal and offshore waters [1]. The quality of frozen fish products deteriorates quickly, therefore proper control must be taken throughout the entire transportation process to prolong their quality and freshness [2]. Most catch dies soon after they leave their natural habitat, whereupon the circulation system ceases to function and various body tissues stop receiving oxygen. Under such anaerobic states, normal physiological functions can no longer continue, thereby producing many abnormal changes. Among these changes, rigor mortis, autolysis and putrefaction have a direct effect on the quality of the product [3]. Once dead, the action of autolytic enzymes and the reproduction of contaminated microorganisms take place, hence the quality of the meat deteriorates rapidly and putrefies. The quality of the seafood products thus relies primarily upon temperature control, which lowers enzyme activity and the reproduction rate of microorganisms [4].

Reefer containers are small, highly-efficient freezers designed to transport frozen seafood products. The interior temperatures of these containers can be adjusted and maintained from within a -25°C to +25°C range [5]. In order to maintain freshness and to ensure safety during transportation, various factors affecting the quality of frozen seafood products are examined. This paper aims to study the operation processes (as shown in fig.1) and the problems faced by the current mackerel and scad fisheries by conducting field surveys of the Suao Fishery Association, the fishing grounds, and related operators.

1.1 Operation Processes

At present, there are eight groups of large scale mackerel and scad large type purse seine fishery based in Suao Harbor. Each group is outfitted with one purse seine boat, two light boats, and two transport boats. After operators have collected the nets, transport boats move in to pick up the catch and use crushed ice to maintain freshness. Depending on the amount of catch, operators return to the harbor with the cargo approximately once every three days. After the catch is unloaded and sorted by size (large or small) into 15-kilogram or 10-kilogram boxes, they are then immediately put into storage at -25°C for rapid freezing. Other than supplying the primary fresh seafood markets, canning factories, and fishing baits for Tuna Lang Liner or Tuna Clipper, the catch is also exported (via reefer containers) to Singapore, the Philippines, and Korea for consumption or as baits [6].

1.2 Shipping and Marketing Problems

According to the results from survey interviews of operators, human factors such as pre-cooling temperatures, delayed in loading, stowage methods, and cut off of power supply are the main causes of cargo damage in the transportation process [7]. Therefore, this study focuses upon the problems faced by reefer container when power supply is cut off and on stowage methods, and also simulates different temperatures to examine the influence these factors have on the freshness of mackerel and scad catch.

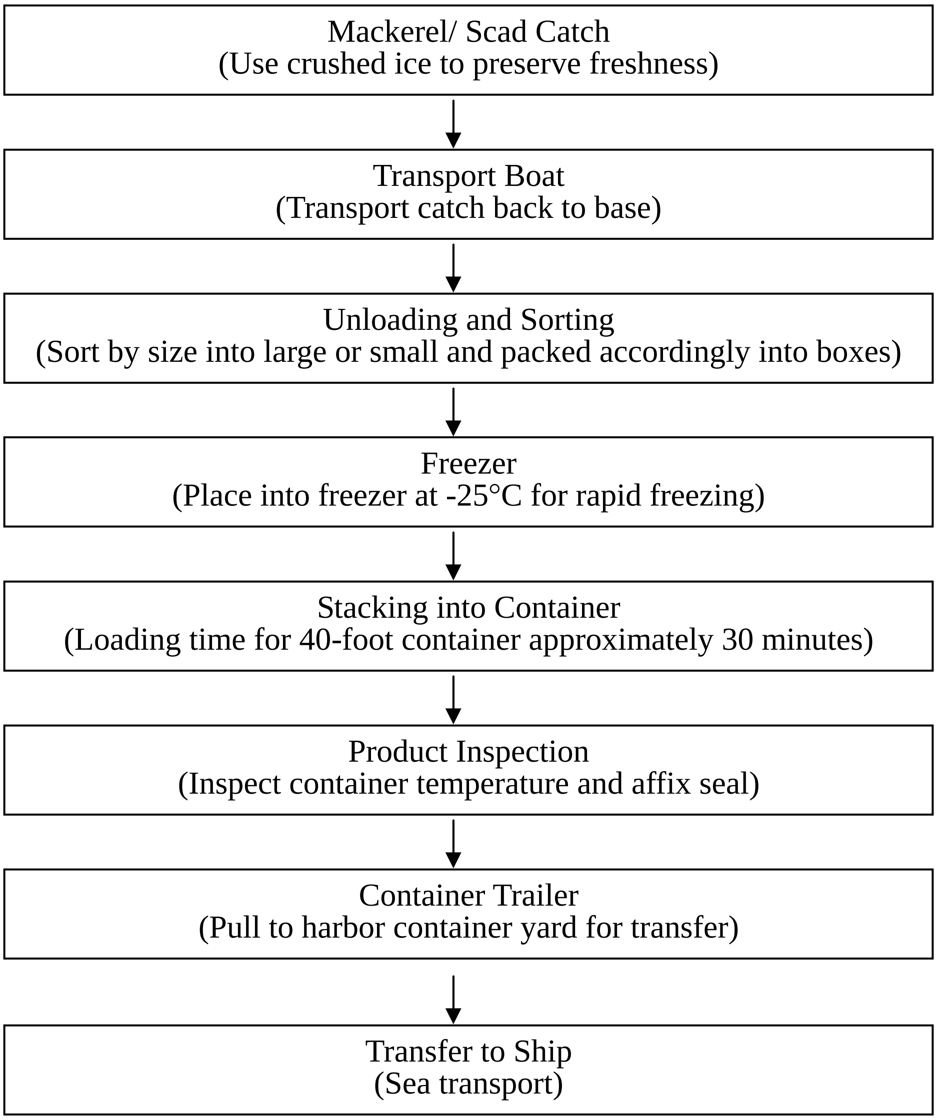

Fig.1 Flowchart for Mackerel/Scad Fishery (Export) Transport Process

II Materials and Methods

This study used mackerel and scad catch provided by Suao frozen food operators. After cleaning, the catch was used as experimental materials. This study took place at the National Taiwan Ocean University’s reefer cargo lab. Equipment used include simulated model reefer containers (see Fig.2), a temperature/humidity recording gauge, a temperature detecting gauge, and a thermometer.

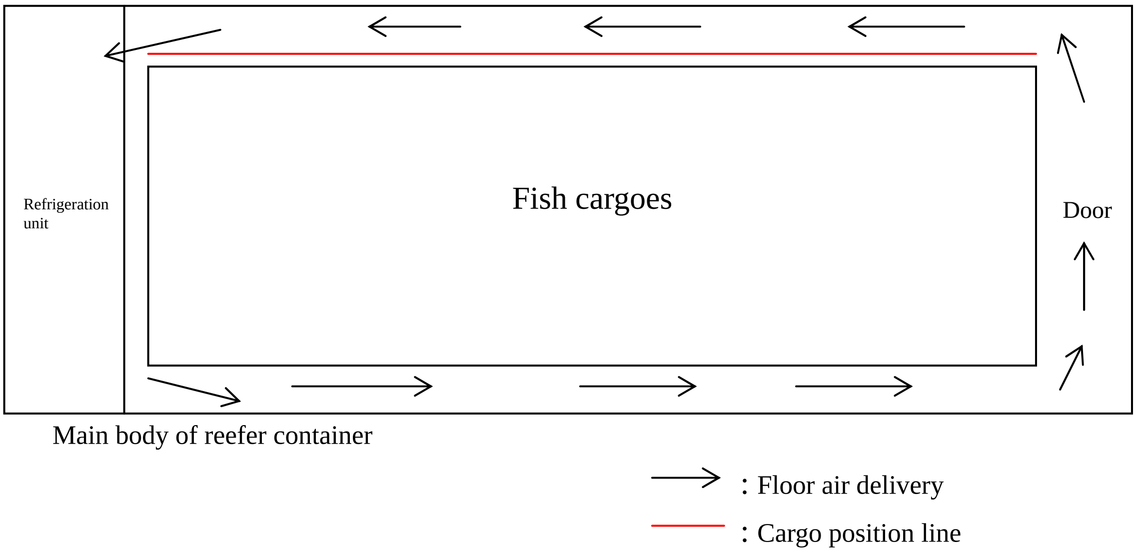

Fig. 2 Simulated model reefer container – front view

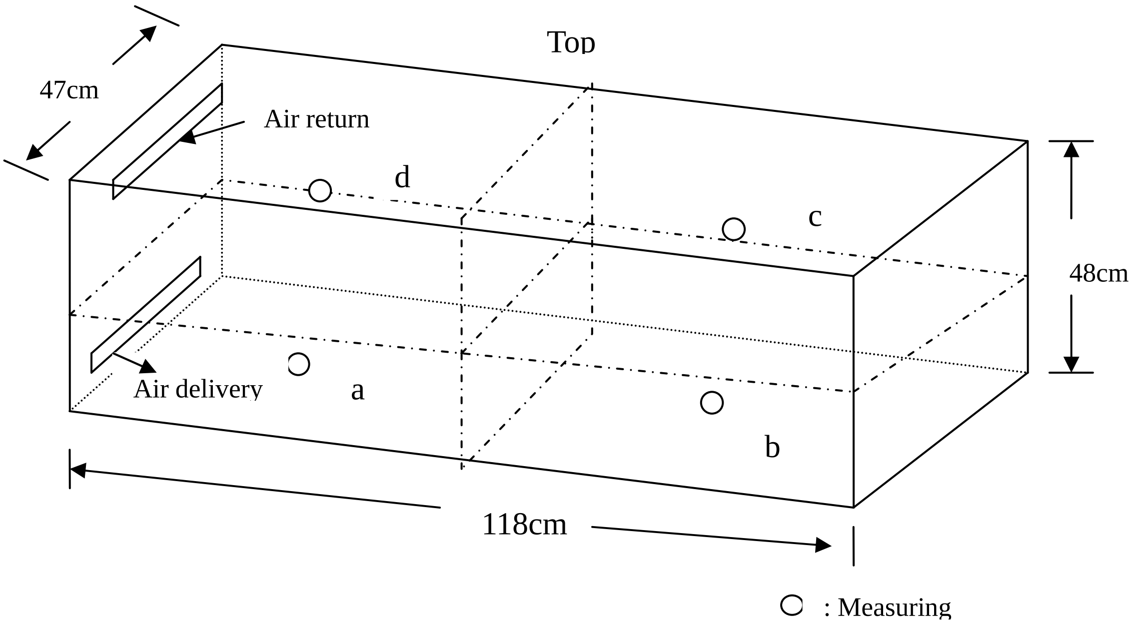

Fig. 3 Points of measured temperature

2.1 Effects of Different Freezing Temperatures on the Pre-cooling Stowage of Mackerel and Scad

In order to compare the effects of different freezing temperatures have on the pre-cooling stowage of mackerel and scad, the fish was placed, respectively, in -25°C and -20°C pre-cooling freezing containers for rapid freezing, and temperatures were measured periodically.

a. Determining the freezing curve

Continuous recording of fish central body temperature, surface body temperature, and interior container temperature changes were measured at multiple measuring points during the freezing process. Freezing time, in hours, were plotted on the horizontal axis against temperatures on the vertical axis to depict temperature changing curve.

b. Central body temperature and surface body temperature changes during freezing process

During the freezing process, a temperature detecting gauge was placed at multiple measuring points to measure the central body temperature. Freezing time was plotted against temperature changes to depict a curve, which was then contrasted against the changes in surface body temperature to understand body temperature changes under pre-cooling and no pre-cooling conditions.

c. Determining the differences between central body temperature and transportation temperature

Various types of pre-cooled mackerel and scad were frozen in -20°C for a day. They were then removed and placed under refrigeration for immediate measurement of central body temperature.

2.2 Effects of Stowage Methods on Loading and Transporting Mackerel and Scad

In order to study the effect of reefer container stowage methods on the distribution of temperature within a container, this study simulated different types of mackerel and scad stowage. Experimental measurements were taken to observe the distribution of temperature within a container, and the advantages and disadvantages of different stowage methods on the effectiveness of cooling circulation were compared.

a. Determining cold air circulation

This experiment used the transportation temperature of -19°C as the control temperature. The items under study were: the measurement of the freezing curve in an empty container, and measurement of temperatures for horizontal, vertical and over load stowage methods. Moreover, temperatures recorded from multiple measuring points (front, middle, back), continuous temperature changes of mackerel and scad catch recorded from multiple measuring points (see figure 3) during the freezing process, and temperature changes within the container were plotted. Freezing time was plotted along the horizontal axis and temperatures were plotted along the vertical axis to depict temperature changing curve.

b. Stowage methods and elements of measurement

Horizontal stowage method: Within the container, air circulates in a horizontal direction. Boxes were stacked in vertical rows with two spacing panels (22 x 37.5 cm each) placed side by side every three layers to form a horizontal circulation space.

Vertical stowage method: Within the container, air circulates in a vertical direction. Boxes were stacked in vertical rows with two spacing panels (22 x 37.5 cm each) juxtaposed against each other in every three columns to create a vertical circulation space.

Over load stowage method: Catch is stacked above the specified height limit, creating an unfavorable air circulation environment.

2.3 Effects of No Power Supply on the Freshness of Mackerel and Scad

a. Changes in temperature following no power supply

During the period when there was no power supply, cold air circulation within the container stoped. and interior temperature gradually increased. Using multiple measuring points, temperature changes within the container were continuously monitored. Freezing time were plotted on the horizontal axis against temperatures on the vertical axis to depict temperature changing curve.

b. Measuring surface body temperature and central body temperature following no power supply

During the period when there was no power supply, multiple-measuring-points temperature detecting gauge was used to measure surface body temperature and central body temperature to plot out a graph of no power time against temperature changes. This curve was compared to surface body temperature changes to understand temperature changes that occur in mackerel and scad cargo after power supply was cut off.

III Results

3.1 Effects of Different Freezing Temperatures on the Pre-cooling Stowage of Mackerel and Scad

According to the results shown in Figure 4, when the cleansed mackerel and scad were subjected to -20°C air blast freezing, surface body temperature began to drop after freezing. After approximately five to six hours, surface body temperature dropped to around -18°C. As freezing time continued, surface body temperature did not appear to drop any further. After seven hours of freezing time, however, after surface body temperature reached the specified transportation temperature of -19°C, central body temperature reaches its lowest point of -15°C.

According to the findings in Figure 5, when using -25°C air blast freezing, surface body temperature dropped to -19°C after five hours of freezing. At that time, the surface of the fish hardens into a frozen layer and central body temperature dropped to 0°C. As freezing time continues, surface temperature did not appear to drop any further. After 16 hours of freezing time, however, when surface body temperature reaches -23°C, the central body temperature dropped to the specified transportation temperature of -19°C.

3.2 Effects of Stowage Methods on Loading and Transporting Mackerel and Scad

As shown in Figure 6, temperature within an empty container subjected to the specified -19°C air blast circulation began to drop immediately after air circulation. After approximately one to two hours, the temperature of the container dropped to approximately -18°C. As freezing time was prolonged, although the surface temperature of the container did not appear to drop, but after 2.5 hours, the interior temperature of the container reached the specified transportation temperature of -19°C.

Tables1 and 2 show that when using horizontal and vertical stowage methods, interior container temperature difference did not exceed 3°C. When the over load stowage method was used, however, the difference exceeded 3°C.

3.3 Effects of No Power Supply on the Freshness of Mackerel and Scad

a. Changes in temperature following no power supply

As shown in Figure 7, during the period when a reefer container lost power, air blast circulation ceased and the interior temperature of the container gradually increased. After five to six hours, container temperature rose to -15.4°C; after 18 hours, the temperature reaches -9.5°C.

b. Measuring surface body temperature and central body temperature following no power supply

As Figure 7 shows, after power was cut off, air blast circulation ceased and the interior temperature of the container gradually rose. After seven to eight hours, surface body temperature rises to -15.6°C and central body temperature rose to -16.1°C. After 18 hours of no power supply, surface body temperature rose to -11.8°C while central body temperature rose to -12.5°C.

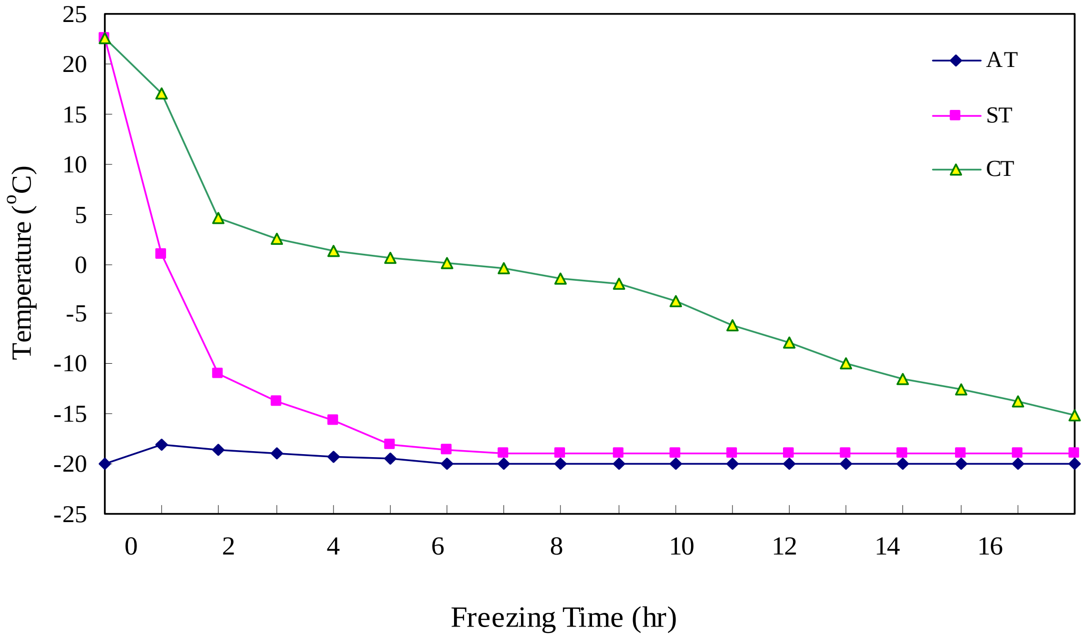

Fig.4 Freezing curve of Mackerel by -20℃ air blast freezer.
AT: air blast temperature, ST: surface temperature,
CT: central temperature.

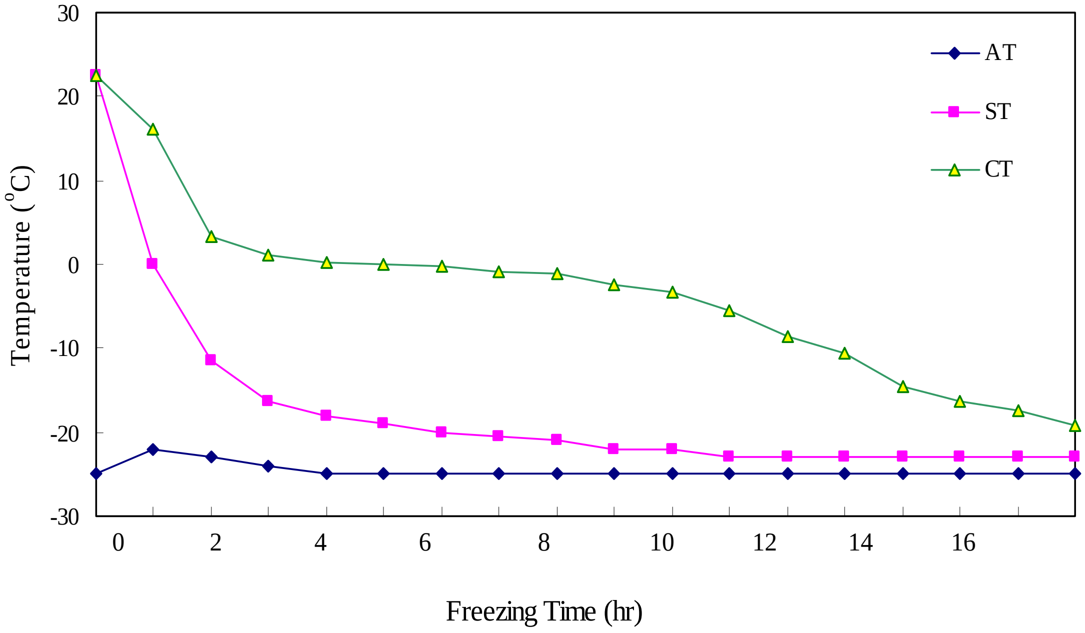

Fig.5 Freezing curve of Mackerel by -25℃ air blast freezer.
AT: air blast temperature, ST: surface temperature,
CT: central temperature.

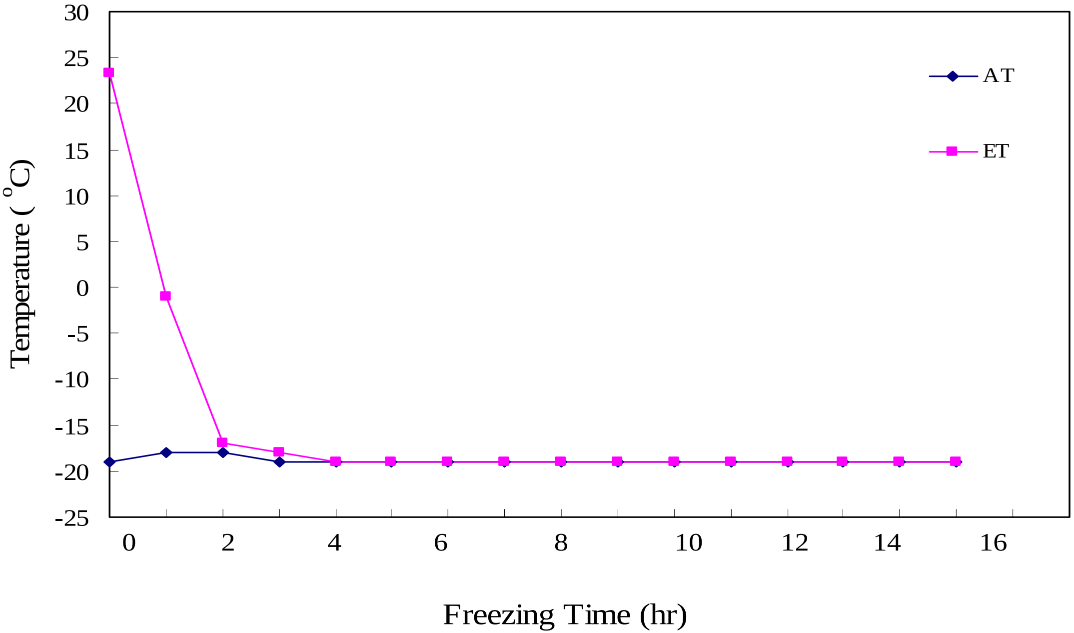

Fig.6 Freezing curve of Empty Container by -19℃ air blast freezer.

AT: air blast temperature, ET: empty container temperature

Table.1 Measured values of temperature distribution at area a~d in reefer container

Position Area	Temperature ℃	Temperature difference ℃ (HS)	Temperature difference ℃ (VS)	Temperature difference ℃ (OS)
a	-19.2	0.1	0.1	0.1
b	-19.0	0.2	0.2	0.5
c	-18.9	0.3	0.5	3.6
d	-18.7	0.5	0.7	4.5

Operation condition: 1.Wind Scale 0.41 m³/min 2. Wind Speed 1.4 m/s 3. Delivery Temperature –19.0℃

Table.2 Effect of stowage methods on the temperature difference in mackerel and scad during reefer container transport

Stowage method	Temperature difference
A[a]	--[b]
B	--
C	+

[a] A: Horizontal stowage method
B: Vertical stowage method
C: Over load stowage method

[b] --: Temperature difference < 3℃
+: Temperature difference > 3℃

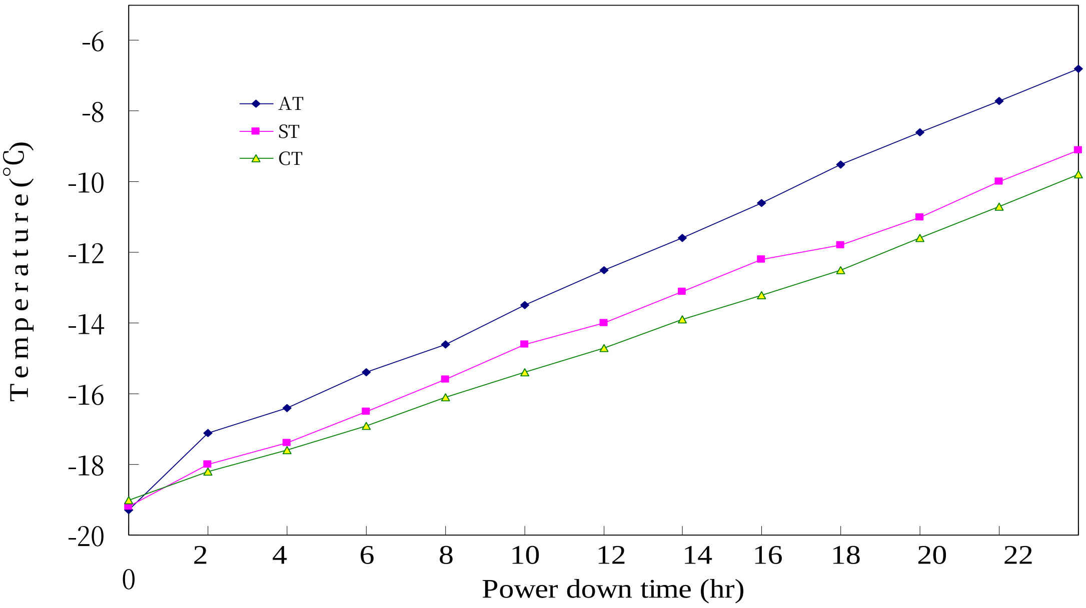

Fig.7 Freezing curve of Mackerel by container power down.
AT: air blast temperature, ST: surface temperature,
CT: central temperature.

IV Discussion

a. From the two different freezing curves, it is apparent that for surface body temperature to reach the required -19°C transportation temperature, seven hours of -20°C air blast freezing method is required; whereas by using the -25°C air blast freezing method, it takes five hours. In order for central body temperature to reach -19°C, 17 hours of -25°C air blast freezing method is required; whereas by using the -20°C air blast freezing method, central body temperature reaches -15.1°C, a 3.9°C difference from the required transportation temperature, and further drop in temperature can no longer be observed. Therefore, using the -25°C air blast freezing method for 17 hours allows central body temperature to reach -19°C.

b. Although over load stowage allows for three to five percent increase in cargo stowage over the horizontal and vertical stowage, but by extending cargo stowage beyond height limits results in poor air circulation at the top of the container. This situation does not occur with horizontal or vertical stowage methods. Results show that with horizontal and vertical stowage, the interior temperature differences of the container do not exceed 3°C; whereas with over load stowage, the interior temperature differences of the container surpass 3°C.

c. When a reefer container loses power, cold air circulation ceases and the interior temperature of the container gradually increases as well was temperature differences. Short-term lack of power supply (transport time from Suao Harbor to Keelung takes two to three hours; Suao Harbor to Kaohsiung takes six to seven hours) has limited effects on frozen mackerel and scad. When human factors, however, delay container transfer that results in longer periods of no power (next-day container transfer) for 18 hours or longer, temperature changes inside the container is apparent. According to transportation agreements, the allowable no-power time is eight hours. After eight hours of no power supply, surface body temperature rises to -15.6°C, central body temperature rises to -16.1°C, and container temperature rises to -14.6°C. If power is cut off for 18 hours, surface body temperature rises to -11.8°C, central body temperature reaches -12.5°C, and the interior of the container reaches -9.5°C. At this time, transport temperature jeopardizes the freshness and quality of the mackerel and scad.

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