Research Article

Interactive effects of storage temperatures and packaging methods on sweet basil

Abstract

Leafy vegetables were packed into packaging under refrigerated temperature in order to prolong its shelf life. When the temperature and packaging approaches are not in optimum condition to the vegetables, the freshness of vegetables will be affected and indirectly increase food wastes. The aim of this project is to study the combined effect of temperature and packaging methods on basil through evaluating its weight loss, chlorophyll content and vitamin C content. The basil was germinated, growth and harvested randomly in a total of 13 weeks and packed and stored under six different conditions (4°C with perforated packaging; 4°C with non-perforated packaging; 20°C with perforated packaging; 20°C with non-perforated packaging; 30°C with perforated and 30°C with non-perforated packaging). Experimental results shown that storage of sweet basil in perforated packaging, at 4°C provided minimum loss weight and maximum chlorophyll and vitamin C retained. In future, a well-planned vegetable freshness index can be proposed to evaluate the freshness by its weight, chlorophyll content, and vitamin C content.

Keywords: sweet basil, storage temperature, packaging

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Introduction

Nowadays, consumers are searching for food with beneficial effect because they are more concerned about their health and wellness. Vegetables and fruits are rich carbohydrate, fibre and vitamin sources. Consumers prefer ready to eat food which vegetable can be consumed right out of the package without washing, to offer consumers high nutrition, convenience, and value while still maintaining freshness.

Packaging is an approach by using materials to wrap or protect goods and normally a presentation of a product. Good packaging can prevent vegetables from physical damage and chemical pollution.[1] Carefully handling the vegetables during loading and unloading can reduce the mechanical damage and proper packaging that not too tight and not too loose packagings affect the market value of the product. Suitable packaging for vegetables reduce the losses during transportation of goods, so that detail study on the packaging technologies were carry out to further reduce the losses and indirectly increase the market value of the product.[2] Shelf life of the product can be enhanced by controlling the oxygen's and carbon-dioxide levels to the desirability of the product longevity within the packaged products.[3] The respiration rate of vegetables decreased the level of CO_2 while O_2 level was increased.[4] Special packaging techniques have been developed to preserve vegetables with high moisture content (perishable product) and decrease the respiration rate. The parameters, such as package length of life, cost and weight (unit load) are considered important during the distribution.

Packaging cannot prevent spoilage of vegetables but can protect it against contamination, damage and excessive moisture loss. Different packaging materials are choose based on the specific food types, like oxygen-sensitive foods require packaging that can prevent oxidation. As emphasis by Sustainable Development Goals (SDGs), many of the issues are interlink. Biodegradable and environmentally friendly plastics are replacing none biodegradable plastic for sustainable and green protocols. As the modern civilization exploiting the resource in the Earth for the sake of living and surviving, there is responsibility to conserve it well in order to sustain it. Thus, there is renewed focus on creating sustainable packaging from materials such as polylactide acid (PLA) plastics, sugar cane pulp, fiber composite, starch-based films, stainless steel packaging and etc[5] and incorporate with Modified Atmosphere Packing (MAP) technique. MAP can be defined as an technique use alternation in the composition of gases to prolong the postharvest life of vegetable and fruits. This technique relies on modification of the atmosphere inside the package to reduce the respiration rate, ethylene sensitivity and production, decay and physiological changes.[6]

Food waste in consumer households are related to human values and perceived value of food. The lifestyle and believe of consumers are the main cause of increase food waste. One can foresee particularly in SDGs programme, consumers reject the food packaging while purchasing food ingredients especially packaging with materials that are not biodegradable. Without a proper knowledge in vegetable packaging and preserving approaches, consumers self-assumption skill will eventually contribute to deterioration of fresh food products.

Leafy vegetable has a short period of freshness lifetime and are highly perishable due to deterioration and water loss.[7] Deterioration and water loss will affect its freshness and its properties. The deteriorate vegetable will be discarded and the amount of food waste will be increased.[8,9] Kantor et al.[10] had observed 10% to 50% postharvest loss from the developed countries while Kitinoja et al.[11] had observed 30% to 80% postharvest loss from the developing countries. Kader[12] has found that 20% from postharvest losses are fruits and vegetables wastage estimated as a consumer and food service losses. Sweet basil, scientific name called *Ocimum basilicum* L., is an aromatic herbal plant that belongs to the *Lamiaceae* family from the tropical regions of South-Eastern Asia and is used as an ornamental, seasoning and medicinal plant around the world. The extracted essential oil from leaves and flowers are used to enhance the aromas for food, perfume and cologne production and in medical therapy.[13] Basil is sensitive to the growing environment especially to the light and temperature. The temperature directly influences the growth and development of the plants which affect the contents and composition of essential oil that determines the usability of the herb for pharmaceutical purposes.[13] Limited study show that the packaging approaches or storage method will affect its nutrient contents in especially in sweet basil. In addition, De Laurentiis et al. [14] reported that fresh fruit and vegetables contribute to 50% of food waste by households. This might due to the unconsidered of purchase or consumption patterns and also lacking of awareness in storing the fresh vegetables and fruits by consumers. So, the experimental design for this study is very simple and the outcomes of this study can provide a preliminary insight to investigate the combined effect of temperature (4°C, 20°C, 30°C) and packaging methods (perforated packaging, non-perforated packaging) on basil through determine its weight, chlorophyll content and vitamin C content.

Methodology

Sample preparation

The sweet basil seeds were germinated and transferred to aquaponic system after 7 days of germination. After 12weeks of transplantation, fresh sweet basil was harvested, package (30g per pack) and stored (4°C with perforated packaging; 4°C with non-perforated packaging; 20°C with perforated packaging; 20°C with non-perforated packaging; 30°C with perforated and 30°C with non-perforated packaging; triplicate). For each experiment, two leaves (approximately uniform size) were collected from each of the treatment, and weighted separately before conduct chlorophyll and vitamin C content experiment.

Weight loss

Weight loss of the samples was calculated based on the changes in weight by using weighing scale. The results were expressed in percentage.

Chlorophyll content

The basil leaves were grinded with a mortar and pestle and put into test tube which containing solvent (acetone). The extraction was left for 1 hour. Then, the supernatants were collected and measured colorimetrically at 646 nm and 663nm with an UV-VIS spectrophotometer. According to McKinney-Arron relationship chlorophyll content was measured as:

$$Chl\ a = 12.21 \times (A_{663}) - 2.81 \times (A_{646}),$$
$$Chl\ b = 20.13 \times (A_{646}) - 5.03 \times (A_{663}),$$
$$Chl\ total = 17.32 \times (A_{646}) + 7.18 \times (A_{663})$$

Where Chl a, chlorophyll a, in mg/kg; Chl b, chlorophyll b, in mg/kg; Chl total, total chlorophylls content, in mg/kg; A_{663}, sample absorbance at 663nm; A_{646}, sample absorbance at 646nm.

Vitamin C content

The leaves sample was grinded in a mortar and pestle together with 50mL of distilled water. Vitamin C content was determined with titration method and starch was used as indicator. The sample was titrated with 0.005 mol L^{-1} iodine solution and endpoint of the titration was identified as the presence of first permanent trace of a dark blue-black colour due to the starch-iodine complex. The titration was repeated another two times with further aliquots of sample solution until obtained concordant results (titres agreeing within 0.1mL).

Statistical analysis

The statistical analysis of data obtained was carried out to analyse the differences among the treatment during storage period by using SPSS (Statistical Package for Social Sciences) version 22.0. All experiments were performed in triplicate and analysed through two-way independent ANOVA analysis. Descriptive statistics, tests of between-subjects effects, Post Hoc (LSD, DUNCAN), and graph of interaction effect tables generated from the losses of weight, chlorophyll content and vitamin C content data from the basil plant (Data not shown). All the statistical data will be tabulated in the form of mean±standard deviations. Statistical significant level is established at $p<0.05$.

Results and discussion

There are total of 36 treatments which 18 of them were first harvested and another 18 were second harvested. Those 18 treatments belonged to the same harvested were divided into 6 sets-perforated packaging stored in 4°C, perforated packaging stored in 20°C, perforated packaging stored in 30°C, non-perforated packaging stored in 4°C, non-perforated packaging stored in 20°C, and non-perforated packaging stored in 30°C. Weight, chlorophyll content and vitamin C content for all samples were measured. All experiments conducted in twice a week.

In this experiment, different temperatures 4°C, 20°C and 30°C were chosen for storage of basil plants. The reason to select in different temperature is every food commodities have their own optimum temperature. Vegetables would be recommended to kept in refrigerated temperature; 4°C in order to prolong the shelf life by slow down the ripening process. But somehow, the vegetables sold in the supermarket are left on the rack under cold condition, around 20°C. Other than that, some vegetables were sold at the morning and night market under ambient temperature, which was 30°C. There were two types of packages which were in perforated and non-perforated. Perforated packaging is a solution to control the atmosphere inside the packaging which those holes allow oxygen and carbon dioxide move freely in and out.

Weight loss

Weight loss was one of the factors to determine the freshness of food commodities.[15] In these experiments, the weight of basil leaves was weighted twice a week until basil leaves fully deteriorated. The mean weight loss and standard deviation (SD) of basil were calculated as shown in Table 1. From Table 1, weight loss of basil stored in temperature 20°C are not significantly different (since they are in one subset) to 4°C and 30°C while weight loss of basil stored in temperature 4°C and 30°C are significantly different from each other since they are not in one subset during the first time harvested the basil. While the weight loss of basil stored in temperature 4°C, 20°C and 30°C are significantly different from each other since they are all in different subset in second time harvested the basil.

Table 1 The mean weight loss and standard deviation (SD) of basil were calculated in different temperature and packaging methods

Loss of weight (g)			
Temperature	Packaging method	Mean±SD	
		1st time	2nd time
4°C	P	NA	$6.247{\pm}1.115^{a}$
4°C	NP	$6.660{\pm}1.485^{a}$	$9.860{\pm}0.652^{a}$
20°C	P	$3.067{\pm}8.700^{ab}$	$12.157{\pm}3.1448^{b}$
20°C	NP	$5.303{\pm}5.354^{ab}$	$16.400{\pm}2.235^{b}$
30°C	P	$5.167{\pm}2.156^{b}$	$21.553{\pm}2.231^{c}$
30°C	NP	$14.837{\pm}0.988^{b}$	$25.213{\pm}1.593^{c}$

[a], The values are means±standard deviation. Within the same row, different superscripts (a-b) are significantly different at $p<0.05$. P, Perforated, NP, Non-perforated, 1st time, first time harvested the basil, 2nd time, second time harvested the basil.

From the table of multiple comparisons (Data no shown), it can concluded as the basil stored in 4°C had significantly lower weight loss than all the other storage temperature. Weight loss was significantly minimum in different packaging treatment store at 4°C as compared to packaging treatments stored at 20°C or 30°C conditions.

Among all the packing treatments, the basil in non-perforated packaging tends to have higher weight loss than perforated packaging. There was no interaction effect as the effect of storage temperature was similar for both non-perforated packaging and perforated packaging. Perforated packaging given better performances compared to non-perforated packaging. The number of holes in perforated packaging should not be excessive, because the condition favoured the disease development as water condensed at the surface of packaging material when the perforations of packaging are too few causes the leafy vegetable wilt easily.

Chlorophyll content

Chlorophyll content is one of the ways to evaluate the freshness of the basil leaves. Total chlorophyll content of basil was determined by a spectrophotometric method. One piece of basil leaf was taken out from each treatment to determine the chlorophyll content. From the Table 2, minimum and maximum chlorophyll content loss of basil in perforated packaging at 20°C (6.362±18.897 mg/kg) and in non-perforated packaging at 30°C (26.607±12.889 mg/kg) in first time harvested the basil, respectively. While during the second time of harvested the basil, minimum and maximum chlorophyll content loss of basil in non-perforated packaging, at 20°C (1.391±25.865 mg/kg) and in perforated packaging at 20°C (23.988±5.889mg/kg), respectively. The chlorophyll content loss of basil stored in temperature 4°C, 20°C and 30°C are not significantly different from each other since they are all in one subset. Several reading in Table 2 show negative reading (NA) which might be due to the inconsistent of leave size and also the time of harvest.[16] According to the research, there are two phases during chlorophyll degradation of the plants. In the first phase, as the mass and the water level decreased in the leaves the pigments became more concentrated. In the following, slight yellowing or loss of green colour indicated the decreased in quality which observed in the medical plant as time passed.[17]

Table 2 The mean chlorophyll loss and standard deviation (SD) of basil were calculated in different temperature and packaging methods

Loss of chlorophyll (mg/kg)			
Temperature	**Packaging method**	**Mean±SD**	
		1st time	**2nd time**
4°C	P	16.692±29.439[a]	NA
4°C	NP	NA	NA
20°C	P	6.362±18.897[a]	23.988±5.889[a]
20°C	NP	NA	1.391±25.866[a]
30°C	P	19.044±19.747[a]	14.881±34.434[a]
30°C	NP	26.607±12.889[a]	NA

[a] The values are means±standard deviation. Within the same row, superscript (a) is not significantly different at p<0.05. P, Perforated, NP, Non-perforated, 1st time, first time harvested the basil, 2nd time, second time harvested the basil.

Vitamin C content

Vegetables are sources of micronutrients, phytochemicals and fibre which help to prevent a number of chronic non-communicable diseases, including cardiovascular diseases, diabetes, obesity, cancer and respiratory conditions.[18] Basils are vegetable that rich in vitamin C content.[19] Vitamin C can be one of the quality aspects to indicate the freshness of vegetables. Vitamin C acts as an important nutritional value in order to maintain and improve health, at the same time preventing from sickness. The presence of vitamin C in food commodities indicated in the quality itself. According to Nordqvist,[19] in the 100g of basil contains 18.0milligrams of vitamin C content.

Due to natural degradation, the decreasing of vitamin C content means the dropping of quality of plants. Vitamin C content was measured to study the relationship between packaging methods and temperature. The mean vitamin C content loss and standard deviation (SD) was calculated as shown in Table 3.

Table 3 The mean vitamin C content loss and standard deviation (SD) of basil were calculated in different temperature and packaging methods

Loss of Vitamin C (mol per L)			
Temperature	**Packaging method**	**Mean±SD**	
		1st time	**2nd time**
4°C	P	2.083x104±1.922x104[a]	1.667x105±3.008x105[a]
4°C	NP	8.057x105±3.467x105[a]	3.890x105±5.547x105[a]
20°C	P	1.555x104±2.925x105[a]	5.277x105±2.677x105[ab]
20°C	NP	2.000x104±4.641x105[a]	8.330x105±5.000x105[ab]
30°C	P	6.667x105±4.165x105[a]	3.890x105±8.671x105[c]
30°C	NP	8.333x105±4.407x105[a]	1.667x105±7.948x105[c]

[a] The values are means±standard deviation. Within the same row, different superscripts (a-b-c) are significantly different at p<0.05. P, Perforated, NP, Non-perforated, 1st time, first time harvested the basil, 2nd time, second time harvested the basil.

From the table above, there was minimum vitamin C content loss of basil at 20°C in perforated packaging ($1.555x10^4±2.925x10^5$ mol per L) while maximum vitamin C content loss of basil at 30°C in non-perforated packaging ($8.333x10^5±4.407x10^5$ mol per L) in first time harvested. While the second time of harvested the basil, there was minimum vitamin C content loss of basil at 30°C in non-perforated packaging ($1.667x10^5±7.948x10^5$mol per L) and 4°C in perforated packaging ($1.667x10^5±3.008x10^5$ mol per L) while maximum vitamin C content loss of basil at 20 °C in non-perforated packaging ($8.330x10^5±5.000x10^5$ mol per L).

The vitamin C content loss of basil stored in temperature 4°C, 20°C and 30°C are not significantly different from each other since they are

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all in one subset (during 1st time). During the second time of harvested the basil, vitamin C content loss of basil stored in temperature 20°C are not significantly different with 4°C and 30°C (since they are in one subset) while basil stored in temperature 4°C and 30°C are significantly different from each other since they are both not in one subset. The basil plants stored at 30°C in all experiments showed the lowest vitamin C content. According to Oyetade et al.,[20] suggested that refrigeration condition (4-5°C) was more suitable for storage of vitamin C source. Refrigeration helps vegetables remain freshness longer and maintains its vitamin C while vegetables stored in room temperature may deteriorate quickly and losses its nutritional value.

Other than that, the perforated packaging used in each temperature (4°C, 20°C and 30°C) showed the lowest loss of vitamin C content compared to non-perforated packaging in both harvested. According to researchers, the holes in the perforation of packaging can prevent leafy vegetables getting wilt easily which is better than non-perforated packaging. However, Lee & Kader[21] proposed that vitamin C content in reduced oxygen, high carbon dioxide concentration atmosphere can reduce its loss which normally can control using MAP.

From the Table 4, it concluded as better prevention of losses in weight, chlorophyll and vitamin C content of basil was at 4°C with the used of perforated packaging method.

Table 4 The summary of best parameter for preventing the losses in weight, chlorophyll and vitamin C content of basil

Tests/Parameters	Packaging methods		Temperature		
	Perforated	Non-perforated	4°C	20°C	30°C
(Time of harvest: 1st) Weight loss	✓		✓		
Chlorophyll content loss		✓	✓		
Vitamin C content loss	✓				✓
(Time of harvest: 2nd) Weight loss	✓		✓		
Chlorophyll content loss		✓	✓		
Vitamin C content loss	✓				✓
Total	4/6	2/6	4/6	0/6	2/6

[a]The table included first time and second time of harvested the basil. Tick (✓) under the packaging methods and temperature in different parameters (weight, chlorophyll content, vitamin C) which resulted effectively in preventing the losses.

Conclusion

Packaging plays an important role in reducing food waste. Storage temperature and packaging approaches in household will directly affected the weight, chlorophyll and vitamin contents of fresh sweet basil. In overall, this study show that temperature management is the most effective approach for prolonging the shelf life of fresh sweet basil through measuring its weight lost, chlorophyll and vitamin contents. Exposure of sweet basil to temperature more than 4°C with non-perforated packaging will cause in desiccation. The awareness on towards zero waste in household especially the smart way to purchase and store the food must be created in order to sustain and secure enough food for all organisms.

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Conflicts of interest

The authors declare no conflicts of interest.

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