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Benefits of using Plastic Crate compared to Poly Sack during Transportation of Vegetables

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ABSTRACT

Broccoli, cabbage and cauliflower are some of the common vegetables that are grown and traded in Bhutan. It is cultivated in one part of the country and then transported to urban areas of the country for marketing. Poly sacks are commonly used for packing and transporting these vegetables. Plastic crates are recommended and promoted for use in packing and transporting vegetables but there is no study that has been conducted to prove their benefits. The aim of this study was to assess the transportation damage and economic benefit of using plastic crates during the transportation of vegetables compared to that of the poly sack. Broccoli, cabbage and cauliflower were harvested in the late afternoon from Chali Gewog, sorted, packed and transported to the market in Bumthang town in the same evening. At the market, vegetables were assessed for transportation damage and physiological loss of weight was recorded. Broccoli, cabbage and cauliflower packed in poly packs reported transportation damage of 8.75, 8.33 and 12.50 heads against 0.96, 0.44 and 0.41 percent for the plastic crate-packed vegetable samples with significant differences at P≤0.05. Poly-packed samples had significantly higher PLW of 2.02 kg, 2.83 kg and 3.40 kg compared to much lower PLW of 0.21 kg, 0.24 kg and 0.36 kg for broccoli, cabbage and cauliflower, respectively. Among the vegetables packed in poly sacks, transportation damage was significantly higher for cauliflower at 12.5 heads compared to 8.75 and 8.33 heads for broccoli and cabbage. Transportation damage was minimal and not significantly different between the three vegetables for plastic crates sample. Harvesting damage of 0.35 was observed in broccoli while cabbage and cauliflower did not have harvesting damage. Physiological loss of weight was significantly higher in cauliflower for both packaging types. The net return from broccoli, cabbage and cauliflower packed in plastic crates was higher at Nu.27779.4, Nu.8252.48, Nu.31127.4 compared to Nu.25232, Nu.7540 and Nu.26852 for poly sack packages, respectively. It is recommended that use of plastic crates for handling and transportation of broccoli, cabbage and cauliflower be encouraged and promoted among the stakeholders.

Keywords: *Broccoli; cabbage; cauliflower; transportation damage; PLW; net return*

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1 Introduction

Fresh fruits and vegetables are an important food for the ever-growing population and play a significant role in human nutrition as a main source of vitamins, minerals and dietary fibres (Hailu & Derbew, 2015). In Bhutan, vegetables are cultivated in all parts of the country for self-consumption in the small backyard garden while others cultivate on a large-scale farm for marketing. Total vegetable production in Bhutan was 32,546.07 MT in the year 2021 with broccoli, cabbage and cauliflower production of 1,156.49 MT, 3,763.33 MT and 1,648.18MT, respectively (NSB, 2021). However, there are huge post-harvest losses along the post-harvest chain due to improper handling practices. According to an unpublished report by the National Post Harvest Center, the post-harvest handling losses of cabbage and chilli were reported to be 10.75 % and 8.05 %, respectively in the surveyed areas around Paro and Mongar (Dorji, 2020). A report on the post-harvest losses of vegetables in Bhutan by the UN reported the post-harvest losses of cabbage at 15-20 % and, cauliflower and broccoli at 15-18 % (Acedo Jr & Easdown, 2015).

The post-harvest losses are enhanced due to their perishable nature. Post-harvest losses of fresh produce occur at different handling stages between harvest and consumption along the post-harvest and market value chain. In developing countries, post-harvest losses of vegetables are reported to be as high as 56 % depending on the commodity (Kinhal, 2021). Losses can be largely prevented with timely and accurate harvesting, refrigerated car use in interregional transport, cold storage and the use of packaging material that can prevent moisture loss. Farmers sell their produce in fresh markets or in wholesale markets. At the retail level, fresh produce is sold in an unpackaged form or is tied in bundles. This kind of market handling of fresh produce critically reduces its shelf life if it is not sold quickly (Elik et al., 2019). Packaging is an important factor in reducing losses, as well as extending the shelf life of fresh fruits and vegetables. Therefore, one of the major reasons that fruits and vegetables are lost at post-harvest stages is improper packaging and the use of unsuitable packaging material. Poor quality packaging materials cannot adequately protect fresh produce from damage and can even accelerate the spoilage of fresh produces. Unfortunately, low-quality packaging materials are widely used in many parts of the world due to their low cost. Especially, the use of poor-quality packaging containers is more common in under-developed and developing countries. Even some of delicate fruit and vegetables are packed in poly-sacks that severely damage the delicate products. According to Singh, Hedayetullah, Zaman, and Meher (2014), as much as 40% of the horticultural crops are lost due to high rates of bruising, water loss and subsequent decay which lead to decreased market value of fresh produce mainly due to improper handling, storage, packaging and transportation. As per Dissanayake et al. (2020), post-harvest losses mostly occur due to improper packaging materials and incorrect packaging methods. The use of rigid containers such as plastic crates, wooden boxes and fiberboard boxes minimizes damage occurring in fresh fruits and vegetables during handling and transportation. In Bhutan, post-harvest losses of the vegetable are 16-22 percent for potato, 15-20 percent for cabbage, 22-25 percentage for tomatoes, 20-22 percent for beans, 30-35 percent for peas and 15-18 percent for cauliflower and broccoli (Acedo Jr & Easdown, 2015). The losses are mainly caused due to inadequate handling, packaging, transportation and storage practices resulting in physical damage and spoilage of the produce.

Plastic crates have been widely used in the transportation of fresh vegetables between regions in many parts of the world. In recent years, the use of plastic crates has been encouraged for the handling and transportation of vegetables in Bhutan. While there are some who have adopted the use of plastic crates for the transportation of vegetables, there are others who still prefer sacks to transport the fresh vegetable mainly because of the perceptions that plastic crates are expensive to buy and also requires to be re-transported after the delivery of goods. Plastic crates are stackable, uniform in size and shape and sturdy and are able to prevent damage to the product being handled. Plastic crates are also easy to clean and capable of retaining their full strength while wet. It has the added benefit of reusing for many years (Kitinoja, 2013). Till now there has been no study that compared the economic benefits of using plastic crates over the use of poly sacks in the transportation of vegetables from farms to markets in Bhutan. This study aimed to determine the reduction in post-harvest transportation damage and economic benefit of using plastic crates compared to poly sack for packaging and transportation of broccoli, cabbage and cauliflower from Chali Gewog, Mongar Dzongkhag to the market in Bumthang.

2 Materials and methods

2.1 Harvesting and preparation for market transport

The Cole crop vegetables namely; broccoli, cabbage and cauliflower were harvested and purchased from a farmer's field in Thempang village, Chali Gewog under Mongar Dzongkhag. A total of 2400 kilograms (800 kilograms of broccoli, 800 kilograms of cabbage and 800 kilograms of cauliflower) of vegetables were purchased and used for the study. Broccoli, cabbage and cauliflower were harvested using a knife in the late afternoon when the weather became cool so as to maintain their freshness for a longer period. The harvested vegetables were moved to a shed area and assessed for harvesting damage (cut, puncture, compression, abrasion, bruising and broken, head damage, etc.). Well-sorted equal quantity of broccoli, cabbage and cauliflower that were free of damage were sorted and packed in plastic crates and poly sack that is most popularly practiced by farmers and vendors in the country. 400 kilograms of broccoli, cabbage and cauliflower were used for each of the packaging types (plastic crates and poly sack). Packaged crates and poly sacks were replicated four times for broccoli and cauliflower while cabbage had three replications. The packed vegetables were transported using a single-cabin bolero vehicle. Broccoli, cabbage and cauliflower were loaded to single cabin bolero and transported to Bumthang town towards the evening on the same day of harvest. The distance from the field in Chali to the Bumthang market is 200 km.

2.2 Physiological loss in weight (PLW)

The vegetables in each replication were weighed before transportation and recorded as the weight of vegetables before transportation. The vegetables were re-weighed individually at the destination market. The physiological loss in weight for vegetables during transportation in the two packaging types was the difference in weight before and after transportation. Weighing of the vegetables was done using a digital weighing scale (WS-10, Bluestar, India). The minimum weighing count of the scale is 50 grams.

2.3 Transportation damage

After the arrival at the destination market in Bumthang town, the heads of broccoli, cabbage and cauliflower were assessed for damages (bruises, cuts, injuries, punctures, etc.,) that must have occurred during the transport in both the packaging type. The number of heads damaged from each replication and packaging type was counted and recorded for analysis. This data was used as the quantity of broccoli, cabbage and cauliflower damaged during transportation from the two packaging types.

2.4 Depreciation cost of plastic crate and cost of poly sack

A technical paper on the use of plastic crates in reducing post-harvest losses and improvement of earnings for fresh produce was referred to calculate the depreciation cost of plastic crates and cost-benefit analysis (Kitinoja, 2013). The depreciation cost of the plastic crate was calculated using the information where the cost of the plastic crate is Nu.650/- with an expected useful life of 3 years. The usage life of a plastic crate in hours is 26,280 hours and the number of hours used per transportation is 24. The cost incurred per usage is Nu.0.59 per use as per the following equation;

$$\text{Cost incurred per usage} = \frac{\text{cost of plastic crate}}{\text{usage life in hours}} * 100$$

The cost of a poly sack is Ngultrum thirty (Nu. 30/-) and this total cost was used in the economic analysis calculation since the sacks were used for a single time.

2.5 Statistical analysis

The data were statistically analyzed using Statistical Package for Social Sciences. Independent sample t-test and Tukey's test was carried out to find the difference in means.

3 Result and discussion

3.1 Between packaging types

The number of heads damaged during transportation was assessed for each of the vegetables and compared between the two packaging types. Transportation damages were significantly higher at $P \leq 0.05$ for samples packed in poly sacks for all the samples compared to the samples from plastic crates (Table 1). Broccoli, cabbage and cauliflower packed in poly sacks reported transportation damage of 8.75±1.5, 8.33±1.5 and 12.5±2.08 numbers of heads, respectively against 0.96±1.1, 0.44±0.09 and 0.41±0.41 numbers of heads for the plastic crate packed vegetable samples. The vegetables packed in plastic crates were properly filled to their capacity and stackable in nature. This ensured that the pressure of weight from vegetable crates did not fall onto each other. This helped in keeping the transportation damage of all three vegetables packed in plastic crates to a minimum. The vegetables packed in poly sacks were stacked upon each other during transportation in the vehicle and the vegetables in the lower part of the vehicle had to take the weight pressure from all the top layers of vegetables packed in the poly sack. As the stacking increased the pressure on the bottom packs increased and this resulted in higher transportation damage for all three types of vegetables packed in poly sacks. The major stretch of the road between Mongar and Bumthang is very rough and unstable and this could have additionally contributed to poly sacks bouncing and rubbing each other thus causing higher transportation damage.

In the post-harvest loss assessment study for apples, it was reported that 9.34 % of apples were partially damaged and 2.70 % damaged totally during the transportation from field to depot. Additionally, 3.69 % of apples were partially damaged while 2.10 % were totally damaged and lost during the transportation from depot to market in Bhutan (Rinchen, Tobgay S., Tshering, & Dorji, 2019). A partial damage of 4.46 % and a complete damage of 1.44 % were reported during the transportation of mandarin fruit in Bhutan from depot to market as per the study by Tobgay et al., 2019. In a transport trial study of eggplant in the Philippines, the compression damage of eggplant packed and transported in polyethylene sack was 54 % while it was reduced to 2.8 % for eggplant packed in plastic crates of 10 kg capacity (Rapusas & Rolle, 2009). The transportation loss of cabbage, carrot and luffa was reduced by 5.8 %, 15.8% and 14.7 %, respectively when plastic crates were used for transportation of these vegetables in Sri Lanka (Wasala et al., 2021). Additionally, the overall visual quality of the vegetables was found to be better retained when transported in plastic crates.

Physiological loss in weight (PLW) per packaging after transportation to the market was assessed from both the packaging type for all three vegetables. Poly-packed samples had significantly higher PLW of 2.02±0.05, 2.83±0.28 kg and 3.4±0.45 kilograms while it was much lower at 0.21±0.01 kg, 0.24±0.01 kg and 0.36±0.02 kilograms for broccoli, cabbage and cauliflower, respectively. The PLW was directly proportional to transportation damage where increased transportation damage resulted in higher PLW. The plastic crate's ability to stack upon each other resulted in lower transportation damage and thus lower PLW. Whereas poly sacks resulted in higher transportation damage that led to increased transpiration from the damaged points and thus increased PLW of the vegetables.

The physiological loss in weight has a direct loss in terms of economic returns since reduced weight means low amount of vegetables to be marketed. The mean physiological weight loss in 2.02 kg of broccoli, 2.83 kg of cabbage and 3.4 kg of cauliflower resulted in monetary losses of Nu.171.7, Nu.99.05 and Nu.323 per sack, respectively. The losses in monetary values for plastic crates samples were much lower at Nu.17.85, Nu.8.4 and Nu.34.2 for broccoli, cabbage and cauliflower at the selling price of Nu.85 for broccoli, Nu.35 for cabbage and Nu.95 for cauliflower.

The lower transportation damage from the plastic crates sample maintained the freshness and attractiveness of the vegetables and vendors were very happy but they were not willing to pay the extra price for it since the customers refuses to buy at an extra price. However, it is recommended that vegetables be transported safely with minimal damage in plastic crates instead of poly sack for premium and long-distance markets.

Table 1. Transportation damage (number of heads) and physiological loss in weight (kg) for broccoli, cabbage and cauliflower between the two-packaging type

Packaging type	Transportation damage (No of heads damaged)			Physiological loss in weight (gm/kg per packaging)		
	Broccoli	Cabbage	Cauliflower	Broccoli	Cabbage	Cauliflower
Poly sack	8.75±1.5a	8.33±1.5a	12.5±2.08a	2.02±0.05a	2.83±0.28a	3.4±0.45a
Plastic crates	0.96±1.1b	0.44±0.09b	0.41±0.41b	0.21±0.01b	0.24±0.01b	0.36±0.02b
P value	0.000	0.001	0.000	0.000	0.004	0.001

Means in the same column with different letters are significantly different between packaging types for each parameter and for each vegetable by independent t-test at $P \leq 0.05$ (Mean ± standard deviation)

3.2 Between vegetables for each packaging type

Harvesting damage was slightly higher for broccoli at 0.35±0.18 number of heads but without any significant difference from cabbage and cauliflower (Table 2). No harvesting damages were reported for cabbage and broccoli. Cabbages and cauliflower were harvested by keeping 3 to 4 outer leaves and this probably protected the heads from getting damaged during harvesting. Harvesting damages seen in broccoli could be due to the injury of side florets that come in the broccoli heads.

For the samples packed in poly packs, transportation damage was significantly higher for cauliflower at 12.5±1.04 heads compared to 8.75±0.75 and 8.33±0.88 heads for broccoli and cabbage. The higher transportation damage of cauliflower in the poly sack could be due to the pressure of weight from each other since cauliflower has more surface area that was exposed and easily got damaged. Transportation damage for the three vegetables was low for plastic crate-packed samples and not significantly different between vegetables as shown in Table 2.

Physiological loss in weight for broccoli was 2.02±0.02 kg and significantly lower compared to the other two vegetables (2.83±0.17 kg for cabbage and 3.40±0.22 for cauliflower) for poly pack samples. Broccoli had the lowest physiological loss in weight of 0.21±0.0 kg even in the plastic crates sample. Cabbage and cauliflower had PLW of 0.24±0.01 kg and 0.36±0.02 kg, respectively and significantly different between the vegetables (Table 2).

Table 2. Harvesting and transportation damage, and physiological loss in weight between vegetables for each packaging type

Vegetable	Harvesting damage	Poly sack		Plastic crates	
		Transportation damage	PLW	Transportation damage	PLW
Broccoli	0.35±0.18[a]	8.75±0.75[b]	2.02±0.02[b]	0.96±0.55[a]	0.21±0.00[c]
Cabbage	0.00±0.00[a]	8.33±0.88[b]	2.83±0.17[a]	0.44±0.06[a]	0.24±0.01[b]
Cauliflower	0.00±0.00[a]	12.5±1.04[a]	3.40±0.22[a]	0.41±0.21[a]	0.36±0.02[a]

Means in the same column with different letters are significantly different between vegetables for each packaging type and for each parameter by Tukey's test at $P \leq 0.05$ (Mean ± standard error)

3.3 Cost-benefit analysis for broccoli between two packaging types

The net return from the sale of 400 kg of broccoli at the market in Bumthang town was estimated at Nu.27,779.4 for plastic crate samples compared to Nu.25,232 for poly sack samples (Table 3 and Figure 1). This translates to broccoli packed in plastic crates earning Nu.2,547.4 more than those packed in poly sacks. The lower physiological loss in weight from the plastic crate sample and the minimal cost of plastic crate per usage (Nu.0.59 per crate per use) when calculated as the depreciation cost over the period of 3 years of expected usage life resulted in fetching higher net return from the sale. The use of plastic crates is recommended for transportation of broccoli to premium and long-distance markets. Cost-benefit analysis of using crates versus woven sacks or traditional baskets was carried out in Rwanda and the researchers found that using plastic crates reduced postharvest losses from 40 % with the woven sacks and 30 % with the traditional sacks to 5 % with the plastic crates. The study also described that plastic crates can be used for several times compared to one or two times for the sacks and the cost of plastic crates would be fully recovered after one use (UC Davis, 2022).

Table 3. Cost-benefit analysis for broccoli between two packaging types

	Plastic crates			Poly sack		
Details	Numbers	Rate (Nu)	Amount (Nu)	Numbers	Rate (Nu)	Amount (Nu)
Packaging type	40	0.59	23.6	16	30	480
Labour	1	500	500	1	500	500
Transportation cost	2 (bolero)		5,000		5,000	5,000
Total cost	5523.6			5,980		
Selling price	391.8*	85	33,303	367.2	85	31,212
Net return**			27,779.4			25,232

*Total weight of broccoli after reaching the market; **Net return is Selling price-Total cost

3.4 Cost-benefit analysis for cabbage between two packaging types

The net return from sales of cabbage packed in plastic crates was Nu.8,252.48 at the market in Bumthang town. The net return from poly sack package was slightly lower at Nu.7,540 for 400 kg of cabbage (Table 4 and Figure 1). The use of returnable plastic crates was studied in Sri Lanka and it was found that the quality and safety of vegetables reaching the consumer were improved significantly (Fernando, 2006). The study also reported that losses for avocados and mangoes were also reduced from 30 % to 6 % when plastic crates were used for handling and transportation.

Table 4. Cost-benefit analysis for cabbage between two packaging types

	Plastic crates			Poly sack		
Details	Numbers	Rate (Nu)	Amount (Nu)	Numbers	Rate (Nu)	Amount (Nu)
Packaging type	28	0.59	16.52	8	30	240
Labour	1	500	500	1	500	500
Transportation cost	2 (bolero)	5,000	5,000		5,000	5,000
Total cost	5,516.52			5,740		
Selling price	393.4*	35	13,769	378	35	13,280
Net return**			8,252.48			7,540

*Total weight of cabbage after reaching the market; **Net return is Selling price-Total cost

3.5 Cost-benefit analysis for cauliflower between two packaging types

The net return from the sale of cauliflower at the destination market was Nu.36,651 from the plastic crate samples. This is Nu.4,275.4 amount more than the net return from poly sack samples that fetched Nu.26,852 (Table 5 and Figure 1). Use of plastic crates for handling, packing and transportation of vegetables is highly recommended since it results in minimal damage and physiological loss in weight and gives high returns. Plastic crates though expensive at first can be used for many years and need not have to procure repeatedly unlike poly sacks which are bought for one-time use. According to one of the reports on returnable plastic crates in post-harvest handling system, users reported that they reuse returnable plastic crates 150 times or more before having to replace them (Kitinoja, 2013). This paper also mentioned that the use of plastic crates can greatly reduce physical damage and reduce fresh fruits and vegetables losses from the typically reported 30 % to 5 % or less.

Table 5. Cost-benefit analysis for cauliflower between two packaging types

	Plastic crates			Poly sack		
Details	Numbers	Rate (Nu)	Amount (Nu)	Numbers	Rate (Nu)	Amount (Nu)
Packaging type	40	0.59	23.6	16	30	480
Labour	1	500	500	1	500	500
Transportation cost	2 (bolero)	5000	5,000		5000	5,000
Total cost	5,523.6			5,980		
Selling price	385.8*	95	36,651	345.6	95	32,832
Net return**			31,127.4			26,852

*Total weight of cauliflower after reaching the market; **Net return is Selling price-Total cost

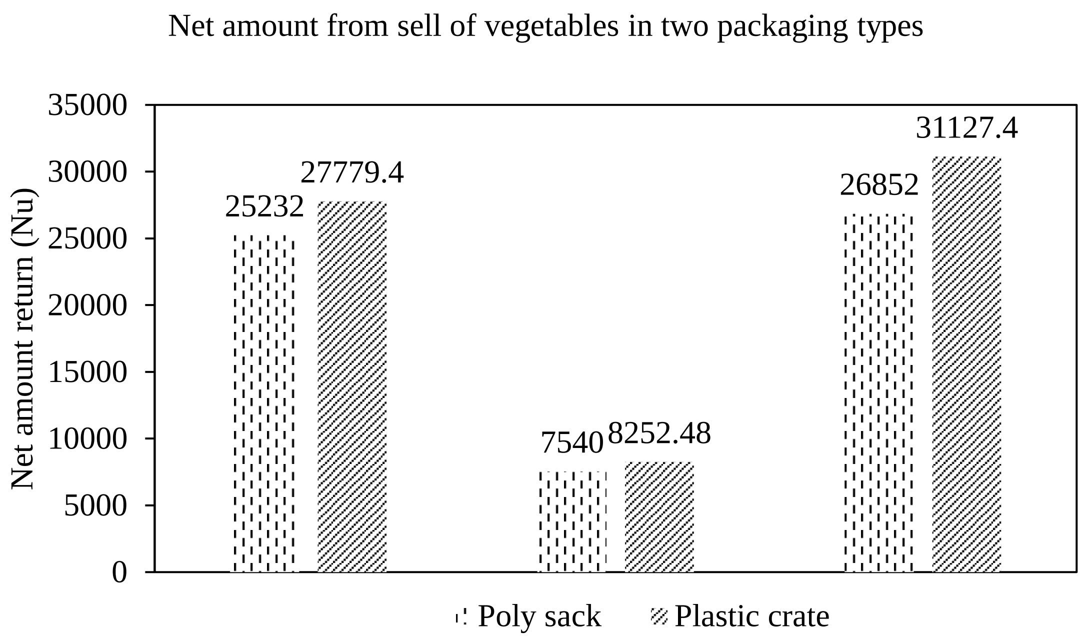

Figure 1. Net return from broccoli, cabbage and cauliflower in the two-packaging type at the market in Bumthang town

4 Conclusion

Packaging and transportation of broccoli, cabbage and cauliflower in plastic crates reduced the transportation damage to vegetables during transportation. Plastic crates maintained the weight of the vegetables with minimum physiological loss. Vegetables packed in poly sacks resulted in higher transportation damage and greater physiological loss of weight that directly translates to a loss of revenue for the stakeholders involved. Broccoli, cabbage and cauliflower packed in plastic crates gave a higher net return compared to those packed in poly sacks. Plastic crates though expensive to buy can be used many times for several years. It can be concluded that the use of plastic crates for packing and transporting can maintain the quality of vegetables through minimized damages, and reduced physiological loss in weight and can thus, enhance the market value. It is recommended that the use of plastic crates be promoted among stakeholders involved in harvesting, handling and transportation of broccoli, cabbage and cauliflower as well as other fresh produces.

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