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Effect of different packaging materials on quality of fresh-cut broccoli and cauliflower at chilled temperature

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Abstract

Temperature management is the most important tool to extend shelf-life and indirectly delay losses of quality parameters in vegetables during postharvest storage. Quality losses are enhanced by use of improper packaging material, extended storage, higher temperatures, low relative humidity, physical damage and chilling injuries. Packaging helps to keep food from drying out and to preserve nutritive values, flavour, texture and colour. Broccoli and cauliflower stored at inappropriate temperature and humidity would easily deteriorate as they are highly perishable. Most of the time, domestic consumers store these vegetables under common refrigerated conditions with or without packaging until being used for consumption. The quality deterioration of these vegetables occurs rapidly in both situations. Thus the aim of this research was to determine the effect of different types of packaging including plastic bag, cling film (shrink wrap) and white paper on the quality parameters including antioxidant activity, total phenolic content and colour of fresh-cut broccoli and cauliflower at chilled temperature 8-10°C for 21 days. Fresh-cut broccoli was found to contain higher amount of total phenolic content (274 mg/100g) and antioxidant activity (179 mg/100g) compared to cauliflower that has total phenolic content (137 mg/100g) and antioxidant activity (163 mg/100g). Total phenolic content and antioxidant activity of broccoli and cauliflower that was packed with plastic bag, shrink wrap and paper decreased after 21 days of storage. Yellowing in broccoli significantly increased, reflecting the b^* values, from 6.9 (control) to 29.89 (cling film), 23.2 (paper) and 24.99 (plastic bag), respectively. Darkening in cauliflower also significantly increased, reflecting the L^* values, from 65.07 (control) to 87.43 (plastic bag), followed by shrink wrap, and paper which was 86.51 and 84.69, respectively, after 21 days. Among the three types of packaging materials, white paper was efficient to maintain the quality (based on colour, antioxidant and total phenolic compounds).

Introduction

Brassica oleracea is the species of plant that includes many common foods such as vegetables, including cabbage, broccoli, cauliflower, kale, Brussels sprouts, collard greens, savoy, kohlrabi and Chinese kale. It is also known as wild mustard or cruciferae vegetables. It is native to coastal southern and western Europe. Glucosinolates (b-thioglucoside N-hydroxysulphates) are compounds that have also received special attention due to their effects on human health. Several aliphatic and indole glucosinolate breakdown products, for example isothiocyanates, phenethyl isothiocyanate, and indole-3-carbinol, are known as excellent cancer-preventing agents (Cartea *et al*., 2011; Yang *et al*., 2014).

Broccoli (*Brassica oleracea* var italica) and cauliflower (*Brassica oleracea* var. botrytis) was chosen for this study as these vegetables are popular among consumers in Malaysia. Broccoli and cauliflower are rich with vitamins, antioxidants and has been shown to be effective in fighting cancer due to anti-carcinogenic compounds (Nath *et al*., 2011; Mohamed *et al*., 2011; Gu *et al*., 2015). The part of the broccoli plant consumed is the fleshy stemmed flowering head which are harvested before the buds open up. Cauliflower has a zesty, slightly spicy texture in both raw and cooked form. Cauliflower is very nutritious, and may be eaten cooked, raw or pickled. Cauliflower is the large, flat, central clusters of flower buds called curds. The inner leaves on some cauliflowers curve inwards to cover the curd (Scalzo *et al*., 2008).

Broccoli and cauliflower are harvested when the flowering heads are compact, attain proper size and retain original colour. Delay in harvesting results in loose curds and discolorations leading to non-marketable crops. The trimming of the inner leaves depends on the mode of packing and transportation (Spokowski, 2010). Immediately after harvest, managing appropriate temperature is an important criterion to extend shelf-life and indirectly delay

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losses of quality parameters in these vegetables during postharvest storage. Awareness of ideal storage temperatures for broccoli and cauliflower is also critical. It is usually common for this type of vegetables to be stored at incorrect temperatures, storage at a lower than recommended temperature that can result in chilling injury, while storage at a higher than optimum temperature will compromise its storage life (Watkins and Nock, 2012).

Additionally, packaging helps to keep these vegetables from drying out and also to preserve nutritive value, flavour, texture and colour. These vegetables are loose packing vegetables which do not need head space. Usually, they are packed tightly to reduce the amount of air in the package. The presence of air may induce potential growth of microorganism on the surface of broccoli and cauliflower. Broccoli are highly respiring that must be rapidly cooled, either by hydrocooling or with crushed, top loaded ice. The head must be cooled to 0–2°C with relative humidity of 95%. As for cauliflower, the use of polyethylene packing reduces decaying, softening, loss of total solids and weight. The consumer package must be ventilated which not only help in vacuum cooling but also prevents CO_2 injury. Also, a thin permeable film (plastic bag) consumer package maintains cauliflower flavour for a longer period (Spokowski, 2010). Shrink wrapping has been used on potatoes, sweet potatoes, apples, onions, sweet corn, cucumbers, broccoli, cauliflower and a variety of tropical fruit (Ben-Yehoshua, 1986; Sonkar and Ladaniya 1999). Shrink wrapping reduces weight loss, minimises vegetables deformation, reduces chilling injury and decay by preventing secondary infection (Rai *et al*., 2009).

Fresh-cut broccoli and cauliflower stored at inappropriate temperature and packaging would easily deteriorate its quality along with the antioxidant and total phenolic content, which are usually sold at supermarkets. Visually, consumers could observe the appearance of yellowing buds and hardened stalk and eventually lead to senescence. These crops generally sold in the retail market without any packaging or sometimes packed. Temperature management is the most important factor to extend shelf-life and indirectly delay losses in nutrients. Type of packaging material can also affect the quality of broccoli and cauliflower. Thus the aim of this study was to determine the effect of different packaging materials (plastic bag, shrink wrapping and white paper) on the quality (i.e. colour, texture, moisture content, antioxidant activity and total phenolic content) of fresh-cut broccoli and cauliflower at chilled temperature (8-10°C) during storage at day 0, 7, day 14, and day 21.

Materials and Methods

Preparation of broccoli and cauliflower

Two Brassica vegetables selected for this study were cauliflower (*Brassica oleracea* var. botrytis) and broccoli (*Brassica oleracea* var italica), purchased from Cameron Highlands, Malaysia. The samples were brought into the laboratory on the day it was purchased. The quality of these vegetables was high. Broccoli and cauliflower were cut and packed into three different packaging and stored at 8°C-10°C (Schreiner *et al*., 2003).Three broccoli and cauliflower packages, respectively, were used i.e. plastic bag, shrink wrap and white paper (to simulate newspaper). Each package of plastic bag, shrink wrap and white paper consists of about 300-400 g samples, respectively. The broccoli and cauliflower was kept in the storage temperature for one month and the vegetables was analysed at day 0, 7, day 14, and day 21 to study the effect of broccoli and cauliflower on colour changes, texture (hardness), total phenolic content, moisture content and activity of antioxidant for different packaging (Raseetha *et al*., 2013).

Determination of moisture content for broccoli and cauliflower

The moisture content was determined by drying method using air oven. Firstly, the aluminium pan with cover was dried for 3 hour in an oven at 105°C. After 3 hours, the aluminium pan was transferred into the desiccator to let it cool and the aluminium pan was weighed after it has attained room temperature. The dried aluminium pan with cover was labelled and weighed accurately. Then, about 5-10 g sample was weighed into the aluminium pan and placed in 60°C oven overnight. Then, the next day, the aluminium pan was cooled in desiccator to room temperature and the weight was recorded. The percentage of moisture content was calculated by using formula below:

Colour determination of broccoli and cauliflower

The colour measurement of broccoli and cauliflower was determined at different storage days (0, 7, 14, and 21). Each sample was taken out from storage temperature (8°C-10°C) on each storage day interval and was measured immediately. Colour of broccoli and cauliflower was measured by using a Minolta CR-300 chromameter, using Illuminant C (6774K) and attached to a DP-Data Processor and a standard white reflection plate (Minolta Corp, Ramsey, NJ) and expressed as L^* value (colour intensity changing from light to dark), chroma (intensity of colour) and hue angle (actual colour). Next, the instrument was positioned with minimal pressure perpendicular to the sample surface and CIELAB measurement required over 8mm diameter interrogation area. A standard plate was used to calibrate the instrument using D65 ilumination source. Colour for each sample was measured three times (Kochhar and Kumar, 2015).

Probe calibration

Changing load cell. Appropriate load cell weight was chosen according to the type of samples to be analysed (5 kg load cell). Then, the load was positioned into the load carrier, the removable location peg was ensured to fit into the calibration platform aperture. The load cell was secured with the 2 Hex headed screws. The calibration platform was fitted in its place and the Hex headed screw was tightened. The plug was connected to its port on the carrier arm stop box and the screws were tightened.

Texture profile analysis (TPA) of broccoli and cauliflower

Each sample was taken out from storage temperature (8°C-10°C) on each storage day interval (0, 7, 14, and 21) and was measured immediately. The sample was positioned at the centre of the platform base. Hardness of vegetable samples was measured. The analysis was repeated in triplicate. The TPA profile obtained was used for data analysis.

Antioxidant activity analysis using FRAP assay of broccoli and cauliflower

FRAP extraction and assay was carried out according to the method of Benzie and Strain (1996) with slight modification. Twenty gram (20 g) of the sample was extracted with 400 ml of boiling water for 10 minutes. After extraction, the sample were blended and filtered with Whatman No.4. The water was removed using rotary evaporator at temperature 55°C. The extract were dried using freeze dryer for one week and continue with analysis after it were transformed into powder form. The dried crude extracts were kept at 4°C prior to the further analysis.

FRAP analysis

Different concentrations of extract (200-1200 μg/ml) in 1 ml of distilled water were mixed with phosphate buffer (2.5 ml, 0.2M, pH 6.6) and potassium ferricyanide, $K_3Fe(CN)_6$, (2.5 ml of TCA (1%). The mixture was incubated at 50°C for 29 minutes. Then, about 2.5 ml of TCA (10%) were added to the mixture, which were centrifuged for 10 min at 179 × g. The supernatant (2.5 ml) were mixed with distilled water (2.5 ml) and $FeCl_3$ (0.5 ml, 0.1%) and the absorbance were measured at 700 nm against a blank using UV-Vis spectrophotometer. Higher absorbance of the reaction mixture indicates higher reductive potential.

Total phenolic content (TPC) of broccoli and cauliflower

TPC extraction and assay were carried out according to the method described by Kahkonen *et al.*, (1999) with slight modification. Twenty gram of sample was extracted with 400 ml of boiling water for 10 minutes. After extraction, the sample were blended and filtered with Whatman No.4. The extracts were dried using rotary evaporator at the temperature of 55°C. The dried crude extracts were kept at 4°C prior to the further analysis.

TPC analysis

The total phenolic content in broccoli and cauliflower samples was determined using Folin-Ciocalteu's reagent. One hundred microlitre (100 μl) of sample (triplicate) were added into test tubes. Then, 0.5 ml Folin-Ciocalteu's reagent were added and shaken for 10 seconds. Next, about 7.9 ml distilled water were added into the test tube and left for 5 mins and 1.5 ml sodium carbonate (7.5 g/100 ml) were added. The content of the tube were mixed thoroughly and stored in the dark for 2 hours. The absorbance were measured at 765 nm using UV-Visible Spectrophotometer. Total phenolic content were expressed as mg gallic acid equivalents (GAE) per 100 g of fresh materials.

Statistical analysis

Each analysis was conducted in three replicates. Data were analysed using SPSS software V.20. Analysis of variance (ANOVA) and Tukey multiple range test were carried out to examine the quality of broccoli and cauliflower at different storage days and packaging.

Results and Discussion

Moisture, colour and texture of broccoli and cauliflower

Moisture content for broccoli in Figure 1(a) significantly decreased from 90% at day 0 to 69.66% at day 21. Moisture content started to decrease after 7 days of storage. Broccoli packed in paper had significantly lower moisture content on day 14 (76%) and day 21(69%) compared to 88% on day 0. Broccoli that was packaged with plastic bag after 21 days of storage retained higher moisture content which is 81.66% compared to broccoli packed with paper (69%). Overall, the analysis showed that

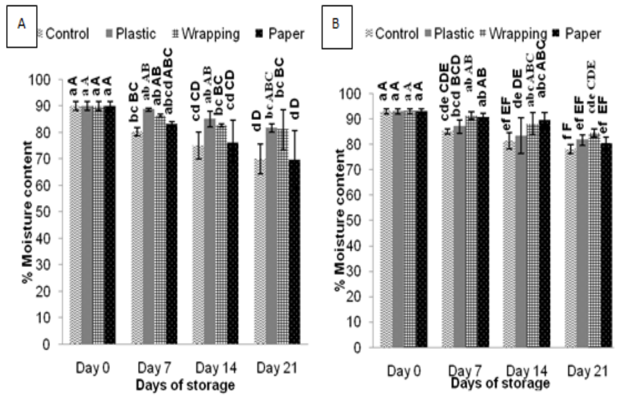

Figure 1. Moisture content (%) in (a) broccoli and (b) cauliflower. Values are expressed as mean ± standard deviation. Mean with different letters were significantly different at the level p<0.05. The small letters were differentiated between each packaging and day of storage while upper cases were differentiated between three type packaging and days of storage.

plastic bag is good for packaging broccoli because it maintains the moisture content of broccoli. Plastic bags, lined boxes, crocks, metal cans with liners, or plastic garbage cans are all items that retain moisture (Arvanitoyannis, 2012). Meanwhile, moisture content for cauliflower significantly decreased from 93% at day 0 to 78% after 21 days of storage (Figure 1b). Cauliflower packed in paper had significantly lower moisture content after 21 days of storage (80%) compared to 93% on day 0. After 7 days of storage, shrink wrap had highest moisture content (91.33%), followed by paper (90.66%) and plastic bag (87%). It showed that shrink wrap is suitable packaging for cauliflower. However, previous study indicated that excessive moisture can accumulate in cauliflower wrapped with cling wrap and stored at 1°C for up to 3 weeks, leading to post harvest spoilage (Dhall *et al.*, 2010).

From Figure 2 (b), a^* values (represents green) displayed increasing trend for all type of packaging from day 0 until 21 days of storage. This simply means that the green colour degraded during storage (Spokowski, 2010). Broccoli packaged with plastic bag at day 7 had higher negative a^* value (-14.32), followed by shrink wrapping (-13.76), white paper (-11.93) compared to control (-10.96). Broccoli wrapped with paper had significant loss of a* values compared to other packaging after 21 days of storage. The b^* value for broccoli (Figure 2c) at day 7 packaged with plastic bag was 17.61, followed by shrink wrap (14.94) and white paper (11.86). After 21 days of storage, broccoli packed in shrink wrap indicated significantly higher b^* value (29.89) compared to other packaging. Plastic bag attributed to delayed colour change due to combined effect of increased humidity and altered atmosphere composition (Rao and Shivashankara, 2015).

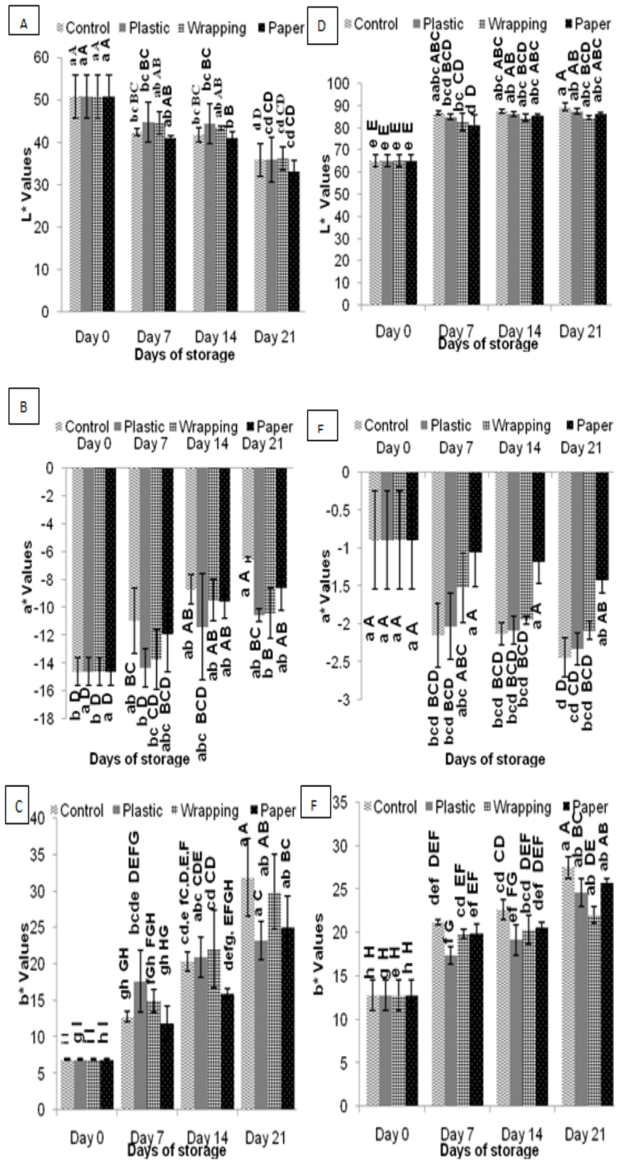

Figure 2. Colour measurement in (a, b, c) broccoli and (d, e, f) cauliflower stored at 0, 7, 14 and 21 days with different type of packaging (plastic, wrapping and paper) under chilled temperature. Values are expressed as mean ± standard deviation. Mean with different letter were significantly at the level p<0.05. The small letters were differentiated between each packaging and day of storage while upper case were differentiated between three type packaging and day of storage.

Meanwhile for cauliflower, Figure 2d showed that L^* values increased significantly from 65.07 (day 0) to 87.43 (day 21). After 21 days of storage, L^* value of cauliflower packaged with plastic bag was the highest (87.43), followed by shrink wrap (86.51), and paper (84.69). From Figure 2f, the highest b^* value at day 7 was cauliflower packaged with paper (19.88), followed by shrink wrap (19.84) and plastic bag (17.4). After 21 days of storage, cauliflower packed in paper indicated highest b^* value (25.75)

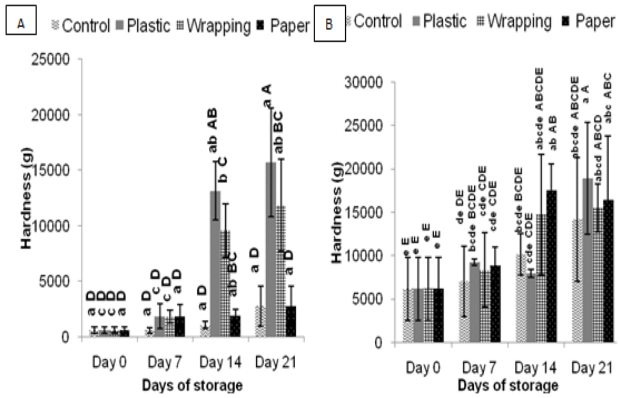

Figure 3. Hardness of (a) broccoli and (b) cauliflower stored at 0, 7, 14 and 21 days under different types packaging (plastic, shrink wrap and white paper) and chilled temperature. Values are expressed as mean ± standard deviation. Mean with different letter were significantly different at the level $p<0.05$. The small letters were differentiated between each packaging and day of storage while upper cases were differentiated between three type packaging and days of storage.

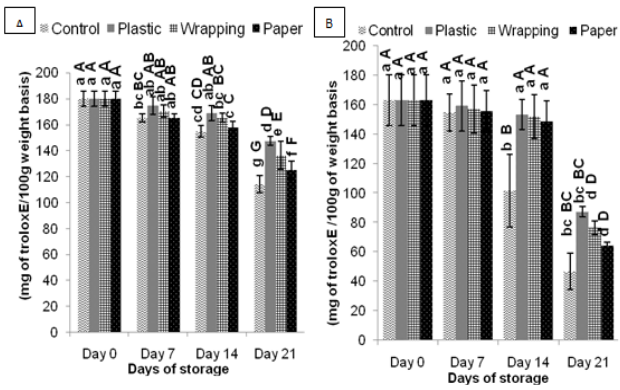

Figure 4. Antioxidant activity measured using FRAP assay (mg/100g) in (a) broccoli and (b) cauliflower stored at 0, 7, 14 and 21 days under different type of packaging (plastic, wrapping and paper) under chilled temperature. Values are expressed as mean ± standard deviation. Mean with different letter were significantly at the level $p<0.05$. The small letters were differentiated between each packaging and days of storage while upper cases were differentiated between three type packaging and days of storage.

compared to others. Overall, plastic bag is suitable for packaging broccoli and cauliflower during storage. This finding is in accordance with previous findings that indicated broccoli packed with 30 m LDPE (low-density polyethylene) was suitable to extend the shelf life during chilled storage (Cho *et al*, 2009).

The hardness of fresh-cut broccoli (Figure 3a) at day 0 is 559.55 g and significantly increased to 15695.76 g in plastic after 21 days of storage. Hardness of fresh-cut broccoli increased because the effect of water loss during storage. Broccoli packaged with white paper has lower hardness because more water loss compared to other packaging. Meanwhile,

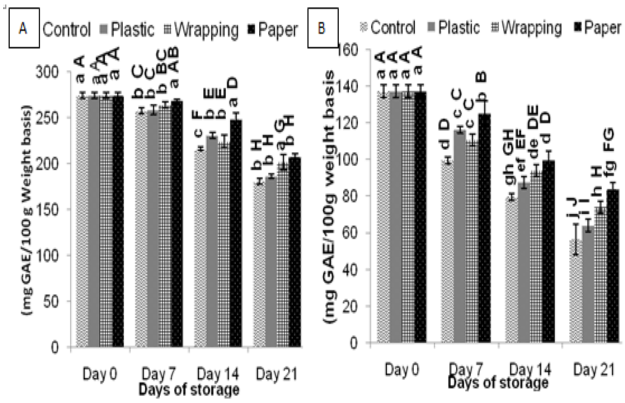

Figure 5. Total phenolic content (mg/100g) in (a) broccoli and (b) cauliflower stored at 0, 7, 14 and 21 days under different type of packaging (plastic, wrapping and paper) under chilled temperature. Values are expressed as mean ± standard deviation. Mean with different letter were significantly at the level $p<0.05$. The small letters were differentiated between each packaging and days of storage while upper cases were differentiated between three type packaging and days of storage.

the texture for cauliflower packed with plastic bag after 21 days of storage increased to 18864.48g, followed by cauliflower packed with shrink wrap (15477.18g) and white paper (16363.18g) compared to control (6146.58g) on day 0.

Antioxidant activity and estimation of total phenolic compounds

Fresh broccoli contained 179.99 mg/100g antioxidant activity measured using FRAP assay (Figure 4a). This value is consistent with previous research using fresh broccoli which was 192.22mg/100g (Bhagat *et al*., 2012). After 21 days of storage, antioxidant activity of broccoli packaged with plastic bag was significantly higher (147.4 mg/100g) compared to other packaging. Meanwhile, fresh cauliflower contained 162.96 mg/100g antioxidant activity (Figure 4b). This value agrees to research conducted by Ferreres *et al*. (2003) whereby the antioxidant activity of fresh cauliflower is 155 mg/100g. After 21 days of storage, antioxidant activity of cauliflower packed with plastic bag was significantly high (87.4 mg/100g), followed by shrink wrap (76.29 mg/100g) and paper (64.44 mg/100g). It was also found that control (unpackaged broccoli and cauliflower) have lower antioxidant activity compared to those being packed which are 114.07mg/100g and 46.66mg/100g, respectively, after 21 days of storage.

Fresh-cut broccoli contained 273.99 mg/100g total phenolic compounds (Figure 5a). This value is consistent with previous researcher whereby the total phenolic content of fresh broccoli is 270 mg/100g (Gawlik, 2008). After 21 days of storage, the total phenolic content of broccoli packed with white paper was significantly high (207.33 mg/100g), followed by plastic bag (201.77 mg/100g) and shrink wrap (186.22 mg/100g). Fresh cauliflower used in this study contained 137.33mg/100g total phenolic (Figure 5b) while previous researcher reported 153mg/100g (Gu *et al.*, 2015). After 21 days of storage, the total phenolic content of cauliflower packed with white paper was significantly higher (83.99mg/100g) compared to other packaging. It was also found that control (unpackaged broccoli and cauliflower) have significantly lower total phenolic compounds compared to those being packed which are 180.66 mg/100g and 56.22 mg/100g, respectively, after 21 days of storage. It is also important to note that severe mechanical handling of vegetables such as broccoli can cause a significant decrease in phenolic contents (Raseetha *et al.*, 2011). Based on previous researches, phenolic compounds identified in cauliflower were ferulic acid, chlorogenic acid, gallic acid and catechin (Ahmed and Ali, 2013). Antioxidant activity and phenolic content varies with broccoli and cauliflower growth development stages, whereby it reaches a peak after three months after sowing and decrease thereafter until being harvested (Soengas *et al.*, 2012). However, during storage, phenolic content decreased drastically irrespective of packaging material from 137.33 mg/100g to 73.99 mg/100g. This research have also shown a decrease of antioxidant capacity in broccoli and indicated the importance of the type of film package on the maintenance of antioxidant capacity during storage. Previous researchers have also reported decrease in antioxidant capacity and phenolic content for broccoli stored in polypropylene films (Serrano *et al*., 2006; Kevers *et al.*, 2007).

Conclusion

From this study, fresh-cut broccoli initially contained higher amount of total phenolic content (270 mg/100g) and antioxidant activity (179.99 mg/100g) at day 0 compared to cauliflower whereby the values was 99.55 mg/100g and 162.96 mg/100g, respectively. Total phenolic content and antioxidant activity of broccoli and cauliflower that was packaged with plastic bag, shrink wrap and white paper significantly decreased from 270 mg/100g to 186.22 mg/100 for broccoli and 179.99 mg/100g to 64.4 mg/100g for cauliflower after 21 days of storage. Among three types of packaging materials, paper packaging was efficient in maintaining the total phenolic content because white paper prevents light penetration onto broccoli and cauliflower. Moreover, fresh-cut broccoli and cauliflower loses water content during storage and it had affected the texture quality. In terms of texture, broccoli and cauliflower became harder after 21 days of storage, even though these vegetables were stored at chilled temperature. Among three types of packaging materials, paper packaging was found to be most suitable to maintain the quality in fresh-cut broccoli and cauliflower. This study can further be explored on different materials that make up paper packaging and evaluate the quality of broccoli and cauliflower or using other types of *Brassica* vegetables.

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