



19. SOME RELATED FACTS AND FIGURES

The following summary of facts and figures related to fish freezing is only presented as a guide. There will be differences between species, due to the effects of seasonal changes and due to processing methods. Even if the information were available, inexhaustible lists would have to be prepared to cover all eventualities. This obviously is not practical in a document such as this and when accurate information is required it should be obtained from the literature recommended in Selected Reading, (Appendix 1) or, in the case of freezing times, pilot scale laboratory tests

Freezing temperature of fish	about -1°C
	55% frozen at -2.2°C
	70% frozen at -5.0°C

Table 30 Heat to be removed when freezing white fish (kcal/kg)

Initial temperature	Final temperature	
(°C)	-30°C	-18°C
40	107.7	100.9
30	98.8	92.0
20	90.1	8.3
15	85.7	78.9
10	81.3	74.5
5	76.9	70.1

$\Rightarrow \Delta H = \text{calor requerido a extraer}$

Specific heat and heat content of a fish (See Table 31 and Figure 49)

Table 31 The enthalpy and specific heat

Temperature (°C)	Enthalpy datum -40 °C (kcal/kg)	Specific heat (kcal/kg °C)
-40	0.00	0.44

-36	1.77	0.45
-32	3.60	0.47
-28	5.55	0.51
-24	7.67	0.55
-20	10.03	0.62
-16	12.69	0.72
-14	14.18	0.78
-12	15.84	0.87
-10	17.73	1.01
-8	19.99	1.27
-6	23.01	1.85
-4	28.05	3.61
-3	32.70	6.34
-2	42.16	15.68
-1	71.16	24.54
0	77.16	0.99
2	78.90	0.87
4	80.65	0.87
6	82.39	0.87
8	84.14	0.87
10	85.89	0.88
12	87.64	0.88
14	80.39	0.88
16	91.94	0.88
20	94.65	0.88
24	98.17	0.88
28	101.69	0.88
32	105.21	0.88
36	108.73	0.88
40	112.25	0.88

	2.5
Frozen whole fish 30 to 100 cm in length frozen in blocks with allowance for pallets, passageways etc.	2.0
Fillets frozen in large blocks with allowance for pallets, passageways etc.	1.25 to 1.56
Frozen fillets in consumer packs in master carton with allowance for pallets passageways etc.	2.5

Yields from cod

Component	Ungutted weight (%)	Gutted weight (%)
Head	21	25
Guts	7 (5-8)	
Liver	5 (2-7)	
Roe	4 (1-7)	
Backbone	14	1
Fins and belly flaps	10	12
Skin	3	4
Fillets, skinned	36	43
Total	100	100



Note: Enthalpy is the heat content of the fish measured above an arbitrary datum of -40°C . The change in enthalpy between 10°C and -30°C will therefore indicate the amount of heat that has to be removed when freezing fish.

Specific heat is a measure of the heat that has to be added or subtracted to change the temperature of the fish by 1°C . Specific heat of the fish is a combination of sensible heat and latent heat at temperatures below 0°C .

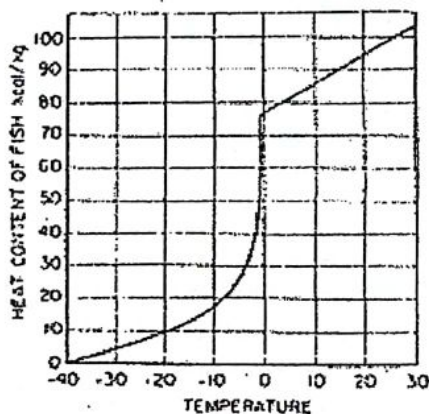


Figure 49 Heat content of lean fish based on a datum of -40°C

Thermal conductivity of fish ($\text{kcal m/h m}^2^{\circ}\text{C}$)

Unfrozen white fish at 0°C 0.37 to 0.5

Frozen white fish at -1°C 1.12 to 1.49

Frozen white fish at -30°C 1.61

Density of white fish muscle (kg/m^3)

at 0°C 1 054 at -20°C 966

Specific heat of white fish (kcal/kg deg C)

Unfrozen 0.9

Frozen 0.4

Stowage rates for frozen fish

densidad de carga en cámara

	(m^3/t)
Whole round fish 25 to 30 cm in length frozen in blocks	1.2
Whole round fish 30 to 100 cm in length frozen in blocks	1.02 to 1.12
Frozen whole fish 30 to 100 cm in length stored as single fish	2.08 to

Table 26 Horizontal plate freezers Average net weight of product per station (kg)

Product and thickness (mm)		Standard plate dimensions (mm)		
		1 550 x 820	1 550 x 1 120	1 930 x 1 120
Whole fish	50	45	59	71
	75	68	88	106
Fish fillet	50	59	77	95
	75	88	116	143

kg/PLaca

Table 28 Horizontal plate freezer -approximate freezing times (Pump circulating system evaporating at -34°C)

Product	Product thickness and freezing times			
	50 mm	62 mm	76 mm	100 mm
Fish fillets	60 min	75 min	105 min	165 min
Whole fish	75 min	90 min	120 min	180 min
Herring/Sprat	60 min	75 min	110 min	170 min
Shrimps in cartons	90 min	135 min	160 min	230 min

Table 31 Horizontal plate freezer refrigeration requirements

Product	Refrigeration requirement (kcal/kg of product)
Fish fillets in trays, 50 mm thick	117
Whole fish in trays, 75 mm thick	105
Prawns in cartons in trays 63 mm thick	103

Horizontal plate freezers

Table 25 Horizontal plate freezer-plate sizes and openings

No. of stations (placas)	Dimensions (mm)		
	Plate sizes Tamaño	Plate openings	
		(max)	(min)
5	1 550 x 820	108	38
6	"	95	38
7	"	90	38
8	"	108	38
8	1 550 x 1 120	108	38
9	1 550 x 820	100	38
9	1 550 x 1 120	100	38
10	1 550 x 820	94	38
10	1 550 x 1 120	94	38
11	"	89	38
12	"	102	38
12	1 930 x 1 120	102	38
13	1 550 x 1 120	90	32
13	1 930 x 1 120	90	32
14	1 550 x 1 120	83	32
14	1 930 x 1 120	83	32
15	1 550 x 1 120	90	32
15	1 930 x 1 120	90	32
16	"	86	32
17	"	82	32
18	"	79	32
19	"	75	32
20	"	70	32

Abertura entre placas.

Table 32 Cost of horizontal plate freezers .

Description	No. of stations	Plate size (mm)	Cost (US\$)
Freezer only	5	1 550 x 820	14 250
Freezer only	20	1 930 x 1 120	27 750
Self-contained unit including refrigeration	5	1 550 x 820	28 500
Self-contained unit including refrigeration	7	1 550 x 1 120	32 250

Selection:

Before any selection can be made, basic information must be established

- i. Quantity of frozen product required per day
- ii. Thickness of product
- iii. Nature of product
- iv. The refrigeration system to be used

The number of cycles per day is:

$$\frac{\text{Operating time / day}}{\text{Freezing time} + \text{loading / unloading time}}$$

When selecting horizontal freezers for 24-h operation, allow 1-2 h less for defrost and cleaning.

The weight of product to be frozen during each cycle:

$$\frac{\text{Total daily throughput}}{\text{Number of cycles / day}}$$

The number of stations required:

$$\frac{\text{Weight of product frozen / cycle}}{\text{Weight load / station}}$$

The nearest whole number is taken. Should this figure be above the maximum available, divide so that suitable equally stationed freezers can be selected.

Refrigeration capacity:

Calculate the total heat content of the product and add 20%.

Refrigeration capacity required:

$$\frac{\text{Total heat / kg} \times \text{weight in freezer}}{\text{Freezing time}} \times 1.2$$

Glazing

Table 41 Heat added and equilibrium temperature after glazing (initial fish equilibrium temperature -30°C)

Glaze (%)	Equilibrium temperature (°C)	Heat added (kcal/kg fish)
1	-28	1.0
2	-26	2.0
4	-23	3.9
6	-20	5.8
10	-14.7	9.6
15	-9.6	14.8
20	-6.3	19.6

Air-blast freezers

Floor area:

The floor area required for a freezer will obviously depend on its freezing capacity, but it also depends on the type of the freezer and the product to be frozen.

Bigger freezers tend to use space more economically as can be seen from the following examples of batch freezers for freezing trays of fish on trolleys:

Capacity (kg/h)	Floor space (m ²)
100	10
1 000	50

A slow freezing product will require a larger freezer than a faster product and this is illustrated by the following comparison:

Freezer	Capacity (kg/h)	Freezing time (h)	Freezer load (kg)
A	100	1	100
B	100	2	200

Both freezers have the same capacity, but due to the longer freezing time in B, the freezer requires to hold double the load of freezer A which will be loaded and emptied twice during the two hour period.

A comparison is made between the floor area requirements of different types of air-blast freezer in Table 23. All freezers have a capacity for freezing 700 kg/h of IQF fillets.

Table 23 Floor space requirement of air-blast freezers

Type of freezer		Floor area (m ²)
Continuous in-line freezer,	10 m/s air speed	215
Continuous in-line freezer,	5 m/s air speed	260
Batch freezer,	5 m/s air speed	85
Continuous spiral freezer,	5 m/s air speed	100
Fluidized bed freezer <u>a/</u>		170