BC Centre for Disease Control
An agency of the Provincial Health Services Authority

Environmental Health Services

Food Issue

Notes from the Field

Safety of novel use of liquid nitrogen and dry ice in the food and beverage industry

Request received from:	Health Authority
Date of request:	Date: April 12, 2017
Issue *(brief description)*:	Review risks and safety of preparation and serving of cereal dipped in liquid nitrogen to produce a fog-like effect called "dragon's breath"

Disclaimer: The information provided in this document is based on the judgement of BCCDC's Environmental Health Services Food Safety Specialists and represents our knowledge at the time of the request.
It has not been peer-reviewed and is not comprehensive.

Summary of search information:

1. Articles were identified by Medline and Cinahl (Ebsco) and Google Scholar. Emphasis was placed on scientific literature review, although grey literature was also included.
2. Search Terms: Variants and Boolean operator combinations of ("Liquid nitrogen" OR nitrogen OR "dry ice") AND (consumption OR consume OR ingest OR ingestion) AND (risk OR contaminat* OR residue OR evaporat* OR illness OR danger OR effect OR perforation OR barotrauma OR "stomach rupture" OR "stomach injury" OR "stomach injuries" OR pneumoperitoneum OR "gas expansion") (Alcohol OR "alcoholic drink" OR "ice cream" OR drink OR food OR frozen OR cereal OR vegetable OR fruit)

Background information:

Liquid Nitrogen:

Liquid nitrogen (N2) is an inert, colorless, clear, liquid, produced by fractional distillation of liquid air. With a boiling point of -196°C, it can be maintained in a liquid state only at very low temperatures. At room temperatures, nitrogen is a gas and needs high pressures to be maintained in a liquid state. This property allows even small quantities of liquid nitrogen to expand to large volumes of gaseous nitrogen (1:700) at room temperatures. The released vapors tend to produce a visible fog-effect due to condensation of the moisture in ambient air. Liquid nitrogen is usually stored in non-pressurized liquid Dewar flasks, fitted with loose fitting caps and pressurized liquid cylinders depending on the setting of their use (example containers shown in Figure 1).[1]

https://www.coleparmer.ca/p/worthington-aka-taylor-wharton-cryogenic-storage- dewars/58575

http://www.tedpella.com/cryo-supplies_html/cryo-dewar.htm

Figure 1. Examples of dewar storage containers for liquid nitrogen

The above mentioned properties i.e. low temperature, lack of toxicity and flammability, make liquid nitrogen ideal for cooling and freezing and thus liquid nitrogen has found its way into a very diverse range of industries: including aerospace, automobile, chemical manufacturing, energy, pharmaceutical, food and beverage and healthcare.[2,3]

Liquid nitrogen has long been in use in the food industry for chilling and freezing food prior to packaging the final product. Traditionally, snack processors used gas flush systems to reduce the oxygen content of the foods to prevent them from becoming rancid prior to packaging. These systems had long tunnels which took up floor space and were difficult to clean in the event of spillage. Use of liquid nitrogen in food packaging has eliminated the need for such gas flushing tunnels and has reduced packaging time.[4]. Use of liquid nitrogen in spice grinding improved the final product, by retaining the volatile oils and flavour in spices ground using cryogenic grinders.[2] It reduces microbial contamination by eliminating heat generation in the production process and reducing oxygen content in the final packaged product. [2,5] According to Chris Johnson, a commercial technology specialist from Air products, newer applications of liquid nitrogen technology in food industry include injection cooling of meat and sauces, which reduce production time as well as bacterial contamination by eliminating heat and oxygen during processing, while at the same time, providing consistent and even meat cuts. It is also used for food surface cooling thus enabling better product layering. Machine component cooling with liquid nitrogen is reported to decrease product build up, allow easier clean up and prevent mold growth.[5]

A review of the literature has identified the use of liquid nitrogen in the following areas of the food industry:

1. Chilling and packaging of food including meat, vegetables and fruits [5-8]
2. Meat grinding and production of meat burgers, nuggets etc.[5]
3. Manufacturing of spices, condiments and rice flour[2,9,10]
4. Beer canning [11]
5. Chilling of sauces, gravies, marinades, custards and purees [5]
6. Ice cream and frozen yoghurt manufacture[5,12-18]
7. Freezing cookie dough[19]

8. Newer trends in use include instant cooling of cocktails at parties, bars and restaurants, preparing instant ice creams from mousse, dragon breath cookies and cereals dipped in liquid nitrogen to create a "cloud" or "smoke" effect. [20-25]

Dry Ice:

Dry ice, which is a solid form of carbon dioxide, is yet another cooling agent often used in the food and beverage industry requiring careful handling.

Figure 2. Dry Ice
https://www.thoughtco.com/why-is-dry-ice-dangerous-606401

Dry ice sublimates at -78.5°C, which means it transforms into vapour state directly from solid state, without an intermediate liquid state. It is not flammable, non-toxic and approved as a food additive .[26] These properties allow dry ice to be used in preserving food, packaging foods like ice cream which needs to be maintained in the frozen state. It can also be used to flash-freeze food, carbonated beverages and ice creams. [27-29] Dry ice blast cleaning method is an innovative process used in food industry to remove stubborn deposits on the processing equipment.[30]

Other areas of dry ice use include the automobile industry, plumbing and theatre productions (for the fog like effect when it sublimates). [29]

What are the risks associated with use of cryogenic products (liquid nitrogen and dry ice), in the food and beverage industry

Food ingredients are traditionally assessed for biological, chemical and physical hazards. Liquid nitrogen is not considered to have human or ecological toxicology effects per sections 11 and 12 of standard Material Safety Data Sheets (MSDS). As both liquid nitrogen and carbon dioxide are non-toxic, these cryogenic products are a concern as a physical hazard and to a lesser degree, biological hazard.

Physical hazard and risk during consumption and handling

CONSUMPTION RISKS: Despite its wide use in many industries, there are few reported injuries associated with the use of liquid nitrogen. Health hazards posed by liquid nitrogen are mainly due to the extreme cold and risk of asphyxiation.[1]

Injuries caused by direct contact with tissues include cold burns of tissues exposed, severe frostbite and even gangrene. Liquid nitrogen pouring over skin, soaking through clothes and leaking through into boots and gloves can be extremely dangerous.[31]. Inhalational injuries include mucosal injury of the airway tracts with risk of mouth ulcers, and perforation of the airway. Exposure to liquid nitrogen can cause asphyxiation due to depletion of oxygen.[32]

The most serious reported incident after inadvertent ingestion of liquid nitrogen has been gastric rupture or perforation. Pollard et al (2013) reported a case of an 18 year old girl with gastric perforation after ingesting an alcoholic drink containing liquid nitrogen.[33]. Similar incidents have been cited in news media in various countries including Malaysia, India and Korea. [23-25,34]

There are also case reports in the literature of gastric rupture and massive pneumoperitoneum, which is the presence of air in the peritoneal cavity, often due to perforation of a hollow viscus, following deliberate ingestion of very small quantities of liquid nitrogen (15-30 ml).[32,35-37]

WORKER RISKS: There have been reported workplace related injuries and even deaths reported in literature when working with liquid nitrogen. These include frostbite on the hands, despite wearing gloves as well as death due to asphyxiation as a result of inhalation of liquid nitrogen vapours. [38-40]

Brief exposures to the skin may not cause harm which is explained by the Leidenfrost effect. This effect is explained by generation of an insulating vapor layer slowing the thermal transfer. An example of Leidenfrost effect from everyday life is water thrown into a very hot frying pan creating dancing droplets skittering on the pan instead of vaporizing. [35] However, such brief exposure to liquid nitrogen can affect delicate tissues such as eyes.[1]

Dry ice is an extremely cold solid and can cause severe frostbite.[41] Improper packaging during transportation and use is known to cause cold injuries.[42,43] Instances of frostbite of esophagus, mouth and oral cavities have also been reported on ingestion of dry ice during chemistry experiments in school as well as during a stage performance involving blowing smoke from dry ice through mouth and nose by keeping dry ice in the floor of the mouth for a long time. [44,45] It has also been reported to cause hypothermic gastric injury and inflammation.[46] Dry ice is an asphyxiant and can cause rapid suffocation. It can lead to central nervous system depression characterized by difficulty in breathing, anxiety and loss of consciousness.[41,46-48] Inadequate ventilation when using, transporting, or storage of dry ice can lead to serious harmful effects and even death due to inhalation of large quantities of carbon dioxide and there have been reports of this in literature.[49,50] Placing dry ice in a glass container with a narrow opening or a closed jar can cause an explosion and injuries due to the shrapnel. This is as a result of expansion in volume of carbon dioxide (one pound of dry ice produces about 250 liters of gaseous carbon dioxide) due to sublimation in the confined space of the glass containers. [51-54]

There are definite worker safety concerns with use of liquid nitrogen and dry ice in food and beverage industry. These have been well highlighted in literature with reported cases as mentioned above as well as other articles on this subject. [2,31]

Biological hazard and food safety risks: Even though liquid nitrogen itself has a low microbial count during production, there is always a risk of contamination during transportation and storage. Liquid nitrogen, if contaminated, can actually become an effective media for preserving fungal and bacterial spores and viruses and in turn, can lead to food-related infections. If the containment vessel is not sanitized, there is a risk of transmission of such food borne illnesses.[55]

Previous guidance on use of cryogenic products (liquid nitrogen and dry ice) in the food and beverage industry from British Columbia

In February 2017, WorkSafeBC published a Risk Advisory on "Liquid nitrogen exposure in food preparation" and classified it as an emerging risk.[56] This advisory emphasises the employers' duty to ensure worker education and training on safe handling, use, storage and disposal of liquid nitrogen along with frequent workplace inspection and up to date policies and procedures to minimize risk. This document can be accessed on WorkSafeBC website using the following link:

https://www.worksafebc.com/en/resources/health-safety/risk-advisory/liquid-nitrogen-exposure-in-food-preparation?lang=en&direct

Previous guidance on use of cryogenic products (liquid nitrogen and dry ice) in the food and beverage industry from elsewhere

There are other guidelines and information on safe use of liquid nitrogen in food and beverage industry published by Ontario Ministry of Labour, Canadian Centre for Occupational Health and Safety and Compressed Gas Association in United States, Government of Manitoba. [1,30,54,57,58]

Balasubramanian (2012) has tabulated the risks, symptoms, precautions and rescue measures associated with exposure to liquid nitrogen in their work on application of cryogenics technology to spice grinding. [2]

Emerging novel practices on the use of cryogenic products (liquid nitrogen and dry ice) in the food and beverage service

Liquid nitrogen use in freezing foods and in presenting artful foods is part of an emerging trend sometimes called molecular gastronomy.[7,59,60] Chefs will use this as an ingredient to rapidly chill glasses, or freeze herbs or other food ingredients, or to create smoke or fog like appearances and special effects in foods and beverages – such as dragon breath cereal. It is most commonly used to rapidly freeze ice-cream.[18,61,62]

Dragon Breath cereal:

Several you-tube videos demonstrate how dragon breath cereal is intended for service. In one video, the person ingesting the cereal does with her mouth closed.[63] She is then reminded to chew with her mouth open to release the dragon breath. This presents two concerns: residual liquid nitrogen could freeze oral tissues or gases formed during chewing and swallowing could expand in the gastric cavity. A

second video shows how the product is intended to be served, in a container that would allow single pieces of the frozen cereal to be removed and eaten one at a time.[64]

Service of foods, beverages and use as a cooling agent:

Liquid nitrogen can be used to rapidly chill cream for ice-cream, or rapidly chill down glassware or other containers for service of foods and beverages. This compound is also used to produce smoke and fog effects. **The main control point is that it is the responsibility of the premises operators to absolutely ensure no food or beverage product with residual liquid nitrogen is served to the consumer to avoid the possibility of liquid nitrogen consumption. A teaspoon (5mL) of liquid nitrogen can expand 700X into a gaseous vapour of 3.5 litres – enough to cause rupture along the gastrointestinal tract (esophagus, stomach or lower) if swallowed. Similar precautions must be taken to avoid consumption of dry ice pellets in beverages or foods.**

Recommendations from BCCDC:

Storage and handling of cryogenics (liquid nitrogen and dry ice) in food industry:

1) Cryogenics should be stored in purpose designed containers specifically for the storage of liquid nitrogen and transferred using appropriate equipment (e.g. Dewar). [58] These products must never be stored in tightly sealed devices or containers.[54]
2) Containment vessels must be clean and sanitized just like all other vessels used in food industry. Liquid nitrogen and dry ice products must be protected from cross-contamination in the food premises environment so potentially harmful micro-organisms are not spread into food sources. Dry ice and liquid nitrogen should be kept covered in non-sealed containers that allow expanding gases to escape.
3) Workers must be provided with appropriate personal protective equipment, including cryogenic gloves and non-absorbent apron, safety goggles and mask when handling these products. Regular food-contact gloves do not protect for exposure to liquid nitrogen. They should be educated about suitable clothing to be used when working with cryogenics.[2,58]
4) The place of storage and use must be well ventilated to avoid risk of asphyxiation injuries and workplace environment should have oxygen monitoring system in place. [2,58]
5) Employers must ensure workers are educated and trained in following the safety guidelines and emergency plan as well as first aid measures outlined by WorkSafeBC and similar organizations regarding safe use of liquid nitrogen and other cryogenics. [58]
6) Transportation of cryogenics must be done with appropriate care. Cryogenic liquid containers should not be moved by rolling them on their lower rim. They should be transported strapped to an appropriate handling device and should always be maintained upright. No passengers should be present in an elevator when transporting the cryogenic containers. [1] Liquid nitrogen is listed under Class 2.2 in Schedule 2 List of Dangerous Goods by Transport Canada and need to be transported as per the Transport Canada regulations for transport of dangerous goods.[65] When

transporting dry ice by rail or road, the containment should be designed to allow release of carbon dioxide to avoid build up pressure and rupture of the containment. [66]

Liquid nitrogen use in Dragon Breath cereals, snacks, and beverages:

7) Food grade liquid nitrogen must be used in food preparation when used as a food ingredient.[3]
8) **There must be no residue of liquid nitrogen in the serving bowl, container, or glass** and no liquid refill should be provided for the patron to handle. [23]
9) Likewise, there must be no possibility that dry-ice pellets in foods or beverages can be consumed. Containers or devices should be used that allow for the dry ice pellets to be segregated, e.g., special straws are available to put a dry ice pellet into, so that the chilling and smoke effects are enjoyed without the possibility of accidentally swallowing the dry ice pellet.
10) For puffs or cereals or snacks dipped into liquid nitrogen, the opening should be narrow to prevent the user from emptying the contents into their hands as this could result in frostbite or cold burns, if there are any residual drops of liquid nitrogen in the packaging. There have been reported incidents of such cold burns reported in the media. A fork or pick utensil should be provided and served with the cereal that allows only one piece of cereal to be picked up at a time [25]
11) Clear instructions should be provided to the end user on how to consume the product and the dangers as well the safety precautions should be clearly outlined.

Additional recommendations:

12) Very little information has been received on how these products are currently being used in food service premises. No peer reviewed literature exists on how these products are being employed in food services, despite anecdotal on-line reports of consumer illness. BCCDC and health authorities should continue to gather reports on how these products are used to assess and recommend safe use.

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