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Vacuum Cooling of Foods

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Abstract

The deterioration of food products may be caused by numerous sources, including physiological breakdown, moisture loss, and microbes. The deterioration of high moisture foods mainly horticultural crops is temperature related and hence reducing the product temperature results in less deterioration and increased shelf life. Vacuum cooling has proven to be a fast way of removing field heat from horticultural crops. Cooling by this method is a specific application of evaporative cooling. The absolute pressure of the atmosphere surrounding the product is reduced, which results in lowering the boiling temperature of water in the product. If the pressure is lowered enough, water will boil at the temperature of the vegetable. Sensible heat is given up by the product to change liquid water into vapour, and the product cools. The success of vacuum cooling is not only restricted to fruits and vegetables it has also reached to other food products like Bread and pastries hence it is a fast and energy-efficient cooling method with a wide range of applications in food processing.

Introduction

Vacuum cooling is a rapid evaporative cooling method for porous and moisture foods to meet the special cooling requirements. Vacuum cooling has been used as an effective method for pre-cooling certain type of horticultural products such as vegetables and fruits to prolong their storage life by reducing post-harvest thermal deterioration. Vacuum cooling has also been successfully applied to the processing procedures for some foods such as liquid and baked foods to improve the processing efficiency by shortening the cooling time. Recent research has highlighted the feasibility of vacuum cooling for cooked meats, fishery products and ready meals, for which rapid cooling is beneficial to controlling growth of micro-organisms and preserving quality of the products.

Vacuum cooling, like vapour-compression refrigeration, is based on liquid evaporation to produce a cooling effect. The difference between vacuum cooling and conventional refrigeration methods is that for the vacuum cooling the cooling effect is achieved by evaporating some water from a product directly, rather than by blowing cold air or other cold medium over the product (Mellor, 1980). Speed and efficiency are two features of vacuum cooling, which are unsurpassed by any conventional cooling method, especially when cooling boxed or palletised products. The products which have tight delivery schedules and strict cooling requirements can be met using vacuum cooling due to its lower functioning time (Malpas,1972). Any product which has free water and whose structure will not be damaged by the removal of such water can be vacuum cooled. The speed and effectiveness of vacuum cooling are mainly related to the ratio between its evaporation surface area and the mass of foods (Noble, 1985).

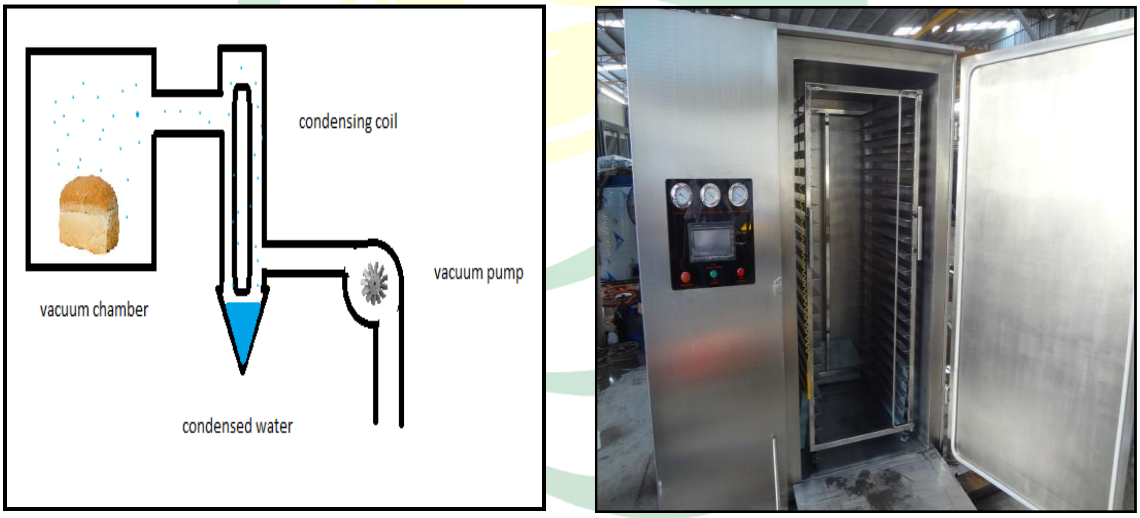
Vacuum cooling principle

Liquid evaporation is the most popular cooling sink in the refrigeration industry. Whenever any portion of a liquid evaporates to become its vapour state, an amount of heat equal to the latent heat of evaporation must be absorbed by the evaporated portion either from the liquid body or from the surroundings, resulting in reduction of the temperature of the liquid body or surroundings (Dossat, 1991). Water boils at 100ºC if it is subjected to the atmospheric pressure (1atm). However, reduction in the imposed pressure on water lowers the boiling temperature of water, that is, water can boil at a lower temperature as 0°C if the imposed pressure is reduced to 611 Pa. The imposed pressure on water determines the minimum temperature, which can cause water to boil to produce a cooling effect (Perry, Green, & Maloney, 1984). If porous and moisture foods are subjected to vacuum pressure, part of water within the foods can boil out to achieve the cooling effect for the food bodies at a temperature as low as the saturation temperature of water related to the vacuum pressure. Generally, most of foods have two main compositions: water and solid texture. Therefore, the refrigerant used in a vacuum cooler is not pure water but one of the food compositions.

Description of a typical vacuum cooler

The porous and moisture foods can be cooled directly by boiling part of the moisture in the foods at a low temperature under vacuum pressure, a vacuum cooler is really a system to maintain the required vacuum pressure. A typical vacuum cooler consists of two basic components: a vacuum chamber and a vacuum pumping system (Longmore, 1974; Sun & Wang, 2001). The vacuum cooling process occurs in two fairly distinct stages: (a) the removal of most of the air in the chamber to the flash point, or the saturation pressure at an initial temperature of foods, with relatively little cooling, and (b) the continuous drop of the pressure in the vacuum chamber to final pressure with main cooling phase of the products. The vacuum chamber, which is normally horizontal with cylindrical or rectangular construction, is used to keep the foods. During the cooling process, the door of the chamber is hermetically sealed and any leakage of air into the vacuum cooler increases the load of the vacuum pumping system (Malpas, 1972).The pumping system may have two elements, which are a vacuum pump and a vapour-condenser. The vacuum pump is usually designed to reduce the pressure in the vacuum chamber from the atmospheric pressure to the saturation pressure at the initial temperature of foods such as vegetables and fruits for 3–10 min (Longmore, 1973). The rotary oil-sealed vacuum pump is widely chosen for a vacuum cooler.

The vapour-condenser in effect acts as a vacuum pump to remove the vapour in the vacuum chamber by condensing the vapour back into water and then drain the water out. However, it should be noted that the cooling effect for foods comes from the water evaporation in foods, and application of a vapour-condenser in a vacuum cooler is only for practical and economical removal of a large amount of vapour generated.



(a) **(b)**

Fig (a) schematic diagram of vacuum cooler (b) commercial vacuum cooler

Conclusions

Vacuum cooling is a rapid cooling technology for porous and moisture foods. The heat of food body is released by evaporating an amount of water within the foods under vacuum pressure directly. The size and shape of food body have no significant effect on the cooling rate of vacuum cooling, which is different from traditional cooling such as slow air, air-blast and water immersion cooling. Weight loss inherently occurs during vacuum cooling since the cooling effect comes from water evaporation. However, weight loss of vacuum-cooled foods can be reduced or compensated by adding a suitable amount of water before vacuum cooling. Vacuum cooling has been widely used to rapidly remove the field heat from certain horticultural and floricultural products to extend their shelf life. Vacuum cooling is also successfully used to the process procedures of some liquid foods and baked foods to improve the cooling efficiency of processing machines and reduce the cooling time. A rapid cooling is important for safety and quality of cooked meats to minimise the growth of surviving organisms.

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