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Original Article

Using Vacuum Cooling Method of Precooling Process of Cabbage

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ABSTRACT

Temperature declining of harvested crops to reach an optimum level during 24 hours after harvesting is the main contributing purpose of pre-cooling methods at which the quality of crops maintain at the best point for customer satisfaction. Vacuum cooling is known as a rapid evaporative cooling technique for any porous product which has free moisture. The aim of this research is to apply vacuum cooling technique for cooling of the cabbage and show the pressure effect on the cooling time and temperature decrease. The results showed pressure 0.7 Kpa reduce the cooling time of cabbage by 17% and 39% compared with 1 and 1.5 Kpa, Respectively .and select pressure 0.7 KPa as the pressure in the final for chamber will lower mass loss. It has been also found that temperature distribution within the products during vacuum cooling despite the cabbage complex structure was homogeneous.
Key words: Cabbage, Vacuum cooling, Time cooling, Mass loss, Pressure.

INTRODUCTION

Vegetables and flowers are living dynamic systems even after detachment from the parent plant. As living biological entities, they respire and transpire [1]. The process of pre-cooling is the removal of field heat which arrest the deteriorative and senescence processes so as to maintain a high level of quality that ensures customer satisfaction [2, 3]. Vacuum cooling mainly depends on latent heat of Evaporation to remove the sensible heat of cooled products [4]. It can be considered a rapid and evaporative cooling method [5]. Generally, vacuum cooling can be applied to any porous product which has free water [3, 6, 7, and 8]. The effect of vacuum cooling on extending the shelf-life of produce has been shown by Burton et al [9] and Martinez and arte [10]. The function of the vacuum pumps and vapor condenser is to provide the vacuum in the chamber [4]. There are two main requirements for using the vacuum cooling: (a) the product should have a large surface area for mass transfer, (b) product water loss should not represent an economic or sensory problem due to weight reduction and possible changes in structure or appearance [11]. The basic principles of the vacuum cooling process are described as follows [5]:

1. At atmospheric pressure (1013 mbar), the boiling temperature of water is 100 °C. This boiling point changes as a function of saturation pressure therefore at 23.37 mbar the water boiling temperature will be 20 °C and at 6.09 mbar, it will be 0 °C.

2. To change from the liquid to vapor state, the latent heat of vaporization must be provided by the surrounding medium, so that the sensible heat of the product is reduced.

3. The water vapor given off by the product must be removed.

MATERIAL AND METHODS

Tests were performed using a laboratory-scale vacuum cooler [Agricultural Machinery and Mechanization Engineering Department of Iran], equipped with a piston vacuum pump. The vacuum volume was approximately 0.335 m^3. The experimental apparatus is presented in Fig. 1.

Variation of surface and center temperature of the products is determined with two calibrated sensors [±1 accuracy]. The sensors are inserted into the samples; one sensor placed in center of cabbage and second under the first leaves of cabbage. Relative humidity [±1% rh] and temperature of vacuum chamber have been measured with the same probe and data are recorded. Also Pressure has been measured from the pipe between the vacuum pumps and vacuum chamber. Experiments were carried out for three different pressures [0.7 KPa, 1 kPa and 1.5

kPa] and three repetitions were performed for each pressure and average data were used. The weights of the foods before and after the cooling process are determined with an electronic balance (with accuracy of ±0.01 g).

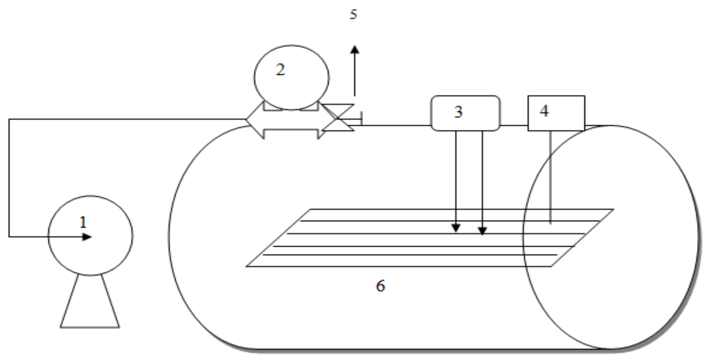

Figure 1. Schematic of the vacuum cooler system (1. Pacuum pump; 2. Pressure measurement; 3. Temperature measurement; 4. Humidity measurement; 5. Vacuum control valve; 6. Vacuum chamber)

RESULTS

In this study, three different vacuum pressures were used for cooling the iceberg lettuce and mass loss and cooling time compared. During vacuum cooling, the variation of the center and surface temperature of the iceberg lettuce, vacuum chamber humidity and temperature, variation of temperature of surface and center of cabbage are measured for three different pressure 0.7 kPa, 1 kPa and 1.5 kPa.

With starting machine and the reduction of pressure in the vacuum chamber, the time at the beginning of boiling is usually called the flash point. For example, the time getting to flash point was after the 5-6 minute of Beginning of the experiment, because the center and surface temperature had not varied. After some minute of beginning cooling, temperature decreased but often the center and surface temperature decrease non-uniformly Due to the temperature gradient in the cabbage. With decreasing the pressure, evaporation and cooling occur through the cabbage and temperatures decrease together. Another reason for faster reduction surface temperature than the center temperature is the cooling effect comes from water evaporating from the samples, and therefore evaporation and cooling of sample start from the surface [Figures 1-3].

Temperature of cabbage should decrease from 30 °C [ambient temperature] to 7°C [storage temperature]. When Fig. 1 is compared with Fig. 2 and 3, it can be seen that cooling time for 0.7 kPa [2100 s] is less than the cooling time for 1 kPa [2400 s] and for the vacuum pressure of 1.5 kPa [2700]. As can be seen from the figures, the temperature distribution during vacuum cooling is homogeneous through the cabbage.

The total cooling time is dependent on the shape of the product, porosity, pore size, the pore distribution within the samples, availability of free water in the pores and set pressure.

Weight loss occurs during vacuum cooling since cooling effect directly comes from Weight losses of iceberg lettuce during vacuum cooling for three different pressures are given in Table 1. Weight loss and the percentage weight loss are closely related to final set pressure. As shown in the table, cooling time depends on set pressure and for low pressure cooling time is shorter.

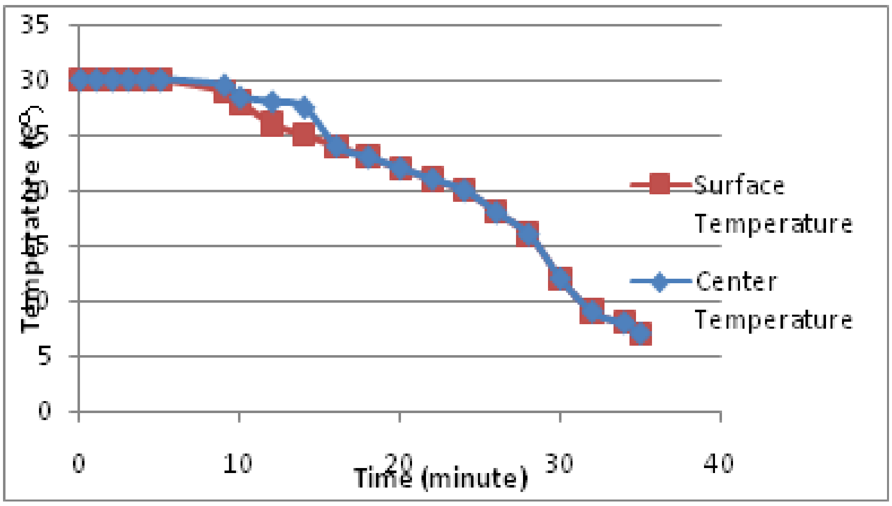

Figure 1. Variation of center and surface temperature of cabbage during of cooling with time for set pressure of 0.7 kPa.

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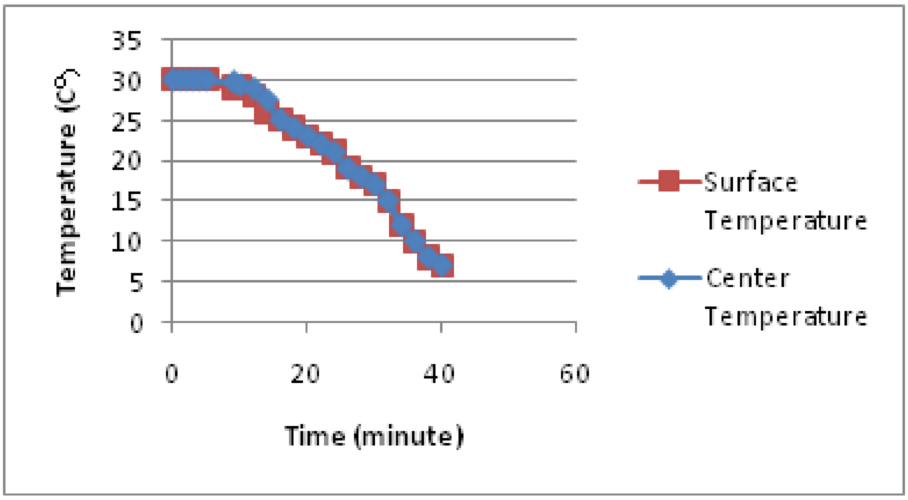

Figure 2. Variation of center and surface temperature of cabbage during of cooling with time for set pressure of 1 kPa.

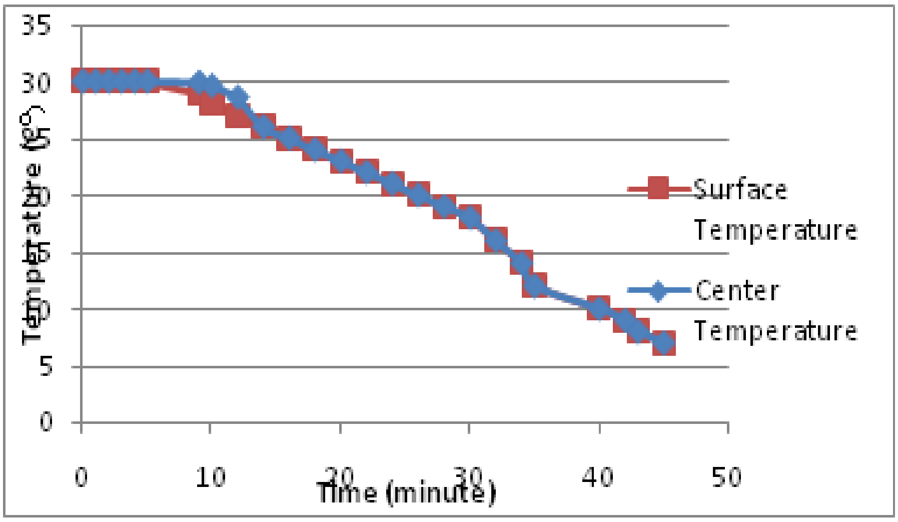

Figure 3. Variation of center and surface temperature of cabbage during of cooling with time for set pressure of 1.5 kPa.

Table 1. Variation of mass loss and mass loss ratio with pressure (vacuum cooling)

Vacuum pressure	0.7	1	1.5
Initial mass (gr)	320	360	370
Final mass (gr)	308.66	307.73	354.5
Mass loss (gr)	11.34	13.46	15.5
Mass loss ratio (%)	3.54	3.74	4.19
Cooling time	2100	2400	2700
Cooled temperature (˚C)	7	7	7

DISCUSSION

Three different pressures have been tested for vacuum cooling of cabbage. Results showed that the temperature drops of cabbage at the surface and at the center are very similar. This study confirmed that vacuum cooling is an efficient method and is suitable for cooling of vegetables such as cabbage. The vacuum cooling (at 0.7 Kpa) of cabbage is 17% and 39% faster than vacuum cooling [at 1 and 1.5 Kpa], respectively. Mass loss during vacuum cooling is unavoidable due to the essence of vacuum cooling. However, as can be seen from Tables 1mass loss for vacuum cooling [at 0.7 Kpa] is also comparable with the other pressures. Percent product yield, mass loss and cooling time where significantly improved by regulation of pressure.

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