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Physicochemical quality of cauliflower as influenced by cling film wrapping during storage

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A B S T R A C T

Compact, medium size, white to creamy cauliflower curds were packed into different packaging techniques like i. without packaging (control); ii. packed in low density polyethylene (LDPE) bag with 1% perforation; iii. wrapped with polyethylene (PE) cling film and iv. newspaper (locally used). Half of each treatment was kept at (6±1°C and 50±5% RH) and the other half was kept at ambient conditions (25±3°C and 60±5% RH). LDPE bag or PE cling film has a great effect to retain firmness and reduce weight loss of cauliflower in both storage conditions. Respiration rate, rot incidence and changes of colour values (lightness and hue angle) was reduced significantly for the cauliflowers packed in LDPE bag or wrapped with PE cling film stored in a refrigerator than that of control (without packaging) and all packaging techniques stored at ambient condition throughout the storage period. Initially, acidity, TSS and ascorbic acid content were 0.26%, 4.7° Brix and 58.7 mg $100g^{-1}$, respectively. Ascorbic acid content was reduced severely in the cauliflower stored in ambient conditions than that stored in a refrigerator. Cauliflower wrapped with PE cling film and packed in an LDPE bag (1% perforation) stored in a refrigerator (6±1°C and 50±5% RH) could retain white colour, good sensory quality, firm and fresh curds with minimum loss in weight, texture and disease incidence up to 18 days and 16 days, respectively.

Keywords: Cling film, Hue angle, Respiration rate, Firmness, Ascorbic acid

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Introduction

Cauliflower (*Brassica oleracea* var. botrytis) is one of the most familiar vegetables all over the world. Its compact flower heads hold essential nutrients and numerous health benefiting phyto-nutrients that help to prevent overweight, diabetes and offer protection from prostate, ovarian, and cervical cancers. It is also a good source of different types of vitamins like B, C, E and K, dietary fibre and folic acid, omega 3 fatty acids, proteins, phosphorus, potassium, iron, magnesium and manganese (Florkiewicz *et al.*, 2014). It is a member in the cruciferous or brassicaceae family of vegetables and has similar nutritional and phyto-chemistry profile as that of other brassica family veggies like broccoli and cabbage. High quality cauliflower heads are white to cream in colour, firm and compact. The curds should be free of mechanical damage, decay, browning, or yellowing, which can result from sun exposure. High respiration rate of cauliflower and its soft tissue make it highly perishable and it is not suited for long-term storage even at low temperature. Quality loss in fresh cauliflower includes yellowing of the curd, floret opening, loss of hardness, the development of an undesirable odour, off-flavours and the risk of microbial development (Licciardello *et al.*, 2013; Zhan *et al.*, 2014). To extend the shelf life of fresh produce without compromising nutritional quality, many methods have been proposed including low temperature, in modified atmosphere packaging (MAP), sanitizing, anti-browning dipping, edible coatings etc. (Albanese *et al.*, 2007).

Physical preservative treatments such as MAP or vacuum packaging been developed in order to extend the shelf life of whole and FC products (Zhan *et al.*, 2014). A large number of FC fruits and vegetables are stored and marketed in MAP in combination with chilled storage or other preservation procedures (Hodges and Toivonen, 2008). MAP refers to the technique of sealing actively respiring produce in polymeric film packages to modify the O_2 and CO_2 concentrations within the package atmosphere (Mir and Beaudry, 2016); those concentrations are reached by the natural interaction between the respiration rate of the product and the transfer of gases through the packaging material (Oliveira *et al.*, 2015). One of the primary effects of MAP is a lower respiration rate, which reduces the rate of substrate depletion and oxidation reactions (Sothornvit and Kiatchanapaibul, 2009). Cantwell and Suslow (2009) reported that cauliflower heads and florets should be stored at 0°C and 95–98% RH to maintain its quality. At 0°C, the respiration rate of cauliflower florets slows down to ~8 ml CO_2 kg^{-1} h^{-1} compared to ~42 ml CO_2 kg^{-1} h^{-1} at 22°C (Cantwell and Suslow, 2009). Dependent on storage temperature and duration, if cauliflower is stored under RH conditions 98%; it favours the microbial activity and spoilage (Hardenburg *et al.*,. 1993). Individual shrink wrapping or cling wrapping, a form of modified atmosphere packaging is used to enhance the storage life and to maintain the harvest freshness of fruits and vegetables. The principal advantage of shrink wrapping are: reduced weight loss, minimized fruit deformation, reduced chilling injury and reduced decay by preventing secondary infection (Dhall *et al.*, 2012). The effect of PE packing including cling wrapping on storage life and quality of cauliflower at 0°C and 2°C & 12°C have been studied by Dhall *et al.* (2010) and Raja *et al.* (2011), respectively.

Controlled atmosphere storage (CAS) differs from MAP. They operate by controlling the temperature, gas composition, and humidity. Various gas composition methods used are; N_2 generation, O_2 control, and CO_2 removal. Unfortunately, CAS systems for mixed produce loads are unrealistic and too costly to control. There variability in respiration rates and ethylene production create too high of a challenge to control and maintain (Lee *et al.*, 1996). MAP can be more beneficial than CAS on extending the shelf life of fresh produce during distribution and handling (Lee *et al.*, 1996). MAP uses barrier properties that are specifically chosen based on the respiration rate of the vegetables. It benefits can range from decreased ethylene production, reduced sensitivity to ethylene, and a delay in ripening (Lee *et al.*, 1995). Berrang *et al.* (1990) studied the effect of cauliflower in CAS environment (18% O_2, 3% CO_2, and 79% N_2) held at 4°C. Their results showed that the cauliflower had a smaller decrease in lightness (L) value compared to the control (Berrang *et al.*, 1990). Browning was also observed in the control versus the controlled atmosphere samples, which is a result from the decline in the L value (Berrang *et al.*, 1990). Unlike broccoli; cauliflower and carrots do not benefit from controlled atmosphere (Suslow *et al.*, 2009). Injury of cauliflower occurs when the oxygen level is less than 2% or the carbon dioxide level is greater than 5% (Suslow and Cantwell, 2009).

Hence in the present studies were attempted to see the feasibility of PE cling wrapping compared with other packing techniques of cauliflower for extension of storage life and maintaining quality at ambient condition (25±3°C and 60±5% RH) as well as in refrigerator (6±1°C and 50±5% RH).

Materials and Methods

Compact, medium size, white to creamy white cauliflower (*Brassica oleracea* var. botrytis) was harvested from the field of a progressive farmer at Gazipur district. Harvesting was done with great care to prevent bruising to the highly sensitive turgid curds. The outer leaves of curds were removed leaving small leaves in each curd. Each cauliflower had an average weight of 1.1 to 1.3 kg. The curds were divided into 4 lots (each 60 curds) and some curds were separated to use for analysing initial physico-chemical characteristics. One lot was unpacked (control) and the other 3 lots were used for 3 packaging technique viz., low density polyethylene (LDPE) with 1% perforation, polyethylene (PE) cling film and newspaper (practiced locally). Half of the packets of each treatment were kept at normal refrigerator (6±1°C and 50±5% RH). Other half of each treatment was kept at ambient condition (25±3°C and 60±5% RH). At each storage interval the data on weight loss, respiration rate, firmness, instrumental colour, decay, ascorbic acid, titratable acidity and total soluble solids (TSS) content of cauliflower curds were recorded. The experiment was laid out in completely randomized block design with 3 replications.

Respiration rate

Respiration rate of cauliflower was assayed of each measurement interval during storage. Each fruit of all treatments were placed in 4000 ml airtight plastic containers equipped with septa and sealed for 2 h at ambient condition. After incubation, 1 ml of gas sample was withdrawn from headspace by a gas-light hypodermic syringe and analyzed using a gas analyzer (CO_2/O_2 gas analyzer, Quantek Instrument, Model No. 902D, USA). The percentage of CO_2 evolved in the container gas was recorded. According to Nasrin *et al.* (2017) respiration rate was calculated based on the total gas volume in the jar, fruit surface volume, fruit weight and incubation time and expressed as ml kg^{-1} h^{-1} of CO_2 evolved.

Firmness/ texture analysis

Firmness analysis was performed using Fruit Texture Analyzer (GUSS, Model No. GS25, SA). Firmness measurement was taken as the maximum penetration force reached during the tissue breakage and determined with 8 mm diameter stainless steel flathead probe, which penetrates in a normal direction at a cross-head speed of 5 mm s^{-1}. After establishing zero-force contact between the probe and the horizontally positioned fruit, specimens were compressed 3 mm at 2 equidistant points along with the equatorial region of each fruit. The maximum penetration force (N) was used as firmness value of cauliflower pieces (Nasrin *et al.*, 2018a).

Measurements of surface colour

External colour of fruit was evaluated with a Chroma Meter (Model CR-400, Minolta Corp., Japan). CIE $L^*a^*b^*$ coordinates were recorded using D65 illuminants and a 10° standard observer as a reference system. L^* is lightness, a^* (-greenness to +redness) and b^* (-blueness to +yellowness) are the chromaticity coordinates. The a^* and b^* values were converted to chroma [$C = (a^{*2} + b^{*2})^{1/2}$] and hue angle [$h° = \tan^{-1}(b^*/a^*)$]. Before measurement, the equipment was calibrated against a standard white tile. Ten readings were taken at different locations on each fruit. The readings were taken at the same position of each sample (Nasrin *et al.*, 2018b).

Weight loss

Cauliflowers were weighed at the beginning of the experiment and thereafter 2 day's intervals during the storage period. It was calculated by the weight difference between initial and specific time interval divided by initial weight and finally denoted by percentage.

Ascorbic acid, titratable acidity and total soluble solids (TSS) content

After all physical analysis, cauliflower was cut into small pieces and homogenised in a grinder to assess the parameters. The ascorbic acid content was determined by using 2, 6-dichlorophenol indophenol titration method as described in AOAC (1994). Ten (10) g of ground sample was suspended in 100 ml of distilled water and then filtered. To determine titratable acidity, sample was titrated with 0.1 M NaOH and pH 8.1 according to AOAC (1994) and expressed as percentage of citric acid.

The TSS content of cauliflower was determined by using a refractometer. Homogenous sample was prepared by blending the fruit flesh. A few drops were taken on prism of the refractometer and direct reading will be taken by reading the scale in meter as described in AOAC (1994).

Decay

Cauliflower decay rating scale was used as used in UV Davis; California provided the sample picture of decayed cauliflower. The scale rated from 1 to 5, 1 = none (no scratch or even rubbing symptom), 2 = Slight decay (slight scratch or rubbing symptom, no black spot), 3 = moderate decay (initiation of black spots, 2-3 numbers), 4 = moderate severe decay (5-6 numbers of black spots with small area) and 5 = severe decay (8-10 numbers of black spots with small area). Decay rating of 5 was considered as the limit for saleability.

Statistical analysis

Data were analysed for analysis of variance using MSTAT-C programme. Means were separated using Duncan's Multiple Range Test (DMRT).

Results and Discussion

Respiration rate

Fig. 1 illustrates the effect of different packaging technique and temperatures on the CO_2 production of cauliflower. Initial respiration rate of cauliflower was 49.46 CO_2 ml kg^{-1} h^{-1} and it was reduced to less than even half when curd was stored at 6±1°C (both packed or unpacked) at 3th days of storage period. The unpacked samples presented higher respiration rate during storage time compared with packed ones at both ambient and refrigeration temperature. The lowest respiration rate was observed in cauliflowers wrapped with PE cling film or packed into 1% perforated LDPE bag at both temperatures throughout the storage period. The explanation for the observed results is the gas barrier between cauliflower tissue and the environment, promoted by PE packaging that modifies the atmosphere around the fruit and so reduces its respiration rate. The intensity of change in the respiration rate of fruits and vegetables depends on the packaging techniques and on the storage conditions of the products. Suslow and Cantwell (1998) reported that the respiration rate of fresh cauliflower was 43-48 CO_2 ml kg^{-1} h^{-1} at 25°C. At 20th day of storage respiration rate was 149.47 ml kg^{-1} h^{-1} in unpacked fresh cut cauliflower where as it was 80.57 ml kg^{-1} h^{-1} in vacuum packed and around 100 ml kg^{-1} h^{-1} in 1% perforated LDPE packed fresh cut cauliflower (Nasrin *et al.*, 2022). The respiration rate of fresh cut cauliflower was significantly higher than that of the uncut cauliflower and was within the range of 238.5 and 157.5 mg kg^{-1} h^{-1} at 15 °C; 120 and 77.5 mg kg^{-1} h^{-1} at 5 °C and 66 and 44.4 mg kg^{-1} h^{-1} at 1 °C for fresh cut and uncut cauliflower (Mashabela *et al.*, 2018).

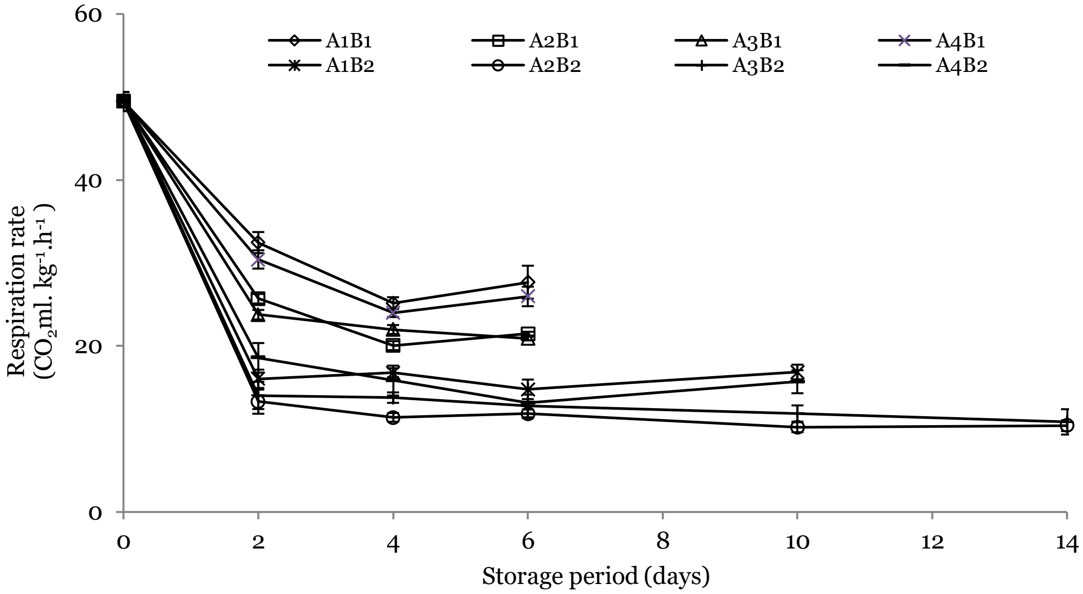

Fig. 1. Respiration rate of cauliflower influenced by packaging techniques and storage temperatures.

A1=Control, A2=1% perforated LDPE, A3= Cling film wrap, A4= Newspaper wrap, B1= Ambient condition (25±3°C), B2= Refrigerated (6±1°C) condition. Vertical bars indicate standard deviation.

Firmness

Firmness or texture is a critical quality attribute in the consumer acceptability of fresh fruit and vegetables. Degradation of insoluble protopectin to the more soluble pectic acid and pectin contribute to a decrease of firmness in fresh fruits and vegetables (Nasrin *et al*., 2020). Cauliflower suffers a rapid loss of firmness during storage period, which contributes greatly to its short postharvest life and susceptibility to fungal contamination. Fruit texture properties are affected by cell turgidity and the structure and composition of the cell wall polysaccharides.

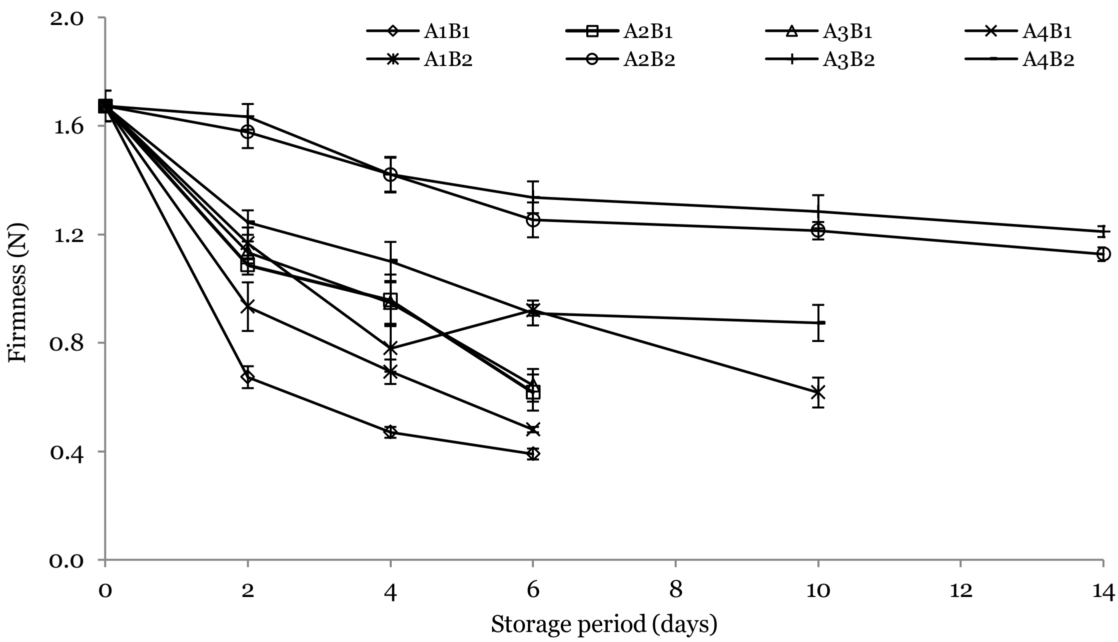

Fig. 2. Firmness of cauliflower influenced by packaging techniques and storage temperatures.

A1=Control, A2=1% perforated LDPE, A3= Cling film wrap, A4= Newspaper wrap, B1= Ambient condition (25±3°C), B2= Refrigerated (6±1°C) condition. Vertical bars indicate standard deviation.

Fig. 2 represents the changes in cauliflower firmness of packed and unpacked fruits during the storage period at 6±1°C and 25±3°C. Initially the firmness value of cauliflower was 1.67N and it was decreased gradually with time but the rate was high of the curds stored at ambient (25±3°C) temperature and low of that stored at refrigerator (6±1°C) in all packaging treatment. Among the treatment, cauliflower wrapped with PE cling film stored at 6±1°C temperature was most firm during the storage period and it lost only 27.54% firmness and 32.00% by the cauliflower packed in LDPE bag at 14th day of storage whereas unpacked cauliflower stored at ambient (25±3°C) temperature had lost almost 77% firmness at 6th day of storage period. Similar results were also found by Dhall *et al.* (2010), cauliflower packed with cling film and LDPE bag stored at 0°C temperature lost 30.87% and 33.33% firmness respectively at 28 days of storage period.

Weight loss

Fruit weight loss is mainly associated with respiration and moisture evaporation through the skin. As cauliflower curd has no peel makes them susceptible to rapid water loss, resulting in shrivelling and deterioration. The rate at which water is lost depends on the water pressure gradient between the fruit tissue and the surrounding atmosphere, and the storage temperature. Low vapour pressure differences between the fruit and its surroundings and low temperature are recommended for the storage of cauliflower. Dehydration will also cause increase in surface-wounding in curd. Wrapping or packaging of curd act as barriers, thereby restricting water transfer and protecting fruit skin from mechanical injuries, as well as sealing small wounds and thus delaying dehydration.

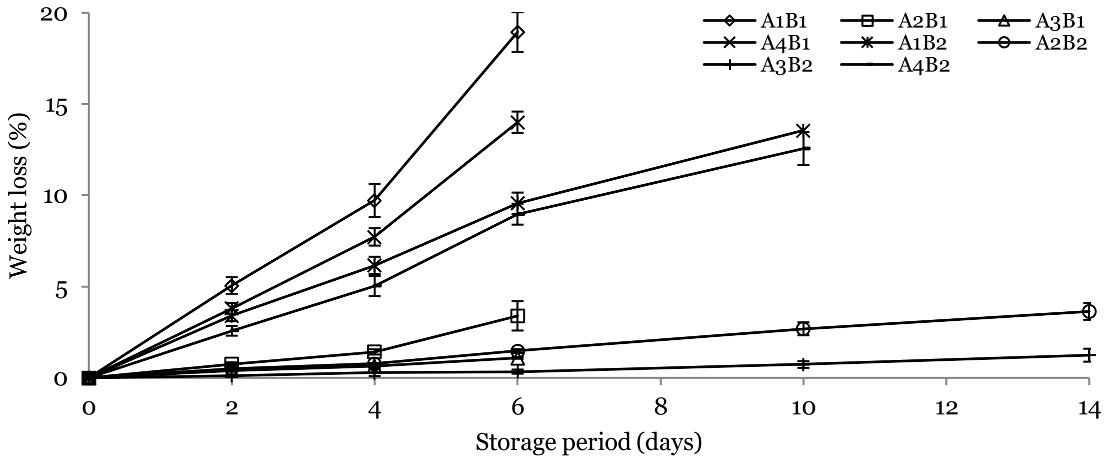

Fig. 3. Weight loss of cauliflower influenced by packaging techniques and storage temperatures.

A1= Control, A2= 1% perforated LDPE, A3= Cling film wrap, A4= Newspaper wrap, B1= Ambient condition (25±3°C), B2= Refrigerated (6±1°C) condition. Vertical bars indicate standard deviation.

Fig. 3 shows weight loss during storage (at 6±1°C and 25±3°C temperature) of different packed cauliflower. All samples demonstrated a gradual loss of weight during storage. Throughout storage, the loss of weight of unpacked fruits was significantly greater than that of packed fruits. At the 6th day, stored at ambient condition, control, curd packed in LDPE bag and wrapped with PE cling film showed 18.90%, 3.39% and 1.09% weight loss, respectively. So, it can be said that LDPE or PE cling film has a great effect to reduce weight loss of fresh produce. Similar results were also found by Dhall *et al.* (2010) that cauliflower packed with cling film and LDPE bag stored at 0°C temperature lost 2.4% and 2.1% weight at 28 days of storage period. The reduction in weight loss wrapped with cling film and packed in LDPE bag may be due to creation of micro-atmosphere inside the wrap or bag which reduced the transpiration losses and respiration rate as the film is differently permeable to O_2 and CO_2 transmission.

External colour

Colour is an important factor in the perception of cauliflower curd quality. Fig. 4 a&b illustrates the changes in surface colour in terms of lightness (L*) and hue angle of cauliflower stored at refrigerator (6±1°C) and ambient condition (25±3°C) packed with different packaging technique. The L* parameter is an indicator of curd darkening. As can be observed in Fig. 4a, the range of lightness was 72 to 87 and all the samples showed decreasing L* values with storage time. Unpacked curds were significantly darker than packed ones throughout the storage period. At 6th day of storage period, L* had decreased by around 18% for control (without packaging) curds stored at ambient condition and by around 14.00%, 11.05% and 8.09% for curds packed with newspaper, 1% perforated LDPE bag and PE cling film wrap, respectively stored at refrigerator (6±1°C).

The hue angle of cauliflower displayed a decreasing trend in all treatments with storage period but the more decreasing tendency was found in cauliflower stored at ambient condition than that stored at refrigerator. On the other hand, cauliflower packed in LDPE bag and wrapped with cling film preserves their original colour than unpacked or wrapped with newspaper one (Fig. 4b). The hue value range for fresh cauliflower was between, 94 to 101, which indicates the yellow region of the colour axis. The lower the number the more yellow, it is indicating a deterioration of cauliflower colour. At 6th day of storage period, hue angle had decreased by around 6.35% for control curd stored at ambient condition and by around 3.95%, 2.16% and 1.84% for fruit packed with newspaper, 1% perforated LDPE bag and PE cling film respectively stored at refrigerator (6±1°C). Spokowski (2010) found the similar results that the range of lightness and hue angle for vacuum packed cauliflower was from 82 to 84 and 94° to 98° during the storage at 3° and 7°C temperature and both values were decreased with increasing storage period.

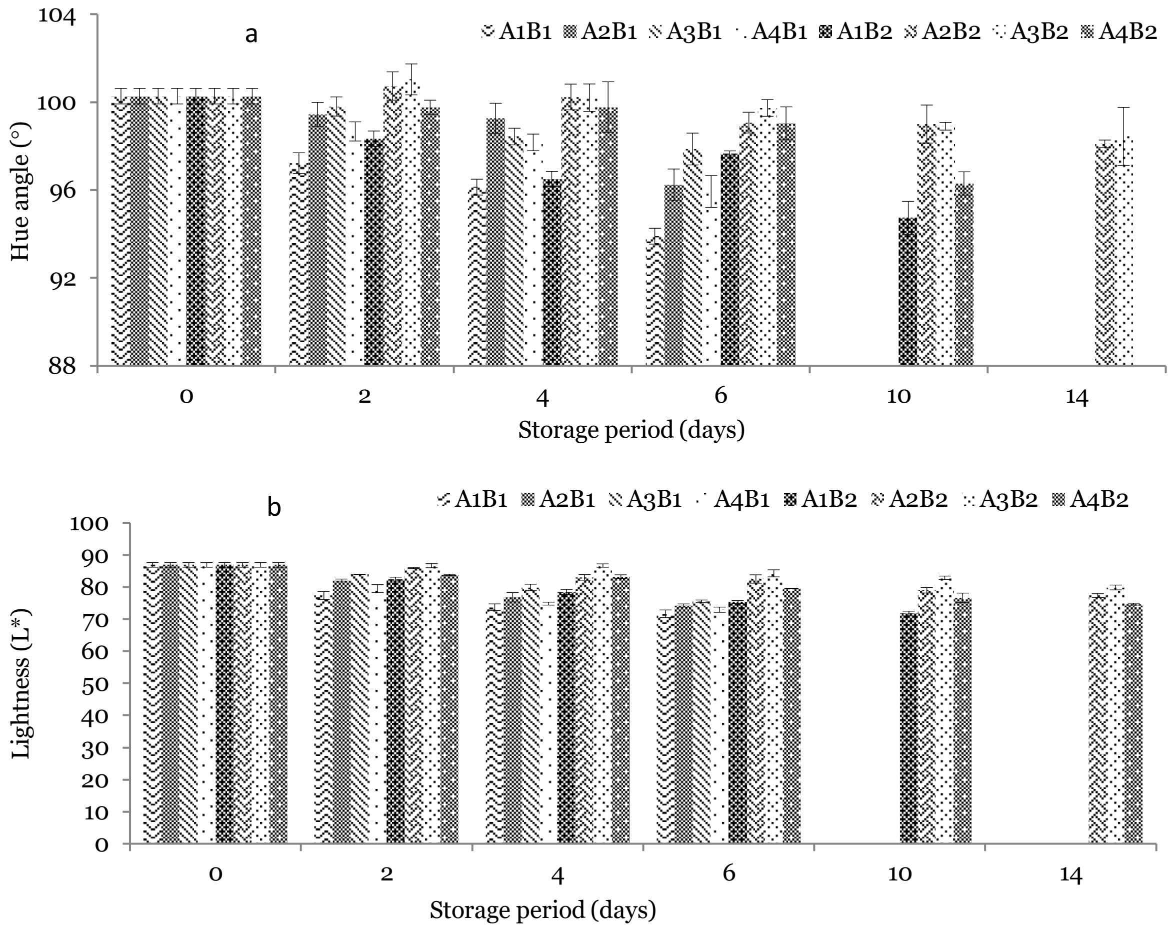

Fig. 4. External colour evolution (a) hue angle and (b) lightness of cauliflower influenced by packaging techniques and storage temperatures.

A1= Control, A2= 1% perforated LDPE, A3= Cling film wrap, A4= Newspaper wrap, B1= Ambient condition (25±3°C), B2= Refrigerated (6±1°C) condition. Vertical bars indicate standard deviation.

Decay

Decay is an important source of postharvest losses of cauliflower, particularly in combination with rough handling and poor temperature control. A large list of bacterial and fungal pathogens causes postharvest losses in transit, storage, and to the consumer. Bacterial Soft-Rot (*Erwinia* and *Pseudomonas*), Black Spot (*Alternaria alternata*), Grey Mold (*Botrytis cinerea*), and Cladosporium Rot are common disorders. The causal pathogens of diseases that appeared on the cauliflower in this study were *Alternaria* spp., *Botrytis* spp. and *Erwinia* spp. The incidence of rot started on 2nd day in control (without packaging) and curds wrapped with newspaper at ambient storage as shown in Fig. 5. Cauliflower wrapped with newspaper, PE cling film and packed in 1% perforated LDPE bag secured 3.33, 1.67 and 2.33 decay score respectively at 14th day of storage at refrigerator (6±1°C). More water was accumulated inside LDPE bag and curd was suffered from rubbing in LDPE bag than that of cling film. That why more spots were created on curds packed in 1% perforated LDPE bag than that of PE cling wrapped curds.

Browning or black spots can be due to bruises and pressure points. Later the affected points turn dark brown to black. When the symptoms are in progress, a fungal attack is seen. Dhall *et al.* (2010) found more fungal decay in cling film wrapped cauliflowers than that packed with LDPE bag stored at 0°C temperature and 95% RH at 28 days of storage period. Which may be due to the high relative humidity within the packaging (Ceponis *et al.*, 1987).

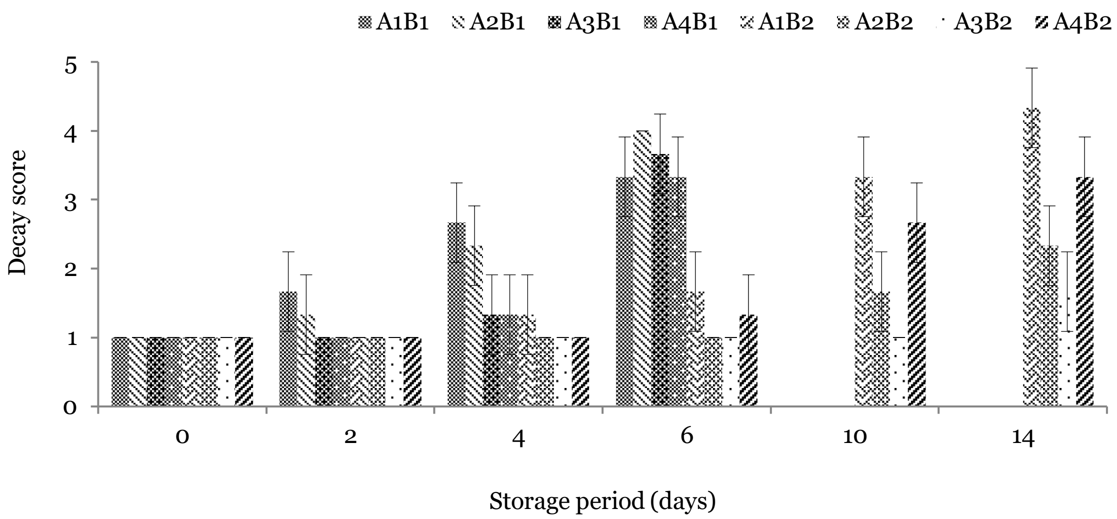

Fig. 5. Decay of cauliflower influenced by packaging techniques and storage temperatures.

A1= Control, A2= 1% perforated LDPE, A3= Cling film wrap, A4= Newspaper wrap, B1= Ambient condition (25±3°C), B2= Refrigerated (6±1°C) condition. Vertical bars indicate standard deviation.

Chemical parameters and shelf life

Initial ascorbic acid in cauliflower was 58.7 mg/100g. At 6th day of storage, ascorbic acid content reduced severely in the cauliflower stored in ambient condition than that stored at refrigerator. Cauliflower packed in LDPE bag or wrapped with cling film preserved more ascorbic acid than cauliflower wrapped with newspaper and control (without packaging) in both temperatures. Initial acidity and TSS is 0.26 % and 4.9° Brix respectively. At 6th day of storage, acidity increased slightly and TSS increased moderately ranged from 4.8° to 5.6° Brix. Maximum TSS was found in control cauliflower as maximum water loss was occurred here. Control cauliflower stored at ambient condition was good up to 3 days whereas, cauliflower packed in LDPE bag and wrapped with cling film stored at refrigerator preserved their quality up to 16 and 18 days respectively. Initially, acidity, TSS and ascorbic acid content was 0.15%, 7.7° Brix and 62.97 mg $100g^{-1}$, respectively in cauliflower was found by Raja *et al.* (2011). He also found slight increase in acidity and decreased in ascorbic acid content during storage period. Titratable acidity, TSS, pH and ascorbic acid content of fresh cut cauliflower were 0.25%, 6.5° Brix, 6.8 and 59.3 mg $100g^{-1}$ (Nasrin *et al.*, 2022).

Table 1. Some chemical parameters and shelf life of cauliflower influenced by packaging techniques and storage temperatures.

Treatment	Ascorbic acid (mg $100g^{-1}$)		Titratable Acidity (%)		TSS (%)		Shelf life (days)
	0 day	6 days	0 day	6 days	0 day	6 days	
A1B1	58.7	39.6d	0.26	0.36	4.90	5.60a	3
A2B1	58.7	43.0c	0.26	0.26	4.90	5.00b	4
A3B1	58.7	42.3c	0.26	0.26	4.90	5.10b	4
A4B1	58.7	39.0d	0.26	0.36	4.90	5.40a	3
A1B2	58.7	48.7b	0.26	0.26	4.90	5.50a	5
A2B2	58.7	53.7a	0.26	0.36	4.90	4.90c	16
A3B2	58.7	54.9a	0.26	0.36	4.90	4.80c	18
A4B2	58.7	50.3b	0.26	0.36	4.90	5.10b	6

A1= Control, A2= 1% perforated LDPE, A3= Cling film wrap, A4= Newspaper wrap, B1= Ambient condition (25±3°C), B2= Refrigerated (6±1°C) condition. Figures having the same letter in a column are not different significantly.

Conclusion

Cauliflower wrapped with PE cling film or packed in LDPE bag (1% perforation) and stored at refrigerator (6±1°C and 50±5% RH) could retain white colour, good sensory quality, firm and fresh curds with minimum loss in weight, texture and spoilage. The shelf life was 18 days for cling film wrapped and 16 days for LDPE packed curd stored at refrigerator, while it was only 3 days for control one stored at ambient condition. More water was accumulated and curd was suffered from rubbing in LDPE bag than that of cling film that creates more spots on curds.

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