

ENERGY SAVINGS FROM OPTIMIZING STORAGE TEMPERATURES OF FRUIT JUICE CONCENTRATES

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Introduction

Since orange juice concentrates are customarily called "FCOJ" (Frozen Concentrated Orange Juice), they are often misunderstood that they are a kind of "frozen food" (or quick-frozen food). Food Sanitation Law in Japan and Japanese Agricultural Standards stipulate the preservation temperature of "frozen food (including fruit juice)" at $-15\text{ }^{\circ}\text{C}$ and $-18\text{ }^{\circ}\text{C}$ or lower, respectively. Regulations in EU as well as in USA have also similar figures. The key point is to know if they are in a frozen state at temperatures around $-18\text{ }^{\circ}\text{C}$ or not. Therefore, we conducted the freezing point measurement of fruit juice concentrates in various conditions as correctly as possible, and it was confirmed that most of the fruit juice concentrates prevailing nowadays (orange: ca.65 °Brix, apple: 65 to 70 °Brix, etc.) have freezing points much lower than $-18\text{ }^{\circ}\text{C}$, being not a kind of "frozen food". And, through the experimental studies on orange juice concentrates, it is realized that by applying the optimum storage temperatures considering the good balance of the quality maintenance and the energy consumption, considerable amount of energy could be saved in the cold chains for such products.

MEASUREMENT OF FREEZING POINTS

Most of reports on the freezing point measurement of fruit juice concentrates so far issued show very small sample size (0.2 to

0.5 ml), and rapid freezing was conducted by using liquid nitrogen for cooling, condition of which are much different from practical ones. This time, based on the JIS K 0065 (Measuring Method of Freezing Point of Chemical Products), we conducted the measurements with the samples of 20 to 500 ml, using a big size freezer. Outline of the measuring apparatus is shown in Fig. 1. Actual freezing point measurements were performed putting the measuring apparatus of Fig. 1 into a big size freezer set at specified temperature. Temperature changes were measured and recorded every 5 seconds using a calibrated thermocouple (copper – constantan). An example of freezing curve out of the measurements is shown in Fig. 2. The freezing point of sample is the rebound ceiling temperature as shown in this figure (as per JIS description). Freezing point is much affected by sample size and freezer temperature. Therefore, freezing points with samples of two (2) different sizes and at several freezer temperatures were measured as shown in Fig. 3, and the temperature of cross point of two plotted lines is considered as the intrinsic freezing point of orange juice concentrates (65 °Brix). This was $-23.3\text{ }^{\circ}\text{C}$. The freezing points of orange juice concentrates from 40 °Brix to 65 °Brix as the result of

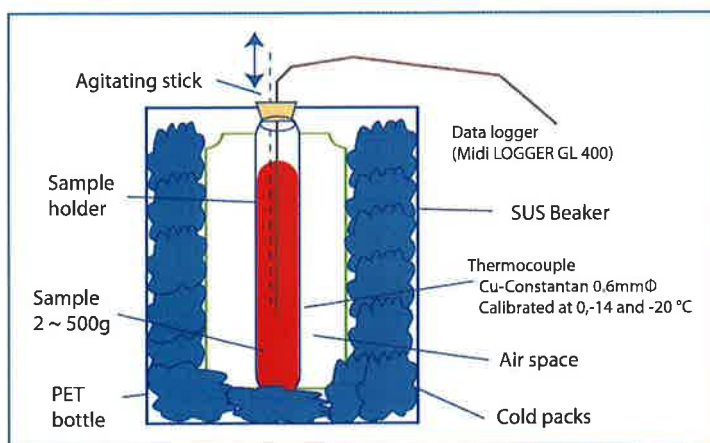


Fig. 1: Freezing point measuring apparatus

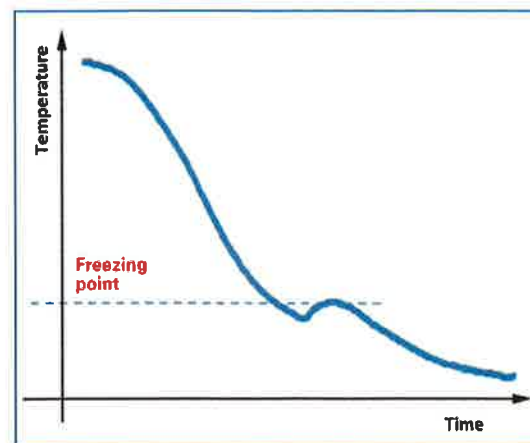


Fig. 2: Example of freezing curve

applying the same method are shown in Fig. 4. The solid line on the top shows the freezing points. As consumer products of COJ (42 °Brix) have freezing point of about -8 °C, they are "frozen foods" which should be preserved at -15 °C (or -18 °C) or lower. We herein use the word "COJ", not "FCOJ", for orange juice concentrates, irrespective of frozen or not, and "AJC" for apple juice concentrates.

Fig. 5 shows the freezing points of COJ and AJC. Since AJC has much fructose content whose freezing point is comparatively low, AJC also has lower freezing point than COJ of the same Brix value. Anyway, it is confirmed that the freezing points of COJ of 65 °Brix and AJC of 65 to 70 °Brix are much lower than -18 °C.

PROPER STORAGE TEMPERATURES

From the viewpoint of the product qualities, it is generally noted that the storage temperatures shall be as low as possible. On the other hand, to study the energy saving, we have to consider the current surplus energy consumption for cold-storing the products. The bulk storage and transportation of COJ (65 °Brix) at the temperature of 20 °F (-6.7 °C) were already established by 1980 in USA, and several technical reports thereon were issued. We, NJT stuff, also performed the experiments of quality change transition of COJ (65 °Brix) for 280 days, as follows; Duration: 280 days, Preservation temperatures: room temperature, +5 °C, -7 °C, -12 °C, Test items: Brix, acidity, color, vitamin C, sensory, amino nitrogen, oil content, bacteria count; and, it was confirmed that no quality degradation was recognized on the COJ preserved at -7 °C throughout the 280 days, while the COJ preserved at +5 °C started quality change after 50 days. Supplemental experiments for COJ (65 °Brix) preserved at 0 °C are now undergoing, and no quality degradation is recognized so far (for 6 months).

The fact that the quality at -7 °C is still stable for a long time would depend on the proper characteristics of COJ (65 °Brix) having pH of about 3.7 and water activity of about 0.83. Considering the product freezing point being much lower than -18 °C and the product quality conditions, storage at -20 °C to -25 °C (mostly performed especially for drum storage in Japan) should be wasteful. Since AJC (65 to 70 °Brix) now prevailing has lower freezing point than COJ (65 °Brix) and lower water activity of about 0.75, the AJC storage temperature could be further higher than COJ's.

As of distribution method of fruit juice concentrates

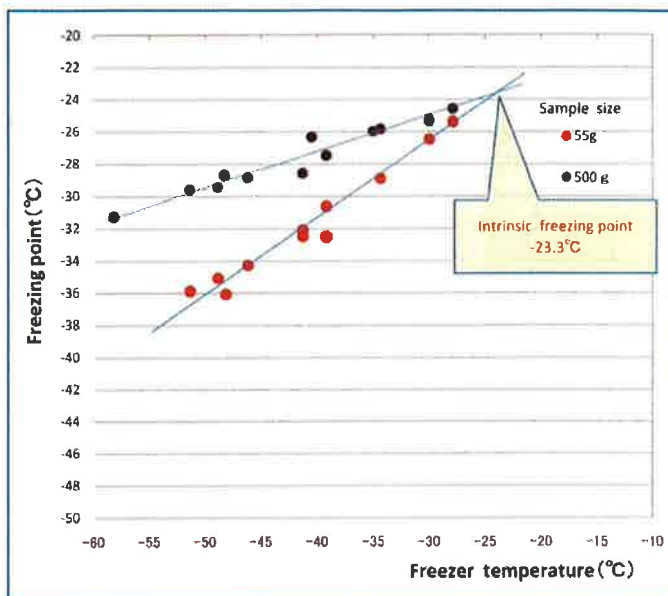


Fig. 3: Relation among freezer temperature, sample and freezing point of COJ (65Brix)

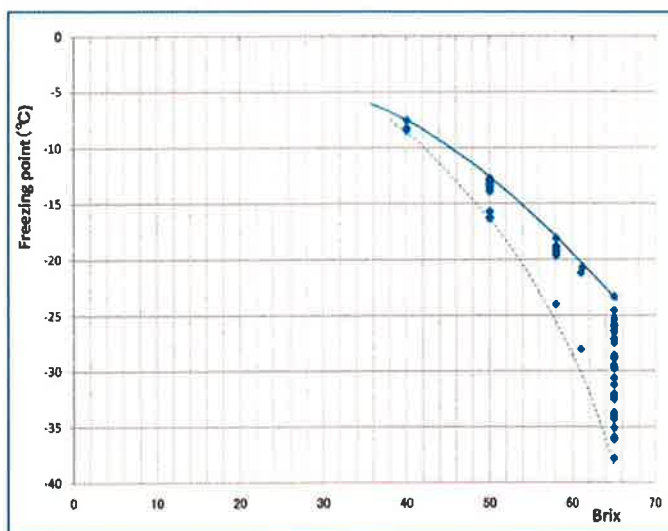


Fig. 4: Freezing points of COJ (40-65 Brix)

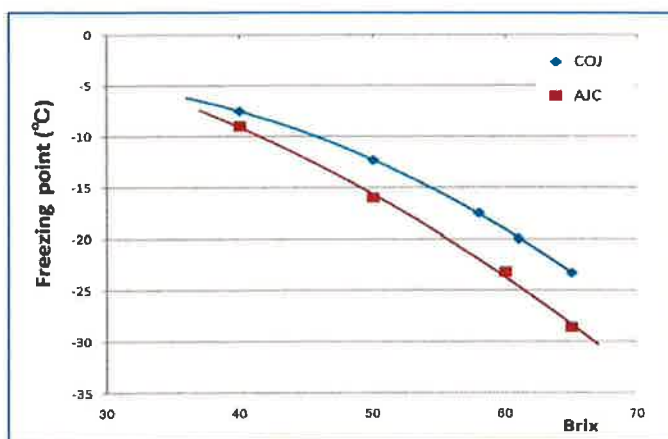


Fig. 5: Freezing points of COJ and AJC

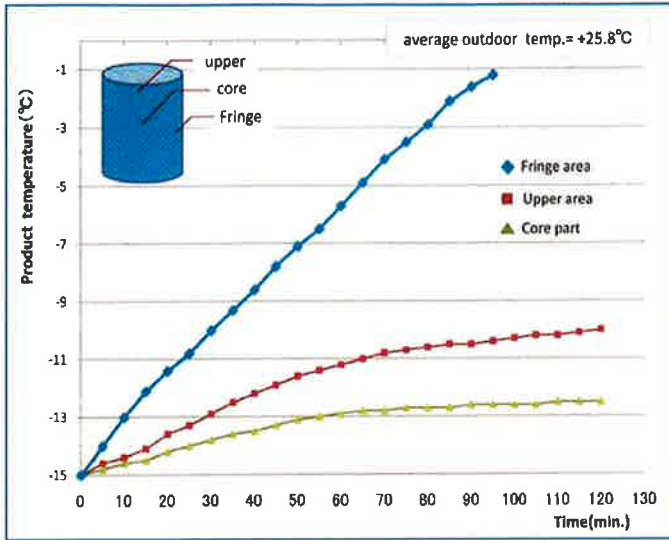


Fig. 6: Temperature changes of drum filled COJ in outdoors

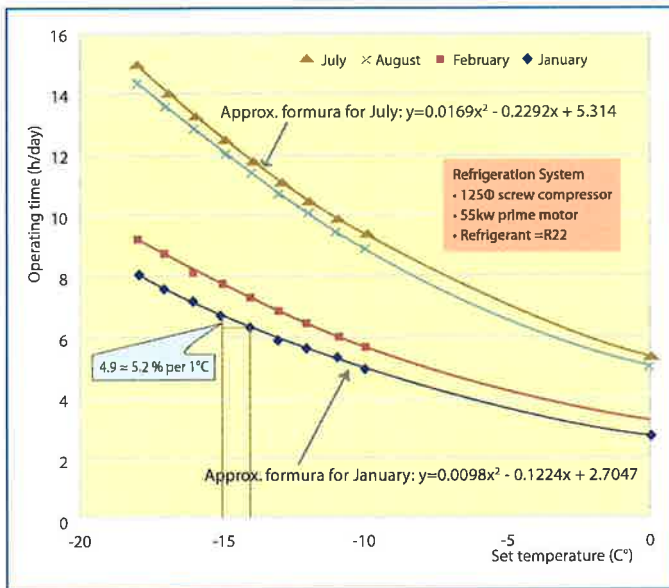


Fig. 7: Refrigeration system operating time vs. cold room set temperature

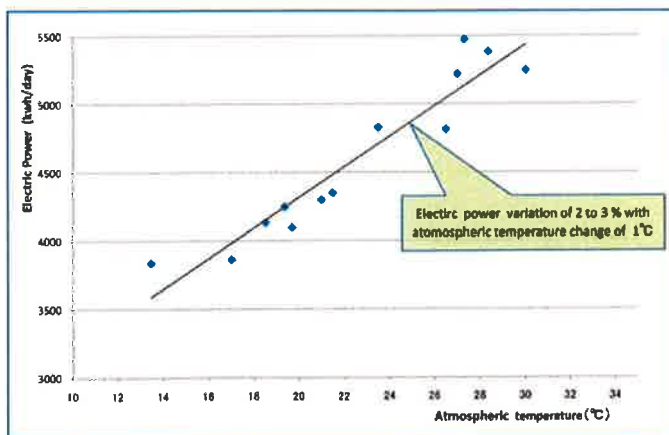


Fig. 8: Relation between atmospheric temperature vs. electric power consumption at the same cold room

in Japan, distribution in drums has higher share comparing to the bulk distribution. We, therefore, studied the possible temperature rise during transportation of drum-filled products from one place to another. The temperature changes of drum-filled products placed outdoors in summer (at average atmospheric temperature of +25.8 °C without direct sun rays) are shown in Fig. 6.

Assuming that the drum-filled products kept at -15 °C are to be dispatched with freezer car, and the time from leaving cold-room to the completion of loading onto the car requires 30 to 40 minutes, the temperature of fringe area of drum-filled products rises to -8.5 °C and that of core part: lower than -13 °C, which has no risk of quality degradation. Even if the loading work takes one hour by some reason, the fringe area temperature will be about -6 °C, thus does not cause any quality problem. The initial temperature of products may be increased by 2~3 from -15 °C (i.e. -12 °C to -13 °C). In case of bulk distribution with heat-insulated tank car (12kL), it is reported that the product temperature (-7 °C) will be risen to about -5.5 °C after 12 hours, at outside average temperature of 30 °C.

STORAGE TEMPERATURES AND ENERGY SAVINGS OF DRUM-FILLED PRODUCTS

We made trial calculations of energy saving effects of NJT cold-room for drum-filled products, by changing the cold-room temperature by 1 °C. With a cooperation of refrigeration equipment manufacturer, the operating time of refrigeration equipment against set temperatures of cold-room (ca. 12,400 m³) of drum-filled products were calculated, the results of which are shown in Fig. 7. As shown in the figure, it is recognized that by increasing the set temperature by 1 °C from -15 °C, equipment operating time is reduced by about 5%.*

*depends on atmospheric temperature, set temperature, etc.

To verify this data, we performed the actual tests on the NJT cold-room for drum-filled products, to see the changes of the equipment operating time, with the change of the set temperature by 2 °C, in the seasons of summer, autumn, and winter. Since it is practically difficult to make operation comparison at the same ambient temperature, we made the compensation data from the operation data with the change of ambient temperature at the same set temperature. This ambient temperature compensation graph is shown in Fig. 8. In such a way, it is confirmed that the equipment operation factor is reduced by

about 6 % with the increase of set temperature of cold-room by 1 °C, which is a little higher than the calculated one (about 5 %) mentioned before.

This value is the case of NJT cold room, and it will be changed depend upon cold room structures, heat insulations, product incoming & outgoing operation and other conditions. There are examples that in case of commercial cold warehouses, energy saving of about 3 % is attained by increasing room temperature by 1 °C. Anyway, if the product owners as consigner and cold-warehouses as consignee settle the storage temperature of the products, reasonably and cooperatively, paying special regard to the products properties, considerable amount of energy saving would be expected comparing to the current situation, and it would contribute to the reduction of carbon dioxide emissions, too.

CONCLUSION

- The freezing point of orange juice concentrates (65 °Brix) prevailing nowadays was correctly measured and it was confirmed to be about -23 °C. That of apple juice concentrates of the same Brix value was further lower,
- Orange juice concentrates (65 °Brix) is not a frozen food, because at the higher temperatures than -23 °C



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(e.g. -15 °C), they are not frozen. Therefore, regulations on frozen food are not applied.

- To expect the energy saving with maintaining the product quality, the proper storage temperature of orange juice concentrates (65 °Brix) will be -7 °C for bulk storage and -10 to -13 °C for drum-filled storage. Higher storage temperatures may be allowed for apple juice concentrates.
- By increasing the storage temperatures of drum-filled products by 1 °C, energy saving of 3 to 5 % will be expected.

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