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Variations in Freezing Times for Shrimp and Crab Products



OREGON STATE UNIVERSITY EXTENSION SERVICE

Variations in Freezing Times for Shrimp and Crab Products

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Pacific shrimp and Dungeness crab, two West Coast species, often arrive at the dock in high volumes over short periods of time. In fact, up to 70% of Oregon's Dungeness crab have been landed during a 1-month period in the winter. This sudden influx of product presents problems in the year-round marketing of these species.

Freezing is one way to deal with the situation, but freezing and cold storage practices can have a serious effect on the quality and value of these products. This publication looks at the the first of these processing operations—freezing—and shows how freezing times were affected on some vacuum-canned products.

The freezer reduces the average temperature of the product to the temperature at which it will be stored. Frozen product is then removed to the cold storage room—a completely separate unit whose job is to store *not* finish up freezing.

Freezing time is the period required to bring the center of the product to some low temperature such as -10°F . The outer layers of product will be colder than that. So after removing product from the freezer, the *average* product temperature will equilibrate at a value lower than that measured at the center. Figure 1 illustrates a typical center-temperature versus time curve, in this case for a 1-pound can of shrimp.

It's important that the processor know how long a product must stay in the freezer before moving it to cold storage and how various factors will affect this freezing time. Why is this so?

- 1. Freezing equipment must be sized to match an expected production schedule, and freeze-time is the measure of how quickly product can flow through this operation.**
- 2. The *rate* of freezing has been shown to affect seafood quality, although this depends on the species and condition as well as other factors.**

One Danish researcher, in reviewing the literature, recommended that most seafoods be frozen at a rate faster than 0.5 cm/hour (calculated by dividing the radius or half the thickness by the freezing time) and that some shellfish may benefit from rates of 1.0 cm/hour or higher.

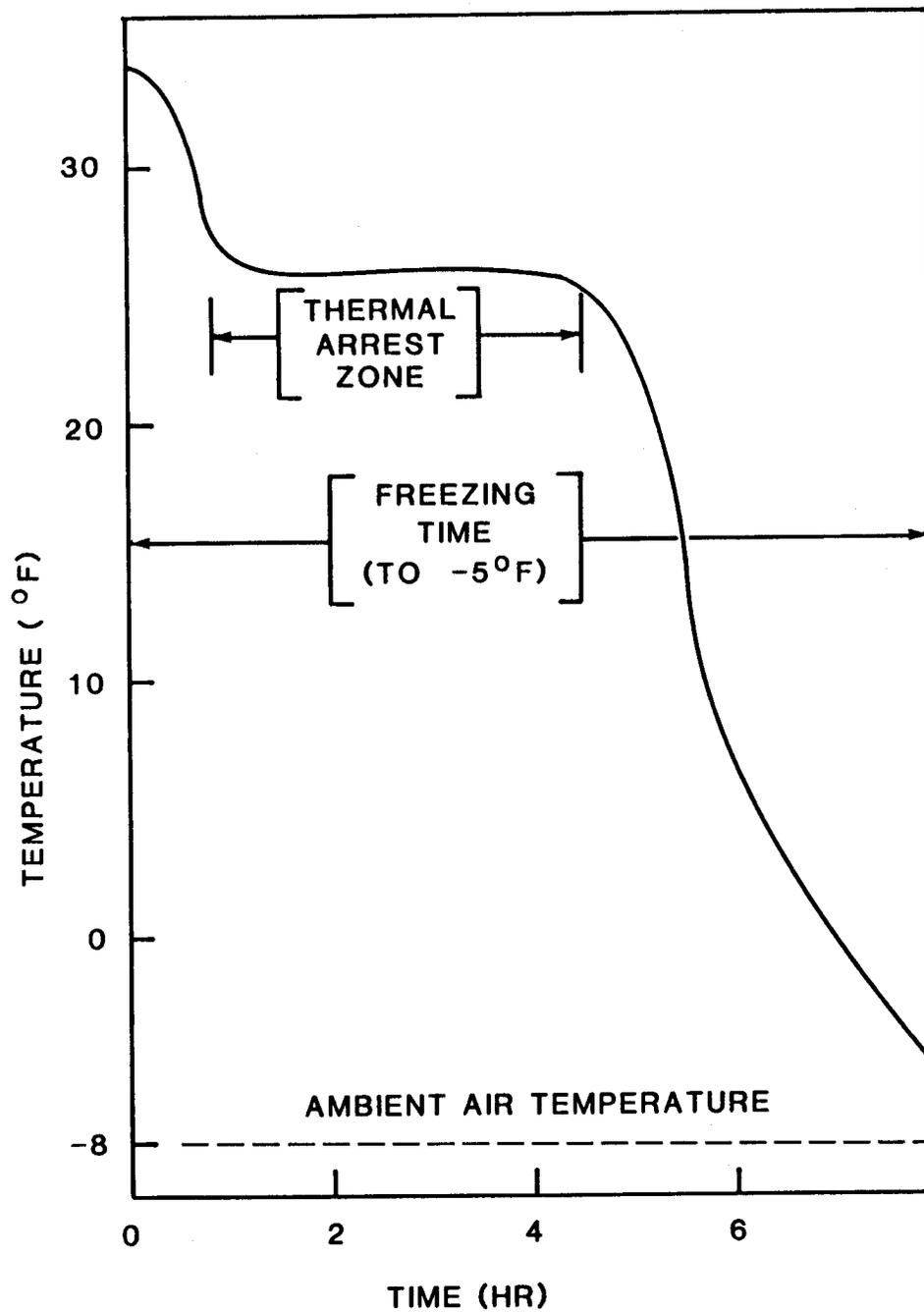


Figure 1.—Center temperature of a vacuum-packed can of Pacific shrimp frozen under some nonideal conditions.

3. The operator must know when to remove product from the freezer.

If the product stays in too long, the freezer becomes a bottleneck in the process, and equipment is not used to its full economic potential. If the product is moved to the cold store too early, the freezing rate at the unfrozen center slows down. (Air velocities and temperature are usually quite different in cold storage.)

What is perhaps more significant is that this incompletely frozen (and relatively warm) product can now cause a temperature rise or fluctuation in the product already in storage. And this fluctuation can cause "freezer burn" (a sublimation drying) and other texture and flavor changes.

4. Ideally, processors want to adjust the freezer to operate at optimum conditions.

For example, lowering the freezer temperature can bring about higher freezing rates and a faster throughput of product. A point is reached, however, when further gains are limited by the heat transfer resistance inside the product. As this limit is approached, a decreased freezer temperature only serves to increase the unit cost of refrigeration.

In a controlled experiment, we measured freezing times for vacuum-canned, processed Pacific shrimp using air velocity and temperatures similar to what one might find in a commercial "sharp freezer" or a cold room with fans. We had two objectives:

- Show that existing mathematical formulas (or "models") are adequate for predicting freezing times in a vacuum-canned particulate seafood like processed shrimp and picked crab.
- Demonstrate the critical factors that influence these freezing times.

Some of the results appear in table 1. For these tests, air temperature was about -8°F , air velocity about 1 meter per second, and "freezing time" was defined as when the center reached 18°F . *Keep in mind that these were not ideal conditions and one should normally strive for a center temperature lower than 18°F .*

Table 1.—Freezing times of vacuum-canned shrimp under some nonideal conditions

Shrimp product	Freezing time to 18°F	Freezing rate
1-pound can in free stream	4.5 hours	1.1 cm/hour
1-pound can when stacked (no heat flows out through the flat ends)	5.5 hours	0.9 cm/hour
5-pound can in free stream	9.5 hours	0.8 cm/hour
5-pound can when stacked	12.5 hours	0.6 cm/hour
5-pound can when packaged in a slotted, corrugated box placed in free stream	18.0 hours	0.4 cm/hour

These results, although not startling, allow us to make some general observations:

1. Freezing time varies strongly with product thickness or diameter.

The thicker the product, the longer it takes for heat to conduct from inside the product to the cold air or brine outside. For cans in these tests, freezing times can be considered roughly proportional to the square of the diameter.

2. Freezing time *can* vary strongly with air velocity—up to a point.

In the experiments, we used air velocities similar to those we had previously measured in a commercial “sharp freezer” that was sometimes used for shrimp.¹

But to examine how freezing time varies with other values of air velocity, we can use a formula, or model. (This is one of the benefits of models—to predict results for some new conditions without having to perform another experiment, which can be a time-consuming and expensive process.)

Figure 2 shows predicted freezing times for two can sizes. For the low air velocity used in our tests, the external air film becomes the major

¹The term “sharp freezer” is really a misnomer because it is not very “sharp” when it comes to freezing things. Even with five blower units operating at one end of the room, velocities were generally less than 1 meter per second (about 2.25 mph)—far less than the 5 meters-per-second velocities designed into many commercial tunnel freezers.

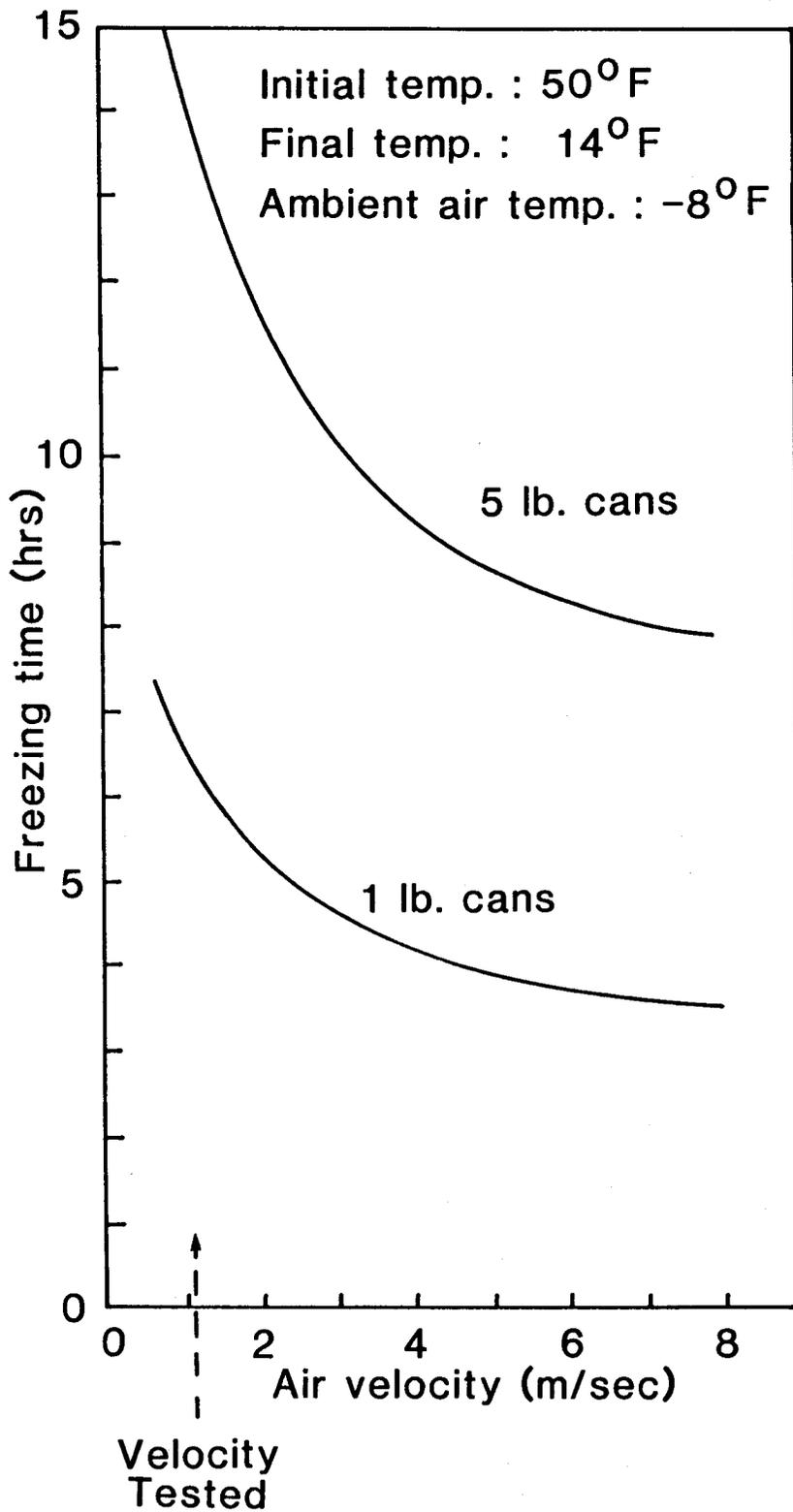


Figure 2.—How freezing times of vacuum-packed cans of Pacific shrimp varied theoretically with air velocity. (Note that an air temperature of -8°F is too high for ideal freezer operation.)

resistance to heat flowing out of the shrimp. This is the “controlling factor.” As shown in the curves, just a slight change in the air velocity will drastically change the air film resistance and thus the freezing time.

But what if the air velocity increases to 5 meters per second or so? At that high velocity, the air film which resists heat transfer now becomes much smaller. The important point is that it is now “small” compared to the resistance *inside* the product—a factor we can’t do much about.

So at this point, any increase in air velocity doesn’t help very much—the curve has flattened out. In fact, increasing the velocity *could* begin to hurt, as the higher speed fans begin to put a lot of additional heat energy into the freezer.

Although brine tends to remove heat more quickly than air, note that for reasons just discussed, a high-velocity air flow can approach swiftly-flowing brine in freezing effectiveness.

3. Other tests (not shown in table 1) demonstrated that lowering the initial product temperature by prechilling will decrease the time required in the freezer.

4. The temperature of the freezing medium (air or brine) will affect freezing times.

The lower the better, keeping in mind that the lower the air temperatures, the higher your refrigeration costs.

5. For the low air velocities used in our experiments, pulling a vacuum in the cans did not increase freezing times by more than about 10%.

As explained above, however, the outer film resistance was “controlling” the process. It is reasonable to expect that for high air velocities (when *internal* resistance controls), vacuum would have a slightly greater effect on freezing time.

6. Finally, the experiments showed that packing the cans into cartons—even cartons having slots in the sides—can have a serious effect on freezing times.

As table 1 shows, under these test conditions the freezing time doubled for the can packed in the carton.

As we’ve mentioned, management of the freezer will often affect conditions in the cold storage room, and it’s in storage that other serious quality changes can take place—a topic we can’t cover here.

Freezing rate, level and uniformity of storage temperature, packaging, and time—all play a role in product quality. Required handling costs and expected return are equally critical factors. How we balance these things to produce good quality seafood is a major interest of us all.

For further reading

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