Shelf-Life and Quality of Cauliflower (*Brassica Oleracea* L. Var *Botrytis*) as Affected by the Type of Polymeric Films and Duration of Modified Atmosphere Packaging

R.K. Adhikari[1@], D.D. Dhakal[2], D.M. Gautam[3], R.B. Thapa[2], K.M Tripathi[3], A.L. Acedo Jr.[4], W. Easdown[4], J.A. Hughes[5] & J.D.H. Keatinge[5]

Abstract

A post-harvest study was conducted during Jan-Feb 2015 in horticulture laboratory at Agriculture and Forestry University (AFU), Chitwan to find out the effect of different polymeric films and time of Modified Atmosphere Packaging (MAP) on shelf life and quality of cauliflowers at ambient room condition (17.4 ± 3.50C and 76 ± 17% RH). The experiment was laid in two factorial Complete Block Design (CBD). Ten heads per package of freshly harvested cauliflowers var. "Snow Mystique" were sealed airtight for 2 and 5 days inside Low Density Polyethylene (LDPE) films of 25µ and 50µ thickness; Polypropylene (PP) films of 25µ and 50µ thickness; cling wrap film and without packaging (control). Temperature and relative humidity of the storage room, weight loss, browning, freshness, shelf life, over all acceptability of curds were the parameters observed. Holding cauliflower for two days in 25µ LDPE and 25µ PP films; and in cling wrap were better among all treatments to maintain freshness and overall acceptability of curds. Holding for five days both in LDPE and PP had negative effect on the quality and storability of cauliflowers. Keeping longer period in MAP resulted browning, fermented odour and rotting in cauliflowers. LDPE was more suitable for MAP as compared to PP film. Based on this study, 25µ LDPE film is found appropriate MAP technology for holding cauliflowers up to two days for transporting from one place to another and for temporary retail storage under ambient room condition.

Keywords: *Browning, low density polyethylene, post-harvest quality, polypropylene, Snow Mystique.*

Introduction

Cauliflower (*Brassica oleracea* L. var. *botrytis*) is an important vegetable crop of Brassicaceae family grown widely around the world including Nepal. In terai and inner terai regions, it is grown as a winter vegetable with high economic importance. The diverse agro-climatic condition in Nepal favours the production of cauliflower in summer season in mid-hills and high hills showing export potentiality as off-season vegetables (Bhattarai, 2011; Dhakal et al. 2009). During fiscal year 2015/16, 550044.8 metric tons of cauliflower was produced in 34967 hectares of land with average productivity of 15.7 mt/ha in Nepal. Similarly, 5172 mt of cauliflower in 431 ha of land with productivity of 12.0 mt/ha was produced in Chitwan district in the same year (MoAD, 2017).

Postharvest loss of vegetables is a global challenge. The range of 15 to 40% reduction in vegetable supply in Nepal is due to postharvest losses (AVRDC, 2015). A market study conducted as a part of this work at Kalimati Fruits and Vegetables Wholesale market showed that 20-30% of post-harvest losses occurred in cauliflower. The curds

[1] Junar Superzone, PMAMP, Sindhuli, Nepal

[2] Institute of Agriculture and Animal Sciences, Chitwan, Nepal

[3] Agriculture and Forestry University, Chitwan, Nepal

[4] AVRDC – The World Vegetable Center South Asia, Hyderabad, India

[5] AVRDC – The World Vegetable Center Headquarters, Shanhua, Tainan, Taiwan

[@] Corresponding author: adhikari.ravikiran@gmail.com

Received on: 17th Sep 2017; Accepted on: 27th Nov 2018; Published on: 15th December 2018

were brought in pickups and trucks from the fields to the market. They were brought in plastic bags and sacks, exposing to sun. There were no refrigerating facilities in the transporting vehicles and the post-harvest losses were high. Literatures showed the possibilities to reduce the existing postharvest losses with the use of different effective technologies. Cold chain management, cold storage, hypobaric storage and controlled atmosphere storage are such examples that can curb the problem (Singh, 2010). However, they may not be feasible for farmers having poor economic condition in developing countries like Nepal. Therefore, this study came in place for developing an appropriate and affordable technology for the farmers and traders involved in the value chain.

Modified atmosphere packaging technology is cost effective and commonly used for fresh vegetables (Mohamed Mahroop Raja et al. 2011). It is a viable option for increasing the shelf life of a commodity and is gaining popularity in many countries. In MAP, simple low-density polyethylene or polypropylene plastic bag or film is used to hold fruits/vegetables during storage, transport and marketing. It is a cheaper storage practice and could be viable in developing countries too. The farmers having low investment capacity can be benefitted by MAP storage practices. This technology could also benefit small volume traders. In the long run, this technology has the potentiality of value addition to the produce including vegetables such as cauliflower. The amount of oxygen decreases and carbon dioxide increases inside MAP because of respiration by the produce, which prolongs its shelf life (Kader, 1983).

The purpose of this study was to evaluate the effect of different types of MAP technologies and duration of holding of cauliflower heads in it on the storability and quality of cauliflowers at ambient condition, so that the developed technology can be utilised in transportation and short-term storage of cauliflowers.

Methodology

The freshly harvested cauliflowers of variety 'Snow Mystique' from the farmers' field were brought to the horticulture laboratory of Agriculture and Forestry University (AFU), Chitwan in plastic bag (farmer's practice). Uniform curds were selected based on maturity stage and size. Outer leaves were removed, while 6-8 inner leaves were kept as per commercial practice. The cauliflowers were kept at laboratory room for 2-3 hours to allow cooling and were randomly divided into 44 units of ten heads each. There were 11 treatment combinations each having four replications. The cauliflowers were sealed inside 25µ and 50µ low-density polyethylene (LDPE) films, 25 and 50µ polypropylene (PP) films, cling wrap film in plastic tray (super market style) and open (control). The packages were opened at 2 and 5 days and cauliflowers were kept up to 10 days for observation. Thus, the effect of MAP was observed for two days and five days. Complete airtight condition was maintained inside the package by sealing the mouth of plastic bag. The experiment was laid in two factorial Complete Block Design (CBD). The two factors taken were the days of opening (2 and 5) and the different types of curd wrapping techniques. All the treatments were kept at ambient condition in the laboratory (17.4±4.40C and 77±7% RH) for two and five days to simulate the appropriate transportation and retail sale period. Observations were made on temperature and relative humidity of storage condition, weight loss and shelf life of the cauliflower. Temperature inside the package was also recorded by temperature gun (Testo 830-T1). Freshness and acceptability of curds were evaluated using 1 to 5 point scale hedonic rating where 1 was for most desirable attribute and 5 was for least desirable attribute. Browning was rated in 1-4 scale where 1- no browning, 2- less than 10% browning, 3- 10-25% browning and 4- more than 25% browning. Results were analysed using software M-STATC and Duncan's Multiple Range Test (DMRT) was used to separate means.

Results and Discussion

Cumulative Weight Loss

The application of MAP for 2 days retained the weight of cauliflower. All MAP treatments minimized weight loss contrary to the non-MAP or control treatment. Under two days MAP condition, the weight loss inside the package ranged from 0.48% (50µ PP) to 0.9% (25µ PP) while it was 3.4% in case of control (Table 1). On 5th day, the cauliflowers held inside 25µ LDPE film showed the lowest weight loss. Similar trend was noticed on tenth day too, without significant variations among the treatments.

Table 1. Cumulative weight loss (%) of 2 days MAP cauliflowers at 2 (opening), 5 and 10 days in ambient condition (17.4±4.4 0C and 77±7 % RH)

Treatment	2 days	5 days	10 days
25µ LDPE	0.5[b]	6.52[c]	20.55
50µ LDPE	0.63[b]	7.17[bc]	21.00
25µ PP	0.9[b]	7.6[bc]	21.03
50µ PP	0.48[b]	8.02[b]	22.40
Cling wrap	0.6[b]	7.15[bc]	20.25
Control	3.4[a]	9.87[a]	21.18
LSD	0.509**	1.23**	ns
SEm	0.169	0.407	0.302
CV(%)	31.18	10.53	7.83
Grand mean	1.08	7.72	21.07

Means representing same letter(s) are not significantly different at 5% probability level as determined by the DMRT. ** denotes significant at 1% probability level.

In 5 days MAP treatment, the weight loss was significantly lower in all MAP cauliflowers (Table 2) than that of control. It ranged from 0.8% (cling wrap film and 25µ PP) to 1.13% (50µ LDPE) in MAP condition, while it was 9.87% in control. After opening the bag on the fifth day, the trend of weight loss remained the same and the effect remained significant until the tenth day.

On 10th day, there were no variations in weight loss among all the MAP treatments, indicating that the rate of weight loss is at similar rate in MAP held cauliflowers after opening of bag. These results are similar with the findings of previous researchers. Reduced weight loss in MAP commodity than that of control was reported in bell pepper (Manolopoulou et al. 2010). Weight loss was found to reduce by four to seven times in LDPE films as compared to PVC film (Artes and Martinez, 1999).

Table 2. Cumulative weight loss (%) of 5 days MAP cauliflowers at 5 (opening), 6 and 10 days at ambient condition (17.4±4.4 0C and 77±7 % RH)

Treatment	5 days	6 days	10 days
25µ LDPE	0.95[b]	5.65[bc]	16.48[b]
50µ LDPE	1.13[b]	6.65[b]	18.48[b]
25µ PP	0.80[b]	4.93[c]	16.27[b]
50µ PP	0.90[b]	5.15[bc]	15.85[b]
Cling wrap	0.80[b]	5.35[bc]	16.63[b]
Control	9.87[a]	13.50[a]	21.17[a]
LSD	0.807**	1.514**	2.489**
SEm	0.267	0.502	0.825
CV(%)	22.25	14.62	9.45
Grand mean	2.41	6.87	17.48

Means representing same letter(s) are not significantly different at 5% probability level as determined by the DMRT. ** denotes significant at 1% probability level.

Browning

Physiological browning is one of the serious problems in MAP packaging of cauliflower. There was no browning of curds while inside MAP but it developed at faster rate after opening of the bag.

Table 3. Browning of cauliflower under MAP application at Rampur, Chitwan, 2015 (17.4±4.4 0C and 77±7 % RH)

Opening of MAP	Treatment	2 days	5 days	8 days	10 days
2 days	25µ LDPE	1b	2.3c	2.8cde	3.2cd
	50µ LDPE	1b	2.6a	3.3ab	3.7ab
	25µ PP	1 b	2.4bc	2.8de	3.0d
	50µ PP	1b	2.4b	3.0bcd	3.5bc
	Cling wrap	1b	2.3bc	2.9bcde	3.4bc
	Control	1.6a	2.1d	2.6e	3.0d
5 days	25µ LDPE	-	1e	2.6e	2.9d
	50µ LDPE	-	1e	3.7a	3.9a
	25µ PP	-	1e	3.2bc	3.7ab
	50µ PP	-	1e	3.7a	3.8ab
	Cling wrap	-	1e	2.8cde	3.2cd
	Control	1.6a	2.1d	2.6e	3.0d
LSD		0.082**	0.090**	0.372**	0.301**
SEm		0.027	0.032	0.129	0.104
CV(%)		5.25	3.50	8.59	6.19
Grand mean		1.1	1.76	3.0	3.4

Means representing same letter(s) are not significantly different at 5% probability level as determined by the DMRT. 1=no browning and 4= maximum browning. ** denotes significant at 1% probability level.

Physiological browning of cauliflower was minimum with the use of MAP for 2 days than that of MAP for five days. Among different MAPs, 25µ LDPE, 25µ PP and cling wrap film had minimum browning while rapid browning was observed with five days MAP treated cauliflowers in 50µ LD and 50µ PP films (Table 3). Physiological browning is mainly because of anaerobic condition inside MAP. Five days storage might have created high level of carbon dioxide but low oxygen concentration inside MAP creating unfavourable environment for normal metabolic process and thus causing physiological abnormalities in the curd. Similar results were obtained by Gomez and Artes (2004) and Artes and Martinez (1999). Though browning was recorded in control cauliflowers, the nature of browning was slightly different and it was necrotic type rather than physiological. Often necrotic browning is also seen as a result of physical tissue damage.

Freshness

All MAP treatments retained the freshness of cauliflowers. MAP treated cauliflowers had greener leaves and fresher curds until 5 days. However, cauliflower under control already lost its freshness (Figure 1). Additional storage of cauliflower in ambient condition (17.4±4.40C and 77±7 % RH) up to 10 days revealed that after opening of PE bag for 5 days, MAP held cauliflowers lost freshness more rapidly as compared to two days MAP. Among different types of MAP, 25µ LDPE film was better for freshness retention, followed by 25µ PP and cling wrap film. Cauliflowers held in 50µ LDPE and 50µ PP for both two and five days lost freshness at faster rate. Thicker plastic film might have created greater barrier for the exchange of gases causing stress to the commodity, which causes faster deterioration of curds after opening of the bag.

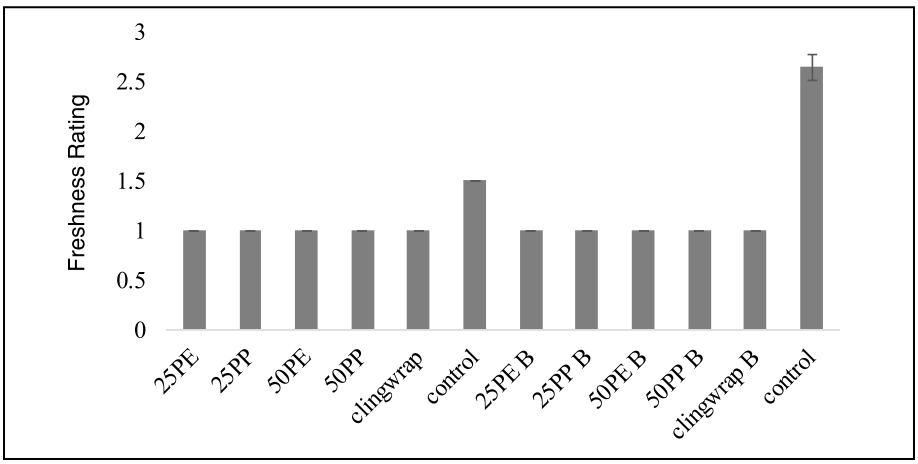

Figure 1 Effect of type and duration of MAP on freshness of cauliflower on the day of opening (2nd day for 2 day MAP and 5th day for 5 day MAP) at ambient condition, (17.4±4.40C and 77±7% RH). B denotes 5 day MAP treatments and error bars represent standard deviation.

Mohamed Mahroop Raja et al. (2011), Jany et al. (2008) and Pal et al. (2002), obtained similar results in cauliflower. Better physical appearance of cauliflower was noticed up to six days at temperature range of 15 to 240C and RH of 64 to 94% up to six days of storage. Higher humidity inside plastic films and decreased rate of metabolic activities of the commodity has contributed to maintain the freshness of commodity in such condition (Jany et al. 2008).

Acceptability of Curds

Visually all the curds were looking acceptable while stored in MAP for both two days and five days. In general, two days MAP duration was better than five days (Table 4). Among different MAPs, 25µ LDPE was found to be the best followed by 25µ PP and cling wrap film.

Table 4. Acceptability of cauliflower at ambient holding after MAP application at Rampur, Chitwan, 2015 (17.4±4.4 ºC and 77±7 % RH)

Opening of MAP	Treatment	2 days	5 days	8 days	10 days
2 days	25µ LDPE	1b	2.6ab	3.1e	3.3e
	50µ LDPE	1b	2.8a	3.6b	3.9b
	25µ PP	1b	2.5b	3.1de	3.4de
	50µ PP	1b	2.7a	3.5bc	3.8bc
	Cling wrap	1b	2.8a	3.5bc	3.7bcd
	Control	1.8a	2.5b	3.4bcd	3.7bcd
5 days	25µ LDPE	-	1.2c	3.3cde	3.6cd
	50µ LDPE	-	1.2c	4.0a	4.4a
	25µ PP	-	1.2c	3.9a	4.3a
	50µ PP	-	1.2c	3.9a	4.2a
	Cling wrap	-	1.2c	3.4bcd	3.6cd
	Control	1.8a	2.5b	3.4bcd	3.7bcd
LSD		0.095**	0.188**	0.257**	0.288**
SEm		0.031	0.065	0.089	0.1
CV(%)		5.88	6.38	5.11	5.27
Grand mean		1.13	2.06	3.50	3.78

Means representing same letter(s) are not significantly different at 5% level of significance as determined by the DMRT. (1= Acceptable very much and 5= not acceptable); ** denotes significant at 1% probability level.

Curds stored in MAP for five days were visually good looking, but after opening the package, they produced off- flavour and were not acceptable. The antagonistic effect of elevated carbon dioxide level on ethylene action influencing secondary metabolism may be the possible cause for fermentative metabolism (Mathooko, 1996). It might also be correlated with ammonia accumulation and progressive decrease in protein content (Tudela et al. 2013).

Temperature Inside The Package

Temperature of the cauliflowers inside the MAP increased as compared to the cauliflower without MAP. It was 15.9ºC in non-MAP curds against the range of 16.7ºC to 17.5ºC in MAP, on the day of packaging (Table 5). On second day, control curds had the temperature of 16.2ºC while it ranged from 16.8 to 17.6ºC on the surface of cauliflower inside the packages. Slightly higher temperature in MAP could be because plastic films create a kind of barrier outside to release the developed heat in the MAP.

Shelf Life

MAP increased the shelf life of cauliflower. Cauliflowers when held for two days in MAP, retained freshness with the maintenance of quality and deteriorated at slower rate. On the other hand, when held for five days in MAP, produce looked fresh until the opening of bag but detected off flavour at opening and also deteriorated at faster rate. 25µ LDPE, cling wrap film and 25µ PP films were better in terms of shelf life elongation among different polymeric films.

Table 5. Temperature (ºC) inside the package influenced by packaging and days after opening at Rampur, Chitwan, 2015

Opening of MAP	Treatment	1 day	2 days	3 days	4 days	5 days
2 days	25 µ LDPE	16.7cd	17.4	-	-	-
	50 µ LDPE	16.7cd	17.0	-	-	-
	25 µ PP	17.2ab	17.5	-	-	-
	50 µ PP	17.1abc	17.4	-	-	-
	cling wrap	16.9bcd	17.6	-	-	-
	Control	15.9e	16.2	-	-	-
5 days	25 µ LDPE	17.0bcd	17.1	16.1	17.3a	17.8a
	50 µ LDPE	17.0bcd	16.9	16.1	17.3a	17.8a
	25 µ PP	16.7d	16.8	15.9	17.2a	17.6a
	50 µ PP	17.0bcd	16.9	16.0	17.3a	17.9a
	cling wrap	17.5a	17.2	16.2	17.4a	18.0a
	Control	15.9e	16.2	16.0	16.7b	16.9b
LSD		0.361**	ns	ns	0.202**	0.537*
SEm		0.125	0.132	0.043	0.067	0.178
CV(%)		1.49	1.75	1.62	0.77	2.02
Grand mean		16.82	17.04	16.04	17.22	17.67

Note: ** denotes significant at 0.01 probability level, * denotes significant at 0.05 probability level and ns denotes not significant at 0.05 probability level

Of all MAPs and storage time, cauliflower stored in ambient temperature after application of 25µ LDPE MAP treatment for two days had the longest shelf life of ten days. Akter et al. (2013) and Singh (2010) also reported increased shelf life with MAP.

Conclusion

The modified atmosphere packaging with 25µ LDPE film, PP film and cling wrap film for two days is beneficial to hold cauliflower for transporting to the market and for storage at retail market. Among these three, 25µ LDPE held cauliflowers for two days was the best. On the other hand, the MAP practice of five days was inappropriate, as the cauliflower wrapped for five days had the pungent/off odour after opening of the package and witnessed rapid degradation of quality, browning and disease development. Trials under different variations such as location, seasons, storage conditions, variation with duration of MAP holding, use of carbon scrubbers and with perforations of plastic films should be some of the avenues for further research.

Acknowledgement

Authors acknowledge USAID/AVRDC-The World Vegetable centre, Taiwan (AVRDC Maconomy Nr.0000195-4AVRDC Contract Nr SC-195-08) and the National Agriculture and Research Development Fund (NARDF), Government of Nepal for partial funding of this study, a part of M.S. thesis submitted to Institute of Agriculture and Animal Sciences, Tribhuvan University, Nepal.

References

Akter, H., M.K. Hassan, M.G. Rabbani and A.A. Mahmud. 2013. Effects of variety and postharvest treatments on shelf life and quality of banana. J. Environ.Sci. & Natural Resources, 6(2): 163-175, 2013.

Artes, F. and J.A. Martinez. 1999. Quality on of cauliflower as influenced by film wrapping during shipment. Eur. Food Res Technol. 209:330-334.

AVRDC. 2015. Fresh, newsletter published by AVRDC-The World Vegetable Center. April issue. Taiwan.

Bhattarai, D.R. 2011. Postharvest technology marketing, handling and processing of fruits and vegetables. Santa Bhattarai, Bhawani Printers, Chabahil, Kathmandu.

Boyhan, G.E., D. Maclean, A.G. Bateman and S. Tate. 2012. Preliminary evaluation of modified-atmosphere storage for pumpkins. International Journal of Vegetable Science, 18:87-92.

Dhakal, D., S.C. Shah, D.M. Gautam and R.N. Yadav. 2009. Response of Cauliflower (*Brassica oleracea* var. *botrytis*) to the application of boron and phosphorus in the soils of Rupandehi district. Nepal Agric. Res. J. (SAS-N). 9:52-60.

Gomez, P.A. and F. Artes. 2004. Keeping quality of green celery as affected by modified atmosphere packaging. European Journal of Horticultural Science, vol. 69, No. 5, pp. 215-219. Retrieved from internet on September 19, 2015. Stable URL: http://www.jstor.org/stable/24126128.

Jany, M.N.H., C. Sarker, M.A.R. Mazumder and M.F.H. Shikder. 2008. Effect of storage conditions on quality and shelf life of selected winter vegetables. J. Bangladesh Agril. Univ. 6(2): 391-400, 2008.

Kader, A.A. 1983. Postharvest quality maintenance of fruits and vegetables in developing countries. From: Post-harvest physiology and crop preservation. Ed. Morris Lieberman. Plenum Publishing Corporation.

Manolopoulou, H., G. Santhopoulos, N. Douros and Gr. Lambrinos. 2010. Modified atmosphere packaging storage of green bell peppers: Quality criteria. Biosystems engineering 106 (2.10) 535-543.

Mathooko, F.M. Regulation of respiratory metabolism in fruits and vegetables by carbon dioxide. Postharvest Biology and Technology, 9(3). pp. 247-264.

MoAD. 2017. Statistical Information on Nepalese Agriculture 2015/16. Agribusiness promotion and statistics division, Ministry of Agricultural Development, Singha Durbar, Kathmandu.

Mohamed Mahroop Raja, M., A. Raja, M. Mohamed Imran and A. Habeeb Rahman. 2011. Quality aspects of cauliflower during storage. International Food Research Journal 18: 427-431 (2011).

Pal, U.S., Md. K. Khan, G.R. Sahoo and N.R. Sahoo. 2002. Post-harvest losses on tomato, cabbage and cauliflower. Agricultural mechanization in Asia, Africa and Latin America.33 No.3. 35-40.

Singh, S. 2010. Modified atmosphere packaging of fresh produce: Current status and future needs. Sandhya/LWT - Food Science and Technology 43: 381–392.

Tudela, J.A., A. Marin, Y. Garrido, M. Cantwell, M.S. Medina-Martinez and M.I. Gil. 2013. Off-odour development in modified atmosphere packaged baby spinach is an unresolved problem. Postharvest Biology and Technology 75:75-85.