Gefrierzeiten Für Kartons Des Knochenlosen Fleisches in Automatischen Luftblasengefrierern

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Der grösste Teil des knochenlosen Rindfleisches, das aus Australien exportiert wird, wird in Kunststoffüberzügen umhüllt, in etwa 25 kg Fleisch fassenden Faserplattenkartons verpackt und zu - 18°C oder unter gefroren. Die automatischen Luftblasengefrierer sind für das Gefrieren in Kartons allgemein genommen worden und es gibt ekonomische Vorteile bezüglich der Konstruktion dieses Gefrierertypes, die ermöglichen, Fleischkartons zu - 12°C in 24 Stunden zum Gefrieren zu bringen.

Teste in Handelsgefrierern haben gezeigt, dass experimentelle Gefrierzeiten mit denen, die vom Nomogram vorhergesagt wurden, nicht übereinstimmten. Solches Nomogram wird für die Konstruktion der Gefrierer weitgehend benutzt. Es war im Stande Veränderungen der Luftgeschwindigkeit, Temperatur und Kartonhöhe zu berücksichtigen, aber es ist festgestellt worden, dass andere Faktoren - wie die Lage des Kartons im Regal, die Kartoninhalt und der Kartontyp - die Gefrierzeiten bedeutsam beeinflussen. Auf experimentellen Beobachtungen basierte Korrekturen werden angegeben und diese werden die obengenannten Faktoren in Betracht ziehen, wenn sie aus dem Nomogram berechneten Gefrierzeiten beigefügt werden.

Freezing times for cartons of boneless meat in automatic air blast freezers

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Most of the boneless beef exported from Australia is wrapped in plastic film, packed in fibre board cartons holding about 27 kg of meat and frozen to minus 18°C or lower. The automatic air blast freezer has become generally accepted for carton freezing, and there are economic advantages in designing such freezers to enable cartons to be frozen to minus 12°C in 24 hours.

Tests in commercial freezers showed that experimental freezer times did not agree with freezing times predicted from a nomogram which is widely used for freezer design. The nomogram was successful in taking account of changes in air velocity and temperature and carton depth, but other factors such as position of carton on shelf, carton contents, and type of carton were found to significantly affect freezing times. Corrections, based on experimental observations, are given, which when added to freezing times calculated from the nomogram, will take these factors into account.

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Les Temps de Congélation Pour des Cartons de Viande Désossée Dans Les Congélateurs à L'air Froid Automatiques

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La plupart de la viande de boeuf désossée exportée de l'Australie est soigneusement conservée dans une enveloppe fine en matière plastique, emballée dans des cartons de fibre de bois pouvant contenir approximativement 27 kg de viande, et congelée à - 18°C ou au-dessous. Le congélateur à l'air froid automatique est généralement accepté pour la congélation en cartons et il y a des avantages économiques attachés à la construction de ce type de congélateur qui facilitent la congélation des cartons de viande à - 12°C en 24 heures.

Des essais relatifs aux congélateurs commerciaux ont montré que les temps de congélation experimentés ne correspondaient pas aux temps de congélation prédits par le nomogramme qui est largement utilisé pour la construction des congélateurs. Le nomogramme a pu tenir compte avec succès de changements de la vélocité de l'air, de la température et de la hauteur du carton, mais il a été constaté que d'autres facteurs, tels que la position du carton sur le rayon, le contenu du carton et le type de carton, affectent d'une manière significative les temps de congélation. C'est pourquoi des corrections basées sur des observations expérimentales sont fournies et celles-ci tiendront compte des facteurs mentionnés ci-dessus quand elles seront ajoutées aux temps de congélation calculés à partir du nomogramme.

Время замораживания картонов с бескостным мясом в автоматических воздуходувных морозилках

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Наибольшая часть бескостной говядины экспортированной из Австралии завернута в тонкие пластические листы, упакована в фибролитные картоны содержащие около 27 кг мяса, и заморожена до -18° или ниже. Автоматическая воздуходувная морозилка широко принята для замораживания картонов, поэтому конструкция таких морозилок позволяющих замораживать картоны до -12° за 24ч., представляет экономические выгоды.
Опыты проведенные в промышленных морозилках показали, что экспериментально полученное время замораживания не соответствовало времени замораживания предсказанным номограммой широко употребляемой для проектирования морозилок. Номограмма была успешна для учета изменений скорости воздуха, температуры и глубины картона, но было выявлено, что другие факторы, как например положение картона на стеллаже, содержание картона и тип картона, значительно влияют на время замораживания. Приведены поправки основанные на экспериментальных наблюдениях, поправки которые учтут эти факторы, если их прибавить к времени замораживания вычесленного по номограмме.

Freezing Times for Boneless Meat in Cartons in Automatic Air Blast Freezers

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Introduction

In the ten years from 1967 to 1977 meat exports from Australia almost tripled, from 360 000 tonnes to 1 million tonnes. Almost all exported meat is boned out, packed in cartons and frozen. Large tonnages go to North America where there is a continuing demand for lean meat for manufacturing purposes.

Primal cuts or meat pieces from chilled sheep and beef carcasses are wrapped in polythene film and packed into fibreboard cartons, each of which contain about 27 kg of meat. Cartons are frozen and stored at or below minus 18°C during subsequent transport and storage. An export abattoir with a kill of 600 cattle daily would pack and freeze 3500 cartons each day. At these rates of production, the high capital cost of an automated freezer can readily be justified by savings in labour and operating costs (1).

Leading manufacturers of refrigeration equipment in Australia developed successful automatic air blast freezers during the 1960's, following the original design of Freeman (2) in New Zealand. Many of the 100 or so Australian export abattoirs have already installed these freezers in sizes up to 10 000 cartons capacity, and more are to be installed in future programmes for expansion and for new works.

Plant Description

Automatic air blast freezers (AABFs) freeze cartons of meat in a tunnel in which fans circulate cold air at high velocity over cartons stacked side by side in rows on the shelves of carton carriers. Shelves are generally of ribbed construction, allowing air to flow under cartons, as well as over their tops, and along their ends. The number of cartons on each shelf, the number of shelves per carrier, and the number of carriers that can be accommodated in the tunnel determine the capacity of the freezer.

In the following description of plant operation, the tunnel is assumed to be filled with fully loaded carriers which have been in the tunnel for the desired freezing period.

A carrier filled with frozen cartons is pushed by hydraulic ram from the lower deck of the tunnel into the loading annex (fig. 1). Frozen cartons on the top shelf are pushed out and the shelf is reloaded with unfrozen cartons. The loading/unloading step may be effected automatically, manually, or by automatic unloading with manual loading. With the top shelf re-filled, the carrier rises to bring the next shelf into the loading position and shelves are unloaded and re-loaded consecutively until the carrier is full of unfrozen cartons. It has now risen to the level of the top deck and hydraulic rams push it into the tunnel, moving along all carriers in the top deck and displacing one into the transfer annex. This carrier is moved down and pushed into the lower deck of the tunnel. It displaces a fully frozen carrier into the loading annex and the operating cycle recommences. The movement of carriers on the upper deck is away from the loading annex, and on the lower deck, towards the loading annex.

A typical tunnel, shown diagramatically in Fig. 1, has a capacity of 3024 cartons, is 18 300 long 3400 high and 8000 wide (all dimensions are in mm) and holds 56 carriers, 28 on the upper and 28 on the lower deck. Each carrier is 3658 long and of rectangular cross section 710 wide x 1514 high. The front and back are open, but the sides are enclosed with steel sheets. Each carrier has 6 shelves, each shelf holding 9 cartons. Carton dimensions are 580 long x 380 wide x 150 high and when 9 cartons are pressed side by side with their long axes across the shelf, the carton stack measures 3420 long, 580 wide and 150 high on a shelf 3658 long, 710 wide and 252 high. This loading gives air passages 710 wide x 102 high between the tops of the cartons on one shelf and the bottoms of the cartons on the shelf above, and 65 wide x 150 high between the ends of the cartons and the sides of the carriers. Evaporators and fans are accommodated between one side of the carrier stack and one of the long outer walls of the freezer. Air circulates over the cartons in upper deck carriers into the fan suction and air delivered from the fans reverses in direction and passes through evaporator coils at lower deck level where it is cooled before passing over cartons in lower deck carriers. Air flow again reverses as it emerges from the lower deck, and then passes through the upper deck carriers back to the fans. Air velocity over the tops of cartons is typically 5 to 6 m/s, and air temperature minus 30°C to minus 40°C.

General Design Factors

The AABF is a fairly recent development and a standard design has not evolved. While retaining the basic principle, freezers exhibit substantial differences in detail design, such as in sizes and method of construction of carriers and shelves, and in size and location of fans and evaporator coils. In addition, the types and sizes of cartons used and carton contents vary from works to works and from day to day (sometimes from minute to minute) as do operating factors, such as production and loading rates, ability to maintain refrigerant temperatures, defrosting method, and frequency.

Freezing Time

If a freezing time of 24 h can be achieved, the tunnel can be designed to hold one day's production of cartoned meat. Cartons loaded one day can be unloaded the next day and put into cold store. For freezing times greater than 24 h, the tunnel must hold more than one day's production. If, for example loading time is 8 h and freezing time is between 32 and 48 h, the tunnel must be designed to hold 2 days' production. In this case, all cartons would be in the tunnel for 48 h and cold air circulation could be adjusted to give a 48 h freezing time. For freezing times between 24 and 32 h, tunnel size need not be increased to hold 2 days' production, for example, for 28 h freezing time, it need only hold 1½ days' production. However, air conditions must then be maintained to suit the 28 h freezing time, and half the daily production would be held for longer than 28 h and so would be frozen to lower than specified temperatures.

When freezing times are longer than 24 h, higher capital and operating costs are incurred for the larger tunnel. While refrigeration costs may be decreased, many works managers see economic advantage in a 24 h cycle, and several 24 h freezers have been supplied.

Prediction of Freezing Times

A nomogram published by CSIRO in 1968 appears to be widely used in Australia and elsewhere (4) to predict freezing times. This nomogram, recalculated in SI units, appears in Fig. 2. It derives from the pioneering work of Earle (3) who established that the following modification of Plank's equation for freezing of large flat slabs satisfactorily correlated freezing times for cartons of meat frozen under his experimental conditions.

$$T = \frac{L}{3600 \times \Delta t} \times \frac{10}{7} \left(P\frac{a}{h} + R\frac{a^2}{k} \right)$$

where
T = freezing time, h
L = latent heat of fusion of meat, J/m^3
Δt = temperature difference, air to meat freezing point, ^oC
a = carton thickness, m
h = heat transfer coefficient, $W/m^2\ ^oC$
k = thermal conductivity of meat, $W/m\ ^oC$
P and R = shape factors

For boneless lean meat, L has a value of $280 \times 10^6\ J/m^3$

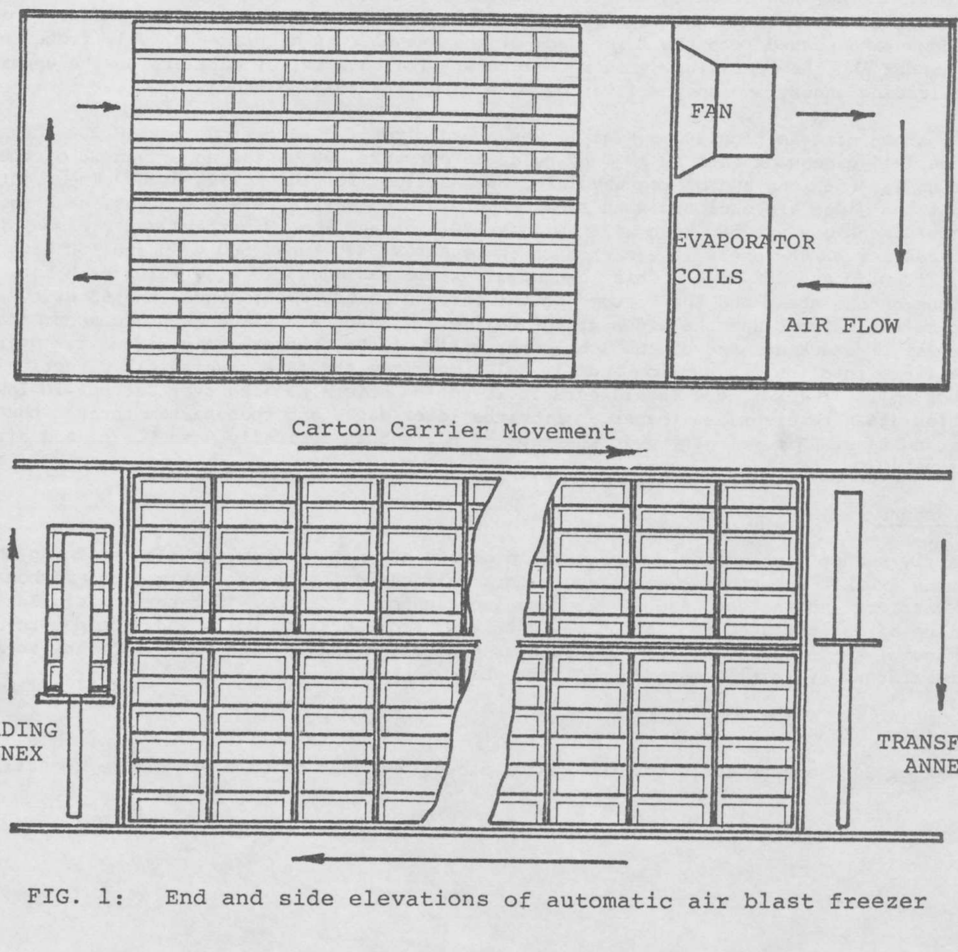

FIG. 1: End and side elevations of automatic air blast freezer

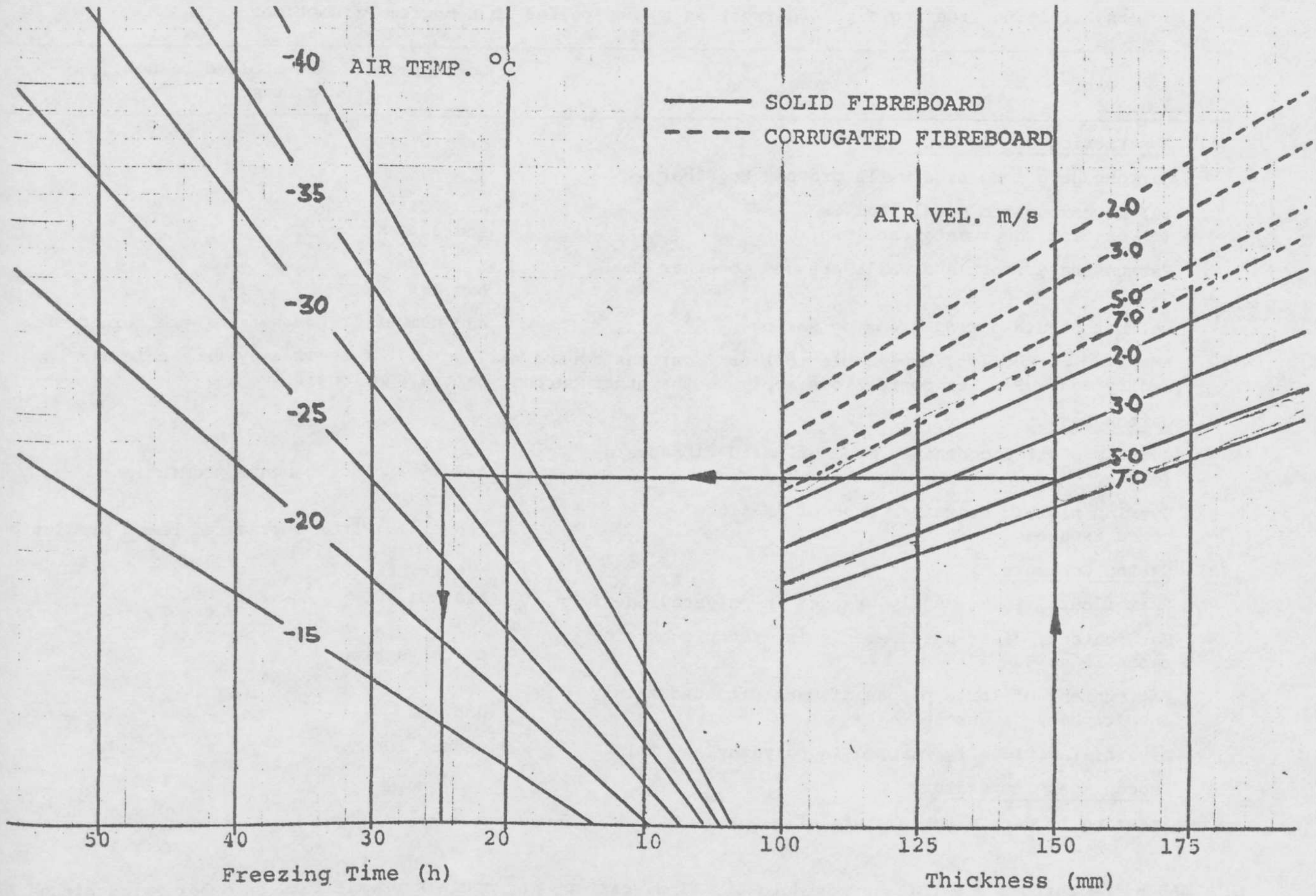

FIG. 2: **Effect of Carton Thickness, Air Velocity & Air Temperature on Freezing Time**

While Plan k's equation may be expected to take account of changes in air velocity, air temperature, carton material and contents thickness, the Earle modification may not be sufficiently accurate to predict freezing times of cartons under conditions existing in commercial AABFs.

Performance of AABFs

To the authors' knowledge, no information has been published on the accuracy of the CSIRO nomogram in predicting freezing times in practical applications in Australia, and only one short paper by Freeman and Earle (5) gives any information on New Zealand installations. It has long been suspected that AABFs designed on the basis of 24 h freezing time have not performed to specification and the Process Investigation Section of CSIRO Meat Research Laboratory was asked to check the performance of one such unit. Tests were subsequently conducted in units at other abattoirs. In the most extensive tests, on a 4000 carton capacity unit, thermocouples were placed in 102 cartons and in 35 other locations to measure meat and air temperatures during a 60 h freezing period. Air velocities were measured over tops and sides of cartons in several parts of the freezer.

Carton centre temperatures gave the expected temperature/time histories - a rapid fall to the freezing plateau at about minus 1°C, then after several hours on the plateau, a rapid fall towards air temperature. Freezing time was taken as the time required for centre temperature to fall to minus 12°C, thereby minimising the possibility of error due to the thermocouple not being placed precisely in the thermodynamic centre of the carton. Air temperatures varied during the test and a time averaged value was taken for subsequent analysis. A description of test work and experimental methods appears elsewhere (6).

Corrections to Predicted Freezing Times

The CSIRO nomogram satisfactorily predicts freezing times under the following conditions:

Carton contents are 27 kg meat pieces, wrapped in polyethylene film.

Contents are frozen from an average meat temperature of 10°C to minus 12°C.

All carton surfaces are exposed to air flow.

Solid fibreboard cartons (7) are box and lid design, board specification 244/117-488/2*.

Corrugated fibreboard cartons (8) are overlap slotted container (OSC) design, board specification 293/293-117/1 (B Flute).

* Specification key: outside liner/inside liner - filler/number of filler plys; board weights in g/m^2.

Table 1

Factors Affecting Freezing Time & Correction to be Applied to Nomogram Predictions

Factor	Corrections to be applied to nomogram freezing time
(1) Restriction of Air Flow	
Cartons have long side walls pressed together -	
(a) on corrugated metal shelves	Add 20%*
(b) on flat sheet metal shelves	Add 30%*
Cartons have short end walls pressed together on corrugated metal shelf	Add 15%
Defrost occurs during freezing period	Add number of hours fans were turned off
*Maximum correction, applicable to 1 or 2 cartons toward the end of the shelf away from cold air entry end. Smaller corrections apply to the other cartons on the same shelf.	
(2) Carton Design	
Overlap slotted container made of solid fibreboard is used	Add 15% to solid board prediction
Overlap slotted container made of 'E-flute' board is used	Deduct 15% from corrugated board prediction
(3) Carton Contents	
Primal cuts, individually wrapped in polyethylene film	Add 10%
Fat content, distributed evenly in meat pieces, in range 15 to 30%	No correction
Fat content of large pieces of meat situated mainly on periphery of carton	Add 10%
Livers, individually wrapped in polyethylene film	Deduct 10%
(4) Frozen Meat Temperature	
Freezing to centre temperature of minus 12°C	Add 5%

In AABFs, no cartons are fully exposed to air flow, cartons may contain primal cuts or other large pieces of meat, and carton design and fibreboard specifications may not be those assumed in the nomogram. These and other known factors influencing actual freezing times are listed in Table 1, and approximate corrections to predicted freezing times based on experimental measurements are given.

In addition to corrections in Table 1, other aspects of plant design and construction may influence freezing times. Air conditions over most of the cartons in a given freezer are reasonably constant but substantial variations in air velocity have been observed in some locations. Typical causes are obstruction of air flow by structural members, and bypassing of air flow on shelves at the loading and transfer ends of the tunnel. A thorough survey of air velocities and temperatures would be required to establish whether such factors exist.

Experimentally-determined freezing times, averaged for a number of cartons under the same conditions of freezing, were found to be within 3 h of freezing time predicted from the nomogram and corrections in Table 1. Freezing times for individual cartons can be up to 4 h different to corrected predicted times.

References

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