STORAGE AT LOW TEMPERATURE MAINTAINS POSTHARVEST QUALITY OF LOWLAND CHINESE CABBAGE

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ABSTRACT

Cabbage are main vegetable consumed in Malaysia, domestic demand 145,054 metric tones in 2002, increasingly by 11% yearly (FAMA, 2003). Cameron Highland producing 92% of the national cabbage production. Limited information about postharvest handling of Chinese cabbage lead to low quality heads. Factors that affect the rate of deterioration such as storage temperature, handling and disease or disorder. In this study, lowland Chinese cabbages were harvested and stored at 0, 2 and 4 °C to investigate the effect of these temperatures on quality during storage. Assessments were made at 0, 1, 2, 3, 4 and 5weeks during storage. Cabbages stored at 0 °C had maintains their total phenolic compound, antioxidant, chlorophyll, ascorbic acid, texture than cabbages stored at 2 and 4 °C. Heads kept at 4 °C lost quality faster than at 0 and 2 °C due to disease occurring earlier. However, cabbage stored at 0°C showed chilling injury symptoms after 7 weeks storage.

Keywords: Chinese cabbage, postharvest storage, low temperature, chilling injury

Introduction

Low-temperature storage is a common method used to extend the shelf life of perishable vegetables like Chinese cabbage (also known as Napa cabbage or bok choy). It is important part of prolonging the postharvest life of cabbage. By storing Chinese cabbage at a lower temperature, it can slow down the deterioration processes and maintain its freshness and quality for a longer time. Cabbage quality gradually declines during low temperature storage because of disease, water loss, and biochemical changes (Suojala, 2003).

Chinese cabbage can be stored 2–6 months at 0–2.5°C. Deterioration of cabbage is associated with stem or seed stalk growth, root growth, internal breakdown, leaf abscission, discolouration, decay and black speck. Previous studies by Gajewski and Skapski, 1994 have shown that Chinese cabbage (Brassica campestris L. ssp. pekinensis (Lour.) Olsson) can be stored for long periods at low temperatures. There is evidence, however, storage temperatures of around 0 °C may induce chilling injury in some cultivars.

Heading lowland Chinese cabbage was chosen for this study due to its good performance in production trials carried out in Malaysia farm. Three storage temperatures, 0, 2 and 4 °C, were used to investigate the differences in postharvest physiology at low storage temperatures. The objective of this study to evaluate the effect of low temperature storage on the quality of lowland Chinese cabbages. These results will be helpful in extending the shelf life of lowland Chinese cabbage and in development of postharvest handling standard operating procedures of lowland Chinese cabbage in Malaysia.

Materials and Methods

Postharvest Handling

Lowland Chinese cabbage was grown at MARDI farm in Selangor using commercial growing practices. Mature cabbages were harvested 9 weeks after transplanting. They were selected, being of uniform size and free of physical damage and fungal infection. The harvested cabbages were trimmed to remove outer wrapper leaves so the head has a clean, compact and fresh appearance. After trimming, the Chinese cabbage head were packed into low density polyethylene (LDPE, 0.04mm) individually to slow down moisture loss. Chinese cabbages then stored at 3 different temperatures which is in 0, 2 and 4 °C for 8 weeks. For each storage removal time and replicate, five cabbages were randomly sampled from the cool room for physical and biochemical analysis and severity of disorders, and overall quality.

Postharvest Evaluation

Postharvest quality evaluation included physical (visual appearance, colour; lightness (L*), hue (h°) and chroma (C*) and texture and chemical (pH, soluble solids concentration (SSC), titratable acidity (TTA), ascorbic acid content), chlorophyll, total antioxidant, and total phenolic compound characteristics. The colour of cabbage was measured using a chromameter (Model CR-400 Minolta, Japan). Each colour value, L*, C*, and h°, was expressed as the means of three measurements. Leaf firmness was measured using a flat steel plate coupled with a texture analyser (TX-XT2i, Stable Microsystems, UK) interfaced to a personal computer. For each leaf, the diameter was measured. Results were expressed as the kg-force in Newtons (N).

Soluble solid contents (SSC) was determined with a digital refractometer (Model DBX-55, Atago Co., Ltd, Japan). The pH values were measured using a pH meter (Hanna Instruments pH 211 Microprocessor pH Meter, RI-USA). TTA was determined by titrating 20 mL of extraction with 0.1 mol L-1 NaOH to pH 8.2. Ascorbic acid was determined by extraction of 10 g of sample with the addition of 100 mL of 3% metaphosphoric acid. Then, 10 mL of extract was titrated immediately with a standard dye solution to first permanent pink endpoint.

Chlorophyll contents in all sample were determined with some modifications of Arnon (1949). One mL of sample and 4 mL of acetone (80% acetone) were well-mixed prior to absorbance (A) measurements at 663 and 645 nm. Total chlorophyll content was reported as µg chlorophyll per 200 mL of sample and was calculated by this equation:
Total chlorophyll = (20.2A645 + 8.02A663)(5/1000)(200)

Total phenolic content measure using The Folin–Ciocalteau method was used with some modifications. In brief, 500 µL of sample, 9.5 mL of distilled water and 0.5 mL of Folin–Ciocalteau reagent were thoroughly mixed in a test tube and incubated at room temperature for 5 min. Two mL of 10% (w/v) sodium bicarbonate was added and incubated for 10 min before reading an absorbance at 730 nm. Gallic acid solution (0–150 µg) was used to generate a standard line. Results were reported as mg Gallic equivalent per 200 mL of sample.

Statistical analysis

Statistical analyses of the treatment responses were conducted using Analysis of Variance (ANOVA) and Least Significance Difference (LSD) to determine whether the comparison between different storage durations showed significant differences ($p < 0.05$) with three replications. The main effect means are presented in the tables and figures. Experimental data are presented as means ± standard deviation of the determinations for each sample. For comparison of more than two means, the mean separation was done by Duncan Multiple Range Test (SAS Inst. 1985).

Result and Discussions

Physical Evaluation

The optimum maturity harvesting of lowland head Chinese cabbage are 9 weeks after transplanting. Highland types of head Chinese cabbage show good storability, which enables a storage period up to 2-3 months in cold store conditions. However, lowland head Chinese cabbage cultivars, due to different morphological structure of their heads, are characterized by worse storability. To prolong their consumption period and to better keep their quality, low temperature storage seems promising. Our study focused on some quality traits which are of the most importance for consumers especially nutritional value in cabbage. The influence of storage temperature on quality of lowland head Chinese cabbage in Malaysia has not been reported in literature, so the scope of the discussion of our results is limited.

Storage of the cabbage caused some texture losses due to transpiration and respiration of the heads (Table 1). Significant differences in texture loss were found between storage at 0 °C and 4°C. Texture loss increased with the increase in storage time. These changes were not significantly difference in the case of 0 and 2 °C storage. The quality of head Chinese cabbage stored at 4 °C deteriorated after 4 weeks showed initial signs of rotting due to infestation by fungi. The infested started at core center of head. Cabbage stored at low temperature keeps vegetables safe by slowing the movement of molecules, causing microbes to enter a dormant stage and prevents the growth of microorganisms that cause both food spoilage and foodborne illness.

In general, head of Chinese cabbage stored at 0°C showed symptoms of chilling injury after 7 weeks of storage. Symptoms presented as brown discoloration and necrosis of leaf tissue between veins. No chilling injury symptoms was observed in cabbage stored at 2 and 4 °C. Porter and Klieber (2002), observed chilling injury oh heads kept at 0 °C lost quality faster than at 2 °C due to chilling injury occurring earlier and more severely than at 2 °C.

The colour of Chinese cabbage heads results from natural pigments presence in the leaves, mainly from chlorophyll, which affects green colour intensity, and carotenoid, which affects yellow colour. The colour of heads is one the most important quality indices of the cabbage. Consumer preference for cabbage colour depends largely on a geographic region, but intensive green colour of the leaves is often associated with freshness of the produce. So, whitening or yellowing of the heads significantly decreases marketability of the cabbage. These changes are usually described as the senescence of the plant tissue. In the experiment, storage of the cabbage resulted in some significant changes in colour parameters of the heads during storage. Lightness, hue and chroma value of the heads, described by L* parameter, ranged from 71.68 before the storage and increased after the storage, which indicates noticeable loss of chlorophyll in the stored heads (Table 1). However, changes in the L*, hue and chroma parameter not

significantly difference on different storage temperature. Basically, low storage temperature conditions significantly inhibited yellowing during storage.

Biochemical Evaluation

Soluble solids content relates to sugars presence in the heads and directly after the harvest the content ranged 2.70-3.4% (Table 2). Storage of the heads resulted in significant decreased of soluble solids content. The highest content of soluble solids in heads stored in 0°C may result from the lowest respiration process under low temperature conditions. In contrast, Cebula et al. (2004) observed a significant decrease of dry matter and total sugars contents after storage of head cabbage. The differences may result from various temperature levels in both experiments.

Vitamin C is one of the important vitamins which are necessary for humans. Head Chinese cabbage is one on the main sources of this vitamin for human population in the temperate climate zone. The amount of vitamin C in head Chinese cabbage immediately after harvest around 23.25 mg/100g (Table 2). Storage of the heads resulted in a decrease of vitamin C content, but for 0°C storage can maintain the Vitamin C content in Chinese cabbage. Some positive effects resulting from 0 °C storage on vitamin C content in vegetables were also reported by Amihud (1977). Vitamin C content of Chinese cabbage was not affected by different temperature at 2°C and 4°C but tended to decrease with the storage period. The decrease in Vitamin C content during storage could be related with the increase in enzymatic activity and senescence process of cabbage.

Chlorophyll is considered to be responsible for the green colour and changes in the chlorophyll content can act as a good index of leaf senescence during storage. The freshly harvested of head Chinese cabbage contained 31.38 ml/g of chlorophyll. The loss of total chlorophyll was significantly higher in storage 2 and 4 °C temperature. The degradation of chlorophyll is due to chlorophyllase enzymes, which mediates conversion to pheophytin a and pheophytin b. The low storage temperature in 0 °C played a major role in maintaining chlorophyll significantly compared to other temperature in this study.

Total phenolic compound decreased with storage time due to wilting, causing water loss and breaking down in break tissue. The total phenolic compound was significantly lower in the Chinese cabbage stored in 4 °C. Antioxidant capacity is a desirable attribute for marketing potential health benefit of fresh vegetables. Table 2 show the effect of different storage temperature and storage time on the total antioxidant in Chinese cabbage. Changes in antioxidant were consistent with the content of Vitamin C and total phenolic compound throughout the storage time. Chinese cabbage storage in 0°C showed the highest antioxidant capacity with the highest total phenolic compound and Vitamin C.

Major changes in the visual quality attributes of lowland cabbage during storage at different temperatures included changes in biochemical content. During storage at 0°C, results showed that Chinese cabbage maintained biochemical such as Vitamin C, antioxidant, phenolic and chlorophyll content. After seven weeks, the outer leaves developed chilling injury. At this point, if the cabbage was unmarketable the outer leaves would be trimmed, exposing less green leaves. Deterioration in the visual quality of cabbage stored at 4°C occurred more rapidly than at the lower temperature. After five weeks the external leaves became brownish and fungi began to grow.

Conclusion

The results obtained from this study provide evidence for the ability of storage lowland Chinese cabbage in low temperature to minimize post-harvest deterioration and maintain the overall quality of Chinese cabbage. Storage at 0 °C enabled the retention of Vitamin C, antioxidants, total phenolic and chlorophyll until seven weeks of storage. However, storage at 2 °C can prolong shelf life of Chinese cabbage until 8 weeks without symptoms of chilling injury.

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Table 1: Main and interaction effect of Chinese cabbage stored at 0, 2 and 4 °C on leaves colour (Lightness, Hue and Chroma) and texture during storage.

Treatments (T)	Physical Changes			
	Texture (N)	Lightness	Chroma	Hue
0°C	45.02b	67.22a	19.85a	107.54a
2°C	50.06ab	73.99a	19.58a	110.59a
4°C	56.72a	74.82a	14.33a	104.45a
Interaction	ns	ns	ns	ns
Day of storage (week) (DS)				
0	49.34B	71.68A	23.06A	111.93A
2	93.83A	78.83A	15.47AB	95.82C
3	82.50A	73.37A	10.95B	98.47BC
4	37.18B	72.33A	14.74B	106.24AB
5	37.90B	72.31A	10.71B	109.74A
Interaction	*	ns	ns	*
TxDS	ns	ns	ns	ns

ns = non significant at p≤0.05.
Mean separation within colums and factors followed by the same letter are not significantly different by Duncan's multiple range test.

Table 2: Main and interaction effects of Chinese cabbage stored at 0, 2 and 4 °C on soluble solid concentration (TSS), Vitamin C, total phenolic compound, antioxidant (DPPH) and total chlorophyll during storage.

Treatments (T)	Biochemical Changes				
	TSS (°Brix)	Vit C (mg/100g)	TPC (mg/100g)	DPPH (% inhibition)	Total Chlorophyll
0°C	3.40a	28.18a	178.84a	64.11a	34.87a
2°C	2.70b	20.57b	105.14b	33.37c	16.63b
4°C	3.16a	19.78b	75.82c	42.02b	16.05b
Interaction	*	*	*	*	*
Day of storage (week) (DS)					
0	3.34A	23.25A	148.73A	45.62C	31.38A
2	3.27AB	20.18B	55.52C	32.33D	14.15C
3	3.73A	23.43A	71.68BC	56.69B	18.76B
4	2.83BC	21.12B	96.13B	37.74D	14.67C
5	2.50C	19.68B	85.26BC	65.99A	12.18D
Interaction	*	*	*	*	*
TxDS	*	*	*	*	*

ns = non significant at p≤0.05.
Mean separation within colums and factors followed by the same letter are not significantly different by Duncan's multiple range test.