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TITLE SLURRY ICE BASED FOOD CHILLING APPLICATIONS

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Synopsis

Environmental concerns over the ozone depletion potential of some CFCs used today have prompted a search for alternative cooling technologies. A number of Dynamic and Static ice production methods have been developed for various applications.

Slurry ice technology is the latest addition to other existing ice production techniques and it has the potential to achieve considerable environmental as well as economic benefits for both central cooling systems and direct ice production for ever expanding ice applications. Any conventional primary refrigerants can be used for slurry ice production.

The cooling capacity of slurry ice can be four to six times higher than that of conventional chilled water, depending on the ice fraction. The nature of the Binary (Crystal) ice formation allows end users to pump the ice and there are many slurry ice-based cooling systems operating around the world. Most air conditioning installations are based on ice storage, where the warm return water is used to melt the ice when required. Slurry ice is also circulated in close loop distribution systems directly for process and product chilling applications.

This paper investigates the advantages and disadvantages of using slurry ice food chilling applications. The most important physical properties and characteristics for Food Grade pumpable ice solution are presented in a form that will help food engineers and consultants to develop effective and efficient Slurry-Ice based Food Chilling system designs.

Keywords;

CFC - Chloro Fluoro Carbon, (TES) Thermal Energy Storage, Slurry-ICE, Binary-ICE, Liquid-ICE, FoodICE

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1.0 - INTRODUCTION

Society's reliance on food cooling technology ranges from domestic refrigerators, to full production of all types of fresh and frozen food production. As a result, modern refrigeration technologies together with a wide range in food processing and preservation infrastructures have evolved around wide spread usage of refrigeration.

Direct or indirect ice usage has also expanded over the years to reduce operational costs and improve food quality and therefore many type of Dynamic and Static ice production methods have been developed for various food chilling applications.

It is vital to establish a balance between "energy consumption" and "environment protection" and therefore any change in refrigeration technology by means of introducing new refrigerants or by adopting new techniques must be carefully balanced to reduce the overall environmental impact.

Environmental concerns over the ozone depletion potential of some CFCs used today have prompted a search for alternative cooling technologies. Slurry ice technology is the latest addition to other existing ice production techniques and it has the potential to achieve considerable environmental as well as economic benefits for direct ice production forever expanding ice applications.

Any conventional primary including natural refrigerants can be used for slurry ice production. The cooling capacity of slurry ice can be four to six times higher than that of conventional chilled water, depending on the ice fraction.

There are many slurry ice-based cooling systems operating around the world and most air conditioning installations are based on ice storage, where the warm return water is used to melt the ice. Slurry ice is also circulated in close loop distribution systems directly for process, district and product cooling applications.

2.0 CURRENT ICE PRODUCTION TECHNOLOGIES

Ice production techniques can be divided into two main groups ⁽¹⁾ namely *Dynamic* and *Static* systems, Table 2.1, and the produced ice can be used either *directly* to chill the product such as fish, vegetables, meat, poultry etc. or indirectly as secondary coolant for the latent heat cooling effect such as ice storage TES systems for air conditioning and process cooling as a secondary cooling medium.

STATIC ICE PRODUCTION	DYNAMIC ICE PRODUCTION
1 - Ice Builders	1 - Plate Harvester
2 - Ice Banks	2 - Tube Harvester
3 - Encapsulated Ice Modules	3 - Flake Ice Machines
a) Balls	4 - Binary Ice Machines
b) Flat Containers	

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Table 2. 1 - Current Ice Production Technology

3 - SLURRY ICE TECHNOLOGY

Slurry-ICE is a suspension of a crystallised water-based ice solution and the icy slurry can be pumped, hence, it is also called "*Binary-ICE*", "*Liquid-ICE*" or "*Pumpable-ICE*" ⁽²⁾. The handling characteristics, as well as the cooling capacities can be matched to suit any application by means of simply adjusting the percentage of ice concentration.

Slurry-Ice comprises microscopic ice crystals giving a total surface area for heat exchanging that is very large in comparison with the conventional ice chilling concept and therefore ice instantly melts to meet the varying product cooling load. This ensures steady and accurate product final temperature control ⁽³⁾.

3.2 SLURRY ICE APPLICATIONS FOR FOOD PROCESSING

The important benefit of slurry ice is the "<u>rapid cooling capacity</u>" compared with air blast and conventional ice / chilled water cooling systems. Hence, it offers significantly reduced cooling times ⁽⁴⁾. Slurry-ICE systems not only offer superior cooling performance and a significant installation cost reduction but the food chilling operating costs can also be reduced due to increased production rates for a given food processing application.

Sea water or alternatively brine solutions are the most commonly used SlurryICE production techniques within the sea food industry ⁽⁵⁾ but they can not be applied for other food chilling applications due to undesirable taste and visual impacts. Hence, the majority of Binary ice applications remain in sea food application with the exception of the poultry and meat industry which is utilised by means of relatively expensive harvester tank arrangements to reduce the salt concentration.

The main criteria for a pumpable food ice application are taste and visual impact of the final product. Hence, the solution MUST not affect taste or appearance. Even a low salt concentration may spoil the food product and when the product is dried some salt based solution leave an undesirable white residue.

Further to extensive research of the commonly used food additives, author has identified a number of potential freeze depressants for pumpable ice production which can be used on food products and a general list of these additives can be found in Table 1. However, further research had to be carried out to establish ideal combinations of these chemicals to form a physically and thermodynamically acceptable SlurryICE solution from the available ice slurry production machinery and their officially acceptable limits as a food additive for the food production point of views.

The main criteria for NO TASTE and NO VISUAL IMPACT remained the main target for this search and following various combination of these fluids, author managed to test and produce satisfactory freeze depressant combination out of the enclosed list to satisfy all the

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criteria mentioned above.

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 $Table\ 1-Food\ Additives\ for\ SlurryICE\ Applications$

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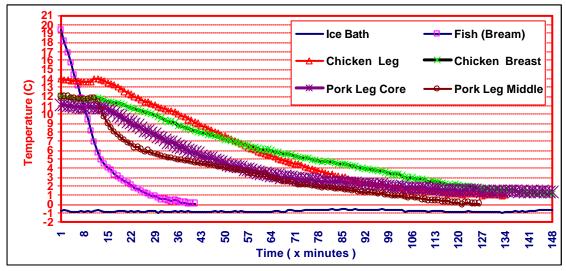
However, freeze depressants can be considered as the first hurdle towards the conquest of a satisfactory pumpable ice solution for food application. Majority of these chemicals causes excessive corrosion problems and the low concentration levels for food application expose the solution to bacterial growth. Hence, it is vital to provide satisfactory Corrosion Inhibitor and Biocide combinations to pass strict food hygiene regulations. Some of the commonly used corrosion inhibitors and biocides are not acceptable for food production or they may cause operational problems for the ice production machine as well as the quality of the pumpable ice solution.

Following extensive tests, an acceptable combination of *FREEZE DEPRESSENT*, *CORROSION INHIBITOR* and *BIOCIDE* mixture has been established to satisfy all the criteria set above. For simplicity, this solution is referred to as FoodICE solution as part of this paper and the thermodynamic and physical properties are included in Table 2.

Temp deg C	Density kg/m³	Kinematic Viscosity mm²/s	Dynamic Viscosity mPas	Specific Heat kJ/kg K	Thermal Conductivity W/m K
30	1031	0.84	0.87	3.977	0.612
25	1032	0.93	0.96	3.969	0.604
20	1033	1.05	1.08	3.960	0.595
15	1034	1.18	1.22	3.951	0.586
10	1035	1.36	1.40	3.942	0.577
5	1036	1.57	1.63	3.933	0.567
0	1037	1.81	1.88	3.924	0.559
-1.5	1037.3	1.91	1.98	3.921	0.556

Table 2 – FoodICE Physical Properties

Majority of the food chilling applications remains above -2 °C, which is considered to be the limit before frost damage. The above solution is used for food chilling testing for various types of food chilling applications and the relevant cooling curves can be seen in Figure 3.2.1, Figure 3.2.2 and Figure 3.2.3 for meat, vegetable and fruit cooling applications respectively.



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Figure 3.2.1 – Meat Cooling Test using FoodICE solution.

Figure 3.2.2 – Vegetable Cooling Test using FoodICE solution.

Time (x minutes)

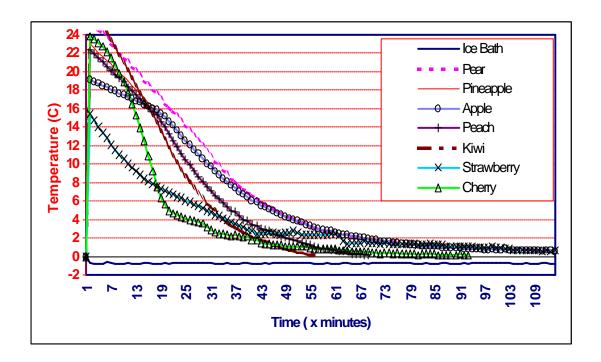


Figure 3.2.3 – Fruit Cooling Test using FoodICE solution.

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Test results indicate significantly reduced cooling times and superior product quality in comparison with conventional techniques. The shelf life of these products is also significantly increased due to the rapid cooling effect.

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4- CONCLUSION

There are many type of slurry ice production machinery operating around the world and a slurry ice rapid food cooling system can provide all the benefits offered by conventional ice /chilled water cooling technologies with additional benefits;

- Hygienic Systems
- Quick Response
- Reduced Equipment Size
- Capital Cost Saving
- Energy Cost Saving
- Energy Saving
- Improved System Operation
- Flexibility for the Future Capacities

Moreover, the pumpable characteristic over any other type of ice production system offers efficient compact equipment design, flexibility of location of storage tank(s) and the most economical capacity and duty balancing for any given food chilling application ⁽⁶⁾.

Storage tank(s) can be placed: under, beside, inside, or on top of a building and can be any shape or size to match building and architectural requirements.

FoodICE is a very versatile cooling medium. The handling characteristics, along with the cooling capacities can be matched to suit any application by means of simply adjusting the percentage of ice concentration.

As they are microscopic the ice crystals melt quickly to meet varying cooling loads instantly.

FoodICE not only offers higher efficiency and cost effective ice production but also its unique pumping and easy handling characteristics provide totally sealed "Hygienic Systems", increased production, flexibility of operating temperature and consistency of application, for optimum results.

Direct contact pumpable ice chills faster, providing instant protection, maintaining freshness and preserving colour. The tightly packed pumpable ice inhibits air entraintment, which is the main cause for causes premature ice melting as in the case of solid ice for transport and storage applications. Hence, **FoodICE** lasts longer in comparison with solid ice.

The challenge for designers and food manufacturers is to explore the possibility of every alternative design solutions, which can minimise the use of energy for the refrigeration system. A FoodICE based cooling systems may be the answer for many food chilling applications for an Environmentally Friendly and Economical alternative.

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