Evaluation of Pressure Effects on Vacuum Cooling of Cabbage

Sahar Rahi [1,*], Houshang Bahrami [2], Mohammad javad Sheikhdavoudi [2] , Arash Davoudi [1]

1. Agricultural Mechanization Engineering, Shahid Chamran University, Ahvaz, Iran
2. Mechanical Engineering of Agricultural Machinery, Shahid Chamran University, Ahvaz, Iran

Rahi.sahar1@gmail.com

Abstract: Pre-cooling is used to lower the temperature of the harvested agricultural products while vacuum cooling is known as a rapid evaporative cooling technique for any porous product which has free water. 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.

[Rahi S, Bahrami B, Sheikhdavoudi M, Davoudi A. **Evaluation of Pressure Effects on Vacuum Cooling of Cabbage.**. *Researcher* 2013;5(2):19-23]. (ISSN: 1553-9865). http://www.sciencepub.net/researcher. 4

Key words: vacuum, cabbage, cooling, pressure, mass loss.

1. Introduction

Vegetables and flowers are living dynamic systems even after detachment from the parent plant. As living biological entities, they respire and transpire (Brosnan and Sun, 2001). 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 (Brosnan and Sun, 1999; Mcdonald and Sun, 2000). Vacuum cooling mainly depends on latent heat of Evaporation to remove the sensible heat of cooled products (Jin, 2007). It can be considered a rapid and evaporative cooling method. Generally, vacuum cooling can be applied to any porous product which has free water (Mcdonald and Sun, 2000; Wang and Sun, 2000; Dostal and Petera, 2004; Houska et al, 1996). The effect of vacuum cooling on extending the shelf-life of produce has been shown by Burton et al (1987) and Martinez and artes (1999). The function of the vacuum pumps and vapor condenser is to provide the vacuum in the chamber (Wang and Sun, 2000). 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 (Haas and Gur, 1987). The basic principles of the vacuum cooling process are described as follows (Dostal and Petera, 2004):

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.

Cheng and sun compared the mass loss of cooked meat product for the different cooling methods such as vacuum cooling, air blast cooling, slow air cooling, and water immersion cooling. They also compared the cooling rate, the weight loss, and the quality of large cooked ham joints. They indicated that despite the highest cooling loss, vacuum cooling significantly increases the cooling rate, and it is the only method that can meet the chilling requirements (Cheng and Sun, 2008).

The aim of this study is to determine the effect of the pressure on the vacuum cooling of cabbage and study of decrease temperature and mass loss during of cooling.

2. Material and Methods

2.1. Theoretical approach

In this section, a simple theoretical analysis of vacuum cooling process based on thermodynamic principles is presented. This analysis is limited to the mass loss based on temperature drop observed during vacuum cooling process. Average specific heat (C_{avg}) of any vegetable can be calculated by the following expression:

$$C_{avg} = 3349a + 837.36 \text{ J/kg K} \qquad (1)$$

Where (a) is the water content. For instance, water content of cabbage is 90% by mass. Therefore, specific heat of cabbage is:

$$C_{cabbage} = 3851.46 \text{ J/kg K}$$

Then the heat required to lower the temperature of a 1 kg cabbage from 30 °C to 7 °C could be calculated by the following expression:

$Q = mc\Delta T$ (2)

2.2. Plant material

Cabbage were bought on day of experiment and was transported to the shahid chamran University of Iran. The temperature of the cabbage during this time was near room temperature (30 °C). samples vacuum cooled 2 h later.

2.3.Vacuum cooling system, measurements and data collection

Testes 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 (see Fig.2). 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 (see Fig.1).

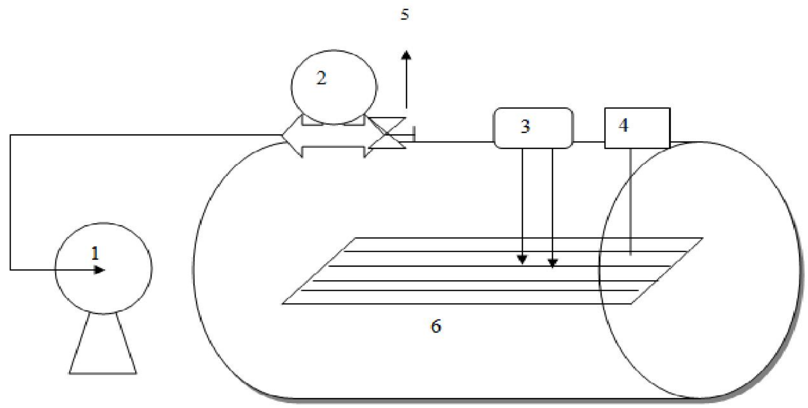

Figure 1. Schematic of the vacuum cooler system (1.vacuum pump, 2.pressure measurement, 3.Temperature measurement, 4.Humidity measurement, 5.vacuum control valve, 6.vacuum chamber)

Figure 2. The measured positions of the cabbage by temperature sensors.

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).

3. Result and Discussion

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 3-5).

Temperature of cabbage should decrease from 30 °C (ambient temperature) to 7°C (storage temperature). When Fig. 6 is compared with Fig. 7 and 8, 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.

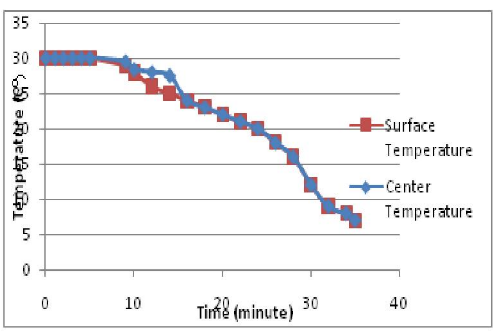

Figure 3. Variation of center and surface temperature of cabbage during of cooling with time for set pressure of 0.7 kPa.

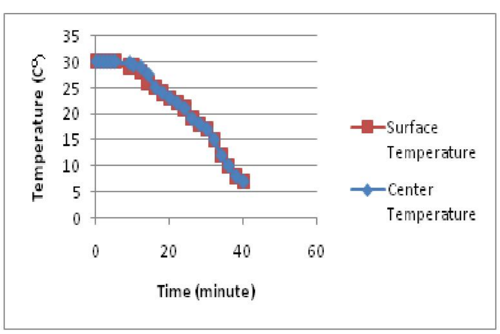

Figure 4. Variation of center and surface temperature of cabbage during of cooling with time for set pressure of 1 kPa.

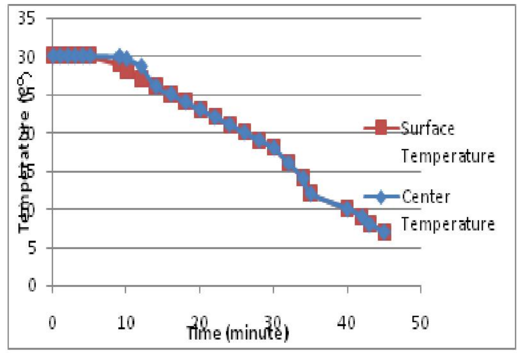

Figure 5. Variation of center and surface temperature of cabbage during of cooling with time for set pressure of 1.5 kPa.

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. Figures 6-8 shows variation of pressure with time. It can be seen from Figs. 6-8 that vacuum pressure in the vacuum chamber decreased rapidly from atmosphere to -95.45 kPa in 300 s (5 min), then declines slightly. When it reaches to set pressure it starts to fluctuate around it. When the pressure is lower or equal to the saturation pressure at the local temperature, water evaporates.

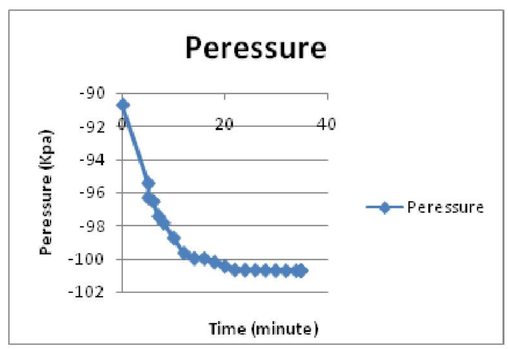

Figure 6. Variation of pressure of vacuum chamber with time for set pressure of 0.7 kPa.

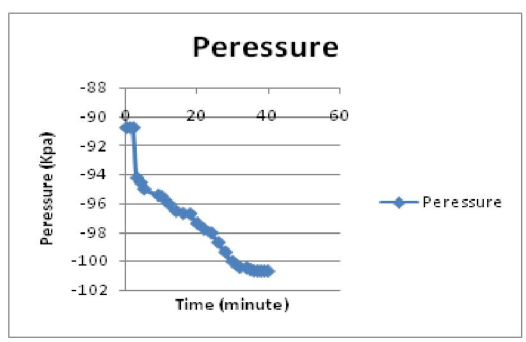

Figure 7. Variation of pressure of vacuum chamber with time for set pressure of 1 kPa.

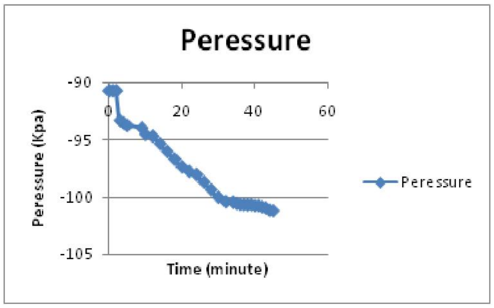

Figure 8. Variation of pressure of vacuum chamber with time for set pressure of 1.5 kPa.

As can be seen from the figure 9, vacuum chamber temperature is almost constant during cooling period, and it is nearly equal to ambient temperature or initial temperature of iceberg lettuce. Since cooling effect for vacuum cooling directly comes from water evaporation from the cooled product, no temperature change occurs at ambient.

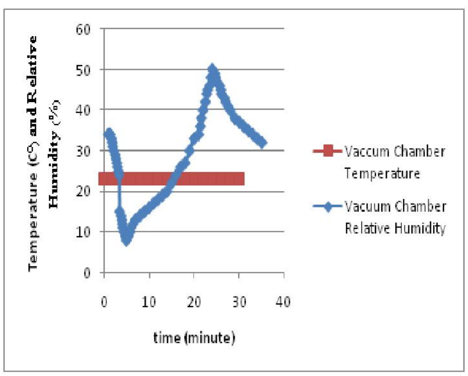

Figure 9. variation of temperature and relative humidity of vacuum chamber with time.

However, Vacuum chamber humidity fluctuates through the process. At the first humidity of chamber decreased due pressure suction, afterwards evaporate water of samples makes humidity increase of chamber. at the end by opening vacuum control valve and entering air into the chamber decrease humidity rate again.

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.can be seen at Section 2, removed heat from the product is:

$Q = mC\Delta T$

$Q = 0.32 \times 3851.46 \times 23 = 28346.74$ J

$Q = 28.3$ kJ

This heat could be used to calculate the amount of water that needs to be vaporized. For instance, the latent heat of vaporization of water at 0.7 kPa pressure is:

$h_{fg} = 2495.6$ kJ/kg K dir

The amount of cooling is equal to the amount of heat necessary to vaporize some of the water (Δm) from the cabbage.

For the cabbage example, this water mass loss can be calculated as the following:

$mC\Delta T = \Delta m h_{fg}$

$\Delta m = 0.011$ kg

In other words, the cabbage experiences a 11 gram mass loss during cooling. This result is not too different from the values obtained in the experiments (see Table 1).

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

Vacuum pressure	0.7	1	1.5
Initial mass (g)	320	360	370
Final mass (g)	308.66	307.73	354.5
Mass loss (g)	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

4. Conclusion

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 1 mass 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.

References

1. Brosnan, T., and Sun, D.W. 2001. Precooling techniques and applications for horticultural products—a review. *International Journal of Refrigeration* 24:154-170.
2. Sun, D.W., and Brosnan, T. 1999. Extension of the vase life of cut daffodil flowers by rapid vacuum cooling. *International Journal of Refrigeration* 22:472-478.
3. McDonald, K., and Sun, D.W. 2000. Vacuum cooling technology for the food processing industry: a review. *Journal of food engineering* 45:55-65.
4. Wang, L., and Sun, D.W. 2004. Effect of operating conditions of a vacuum cooler on cooling performance for large cooked meat joints. *Journal of food engineering* 61:231-240.
5. Dostal, M., and Petera, K. 2004. Vacuum cooling of liquids: mathematical model. *Journal of food engineering* 61:533-539.
6. Houska, M., Podloucký, S., Žitný, R., Gree, R., Sestak, J., Dostal, M., and Burfoot, D. 1996. Mathematical model of the vacuum cooling of liquids. *Journal of Food Engineering* 29:339-348.
7. Burton, K., Frost, C., and Atkey, P. 1987. Effect of vacuum cooling on mushroom browning. *International Journal of Food Science & Technology* 22:599-606.
8. Martínez, J., and Artes, F. 1999. Effect of packaging treatments and vacuum-cooling on quality of winter harvested iceberg lettuce. *Food research international* 32:621-627.
9. Haas, E., and Gur, G. 1987. Factor affecting the cooling rate of lettuce in vacuum cooling installations. *International journal of Refrigeration* 10:82-86.
10. Cheng, Q., and Sun, D.W. 2008. Factors affecting the water holding capacity of red meat products: A review of recent research advances. *Critical reviews in food science and nutrition* 48:137-159.
11. Jin, T. 2007. Experimental investigation of the temperature variation in the vacuum chamber during vacuum cooling. *Journal of food engineering* 78:333-339.

1/8/2013