INNOVARE JOURNAL OF AGRICULTURAL SCIENCE

Vol 11, Issue 5, 2023 ISSN - 2321-6832

Research Article

MODIFIED ATMOSPHERE PACKAGING OF CAULIFLOWER FOR ENHANCING THE EFFECTIVENESS OF COOL BOT COLD STORAGE TO PRESERVE THE POSTHARVEST QUALITY IN NEPAL

SUPRABHA PANDEY*, GAUTAM IP, DHAKAL M, GHIMIRE D, POUDEL S

National Horticulture Research Centre, Lalitpur, Uttar Pradesh, India. Email: suprabhapandey52@gmail.com

Received: 8 August 2023, Revised and Accepted: 21 August 2023

ABSTRACT

In recent years, cool bot storage was introduced to smallholder farmers in Nepal as a low-cost alternative to cold storage. The present study was carried out to evaluate the efficacy of different poly films in perforated modified atmosphere packaging on the postharvest life of cauliflower in cool bot-equipped cold rooms and ambient room conditions in the years 2019 and 2020 in the month of December. The cauliflower curds (hybrid variety White Top) were harvested from commercial vegetable growers at a fully mature stage. The compact and mature curds were harvested in the morning and brought to the National Horticulture Research Centre in Khumaltar. The curds were kept overnight for pre-cooling. Four different poly films (25 μ, 50 μ, 75 μ, and 100 low-density polyethylene with 16 perforations were used during storage in two different storage conditions. The study was conducted in a completely randomized block design. Curds were kept at ambient room conditions (15.5°C, 58% RH) for 10 days and at cool, bot devised, cold storage (11.25°C, 96% RH) for 15 days and analyzed for various postharvest quality parameters every 5 days of storage. The results modified atmosphere packaging i.e.50μ LDPE was found effective in cauliflower stored in ambient room conditions with quality perspective but the packaging didn't provide additive effects in shelf life and quality of cauliflower in cool bot storage conditions.

Keywords: Cauliflower, storage, Coolbot, Shelf life, Packaging.

 DOI: http://dx.doi.org/10.22159/ijags.2023v11i5.49079. Journal homepage: https://innovareacademics.in/journals/index.php/ijags

INTRODUCTION

Cauliflower (*Brassica oleracea var. botrytis*) is a cash crop and the number one vegetable crop in terms of production and value in Nepal. The popularity and high consumer demand for cauliflower stem from its nutritional quality and health benefits. Cauliflower contains high levels of vitamins C and B, calcium (ca), Iron (Fe), and phosphorus (P), and is known to have health-promoting benefits. Post-harvest losses of vegetables vary with commodity, location, value chain system, and value chain actor. The loss estimates vary considerably, with maximum average losses of up to 50% or higher in developing countries (Acedo *et al*., 2015; Weinberger and Acedo, 2011). Vegetable loss is approximately 17% of the total harvest, with the greatest burden of physical loss on farmers in southeast Asia (Kula *et al*., 2015).

Post-harvest handling is a set of operations undertaken from the time of harvest up to the time just before consumption or just before processing (Kanlayanarat and Acedo, 1997). The perishability of the product, which is very high for fruits and vegetables; the bulkiness of the product, which adds to transportation inconveniences, storage, and labor costs; the quality of the products, such as color, freshness, smell, etc. (Mbuk *et al*., 2011). Cold chain management is important in slowing down the deterioration processes that take place in harvested commodities (Senthilkumar *et al*., 2015), thereby extending shelf life and the marketing period (Borompichaichartkul *et al*., 2009). In sub-tropical climates, low-cost cold storage technology is vital to small-income farmers and little-scale agro-processors (Kitinoja and AlHasan, 2012; Workneh, 2010). Nowadays, low-cost cold storage facilities, viz., evaporative cooling and CoolBot cooling, are becoming so popular and obtainable for small-income growers (Saran *et al*., 2010; Kitinoja and Thompson, 2010; Kitinoja and AlHasan, 2012). Therefore, the researchers suggested that small-income farmers use low-cost cooling facilities to prolong the life span of the harvested fruits and vegetables and decrease losses post-harvest (Roy and Pal, 1994; Saran *et al*., 2010; Workneh, 2010). A cool bot system is a viable option for smallholder farmers who can't afford the expensive conventional cold rooms since it's cheaper. It also saves up to 60% of the electricity bills; hence, smallholder farmers organized in groups can benefit from it (Dubey, 2011). Modified atmospheric packaging (MAP) has also been used effectively to prolong the shelf life of many fresh vegetables in many countries during storage and marketing (Jha and Chopra, 2006; Dadhich *et al*., 2008; Nasrin *et al*., 2008; Odesola and Onyebuchi, 2009).

Also, farmers can use Coolbot as cold storage for seasonal fruits and vegetables. Being able to extend shelf life and save cauliflower from spoilage with coolbot and AC technology with MAP might help overcome existing post-harvest management challenges in Nepal. Therefore, the current study aimed to optimize the temperature during storage using cool bot facilities while evaluating the physicochemical characteristics of stored cauliflower curds to extend shelf life and reduce postharvest losses.

METHODS

The study was carried out at the laboratory of the National Horticulture Research Centre in Khumaltar, Nepal, to identify the appropriate packaging material in MAP to extend the shelf life of cauliflower through the minimization of post-harvest losses in storage conditions. Fully matured compact cauliflower curds were selected and stored in ambient storage (15.5°C, 58% RH) and cool bot storage (13.25°C, 96% RH) with four different packaging materials (25 μ, 50 μ, 75 μ, and 100 low-density polyethylene (LDPE)) and without MAP. The study was conducted in triplicate, using five samples for each treatment. The packaging was done with the standard 16 pinholes per package.

Parameters measured

Data on postharvest loss and physicochemical and nutritional quality were gathered at 5-days intervals in storage conditions. Temperature and relative humidity were recorded daily by using a temperature-RH meter (Figure 1).

Physiological weight loss (PWL %)

The experimental samples were weighed on the 1st day and every 5 days at intervals using a digital balance (SACLTREC SPB42). The difference between the initial and final weight of the fruit was considered total weight loss during the storage interval and expressed as a percentage.

PWL%= initial weight-final weight/initial weight×100

Total soluble solids (TSS°B)

TSS was measured with the help of a pocket Brix-Acidity Meter (Model: PAL-BX/ACID F5 Cat. No. 7100) in degree Brix by placing two to three drops of clear juice on the prism surface.

Titratable acidity (TA)

The extracted cauliflower juice was diluted to 1:50 ratios, and TA was recorded using a pocket Brix-Acidity Meter (Model: PAL-BX/ACID F5 Cat. No. 7100) in percentage by placing 1–2 drops of diluted juice on the prism surface.

Vitamin C

The ascorbic acid in samples was measured by the volumetric method as per the reference from Sadasivsm and Manickam (1991). The following formula was used to calculate the ascorbic acid content:

Amount of ascorbic acid=0.5 mg×V2mL×12 mL×100/V1 mL×5 mL×wt. of sample

Where V1=amount of dye consumed during the titration

V2=amount of dye consumed when the supernatant was titrated with 4% oxalic acid

RESULTS AND DISCUSSION

Temperature and relative humidity

Coolbot storage expectedly maintained lower temperatures than ambient temperatures. Average temperatures in the cool bot measured daily during storage ranged from 12.5 to 14.4°C, while ambient temperatures ranged from 15.1 to 15.5°C.

PWL (%)

The influence of various poly films of LDPE packaging stored in ambient and cool bot storage conditions on cauliflower's PWL percentage was studied. The weight loss percentage was calculated every 5 days of the interval as shown in Table 1.

On Day 5 of storage, significantly the highest PWL% (12.16%) was found in the curds packed in 100 μ LDPE with 16 pinhole perforations in ambient storage conditions, and the lowest PWL% (3.96%) was found in unpacked curds in cool bot storage conditions, followed by 5.14% in curds packed in 50 μ LDPE with 16 pinhole perforations in cool bot storage conditions.

Similarly, on day 10 of storage, the highest significant PWL% (21.93%) was found in the unpacked curds in ambient conditions, and the lowest PWL% (8%) was found in unpacked, curds in cool bot storage, followed by 8.94% in the curds packed in 50 μ LDPE with 16 perforations in cool bot storage conditions.

The curds stored in ambient storage conditions were removed from the study on day 10 of the study as the curds were beyond consumer acceptance, i.e., <50% acceptability, which is verified by visual appearance.

On Day 15 of storage, the highest PWL% (16.20%) was observed in curds packed in 75 μ LDPE with 16 perforations stored in cool bot storage, and the lowest PWL% (10.36%) was observed in unpacked curds stored in cool bot storage, followed by curds packed in 50 μ LDPE with 16 perforations (12.11%) stored in cool bot storage.

Cauliflower has high water loss and problems with microbiological contamination during commercialization. Chitarra and Chitarra (2005) mentioned moisture loss ranging from 3% to 5%, and more than this may make the vegetable inappropriate for consumption. Similarly, Kramchote *et al*. (2012) reported that weight loss increased with storage much more rapidly at ambient (28°C) than at 4 or 10°C for Chinese cabbages. Reducing the weight of fresh fruits and vegetables is due to water loss by respiration and transpiration. Furthermore, the type of packaging increases the moisture inside the package and reduces weight loss (Reche *et al*., 2019).

TSS°B

According to the Table 2 on Day 5 of storage, significantly the highest TSS (7.4° Brix) was found in the curds packed in 100 μ LDPE packaging with 16 pinhole perforations in cool bot storage condition, and the lowest TSS (4.65° Brix) was found in the curds packed in 75 μ LDPE in cool bot storage, followed by 5.38° Brix in the curds packed in 25 μ LDPE packaging in ambient storage condition.

Similarly, on Day 10 of storage, the highest significant TSS (6.35° Brix) was in the curds with no MAP in cool bot storage, and the lowest TSS (4.72° Brix) was in the curds packed in 75 μ LDPE with 16 pinhole perforation in ambient storage, followed by 5.07° Brix in 25 μ LDPE packaging in cool bot storage condition. The trend of TSS is slightly increasing up to day 10 and then decreased comparatively.

On Day 15 of storage, the highest TSS (6.05° Brix) was found in curds kept in the open tray in cool bot storage and the lowest TSS (4.13° Brix) in curds packed in 50 μ LDPE packaging in cool bot conditions.

The rapid increase in TSS content in fruits under control treatment is due to faster loss of water, utilization of starch and polysaccharides as energy and conversion into soluble sugar, and a decrease in TA due to consumption as the energy source for respiration and other physiological processes after harvest (Wills *et al*., 1998).

TA

The influence of various poly films of LDPE packaging stored in ambient and cool bot storage conditions on the TA% was also studied as shown in Table 3. The TA% was calculated every 5 days at intervals. At day 10 of storage, the significantly highest TA (1.143%) was found in the curds, with no MAP in the open tray in the cool bot storage condition. Similarly, at Day 15 of storage, the significantly highest TA (0.583%) was recorded in cauliflower stored in coolbot storage with no MAP, and the lowest TA was found in curds packed in 25 μ LDPE in coolbot storage conditions.

In contrast, total TA (TTA) in all fruits decreased gradually as ripening progressed, irrespective of storage conditions or packaging. However, cold-stored fruits that were packed in Activebag® had a delayed rate of TTA reduction. The reduction of TTA with ripening is attributed to the use of organic acid (the dominant acid in mangoes is citric acid) as a substrate in respiration (Gidagiri *et al*., 2020). No particular trend of TA change was observed with packaged and unpackaged cauliflower under both storage conditions.

Ascorbic acid content (mg/100 g)

The significant effect on the ascorbic acid content of cauliflower curds was noticed in various packaging films stored in storage conditions, as shown in the table below. On day 5 of storage, the highest ascorbic acid content (31.75 mg/100 g) in 50 μ LDPE MAP was in the cool bot and the lowest (17.18 mg/100 g) in 50 μ LDPE MAP in ambient storage conditions. After that, the ascorbic acid content showed a decreasing trend in all samples up to day 15 of storage. At day 10 of storage, the cauliflower curds packed in 75 μ LDPE MAP in ambient showed the highest ascorbic acid content (21.18 mg/100 g), and the curds packed in 50 μ LDPE MAP in ambient showed the lowest (12.16 mg/100 g) content. Following the decreasing trend, the ascorbic acid content was found to be minimal (10.47 mg/100 g) in curds packed in 25 μ LDPE MAP in a cool bot at day 15 of storage (Table 4).

Probably, this variation in the vitamin C content of cauliflower is related to the respiration rate of fruit during storage, which is

Table 1. Effect of modified atmospheric packaging and storage condition on PWL % in cauliflower in years 2021 and 2022, Khumaltar

Treatment	Physiological weight loss (%)								
	2021			2022			Pooled		
	Day 5	Day 10	Day 15	Day 5	Day 10	Day 15	Day 5	Day 10	Day 15
25 µ LDPE MAP in coolbot	8.26	9.93	13.8	7.43	8.95	11.98	7.84	9.44	12.89
50 µ LDPE MAP in coolbot	5.09	9.81	12.85	5.19	8.07	11.98	5.14	8.94	12.11
75 µ LDPE MAP in coolbot	7.39	12.63	16.9	7.57	11.11	15.5	7.48	11.87	16.2
100 µ LDPE MAP in coolbot	6.84	9.25	12.79	6.99	9.71	11.63	6.91	9.48	12.21
No MAP in Coolbot	2.99	7.48	10.32	4.93	8.52	10.4	3.96	8	10.36
25 µ LDPE MAP in ambient	8.5	19.8	Disposed	8.98	10.34	Disposed	8.74	15.07	Disposed
50 µ LDPE MAP in ambient	10.13	15.28	Disposed	9.5	12.76	Disposed	9.82	14.02	Disposed
75 µ LDPE MAP in ambient	10.54	15.57	Disposed	9.32	13.93	Disposed	9.93	14.75	Disposed
100 µ LDPE MAP in ambient	12.87	17.16	Disposed	11.44	15.59	Disposed	12.16	16.38	Disposed
No MAP in ambient	11.51	22.23	Disposed	11.43	21.63	Disposed	11.47	21.93	Disposed
GM	8.41	13.91	6.67	8.28	12.06	6.09	8.35	12.99	6.38
F-test	**	**	**	**	**	**	**	**	**
LSD	1.503	2.255	1.348	1.502	1.502	1.637	1.079	2.584	1.099
CV%	10.50	9.40	11.80	10.60	10.60	4	11.10	17	14.80

MAP: Modified atmosphere packaging, PWL: Physiological weight loss, LDPE: Low-density polyethylene, NS, ** and *** indicate non-significant, significant at P<0.05, and significant at P<0.01, respectively.

Table 2. Effect of modified atmospheric Packaging and storage condition on total soluble solids in cauliflower in 2021 and 2022 in Khumaltar

Treatments	TSS °Brix								
	2021			2022			Pooled		
	Day 5	Day 10	Day 15	Day 5	Day 10	Day 15	Day 5	Day 10	Day 15
25 µ LDPE MAP in coolbot	7.03	4	5.7	6.1	6.133	5.8	6.57	5.07	5.8
50 µ LDPE MAP in coolbot	4.4	4.93	3.63	5.96	5.5	4.13	5.18	5.22	4.13
75 µ LDPE MAP in coolbot	5	4.76	3.2	4.3	6	4.08		5.38	4.08
100 µ LDPE MAP in coolbot	9	4.03	4.63	5.8	6.3	4.83	7.4	5.17	4.83
No MAP in Coolbot	6.03	6.63	4.83	5.66	6.06	6.05	5.85	6.35	6.05
25 µ LDPE MAP in ambient	4.4	5.3	Disposed	6.36	6.1	Disposed	5.38	5.7	Disposed
50 µ LDPE MAP in ambient	4.67	4.3	Disposed	6.76	5.96	Disposed	5.72	5.13	Disposed
75 µ LDPE MAP in ambient	5.33	3.53	Disposed	5.96	5.9	Disposed	5.65	4.72	Disposed
100 µ LDPE MAP in ambient	4.43	4.8	Disposed	6.36	5.36	Disposed	5.4	5.08	Disposed
No MAP in ambient	5.6	5.8	Disposed	6.3	6.73	Disposed	5.95	6.27	Disposed
GM	5.59	4.81	4.39	5.96	6.07	4.97	5.77	5.41	4.97
F-test	*	**	**	**	**	**	*	*	**
LSD	1.97	0.84	0.77	0.21	0.23	0.74	1.35	1.03	0.74
CV%	20.60	10.20	20.60	2.10	2.30	25.70	20.20	16.60	25.70

MAP: Modified atmosphere packaging, TSS: Total soluble solids, LDPE: Low-density polyethylene, NS, ** and *** indicate non-significant, significant at P<0.05, and significant at P<0.01, respectively.

Table 3. Effect of modified atmosphere packaging and storage condition on tritatable acidity (TA%) in cauliflower in 2021 and 2022 in Khumaltar

Treatment	TA%								
	2021			2022			Pooled		
	Day 5	Day 10	Day 15	Day 5	Day 10	Day 15	Day 5	Day 10	Day 15
25 µ LDPE MAP in coolbot	1.047	0.733	0.283	0.75	0.593	0.586	0.898	0.663	0.435
50 µ LDPE MAP in coolbot	0.333	0.67	0.273	0.913	0.663	0.706	0.623	0.667	0.49
75 µ LDPE MAP in coolbot	0.513	0.503	0.303	0.623	0.663	0.683	0.568	0.583	0.493
100 µ LDPE MAP in coolbot	0.55	0.23	0.43	0.737	0.763	0.626	0.643	0.497	0.528
No MAP in Coolbot	0.653	1.09	0.32	1.177	0.197	0.846	0.915	1.143	0.583
25 µ LDPE MAP in ambient	0.483	0.303	Disposed	1.117	0.863	Disposed	0.8	0.583	Disposed
50 µ LDPE MAP in ambient	0.44	0.277	Disposed	1.057	0.673	Disposed	0.748	0.475	Disposed
75 µ LDPE MAP in ambient	0.417	0.173	Disposed	1.327	0.553	Disposed	0.872	0.363	Disposed
100 µ LDPE MAP in ambient	0.387	0.703	Disposed	1.213	0.707	Disposed	0.8	0.205	Disposed
No MAP in ambient	0.297	0.343	Disposed	1.163	1.137	Disposed	0.73	0.74	Disposed
GM	0.512	0.503	0.161	1.008	0.781	0.345	0.76	0.642	0.253
F-test	ns	**	**	ns	*	**	ns	**	**
LSD		0.249	0.07		0.289			0.3044	0.189
CV%	52.70	29	10.20	28.20	21.60	13.20	55	40.80	64.50

MAP: Modified atmosphere packaging, TA: Titratable acidity, LDPE: Low-density polyethylene, NS, ** and *** indicate non-significant, significant at P<0.05, and significant at P<0.01, respectively.

Table 4. Effect of modified atmospheric Packaging and storage condition on vitamin C content (mg/100g) solids in cauliflower in 2021 and 2022 in Khumaltar

Treatment	Ascorbic acid (mg/100 g)								
	2021			2022			Pooled		
	Day 5	Day 10	Day 15	Day 5	Day 10	Day 15	Day 5	Day 10	Day 15
25 µ LDPE MAP in coolbot	25.92	20.2	10.57	26.77	19.46	10.66	25.07	20.95	10.47
50 µ LDPE MAP in coolbot	31.91	18.19	15.42	32.07	16.25	14.28	31.75	20.12	16.56
75 µ LDPE MAP in coolbot	19.35	17.5	12.9	19.23	17.34	13.36	19.46	17.65	12.44
100 µ LDPE MAP in coolbot	15.91	13.52	11.77	17.85	14.37	12.17	13.97	12.68	11.38
No MAP in Coolbot	22.56	19.05	15.26	24.13	19.64	16.42	20.99	18.45	14.1
25 µ LDPE MAP in ambient	26.26	20.76	Disposed	25.43	21.29	Disposed	27.08	20.24	Disposed
50 µ LDPE MAP in ambient	17.74	13.48	Disposed	18.29	14.81	Disposed	17.18	12.16	Disposed
75 µ LDPE MAP in ambient	27.21	20.95	Disposed	26.67	20.72	Disposed	27.74	21.18	Disposed
100 µ LDPE MAP in ambient	26.78	21.04	Disposed	27.54	21.49	Disposed	26.01	20.58	Disposed
No MAP in ambient	23.02	16.19	Disposed	19.41	13.96	Disposed	26.62	18.42	Disposed
GM	23.66	18.09	6.59	23.74	17.93	6.69	23.59	18.24	6.49
F-test	**	**	**	**	**	**	**	**	**
LSD	2.681	2.136	2.136	3.653	2.73	2.16	2.315	2.511	2.19
CV%	9.80	10.20	10.20	9	8.90	18.80	5.70	8.00	19.70

MAP: Modified atmosphere packaging, LDPE: Low-density polyethylene, NS, ** and *** indicate non-significant, significant at P<0.05, and significant at P<0.01, respectively.

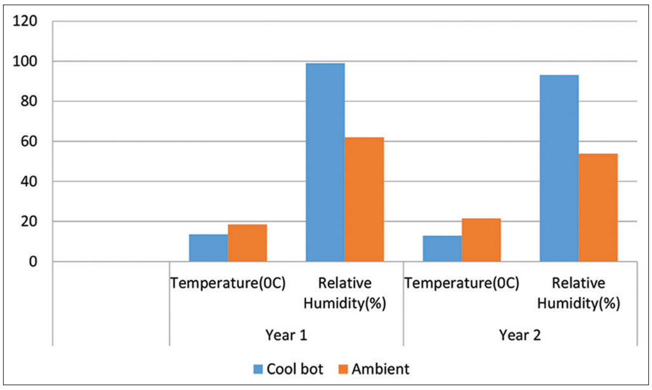

Figure 1: Temperature and relative humidity during cool bot and ambient storage of cauliflower of 15 days in year 2021 and 2022

effectively inhibited by controlling the atmosphere. The concentration of vitamin C in fruits is considered a quality factor; hence, it is highly vital to monitor during processing and storage (Mditshwa *et al*., 2017). Also, the vitamin C content is influenced by various postharvest factors, including packaging atmosphere and postharvest stress (Mditshwa *et al*., 2017). These observations are in parallel with those reported by others (Böttcher, 1986; Watada, 1987). It was concluded that low O2 and high CO2 concentrations inhibited losses in ascorbic acid content.

CONCLUSION

Fresh cauliflower curds packed by different packaging techniques in two different storage conditions preserved their color, moisture, weight, fresh-like appearance, and overall consumer acceptability for more days than the control condition. Curds were kept at ambient room conditions (15.5°C, 58% RH) for 10 days and at cool bot devised cold storage (11.25°C, 96% RH) for 15 days and analyzed for various postharvest quality parameters every 5 days of storage. On Day 10 of storage, 50µ LDPE MAP in Coolbot showed a minimum PWL (8.94%) with TSS (5.220 Brix) and TA (0.667%). MAP, i.e., 50 µ LDPE, was found effective in cauliflower stored in ambient room conditions from a quality perspective, but the packaging did not provide additive effects on the shelf life and quality of cauliflower in cool bot storage conditions. The results also confirm the beneficial effect of low-cost cool bot storage technology in cauliflower, so that smallholder farmers and wholesalers could hold the vegetable supply for some more days to get a higher market price. The effectiveness of modified atmospheric packaging and cool bot storage was not found to be much more effective, as the curds kept in the open tray in cool bot storage were found to be of the best quality after 15 days of storage.

ACKNOWLEDGMENT

We would like to acknowledge the value chain development of the fruits and vegetables project in Nepal for financial aid through the project, which was implemented by the National Horticulture Research Centre (NHRC). Heartly thanks to the NHRC team for their cooperation and support to implement the activities on the way.

REFERENCES

Acedo, A. L. Jr., & Easdown, W. (2015). Postharvest losses of vegetables in South Asia. *UNESCAP-CAPSA Palawija Newsletter*, *32*(2), 1-5.

Borompichaichartkul, C., Kanlayanarat S., & Acedo, A. (2009). *Horticultural chain management for countries of Asia and the Pacific region: "Cooling and cold storage"*. Rome: FAO.

Böttcher, H. (1986). Changes in the dry matter and saccharides of of cauliflower (*Brassica oleracea var. botrytis* L.) during storage. *Gartenbau*, *34*(8), 409-422.

Chitarra, M. I. F., & Chitarra, A. B. (2005). *Pós-colheita de frutas e hortaliças: Fsiologia e manuseio* (pp. 785). Lavras: UFLA.

Da Silva, C. A., & Mhlanga, N. (2011). In *Innovative policies and institutions to support agro-industries development* (pp. 353-373). Rome, Italy: FAO.

Dadhich, S. M., Dadhich, H., & Verma, R. C. (2008). Comparative study on storage of fruits and vegetables in evaporative cool chamber and in ambient. *International Journal of Food Engineering*, *4*(1), 1-11.

Dubey, N. (2011). *Technologies for horticultural development: CoolBot provides inexpensive, effective cooling*. Retrieved July 16, 2014, from https://hortcrsp.ucdavis.edu/main/media/technologies_coolbot.pd

Gidagiri, P., Jhaleghar, J., Jagadeesh, M. D., Babu, S. L., Meti, S., & Padashetti, B. (2020). Studies on zeolite-LDPE composite bags to extend the shelf life of acid lime fruits stored at ambient conditions. *International Journal of Current Microbiology and Applied Science*, *9*(2), 2673-2682.

Jha, S. N., & Chopra, S. (2006). Selection of bricks and cooler pads for construction of evaporatively cooled storage structures. *Journal of the Institution of Engineers* (*India*): *Agricultural Engineering Division*, *87*, 25-28.

Kanlayanarat, S., & Acedo, A. L. (1997). Introduction of postharvest technology of agricultural produce. In *Postharvest handling system of agricultural products. A training manual*. Thonburi, Bangkok, Thailand: King Mongkut's Institute of Technology.

Kitinoja, L., & AlHassan, H. Y. (2012). Identification of appropriate postharvest technologies for small scale horticultural farmers and marketers in Sub-Saharan Africa and South Asia-part 1, postharvest losses and quality assessments. *Acta Horticulture*, *934*, 31-40.

Kitinoja, L., & Thompson, J. F. (2010). Pre-cooling systems for small-scale producers. *Stewart Postharvest Review*, *6*(2), 1-14.

Kramchote, S., Srilaong, V., Wongs-Aree, C., & Kanlayanarat, S. (2012). Low temperature storage maintains postharvest quality of cabbage (*Brassica oleraceae L. var. capitata*) in supply chain. *International Food Research Journal*, *19*(2), 759-763.

Kula, O., Turner, C., & Sar, S. (2015). *An analysis of three commodity value chains in Cambodia: Rice, horticulture, and aquaculture*. Retrieved September 22, from https://www.marketlinks.org/sites/default/files/resource/files/LEO_Cambodia_Value_Chain_assessment_FINAL_508_Compliant_v3.pdf

Mbuk, E. M., Bassey, N. E., Udoh, E. S., & Udoh, E. J. (2011). Factors influencing post harvest loss of tomato in urban market in UYO, Nigeria. *Nigerian Journal of Agriculture, Food and Environment*, *7*(2), 40-46.

Mditshwa, A., Magwaza, L. S., Tesfay, S. Z., & Opara, U. L. (2017). Postharvest factors affecting Vitamin C content of *Citrus* fruits: A review. *Scientia Horticulturae*, *218*, 95-104.

Nasrin, T. A. A., Molla, M. M., Hossaen, M. A., Alam, M. S., & Yasmin, L. (2008). Effect of postharvest treatments on shelf life and quality of tomato. *Bangladesh Journal of Agricultural Research*, *33*(3), 579-585.

Odesola, I. F., & Onyebuchi, O. (2009). A review of porous evaporative cooling for the preservation of fruits and vegetables. *Pacific Journal of Science and Technology*, *10*(2), 935-941.

Reche, J., Garcia-Pastor, M. E., Valero, D., Hernandez, F., Almansa, M. S., Legua, P., & Amoros, A. (2019). Effect of modified atmosphere packaging on the physiological and functional characteristics of Spanish jujube (*Ziziphus jujuba* Mill.) cv 'Phoenix' during cold storage. *Scientia Horticulturae*, *258*, 108743.

Roy, S. K., & Pal, R. K. (1994). A Low-cost Cool Chamber: An Innovative Technology for Developing Countries. In *ACIAR proceedings-Australian centre for international agricultural research (Australia).*

Saran, S., Roy, S. K., & Kitinoja, L. (2010). Appropriate postharvest technologies for small scale horticultural farmers and marketers in Sub-Saharan Africa and South Asia-part 2. Field trial results and identification of research needs for selected crops. In *Proceedings of the XXVIII international horticultural congress on science and horticulture for people* (*IHC2010*)*: International symposium on 934; Lisbon, Portugal*.

Sadasivam S, Manickam A. Carbohydrates. In: Biochemical Methods for Agricultural Sciences. Coimbatore: Newage International Publiser; 1991.

Senthilkumar, S., Vijayakumar R. M., & Kumar, S. (2015). Advances in precooling techniques and their implications in horticulture sector: A review. *International Journal of Environmental and Agriculture Research*, *1*(1), 1-30.

Weinberger, K., & Acedo, A. Jr. (2011). Development and diffusion of vegetable postharvest and processing technologies in the greater Mekong subregion of Asia.

Wills, R. B. H., Mc-Glasson, B., Graham, D., & Joyce, D. (1998). *Postharvest: An introduction to the physiology and handling of fruits, vegetables and ornamentals*. New South Wales: University of New South Wales Press Ltd.

Workneh, T. S. (2010). Feasibility and economic evaluation of low-cost evaporative cooling system in fruit and vegetables storage. *African Journal of Food Agriculture, Nutrition and Development*, *10*(8), 2984-2997.