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The Effect of Vacuum Cooling of Some Products on the Ratio of Weight Loss

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Abstract: In this study, weight loss and the methods to reduce weight loss were determined as well as the parameters of pressure, temperature and time during the vacuum cooling of lettuce, cauliflower, cabbage and spinach at low evacuation rate using three different methods and these were compared with the studies made before. The weight loss for every 1°C ratios of products with high specific volume values during vacuum pre-cooling practices are also high, since they can release the water inside their structure more easily. However, they are more suitable to vacuum pre-cooling compared with the other products. Spraying water onto the products which could not release their water readily, during vacuum pre-cooling reduces the weight loss for every 1°C and also increases the cooling rate. In this connection one can say that spraying water onto the lettuce, cabbage, cauliflower, spinach and thereafter covering them with perforated PVC film before cooling in the vacuum cooling process is a factor significantly reducing the weight loss for every 1°C and total weight loss.

Key words: Vacuum cooling, lettuce, cabbage, cauliflower, spinach, weight loss

INTRODUCTION

Vacuum cooling has been used as a pre-cooling treatment for products such as lettuces (Ahoroni and Kalmanovitz, 1971; Hayakawa *et al*., 1983; Haas *et al*., 1986; Chen, 1986; Yanniotis and Schwartzberg, 1986; Thompson *et al*., 1987; Isenberg *et al*., 1986; Turk and Çelik, 1993; Martinez and Artez, 1999), mushrooms (Carol *et al*., 1987; Frost *et al*., 1989), broccoli (Perrin, 1982), asparagus (Ryall and Peizer, 1982), artichokes, cucumbers, carrots (Hayakawa *et al*., 1983), peppermints, dills, garden rockets (Hass and Gur, 1987), green onions (Shaw and Kou, 1987) and cut flowers (Wiersma, 1971; Sun and Brosnan, 1999; Brosnan and Sun, 2001, 2003) to remove field heat and thus extend shelf life and quality.

The major advantage of vacuum cooling over other techniques of cooling is the short time required to cool a suitable product to a given temperature (Mc Donald and Sun, 2000). However, the weight loss of vacuum cooled foods may be reduced by adding a suitable amount of water to the cooled foods (Wang and Sun, 2001). Studies towards decreasing the weight loss in different products on the basis of years were aimed at eliminating this disadvantage.

Ryall and Peizer (1982) reported the weight loss in asparagus as the result of lowering the temperature from 20 to 8°C within 25 min as 1.4% and the weight loss resulting from the wetting of product before cooling as 0.5%. The weight loss during vacuum cooling for every 10°C reduction in temperature was determined as 2.1, 2.8 and 3.4% for lettuce, artichoke and carrot, respectively (Hayakawa *et al*., 1983). The weight loss in mushrooms that were vacuum precooled 6 h after harvest was found as 1.9%, whereas the weight loss after air-pre-cooling was found as 0.7% (Frost *et al*., 1989). Martínez and Artéz (1999) determined the weight loss ratio in iceberg-type lettuces precooled without covering as 4.75%, while in lettuces covered with polyethylene film, this ratio was found as 0.93%. Sun and Brosnan (1999) determined that the weight loss which was between 2.5 and 3% under normal conditions could be lowered to 1.5% by wetting the products before vacuum cooling, in a study on vacuum cooling of cut narcissus flowers. Mc Donald and Sun (2000) reported that weight loss was an important problem associated with vacuum cooling, however, wetting the products before cooling had a reducing effect on weight loss and the weight loss in vegetables after vacuum cooling would be lettuce 1 and 5%. Brosnan and Sun (2003) determined in their study on the effect of evacuation rate on weight loss in cut lilies that the weight loss was 5.4% with 374 mbar min^{-1} evacuation rate and 3.7% with 8.5 mbar min^{-1} evacuation rate.

In this study, weight loss and the methods for reducing weight loss as well as the parameters of pressure, temperature and time were determined during vacuum cooling of lettuce, cauliflower, cabbage and spinach under low evacuation rates with three different methods.

MATERIALS AND METHODS

The trials were realized in Vacuum pre-cooling experimental system that was made by the University of Uludag, Faculty of Agriculture, Department of Agriculture Machinery, Bursa, Turkey. The system consisted of vacuum chamber, vacuum pumps, condenser and measuring devices (Fig. 1) (Ryall and Pizer, 1982; Isenberg *et al*., 1986; Amirante and Renzo, 1989; Houcéka *et al*., 1996; Sun and Brosnan, 1999; Mc Donald and Sun, 2000; Wang and Sun, 2001; Isik, 2002; Landfeld *et al*., 2002; Brosnan and Sun, 2003; Sun and Hu, 2003).

Vacuum pumps were two oil rotary vacuum pumps with speeds of 8.4 $m^3 h^{-1}$ and 12 $m^3 h^{-1}$. In addition, a compressor with an electrical motor power of 0.368 kW was used in the cooling system connected to the condenser in vacuum chamber. An analog-membrane vacuum meter with a range between 760 and 0 mmHg values was used for measuring the pressure in the system. Weightings were done using a BASTER-brand digital precision balance with 1 g sensitivity. Thermocouples with 0.2 mm diameter were used in temperature measurements (Sun and Brosnan, 1999). Temperature values were collected in data acquisition system and transferred to the computer.

The products used in the study were obtained from local farms of Bursa region and then were transported to Laboratory of Department of Agriculture Machinery on harvest temperatures.

Vacuum pre-cooling trials were realized in four different products with three different methods and low evacuation rate (0.343 kPa min^{-1}). In the first method, the thermocouples were inserted into the center of the case for a sensitive measurement of the temperature in the center of the product after the weighted products were put into vacuum chamber (Mc Donald *et al*., 2001; Landfeld *et al*., 2002), while in the case of spinach, they were placed into the center of the bunch. The second thermocouple was hanged freely into the center of the chamber. External ambient temperature was measured by a third thermocouple placed around. The values of weight loss, temperature, time and pressure were recorded during trials.

In the 2nd method, approximately 5 mL of water was pulverized on each product directly in a uniform manner after the product was weighed (Chen, 1988; Sun and Brosnan, 1999; Brosnan and Sun, 2001), whereas in the 3rd method, the product was covered with perforated PVC stretch film fallowing water pulverization (Haas *et al*., 1986, 1987; Martinez and Artes, 1999). Other stages were realized as described in the 1st method.

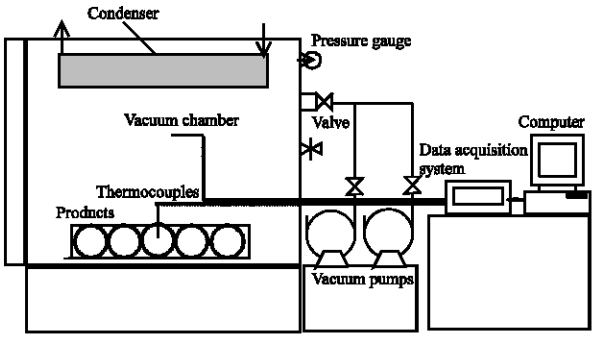

Fig. 1: Schematic diagram of the experimental vacuum cooler

RESULTS AND DISCUSSION

Physical characteristics of the products used in the trials are given Table 1. The results of the trial carried out on lettuce are given in Fig. 2. The cooling period at the point at which the product temperature reached 4°C is 33 min, while the pressure at this point is 0.60 kPa. The trial was stopped at this point since lowering the pressure below 0.60 kPa and prolonging cooling period lead to freezing in the product and reduce its market value. At the end of the trial, a weight loss of 4.20% was recorded in lettuce (compared with 4.75% by Martínez and Artés, 1999; 1-5% by Mc Donald and Sun, 2000). A weight loss of 2.8% (2.1% by Ryall and Peizer, 1982) is in equation for every 10°C decline in temperature and 0.28% for every 1°C. The temperature of wetted lettuce was lowered to 3°C

Table 1: Physical characteristics of the products

Products	Mean weight (g)	Mean diameter (mm)	Specific volume ($dm^3 kg^{-1}$)
Cabbage	1863	180	1.127
Cauliflower	1445	155	1.176
Lettuce	1540	-	1.538
Spinach*	1200	-	1.787

* Bunched

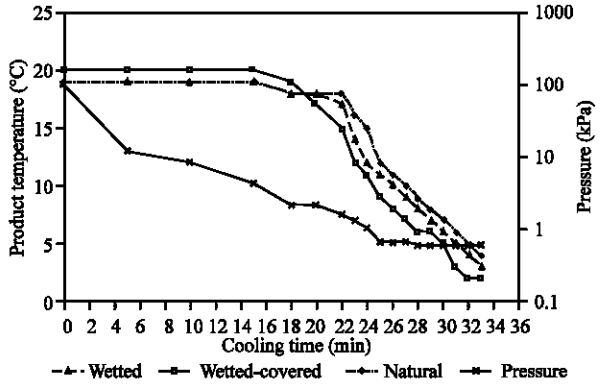

Fig. 2: Experimental results of lettuce in vacuum cooling

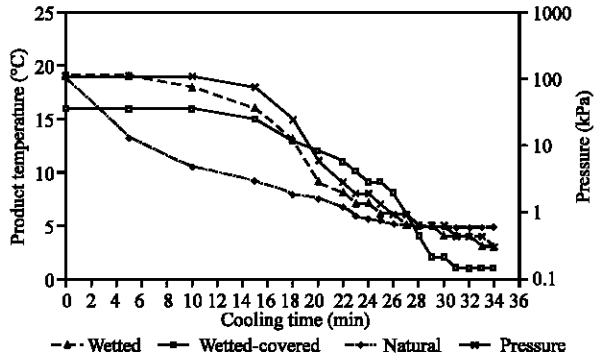

Fig. 3: Experimental results of cauliflower in vacuum cooling

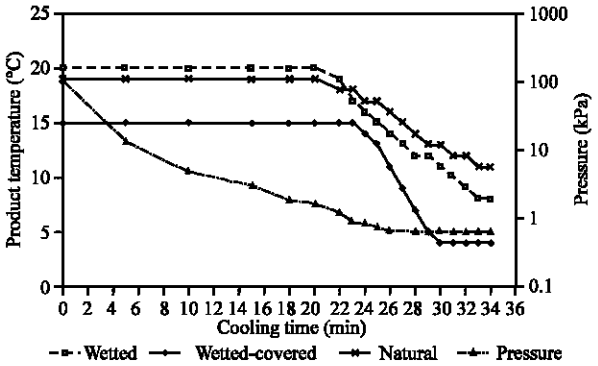

Fig. 4: Experimental results of cabbage in vacuum cooling

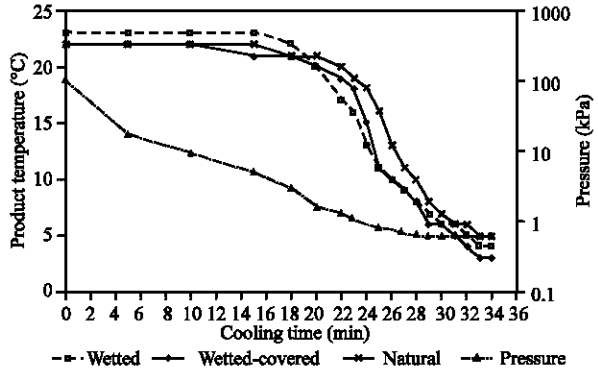

Fig. 5: Experimental results of spinach in vacuum cooling

at the end of 33 min trial period. Weight loss was determined as 3.13%, being lower compared with natural lettuce trial.

The temperature of wetted and covered with perforated PVC stretch film was lowered to 2°C in the 33rd min of the trial period, with a temperature reduction of 18°C. The weight loss in lettuce at the end of the trial was found as 2.03%.

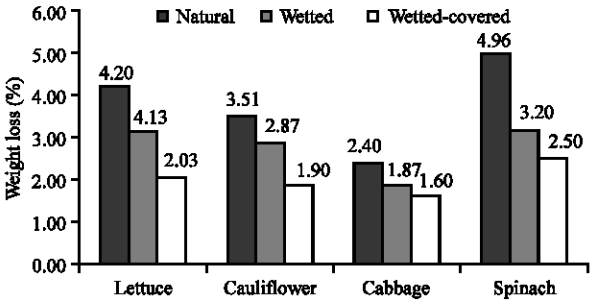

Fig. 6: Weight loss of products

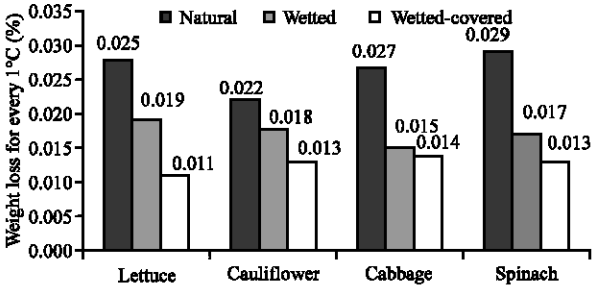

Fig. 7: Weight loss for every 1°C of product temperatures

Results of cauliflower are given in Fig. 3. The product temperatures reached 3°C at the end of the 34th min, 3°C at the end of 33rd min and 1°C at the end 31st min, natural, wetted and wetted-covered, respectively.

The temperature of cabbages was lowered to 11°C at the end of the 33rd min (Fig. 4). The weight loss was found as 2.40%. The product temperature was lowered to 8°C from 20°C and to 4°C from 15°C, wetted and wetted-covered, respectively. Weight losses in wetted and wetted-covered cabbage were determined as 1.87 and 1.60%, respectively.

The initial temperature was 22°C in the spinach trial (Fig. 5). The product temperature reached 5°C in the 33rd min of trial with a reduction of 17°C. Cooling trials of wetted spinach were started with a product temperature of 22°C and the temperature was lowered to 4°C at the end of the 33rd min. Wetted plus covered spinach were started with a product temperature of 22°C and the temperature fell down to 3°C at the end of the 33rd min.

When Fig. 6 is examined, it can be seen that the highest weight losses were in spinach (4.96%), followed by lettuce (4.20%). These values were 3.51 and 2.40% in cauliflower and cabbage, respectively. Reduction was observed in weight loss when the products were subjected to cooling after being wetted. Weight loss ratios were determined as 2.50, 2.03, 1.90 and 1.60%, in spinach, lettuce, cauliflower and cabbage, respectively at the end of the trials realized on wetted plus perforated PVC stretch film covered products.

Considering these values, it may be said that spraying water onto the products followed by covering with PVC stretch film before cooling in vacuum pre-cooling method is a factor significantly reducing the weight loss.

Another important parameter that should be examined nearby total weight loss is the weight loss for every 1°C (Fig. 7). When the products at natural state are examined, the weight loss required for decreasing the temperature of 1 kg of product by 1°C was observed to be 0.028, 0.022, 0.027 and 0.029% in lettuce, cauliflower, cabbage and spinach, respectively.

When the Table 1 and Fig. 6 are examined, it can be seen that weight loss are at high rates in the natural spinach (4.96%) which has high specific volume (1.787 $dm^3 kg^{-1}$) than the others. Lettuce (4.20%), which was on the second order with respect to weight loss, was also the second with regard to specific volume (1.538 $dm^3 kg^{-1}$). These two products are followed by cauliflower (3.51%) and cabbage (2.40%), with regard to these two parameters.

The existence of a linear relation between the specific volume of the product and the weight loss resulting from vacuum pre-cooling is remarkable when the weight losses values are examined.

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