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The Effect of Precooling of Lettuces and Green Beans on the Ratio of Weight Loss and Net Weight after Storage

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Abstract: In this study, we investigated the effects of precooling and not precooling lettuce types Lital and Yedikule to +2 and +4°C and fresh bean types Aysekadin and Rodop to +8°C in a vacuum cooler on the weight loss and net weight of the products at the end of storage. No statistical difference in poststorage weight loss was found between vacuum precooling treatments in the lettuce trials; however, there was a significant ($p<0.01$) effect of vacuum precooling on poststorage weight loss in beans. Packaging of precooled products affected weight loss of lettuces and beans ($p<0.01$) and ($p<0.05$) significance, respectively. The weight loss in packaged products at the end of the vacuum cooling process was 1.82 and 0.74% in lettuces and beans, respectively, whereas in unpackaged products it was 5.05 and 2.41%. Plant types and packages affected the net weight of lettuces significance ($p<0.01$). Lital was the best product type with 42.34% net weight and packaging products was the best method with 44.95% net weight. No change in net weight was observed in the beans because there was no spoilage after storage.

Key words: Vacuum cooling, lettuce, weight loss, storage, green bean

INTRODUCTION

Spoilage of fresh fruits and vegetables is due to physiological and biological activity continuing after harvest, as well as to respiration. This biological retrogression leads to serious damage to the products and the extent of the damage increases with temperature and time. It is possible to prevent the spoilage of fruits and vegetables by cooling immediately after harvest. The cooling process is realized by precooling the produce until it reaches the cold stores or the market (Gormley, 1975; Amirante and Renzo, 1989).

Vacuum precooling is achieved by rapid evaporation of the water in the structure of fruits and vegetables under vacuum (Houśka *et al*., 1996; Wang and Sun, 2002a,b; Dostál and Petera, 2003). The removal of water from the product by evaporation in vacuum cooling starts at the point at which the pressure in the vacuum chamber falls to the saturation pressure value corresponding to the initial temperature of the product. This point is called the flash point (Amirante and Renzo, 1989; Isik, 2002; Wang and Sun, 2002a; He and Li, 2003). If the pressure in the vacuum chamber is further reduced, the evaporation of water and cooling of the product continues until the desired product temperature is reached. The desired product temperature in the chamber is reached at 0°C and 0.6 kPa pressure. Pressures lower than 0.6 kPa cause the product to freeze (Wang and Sun, 2002a). It not recommended going below this pressure if the aim is to evaluate the products to be cooled fresh in the market (Isenberg *et al*., 1986).

Vacuum cooling removes field heat and thus extends shelf life and quality. The process has been used as a precooling treatment for products such as lettuces (Ahoroni and Kalmanovitz, 1971; Chen, 1986; Hayakawa *et al*., 1983; Isenberg *et al*., 1986; Yanniotis and Schwartzberg, 1986; Haas and Gur, 1987; Thompson *et al*., 1987; Turk and Celik, 1993; Martínez and Artéz, 1999), mushrooms (Gormley, 1975; Carol *et al*., 1987; Frost *et al*., 1989), broccoli (Perrin, 1982), asparagus (Ryall *et al*., 1982), artichokes, cucumbers, carrots (Hayakawa *et al*., 1983), peppermints, dill, garden rockets (Haas and Gur, 1987), green onions (Shaw and Kou, 1987) and cut flowers (Wiersma, 1971; Sun and Brosnan, 1999; Brosnan and Sun, 2001, 2003).

The major advantage of vacuum cooling over other cooling techniques is the short time required to cool a suitable product to a given temperature (McDonald *et al*., 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).

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Several studies have been directed towards minimizing the weight loss associated with the vacuum cooling of products. Ryall and Peizer (1982) reported that the weight loss of asparagus after lowering the temperature from 20 to 8°C in 25 min was 1.4% and the weight loss resulting from the wetting of the product before the cooling process was 0.5%. Hayakawa *et al.* (1983) found that a 10°C decline in temperature with vacuum cooling resulted in weight losses of 2.1, 2.8 and 3.4% in lettuces, artichokes and carrots, respectively. The weight loss of mushrooms vacuum cooled 6 h after the harvest was 1.9%, whereas it was 0.7% when they were precooled by air (Frost *et al.*, 1989). Martínez and Artéz (1999) coated winter-harvested iceberg type lettuces with polypropylene (PP) film and found weight loss ratios of 4.75% for barely cooled and 0.93% for precooled lettuces. In the vacuum precooling trials with cut daffodil flowers, Sun and Brosnan (1999) determined that weight loss, which ranged from 2.5 to 3% under normal conditions, could be reduced to 1.5% by wetting the products before vacuum precooling. McDonald and Sun (2000) emphasized that weight loss is an important problem in vacuum cooling; however, wetting the products before cooling had a reducing effect (1-5%) on weight loss in vegetables after vacuum cooling. Brosnan and Sun (2003) investigated the effect of evacuation rate on weight loss in cut lily flowers and determined weight losses of 5.4 and 3.7% at evacuation rates of 37.4 and 0.85 kPa min^{-1}, respectively.

There are limited studies on the effect of vacuum precooling on poststorage shelf life and weight loss. Martínez and Artéz (1999) reported in their studies on the shelf life of lettuces that vacuum precooling reduced the spoilage of the core leaves and leaf vessels. Brosnan and Sun (2003) determined that vacuum precooling at different rates did not have any effect on the vase life of cut lilies.

In this study, weight loss ratios, the effect of vacuum precooling on poststorage weight loss and net weight values after storage were determined, as well as the parameters of pressure, temperature and time during vacuum precooling of lettuces and beans.

MATERIALS AND METHODS

Lettuce types Yedikule and Lital (*Lactuca sativa* var. longifolia) were used as material in the trials. Perforated gelatin films used in commercial precooling applications were used as packaging material. The average weight of lettuces used in the trials was 1540 g and their mean specific volume was 1.538 $dm^3 kg^{-1}$.

Aysekadin and Rodop types were used in the trials with green beans (*Phaseolus vulgaris* var. communis). Half of the beans were packaged with perforated gelatin films before being placed in plastic containers (10×20×10 cm) and the other half were placed directly into the containers without packaging. Material with an approximate weight of 500-800 g was placed into each container.

A schematic diagram of the vacuum precooler with 5 t capacity is given in Fig. 1. The facility contains a vacuum chamber, vacuum pumps, condenser and measurement devices for measuring and controlling temperature and pressure (Gormley, 1975; Ryall and Peizer, 1982; Isenberg *et al.*, 1986; Amirante and Renzo, 1989; Sun and Brosnan, 1999; Wang and Sun, 2001; Brosnan and Sun, 2003).

Lettuces taken into the trial were separated into 3 groups: nonprecooled, precooled to +2°C and precooled to +4°C. Half of the products in each of the 3 groups were taken into the trial without packaging, whereas products

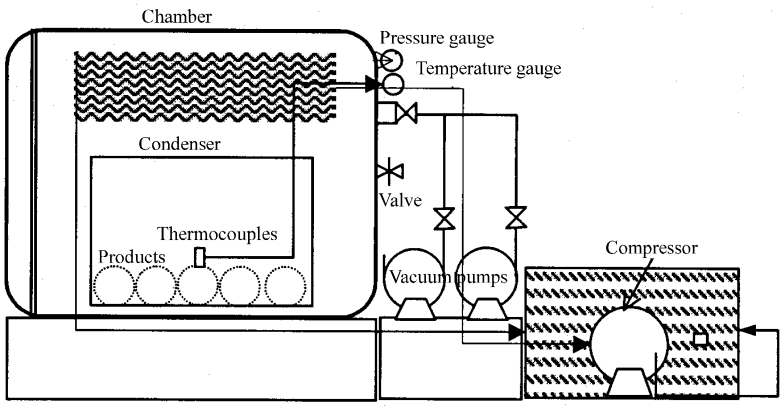

Fig. 1: Schematic diagram of the vacuum precooler

in the other half were packaged in perforated packaging material. For the trial with green beans, the products were divided into 2 groups: nonprecooled and precooled to +8°C. Again, half of each group of the beans was packaged in packaging material, before being stored.

The products that were thoroughly precooled were put into cold stores at between -0.5 and +0.5°C and 90% Relative Humidity (RH) for lettuces and at between 5.5 and 6.5°C and 90% RH for beans, together with nonprecooled products. Lettuces and beans were stored for 3 and 2 weeks, respectively and then they were kept at ambient conditions for 3 days to represent their shelf life.

The trials were established in three replicates, being three parallels in each replicate and six experimental materials in each parallel and the results obtained were subjected to analysis of variance using Duncan's test.

The precooled products were weighed with a digital balance at 1 g precision before and after vacuum precooling to determine weight loss and percentage weight loss ratios. The weights of the products that were precooled or not precooled were determined before and after storage and the percentage weight loss ratios after storage were determined. Net weight was determined after the removal of injured parts in the stored products and net weight loss ratios after storage were determined as percentages.

The temperature, pressure and time values during the precooling process were determined using measurement devices attached to the vacuum precooler and transferred to the computer for calculating the average cooling rate.

RESULTS AND DISCUSSION

Changes in pressure and temperature during the vacuum precooling of lettuces for the +2 and +4°C treatments are given in Fig. 2. Lettuces precooled to +2°C were precooled from 18.1 to 2.1°C within 28 min with an evacuation rate of 0.322 kPa min^{-1} and lettuces precooled to +4°C were precooled from 18.1 to 4.1°C within 25 min with an evacuation rate of 0.387 kPa min^{-1}.

Table 1: Effect of packaging on weight loss of lettuces during vacuum cooling*

Application	Weight loss (%)
Perforated packaging	1.82[a]
No packaging	5.05[b]

* Values followed by different letter (s) are significant ($p<0.01$)

Table 2: Effect of packaging on poststorage weight loss of lettuces*

Application	Weight loss (%)
Perforated packaging	3.57[a]
No packaging	10.88[b]

* Values followed by different letter (s) are significant ($p<0.01$)

No statistical difference in weight loss was found between the +2 and +4°C treatments. Mean weight loss in the group precooled to +2°C was 4.10% and was 2.76% in the group precooled to +4°C (Fig. 3).

Statistical analysis revealed that the packaging of products affected vacuum precooling weight losses significance ($p<0.01$). The weight loss as a result of packaging of the products to be precooled was 1.82%, whereas the weight loss in nonpackaged products was 5.05% (Table 1). Isenberg *et al.* (1986) found values of 1 and 4.7% and Martínez and Artéz (1999) found values 0.93 and 4.75% for packaged and unpackaged products, respectively, which supports the idea that the packaging reduces weight loss during vacuum precooling.

The effect of packaging of products on poststorage weight loss was significant ($p<0.01$) (Table 2). The covered products gave the best values after storage, with a weight loss ratio of 3.57%.

Poststorage weight loss ratios, as influenced by vacuum precooling treatments, are given in Fig. 4.

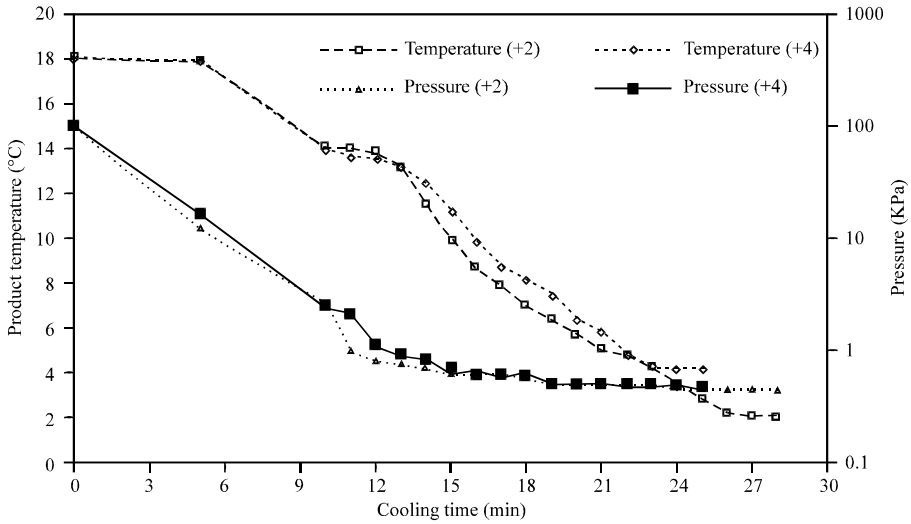

Fig. 2: Experimental results of vacuum cooling of lettuces at +2 and +4°C treatments

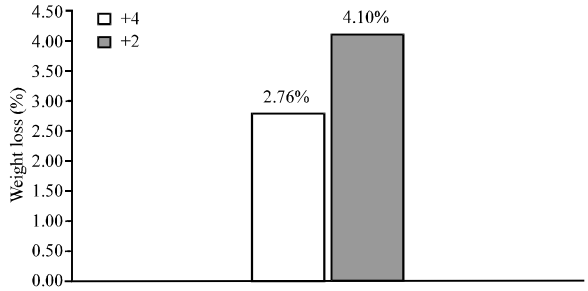

Fig. 3: Weight loss of lettuces during vacuum cooling at +2 and +4°C treatments

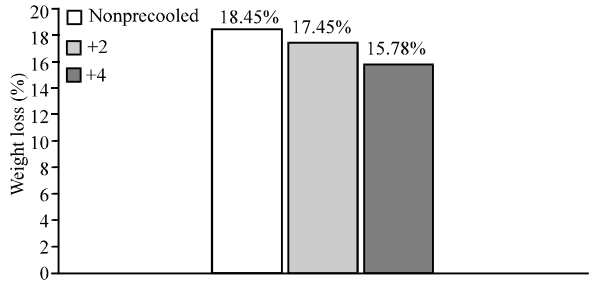

Fig. 4: Poststorage weight loss rate of lettuces during nonprecooling and vacuum precooling at +2 and +4°C treatments

Poststorage weight loss was 18.45% in the nonprecooled product group and 17.45% in the +2°C treatment; the lowest value (15.78%) was obtained in the group vacuum precooled to +4°C. Although there was a numerical decline with respect to weight loss in the storage of lettuces following vacuum precooling, no statistical difference in poststorage weight loss was found between the vacuum precooling groups and the nonprecooled group.

Table 1 and 2 indicate that the packaging of lettuces before precooling and storage is important for minimizing weight loss during precooling and during storage. Unpackaged products lost considerable weight (10.88%) because of excessive water loss. For the packaged products, weight loss values were much lower (3.57%) because water loss was completely inhibited.

Vegetable type and packaging affected net weight significance ($p<0.01$) (Table 3 and 4). Lital gave the best product-type values with 42.34% net weight and covered products gave the best method value with 44.95% net weight.

No statistical difference was found between the groups with different vacuum precooling temperatures. The group precooled to +2°C gave the best value with 42.20% and the product group precooled to +4°C and the nonprecooled product group gave net weight values of 39.40 and 38.75%, respectively.

These results indicate that packaging lettuces before storage is an important factor in reducing net weight loss after storage, because it reduces moisture loss and losses due to spoilage.

Changes in temperature and pressure throughout vacuum precooling of green beans for the +8°C treatments are given in Fig. 5. The green bean products were precooled from 34.7 to 8.1°C within 39 min at an evacuation rate of 0.189 kPa min^{-1}.

Table 3: Net weight of different types of lettuce after 3 days of shelf life*

Product type	Net weight (%)
Lital	42.34[a]
Yedikule	37.18[b]

* Values followed by different letter (s) are significant ($p<0.01$)

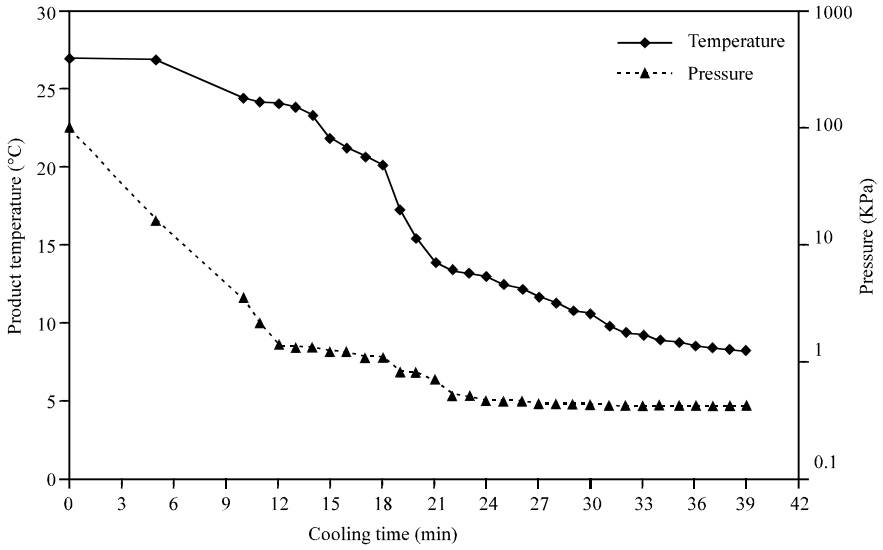

Fig. 5: Experimental results of vacuum cooling of green beans

Statistical analysis determined that the packaging of products taken to precooling significantly affected weight loss ($p<0.05$). The effects of packaging the products during vacuum cooling on weight loss in green beans are given in Table 5.

Packaging was found to significantly reduce weight loss in terms of moisture loss during vacuum precooling. There was a weight loss of 0.74% during vacuum precooling of packaged products, whereas this value was 2.41% in unpackaged products.

Product type affected weight loss ($p<0.01$) during the vacuum precooling of beans. Aysekadin beans lost less weight (0.36%) during vacuum precooling than did Rodop beans (2.40%) (Table 6).

Packaging and precooling practices significantly affected weight loss during storage ($p<0.01$) and product type was effective at $p<0.05$. The effect of packaging on weight loss after storage is shown in Table 7, which shows that the poststorage weight loss ratios of packaged beans were approximately one-third of the weight loss ratios of unpackaged beans. Therefore, it is possible to say that the storage of beans after packaging is an important factor in reducing weight loss.

Values related to the effect of precooling on weight loss after storage are given in Table 8. The precooling of beans to +8°C before storage led to an increase in weight loss during storage, as can be seen in Table 8. There was a weight loss of 7.47% after storage in the products precooled to +8°C compared with 4.51% in the products that were stored without precooling. When the effect of product type on weight loss after storage is considered, Rodop beans had the highest weight loss ratio with 8.27% (Table 9).

No change was determined in the net weight after storage, because no decay or spoilage was observed in beans after 3 days of shelf life.

Table 4: Effect of packaging on the net weight of lettuces*

Application	Net weight (%)
Perforated packaging	44.95[a]
No packaging	34.58[b]

* Values followed by different letter (s) are significant ($p<0.01$)

Table 5: Effect of packaging on the weight loss of beans during vacuum cooling*

Application	Weight loss (%)
Perforated packaging	0.74[a]
No packaging	2.41[b]

* Values followed by different letter (s) are significant ($p<0.05$).

Table 6: Effect of product type on weight loss of beans after vacuum cooling*

Product type	Weight loss (%)
Aysekadin	0.36[a]
Rodop	2.40[b]

* Values followed by different letter (s) are significant ($p<0.01$)

Table 7: Effect of packaging on weight loss of beans during storage*

Application	Weight loss (%)
Perforated packaging	2.75[a]
No packaging	9.24[b]

* Values followed by different letter (s) are significant ($p<0.01$)

Table 8: Effect of precooling on weight loss of beans during storage*

Application	Weight loss (%)
Precooling (+8°C)	7.47[a]
Nonprecooling	4.51[b]

* Values followed by different letter (s) are significant ($p<0.01$)

Table 9: Effect of product type on weight loss of beans during storage*

Application	Weight loss (%)
Rodop (+8°C precooling)	8.27[a]
Aysekadin (+8°C precooling)	6.68[b]

* Values followed by different letters are significant ($p<0.01$).

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