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Research Article

Effect of vacuum cooling on physico-chemical properties of holy basil (*Ocimum sanctum* Linn.)

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Abstract

The effect of vacuum process parameters on cooling time, weight loss percentage and temperature variation for the cooling process of holy basil were investigated. Vacuum cooling of holy basil packed in PVC film wrapped foam trays and holed plastic boxes using different vacuum pressure reductions were examined. Cooling holy basil packed in PVC film wrapped foam trays to 13 ± 1°C, the most ideal temperature to store holy basil from the results of the study, consumed longer cooling times than holy basil packed in holed plastic boxes. Lower final pressure caused higher weight loss. The optimum condition for vacuum cooling process of holy basil packed in PVC film wrapped foam trays with initial temperature of 21-24°C was at the final pressure of 12 mbar with pressure reduction of 3 minutes. For holy basil packed in holed plastic boxes with the initial temperature of 21-24°C, the optimum condition was the final pressure at 12 mbar with pressure reserving time of 1 minute. The cooling time of holy basil packed in PVC film wrapped foam and holed plastic boxes were 14 and 12 minutes and the weight loss percentages during the vacuum cooling process were 1.17 and 1.25, respectively. The effect of vacuum cooling and type of packaging on the physico-chemical properties of holy basil stored at 13°C were investigated as well. The results showed that vacuum cooling had no effect on the loss of fresh weight, the change of colour, or the amounts

of vitamin C and chlorophyll in holy basil, but was an important factor in maintaining longer shelf life when compared to basil not vacuum-cooled. Type of packaging had significant effect on fresh weight loss, phenolic content and antioxidant activity but had no effect on the amounts of colour change, vitamin C and chlorophyll. The research also exemplified that holy basil precooled and stored under these optimal conditions are significantly better preserved with longer shelf life of about 7 days as opposed to the normal length of 4 days.

Keywords: post-harvest, fresh herbs, transport, packaging, physico-chemical, shelf life, pressure reserving technique, Thailand

Introduction

Holy basil *(Ocimum sanctum Linn)* is a herb grown in Thailand with high export potential, particularly if transported fresh to European countries. The Royal Project Foundation has been exporting basil, as well as other herbs and vegetables to Europe and other overseas markets. However, holy basil constantly deteriorates in quality throughout their storage life and during transportation.

Vacuum cooling technology is a proven technology widely applied on post-processing of harvested agricultural products, particularly mushrooms and lettuce [1, 2, 3]. The technology is particularly suited to leafy vegetables [4]. Vacuum cooling is a rapid evaporative cooling technique, which is achieved by boiling part of the moisture in the food under vacuum conditions [5]. The advantages of vacuum cooling include shorter processing time, extended product shelf life, improved product quality and safety [6]. Zhang and Sun [7] reported that vacuum cooling combined with spraying water proved to be a suitable as a rapid cooling method for cooked broccoli and carrot slices. The handling process of the multi-stage vacuum pressure reserving technique can effectively lower both the internal and external temperatures of the cabbage, including its complex internal structure which is tightly wrapped, making the two temperatures nearly identical and effectively saving energy required by the vacuum cooling process [8]. Rennie *et al* [9], examined the effect various rates of pressure reserving technique on extending the shelf life of lettuce. Cheng [3] investigated the effect of vacuum cooling in combination with hydro-cooling and vacuum drying on harvested bamboo shoots. The experimental results showed that multi-stage vacuum pressure reserving technique combined with hydro-cooling could reduce the temperature of bamboo shoots efficiently. It was proven to prolong the storage time and improve the freshness, preserving quality efficiently. Vacuum cooling process is a new technology that the Royal Project Foundation is using as a technique to prolong the shelf life and improve the quality of vegetables. Unfortunately, no complete information on an appropriate application for holy basil has been obtainable so far. Therefore, this research on what would be the parameters for set-up is being conducted in order to achieve the overall effectiveness should this new technique be implemented. The research study was conducted to find out optimum storage temperatures, optimum cooling process parameters and effects of vacuum cooling under different packaging on physico-chemical properties of the herb.

Materials and Methods

Study on optimum storage temperatures for holy basil

A study was conducted to investigate optimum storage temperatures for holy basil. Holy basil leaves and stems were graded, defects and undesirable parts trimmed off, then packaged in PVC (polyvinylchloride) film wrapped foam trays. The plant materials were stored under 4 storage temperatures of 4, 7, 10 and 13°C then observation on the change of external qualities was made as follows: loss of fresh weight, colour change; colour was expressed as L value (L*), chroma (C*) and hue angle (h°) using a colorimeter (Chromameter, Minolta CR-310) and shelf life.

Study on optimum process parameters for vacuum cooling of holy basil

The vacuum cooling system used in this experiment included vacuum chamber, vacuum pumping system, condenser, refrigerator and automatic control and operation system. The details of the vacuum cooling system are presented in Fig 1. The system was built by Hussmann Co., Ltd. (USA).

Holy basil leaves and stems were graded, defects and undesirable parts trimmed off, then put into 2 types of ready-to-sell packages. 80 grams of holy basil were first weighed in separate lots and each then placed in a PVC (polyvinylchloride) film wrapped foam trays sized 6”x 7”x 11.5” with 40 holes in each with the diameter of 0.5 mm. Similarly, lots of 50 grams each of holy basil were placed holed plastic boxes (12 holes with 1 cm. diameter each) sized 3.5”x 5.2”x 2.5” (Fig. 2). A total of 800 grams of herbs was spread in each polypropylene basket for a total of 60 baskets. The initial weight and temperatures of holy basil were measured and recorded, then all baskets placed inside the cooling chamber (Fig. 3). The holding pressures for vacuum cooled holy basil packed in foam tray were set at two different levels; 11 and 12 millibars; and at 3 levels of the vacuum pressure reserving; 2, 3 and 4 minutes, respectively for each level of pressure. The holding pressures for vacuum cooled holy basil packed in holed plastic boxes were set at two different levels; 11 and 12 millibars; and at 3 levels of the vacuum pressure reserving; 2, 3 and 4 minutes, respectively for each level of pressure. Chamber pressure, temperature, relative humidity percentage and produce centre temperature were recorded every minute from the beginning through to the end of the cooling process. After immediate removal of the produce from the cooling chamber, the basil was weighed and recorded. Energy consumption of the vacuum cooling process was measured and energy costs in Thai baht were calculated.

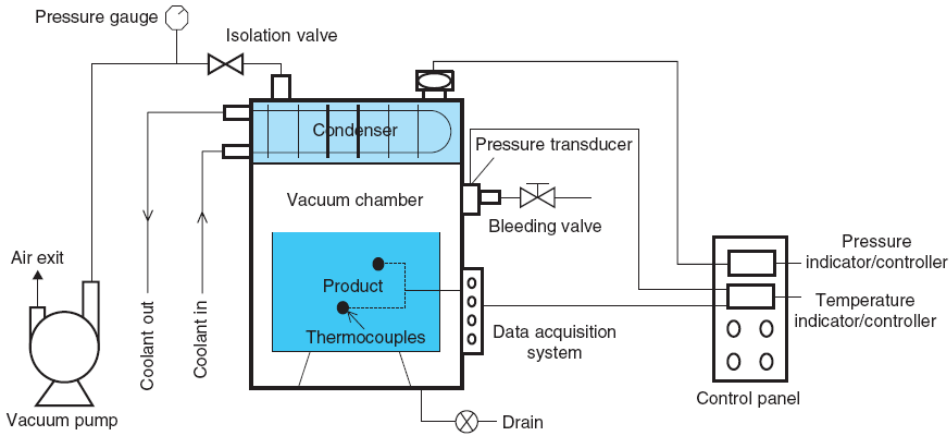

Figure 1. Schematic diagram of the research vacuum cooler.

Figure 2. Arrangement of holy basil packed in holed plastic box (left) and PVC wrapped foam tray (right).

Study the effect of vacuum cooling on physico-chemical properties of holy basil after vacuum cooling

This study was conducted on physico-chemical qualities of holy basil vacuum-cooled at the best condition from the second experiment using holding pressure of 12 millibars and with holding time of 1 and 3 minutes for basil packaged in foam tray and holed plastic box, respectively. The plant materials harvested at commercial maturity stage were graded, defects and undesirable parts trimmed off, then put into the 2 types of ready-to-sell packages mentioned above then precooled using the vacuum cooling system and stored at 13°C until the end of its storage life. Physico-chemical properties were analyzed every day as follows: weight loss percentage, colour was expressed as L value (L*), chroma (C*) and hue angle (h°) using a colorimeter (Chromameter, Minolta CR-310), ascorbic acid was extracted and analysed [10],

chlorophyll was extracted and analysed [11], total phenolic content was determined by the Folin-Ciocalteus method using gallic acid as a standard [12, 13]. The antioxidant activity of the extracts was determined in terms of hydrogen donating or radical scavenging ability, using the stable radical DPPH [14, 15].

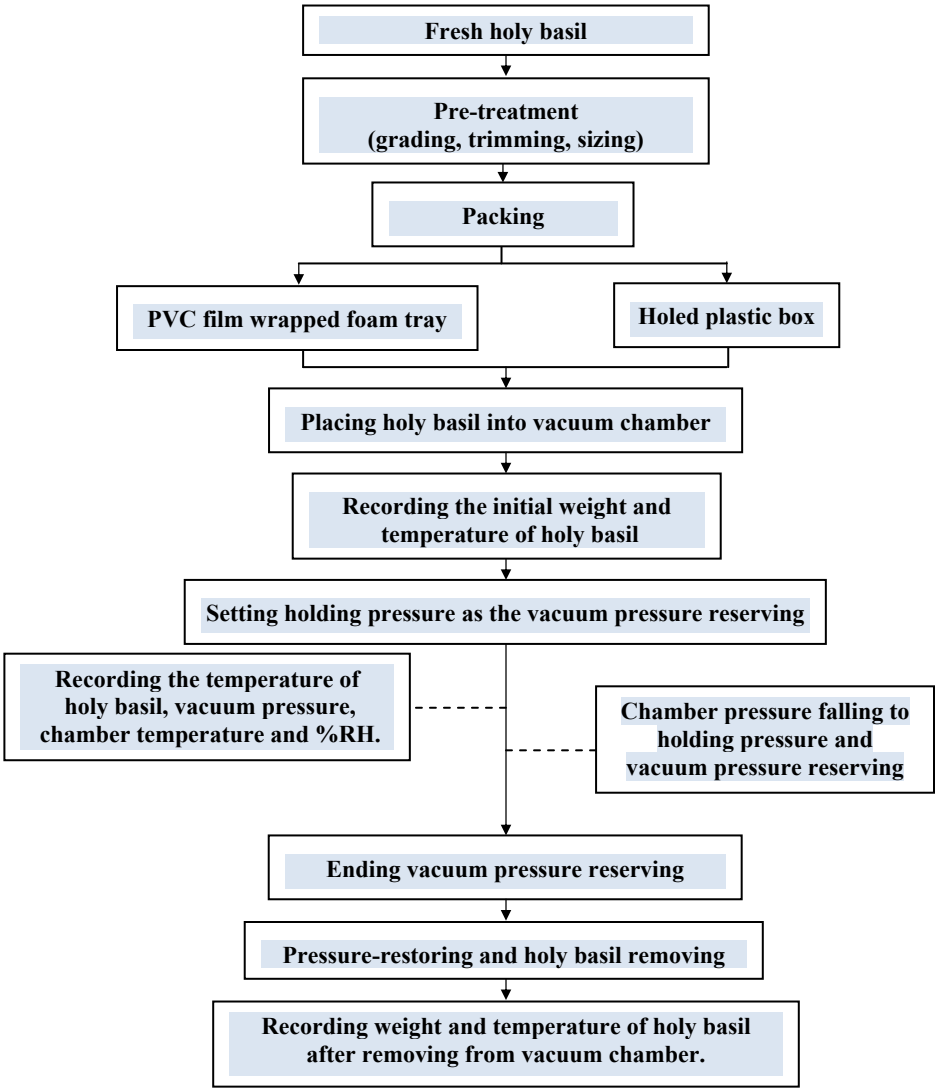

Figure 3. Flow chart showing the vacuum cooling process.

Results and Discussion

Study on optimum storage temperatures for holy basil

Table 1 displays the physical properties of holy basil stored at different temperatures. Holy basil stored at 4, 7, 10 and 13°C lost their fresh weight continuously with storage time. For holy basil stored for 3 days, the fresh weight loss after storage at 10 and 13°C amounted to 3.75 and 3.60%, respectively (Table 1), which was significantly ($p<0.05$) higher than the fresh weight loss when stored at 4°C. Regarding the colour change, the hue angle of holy basil stored at 7°C was found to be the lowest value of 111.54 degrees and significantly ($p<0.05$) differed with basil stored at 10°C. Hue angle of basil stored at 10°C showed the highest value of 113.76 degrees. There was no significant difference on L* and C* values in basil stored at 4, 7, 10 and 13°C for 3 days ($p>0.05$). Deterioration in quality of holy basil and sweet basil was attributable to chilling injury, occurring especially at the temperature of 4°C, starting from a dark brown patch underneath the leaves. Growing more severe, the dark brown patch turned black with tissues setting back a little.

Table 1. Physical properties of holy basil stored at different temperatures after 3 days of storage.

Storage Temperature	Weight Loss (%)	L*	Chroma	Hue angle (degree)	Shelf Life (days)
4°C	1.22^{c}	52.13	18.24	112.48^{ab}	3^{d}
7°C	3.34^{b}	51.87	18.19	111.54^{b}	5^{c}
10°C	3.75^{a}	51.54	18.30	113.76^{a}	7^{b}
13°C	3.60^{ab}	52.35	17.98	112.88^{ab}	8^{a}

Mean separation within columns by LSD, p = 0.05

Study on optimum process parameters for vacuum cooling of holy basil.

Optimum process parameters for holy basil vacuum cooled in PVC film wrapped foam trays and holy basil vacuum cooled in holed plastic boxes and the measuring indices of vacuum cooling processes are displayed in Table 2. In intending to cool basil to 13 ± 1°C, several sets of parameters were investigated. The experimental results showed that the optimum condition for vacuum cooling process of basil in PVC film wrapped foam tray and for holy basil in holed plastic boxes with the initial temperature of 21 - 24°C precooled with the best parameters obtained for the holding pressure at 12 mbar, was the holding time of 3 and 1 min, respectively. The total cycle time for foam tray package and holed plastic box were 14 and 12 min. In terms of weight loss percentage, the research also exemplified that herbs packaged in foam trays precooled under the optimum cooling parameters had a minor difference in weight loss percentage of 1.17 than herbs packaged in holed plastic boxes (1.25%). Economic analysis showed that the vacuum cooling had an additional cost of 0.022 baht/kg for foam tray package and 0.017 baht/kg for holed plastic box (35.93 baht = 1 US$).

Table 2. Optimum process parameters for holy basil vacuum cooled in PVC film wrapped foam tray and holy basil vacuum cooled in holed plastic box and measuring indices of vacuum cooling processes.

Process Parameters/Measuring Indices	Holy Basil Vacuum Cooled in PVC Film Wrapped Foam Tray	Holy Basil Vacuum Cooled in holed plastic box
Holding pressure (mbar)	12 mbar	12 mbar
Holding time (min)	3 min	1 min
Cycle time (min)	14 min	12 min
Initial core temperature of holy basil (°C)	21-24 °C	21-24 °C
Final core temperature of holy basil (°C)	12-14 °C	12-14 °C
Weight loss (%)	1.17 %	1.25 %
Energy consumption (kWh)	0.10 kWh	0.09 kWh
Electrical Expense (baht/kg)	0.022 baht/kg	0.017 baht/kg

The variation mechanism of temperature in the vacuum chamber during vacuum cooling can be expressed as follows: first, the total pressure in the vacuum chamber is the sum of the partial pressure of air and water vapour. During vacuum cooling, the air is evacuated by vacuum pump and water vapour condenses into water in the vapour-condenser. The total pressure in the vacuum chamber is reduced from atmosphere to the set holding pressure. With the reduction of pressure in the vacuum chamber, the time at the commencement of boiling is called the "flash point". For the vacuum cooling process of packaged holy basil in foam trays, the variation of temperature in the vacuum chamber is shown in Figure 3. The initial temperature in the vacuum chamber was 13.9°C. It can be seen from the graph that the temperatures in the vacuum chamber have some fluctuations during the vacuum cooling process. The variation of chamber temperature can be divided into three different parts: part I, part II and part III as shown in Figure 4. The temperature rose from 13.9 to 17.9 °C during the first part. It can be explained by the fact that since the initial temperature of holy basil was at 21.4°C and the chamber temperature was 13.9°C, the water vapour was able to evaporate from the plant at this temperature, which in turn increased the temperature in the vacuum chamber as opposed to the chamber relative humidity. Subsequently, most of the vapour is condensed in the vapour-condenser. Together with the reduction of the temperature of the herb and the vacuum pressure in the vacuum chamber, the temperature in the vacuum chamber decreased from 17.9 to 13.3°C (part II). In the third part (part III) as shown in Figure 4, the pressure in the vacuum chamber, dropped rapidly from 154.1 to 12.0 mbar, reaching the reserve pressure of 12.0 mbar, and held for 3 minutes and the temperature in the vacuum chamber decreased sharply from 13.3 to 9.3°C. The cooling rates of holy basil in both packages are low at the beginning. However, after 10 min, cooling rates of the herb become high. The vacuum pressure decreased continuously until reaching the reserve pressure, then held at the holding pressure for the reserve time set at 3 minutes. When the bleeding air valve was switched on, air at a room temperature entered into the vacuum chamber causing an increase in the temperature in the vacuum chamber. The final temperature in the vacuum chamber was 9.6°C. Weight loss occured during vacuum cooling since the chamber cooling effect directly comes from water evaporation from the herb. Weight

losses of holy basil during vacuum cooling for two different holding pressures are displayed in Table 2. Weight loss percentage is closely related to the holding pressure. For the same holding time, the lower pressure used, the higher weight loss was experienced. Table 2 demonstrates that cooling time depended upon the holding pressure and holding time. Type of packaging also attributed to the weight loss, since large opening surface area of the packaging directly affected the amount of water evaporated. Holy basil packed in PVC wrapped foam tray lost less weight than holy basil packed in plastic boxes during the vacuum cooling process.

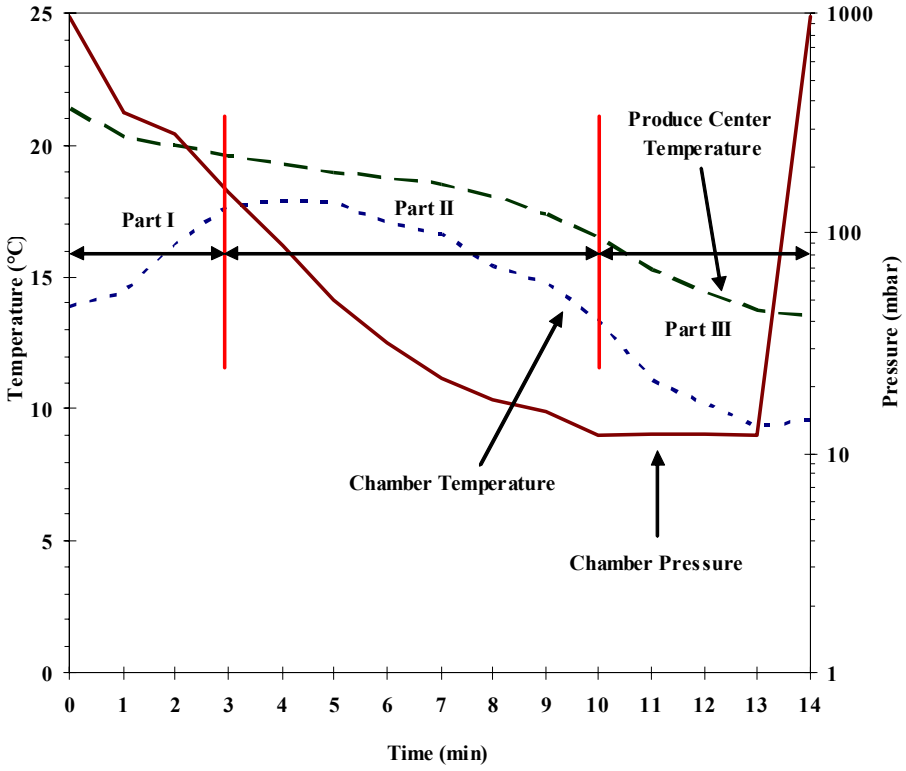

Figure 4. Temperature, pressure history in the vacuum chamber and cooling curve of holy basil package in PVC wrapped foam tray during vacuum cooling at 12 mbar with 3 minutes reserving time.

Study of the effect of vacuum cooling on physico-chemical properties of holy basil after vacuum cooling

This experiment investigated the effect of vacuum cooling and type of ready-to-sell packaging on the physico-chemical properties of holy basil stored at 13°C, the most appropriate temperature to store holy basil determined from the first experiment. The results showed that vacuum cooling had no effect on the loss of fresh weight (Table 3), the change of colour, the amount of vitamin C and chlorophyll a, b, and total chlorophyll in holy basil, but was an important factor in maintaining longer shelf life than those of holy basil not vacuum-cooled. Weight loss percentage of plant material continued to increase in all treatments throughout the storage period. The amounts of vitamin C tended to decrease with storage time. The chlorophyll

Table 3. Influences of vacuum cooling and packaging on physical properties (mean of ± S.E.) of holy basil stored for 4 days.

Treatment	Weight Loss (%)	L* Value	C*	Hue Angle
Vacuum Cooling Process				
-With Vacuum Cooling	3.67±1.02	47.24±3.38	13.80±2.57	103.36±4.82
-Without Vacuum Cooling	4.37±1.96	47.80±2.79	14.02±1.60	103.79±1.77
Type of Packaging				
-PVC wrapped foam tray	2.82±0.25[b]	49.28±2.55[a]	13.78±1.55	104.94±1.49
-Holed Plastic Box	5.22±1.38[a]	45.76±2.44[b]	14.04±2.60	102.21±4.49

a, b and total chlorophyll (Table 4) tended to decrease with storage time, which correlated with the diminishing green colour. The amounts of total phenolic content and antioxidant activities of holy basil after vacuum cooling were significantly lower than those found in holy basil without vacuum cooling. It was found that total phenolic content and antioxidant activities increased until the end of the storage. Deterioration in quality of holy basil, which was is a shelf life indicator, was attributable to chilling injury, starting from a dark brown patch underneath the leaves. Growing more severe, the dark brown patch turned black with tissues setting back a little.

Table 4. Influences of vacuum cooling and packaging on chemical properties (mean of ± S.E.) of holy basil stored for 4 days.

Treatment	Ascorbic acid (mg/100 g)	Chlorophyll a (mg/100 g)	Chlorophyll b (mg/100 g)	Total Chlorophyll (mg/100g)
Vacuum Cooling Process				
-With Vacuum Cooling	2.89±1.06	0.455±0.05	0.212±0.03	0.667±0.09
-Without Vacuum Cooling	3.85±1.22	0.416±0.05	0.193±0.03	0.609±0.07
Type of Packaging				
-PVC wrapped foam tray	2.89±1.06	0.457±0.06	0.217±0.04	0.674±0.10
-Holed Plastic Box	3.85±1.22	0.414±0.03	0.188±0.01	0.602±0.04

Type of packaging had a significant effect on fresh weight loss, phenolic content, antioxidant activities and shelf life, but had no effect on the amounts of vitamin C and chlorophyll (Table 4). Holy basil packed in PVC film wrapped foam trays suffered a smaller loss of fresh weight and at the same time measured lower amounts of phenolic content, but lower antioxidant activities than basil packed in holed plastic boxes. Total phenolic content and antioxidant activities of holy basil packed in different types of packaging during 4 days storage are displayed in Table 5. Total phenolic content and antioxidant activities of both types of packaging were generally increased with increasing storage time and significant higher in holy basil with vacuum cooling process. Total phenolic content and antioxidant activity of holy basil

Table 5. Influences of vacuum cooling and packaging on total phenolic content and antioxidant activity (mean of ± S.E.) of holy basil stored for 4 days.

Treatment	Total Phenolic Content (µg GAE/g fresh weight)	Antioxidant Activity (µg GAE/g fresh weight)
Vacuum Cooling Process		
-With Vacuum Cooling	4,782.48±381.01[b]	626.46±46.01[b]
-Without Vacuum Cooling	6,658.66±622.92[a]	968.26±83.29[a]
Type of Packaging		
-PVC wrapped foam tray	5,837.10±1480.70[a]	816.08±241.90[a]
-Holed Plastic Box	5,604.05±480.82[b]	778.64±116.17[b]

packed in PVC wrapped foam tray were significantly higher than holy basil packaged in holed plastic boxes. This finding is likely attributable to the stress on the plant material. The results also indicated that antioxidant activities of holy basil were correlated with total phenolic content and were affected by vacuum cooling as well as packaging type. The increase in total phenolic content of the holy basil throughout the storage was likely attributable to continuous loss of moisture from the herb. There was no interaction effect between vacuum cooling and type of packaging on the loss of fresh weight, the change of colour, the amounts of vitamin C and chlorophyll in holy basil, but significantly affected total phenolic content, antioxidant activity and shelf life. This research also exemplified that holy basil precooled and stored at 13°C is significantly better preserved, with longer shelf life of 6 to 7 days, depending upon the type of packaging as opposed to the normal length of 4 days (Table 6).

Table 6. Influences of vacuum cooling and packaging on shelf life of holy basil stored at 13°C.

Treatment	Shelf life
Vacuum Cooling Process	
-With Vacuum Cooling	6.00±1.04[a]
-Without Vacuum Cooling	4.50±1.62[b]
Type of Packaging	
-PVC wrapped foam tray	6.50±0.52[a]
-Holed Plastic Box	4.00±1.13[b]

Conclusions

The study on optimum storage temperatures revealed that the most appropriate temperature to store holy basil was 13°C, with a storage life of 8 days. The optimum conditions for vacuum cooling process of holy basil in PVC film wrapped foam tray and for holy basil in holed plastic box with the initial temperature of 21 - 24°C precooled with the best parameters obtained for the holding pressure at 12 mbar, were the holding time of 3 and 1 min, respectively. In terms of

weight loss percentage, the research also exemplified that herbs packaged in foam trays precooled under the optimum cooling parameters had less weight loss percentage of 1.17 than herbs packaged in holed plastic boxes (1.25%). Weight loss percentage is closely related to the holding pressure, holding time and type of packaging. The vacuum cooling had no effect on the loss of fresh weight, the change of colour, the amounts of vitamin C and chlorophyll a, b, and total chlorophyll in holy basil, but was an important factor in maintaining longer shelf life than when compared to holy basil not vacuum-cooled. Type of packaging had a significant effect on fresh weight loss, phenolic content, antioxidant activities and shelf life, but had no effect on the amounts of vitamin C and chlorophyll. The shelf life of holy basil vacuum cooled and packed in PVC wrapped foam tray was the highest at 7 days. From this research, it can be concluded that vacuum cooling and optimal type of packaging could help prolong the storage life of holy basil.

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