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Characterization of Post-harvest Losses along the Supply Chain of Vegetables in Punjab

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ABSTRACT

Background: The loss of vegetables is immense which is accrued to its perishability and sub optimal level of post-harvest management. There is a technological gap in adoption of harvesting and post-harvesting practices by farmers. There is sparse qualitative and quantitative assessment of post-harvest losses of vegetables in Punjab. The objective of the study is to identify the operation and channel where the losses are crossing the threshold, to estimate the extent of losses and characterize them at various post-harvest operations and levels for selected vegetables in Punjab and to analyse the factors responsible for post-harvest losses.

Methods: The sample in survey location consisted of all the stakeholders of supply chain network for vegetables in the state of Punjab, India. The stakeholders consisted of farmers, wholesalers and retailers. The study adopted cluster sampling technique. The clusters selected for the study were Nakodar, Malerkotla and Baba Bakala Sahib and the vegetables selected for the study were potato, pea, tomato, okra and cauliflower. Further snowball sampling technique was used to select 80 farmers from each cluster, making up a total sample of 240 farmers and one reference each for wholesaler and retailer was identified in every cluster. Then using snowball technique, 2 wholesalers and 10 retailers were selected from each cluster. Thus, making total sample of 10 wholesalers and 30 retailers were selected for the study. The instrument used for the data collection was a structured interview schedule. The one-way ANOVA and Tukey's Honest Significant Difference test were employed to understand the significant difference in post-harvest losses between the selected vegetables and along the supply chain.

Result: The results revealed that the maximum losses were observed in tomato crop at farm level (17.71%) and retailer level (30.10%) whereas at wholesaler level maximum losses were recorded in pea (8.19%). The extent of losses at farm level has been higher as compared to wholesaler level and it was highest at the retailer level. At farmer's level it was observed that there have been significantly higher losses in tomato crop (17.7±13.35). At retailer level, significantly higher losses were observed in tomato (30.10±15.80) whereas at wholesaler level, significantly higher losses occurred in pea (12.29±3.15). There was no significant difference in losses between farmer and retailer level. Major cause of loss reported by tomato growers (88.6%) was infestation of fruits with disease and insect. Main reason of post-harvest losses in okra and cauliflower as stated by farmers were bruises/blackening and over maturity. Since the findings reveal that the major losses in the supply chain of vegetables was due to lack adoption of harvest and post-harvest practices at farmer's level. It is suggested that field level training should be imparted to farmers regarding post-harvest management techniques.

Key words: Post-harvest losses, Supply chain, Vegetables.

INTRODUCTION

In India, which has put forth the nutritional security as a dimension to achieve the Sustainable Development Goals, the vegetable production is earmarked at 61.09 lac tonnes in the year 2021 (Thind and Mahal, 2021). United Nations has proposed seventeen Sustainable Development Goals in 2015 and moving towards more sustainable pattern of consumption and production patterns is one amongst those goals. This put forths the creation of more efficient production and supply chains. Every year, estimated world losses or wastes are about one third of the food produce (Anonymous, 2018b). The production and distribution function of the vegetables in India follows the traditional supply chain model which involves stakeholders *viz*; farmers, wholesalers, retailers and consumers. Generally, the traditional supply chain model followed in the country for vegetables with a share of around 95-98 per cent (Modi *et al.,* 2009). The highest quantity of the potato in summer season was observed to be marketed through traders, maximum to wholesalers followed by retailers and small portion directly sold to the consumer. It was cited by Rajvardhan *et al.* (2020), under supply chain; Producer→Traders →Wholesaler→Retailer→ Consumer, the trader purchased 62.13 per cent of total volume of potato directly from the potato producer and disposed-off to retail market. Kedrisi *et al.* (2023) carried out study on Marketing Pattern Analysis of the King Chilli Cultivation in Peren District of Nagaland and reported that four marketing channels of King chilli in Peren district were followed in study area, *viz*., Producers-Consumer, Producers-Wholesalers-Retailer-Consumer,

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Producer-Retailer-Consumer and Producer-Commission agent- Wholesaler-Retailer-Consumer. Amongst the above identifies channels, Producer-Retailer-Consumer channel was the most commonly used and efficient channel. The extremely perishable nature of vegetables, its seasonality bulkiness and the large gap between the production and the sub-optimal management of post-harvest technology which includes harvesting, collection, sorting, packaging, storage and transportation processes result in the loss of a large amounts of vegetables at different stages (Viswanadham, 2007). Various national and international agencies aim to decrease per capita global waste and reduce food losses along production and supply chains which accrues to post-harvest losses (FAO, 2022). Since more than 90 per cent of the vegetables are disposed through commission agents or wholesalers and a small proportion is being sold through retailers or directly to the consumers provides 75 per cent of the total net margin of the entire supply chain to the intermediaries (Modi *et al*., 2009). Satyam (2016) conducted a study on the post-harvest loss in vegetables in the Varanasi district of Uttar Pradesh. This study revealed that at the producer level, post-harvest losses were highest in tomatoes (12.49%), followed by okras (10.52%) and brinjal (9.20%) and minimum in Cauliflower (5.20%). Maximum losses at retail level were in tomato, followed by okra, eggplant and pepper. Cumulative maximum post-harvest losses were found in tomatoes, followed by okra, eggplant and pepper.

Punjab state in India holds an eminent position in the horticultural map of the country with 273.25 thousand hectares of area under vegetable crops. It can be stated that fresh vegetables have high export potential in long term. Punjab ranks sixth in the national average production for potato cultivation and third for pea cultivation (Thind and Mahal, 2021).

It is estimated that per capita per day availability of vegetables in the state is less than 200 g (Thind and Mahal, 2021). The horticultural produce bears a great nutritive as well as economic value. Fruits and vegetables constitute main component of a healthy diet. They are considered as the rich sources of vitamins, minerals and carbohydrates and fats. In addition to the nutrients provided by fruits and vegetables, they also play a great role as antioxidants, bioflavonoid, flavour compounds and dietary fibres. To guarantee the nutritional security of the population of India, National Horticulture Mission developed a plan as a part of 10^{th} –five year of doubling horticultural production of the country (Anonymous, 2018a).

In India, the major reasons for the occurrence of postharvest losses are that production is not associated with marketing, there are negligible storage, packaging, transport and handling technologies are available for perishable crops like vegetables. Thus, tremendous produce is wasted during these post-harvest operations (Kumar, 2004). Moreover, nearly no grading is followed at farmer's level (Mitrannavar, 2012). Anamika *et al.* (2023) reported lack of cold storage and warehouse facilities (72.38%), high transportation cost (68.83%) and quality deterioration during transportation (61.07%) as major constraints faced by tomato growers. Singh and Hansra, (2021) stated that 78.67 per cent of self-help group members and 82 per cent of non self help group members reported the problem of distance from market as major constraint.

Further, there is wide gap between post-harvest technologies produced in research institutions and adoption of such technologies by small scale farmers and rural households. It has been observed that technical intervention in food processing and preservation aspects through training programmes increased the knowledge level of small-scale farmers (Meena *et al.,* 2009). Gupta *et al.* (2021) conducted a study on adoption gap analysis in tomato cultivation in Banda District of Bundelkhand (U.P.) and reported 46.40 per cent, 33.10 per cent and 6.53 per cent of technological gap in adoption was observed in harvesting and post-harvest practices in small and marginal farmers respectively.

There has been sparse qualitative and quantitative assessment information of post harvest losses of vegetables in Punjab, whereas few authors quote it to be around 20 per cent which is suggested to be a guess estimate (Thind and Mahal, 2021). Focal causes of post-harvest losses are lack of technological advancement and processing industries, post-harvest losses and short shelf-life of vegetables (Selvakumar, 2014). There has been no formal quantitative field surveys determining the extent of losses at various post-harvest stages practiced by the farmers. Even it is pertinent to state that the magnitude of vegetable produce lost carried forward in the supply chain till the consumers is not determined in the previous studies. The objectives of this paper is (i) to identify the operations and channels where losses are considerable, (ii) to estimate the extent of losses and characterise them at various post-harvest operations and levels for selected vegetables in Punjab and (iii) to analyse the factors responsible for post-harvest losses.

MATERIALS AND METHODS

The present study was conducted in Punjab state of India, which has been classified into three agro-climatic zones on the basis of homogeneity, rainfall pattern, distribution, soil texture, cropping patterns *etc*. These zones are, Sub-Mountainous Zone, Central Zone and Arid-Irrigated Zone.

The Central Zone of Punjab has the maximum area under vegetable cultivation. Amongst this zone three concentrated areas or clusters of vegetable cultivation Nakodar (Jalandhar), Baba Bakala Sahib (Amritsar) and Malerkotla (Sangrur) were selected purposively for the study as shown in Fig 1. Based on the area and production five major vegetables viz., potato, cauliflower, tomato, okra and peas, were selected for the estimation of post-harvest losses. This selection of clusters and vegetables has been illustrated in Table 1.

The sample consisted of all the stakeholders of the existing supply chain of vegetables in India *viz*., farmers, wholesalers and retailers. The sampling method used was

snowball sampling which is defined as a technique for locating research subjects in which a subject gives the researcher the name of another subject who in turn gives the name of another (Vogt, 1999). According to Spreen, (1992), snowball sampling can be placed within a larger set of link tracking methodologies that seek to leverage the social networks of identified respondents to provide the researcher with an ever-growing set of potential contacts and reach populations that are difficult to be sampled. In the present study, this technique was used to select 80 farmers from each cluster, making up a total sample of 240 farmers. Similarly, one reference each for wholesaler and retailer was identified in every cluster and using snowball technique 2 wholesalers and 10 retailers were selected from each cluster. Thus, total 10 wholesalers and 30 retailers were selected as sample for the study.

The instrument used for the data collection was an interview schedule. The extent of losses at various post-harvest operations and levels for selected vegetables has been operationally defined in the current context to be the measurable quantitative and qualitative loss in vegetables during different operations and levels of postharvest system. It was measured at 3 levels *viz*; farm level, wholesaler level and retailer level which were the major stakeholders of the supply chain. The characterizations of post-harvest losses in vegetables were studied in terms of qualitative analysis and observations made during the data collection. Samples were also collected from the stakeholders for assessing the visual perception for the rejection of the produce at different stages for different vegetables and discussion with key informants were also held to characterize the post-harvest losses. The enquiry at farm level included the parameters like; method of harvesting, equipment used, quantity handled, quantity lost and causes of loss, etc. At wholesaler/ retailer level, it was done in terms of previous balance, addition during enquiry period, quantity withdrawn during enquiry period, total quantity stored, type of storage, quantity lost and causes of loss. The quantitative loss in a given farm operations at farm level, retailer and wholesaler level were recorded. The loss percentage obtained for the crop was estimated by dividing the total quantity lost by the total quantity handled (Jha *et al*., 2015). The total post-harvest losses were estimated as the sum of all the losses at the various postharvest stages.

The one-way ANOVA and Tukey's Honest Significant Difference test were employed to understand the significant difference in post-harvest losses between vegetables and levels of supply chain. Data was processed into statistical analysis using software Statistical Package for the Social Sciences (SPSS) statistics, version 16.0.

RESULTS AND DISCUSSION

Socio economic characteristics of farmers

The socio-economic characteristics of farmers sampled for the study are presented in Table 2. Majority of them

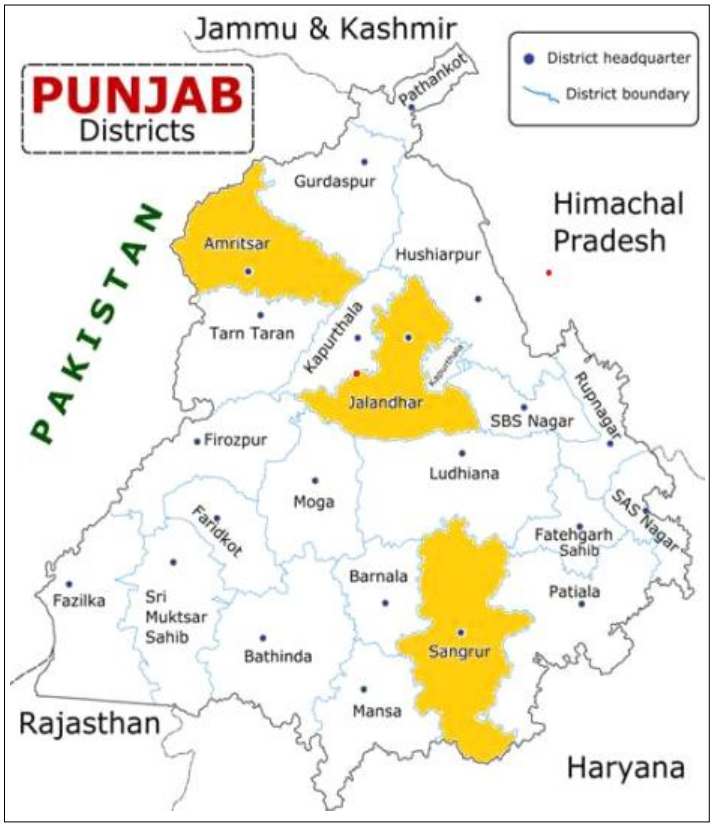

Fig 1: Map of Punjab showing selected districts for study (adapted from Wikigringo 2008).

aged between 34-51 years and the mean age score of the farmers was 44. Majority of the farmers were educated up to matric level. Cent per cent of the farmer's main occupation was farming.

Further data in Table 2 data revealed that about half of the farmers covered under category of large operational land holding with mean score of 27.94 ha. Majority of the farmers possessed experience of more than 22 years in farming. More than 50 per cent of the farmers had low level of participation in extension activities with mean score of 5.91 times participated in last six months. The study findings revealed that about 87.92 per cent of farmers had low level of participation in social organizations with mean score of 2.6 times participated. About 48 per cent of the farmers had medium level of extension contacts.

Table 1: Detail of selected vegetable clusters selected for the study.

Districts	Clusters	Vegetables cultivated
Amritsar	Baba Bakala Sahib	Potato
Jalandhar	Nakodar	Pea, Tomato and Okra
Sangrur	Malerkotla	Cauliflower and Okra

Extent of losses at various post-harvest operations along the supply chain

The data illustrated in Table 3 reveals that the maximum losses were observed in tomato crop at farm level (17.71%) and retailer level (30.10%) whereas at wholesaler level maximum losses were recorded in pea (8.19%). The extent of losses at farm level has been higher as compared to wholesaler level and the highest at the retailer level. The reductionof vegetable quality and shelf-life is largely dependent on the harvesting time. However, farmers harvest immature crops which become susceptible to mechanical damage and deterioration. The over mature vegetables have lower shelf life and physiological disorders.

Data presented in Table 4 reveals that at farmer's level there has been significantly higher losses were observed in tomato crop (17.7±13.35%) followed by cauliflower, okra, potato and pea. Further at retailer level, it can be observed that there has been significantly higher losses in tomato

Table 2: Distribution of the farmers according to their socio-personal characteristic. (N=240)

Socio-personal characteristics	Category	Frequency (f*)	Percentage (%)	Mean±SD
Age (years)	Young (17-34)	36	15	44±11
	Middle (34-51)	137	57.8	
	Old (51-68)	67	27.92	
Education	Illiterate	2	0.83	3.43±1.17
	Primary	60	25.00	
	Secondary	64	26.67	
	Matric	73	30.42	
	Senior secondary	15	6.25	
	Graduation and above	17	7.08	
Occupation followed *	Farming	240	100.00	-
	Dairy	45	18.75	
	Other	24	10.00	
Operational land holding (acres)	Marginal (<2.5)	4	1.67	27.94± 18.20
	Small (2.5-5.0)	8	3.33	
	Semi-medium (5-10)	13	5.42	
	Medium (10-25)	80	33.33	
	Large (>25)	134	55.83	
Farming experience (years)	<11	87	36.25	22.90±11.21
	11-34	150	62.50	
	>34	3	1.25	
Participation level in Extension activities	Low(0-5)	136	56.67	5.91±4.50
	Medium (5-10)	44	18.33	
	High (10-15)	60	25	
Level of social participation	Low (0-4)	211	87.92	2.60±1.95
	Medium (4-8)	27	11.25	
	High (8-12)	2	0.83	
Level of extension contacts	Low (0-11)	114	47.5	12.48±7.32
	Medium (11-22)	117	48.75	
	High (22-33)	9	3.75	

*Multiple responses.

(30.10±15.80%) followed by okra, cauliflower, pea and potato whereas at wholesaler level, significantly higher losses occurred in pea (12.29±3.15%) followed by okra, cauliflower, tomato and potato. There was no significant difference in losses between farmer and retailer level. Losses recorded were highest in tomato at farmer's and retailer's level due to its short shelf life and delicate skin. Moreover, tomato is more prone to physical injury due to rough handling. The findings were in line with Satyam, (2016) and Verma, (2015), who reported maximum losses in tomato crop at farmer and retailer level.

The data in Table 4 illustrates difference in losses in vegetables between three levels of supply chain. Significantly higher losses in cauliflower (23.52±17.83%), okra (24.50±11.25), potato (16.92±10.98), tomato (30.10±15.80) and pea (16.92±10.98) were recorded at retailer level. Maximum losses were recorded at retailer level since grading of the vegetables at farmer and wholesaler level was not efficiently done and reached to the retailer with insect and disease infestation, physically injured fruits, over-mature pea and cauliflower curds. It was stated by the respondents that the size of potatoes were too small and were rotten.

Table 3: Extent of losses at various post-harvest operations at farm level, wholesaler and retailer level.

Crop	Total loss in farm level operation (per cent)	Total loss at wholesaler level (per cent)	Total loss at retailer level (per cent)
Potato	4.44±2.55	0.05±0.02	12.34±3.14
Tomato	17.71±3.64	2.28±2.06	30.10±3.94
Cauliflower	6.79±2.55	2.44±1.89	23.52±4.19
Okra	5.57±2.77	3.94±2.34	24.50±3.33
Pea	5.20±3.27	8.19±2.49	16.92±3.29

Extent of post-harvest losses at farm level

Extent of post-harvest losses at farm level is presented in Fig 2. Maximum losses were observed in tomato crop (17.71%) followed by cauliflower (6.79%), okra (5.57%), pea (5.2%) and potato (4.44%). The extent of losses at farm level has been higher as compared to wholesaler level and the highest at the retailer level. The determination of vegetable quality and shelf-life is largely dependent on the harvest time. However, farmers harvest immature crops which become susceptible to mechanical damage and deterioration. The over mature vegetables have lower shelf life and physiological disorders.

Factors affecting post-harvest losses in the supply chain

Potato was harvested either mechanically or manually whereas all other four vegetables were harvested manually. For harvesting potato, 58.62 per cent of the farmers used

Table 4: Extent of losses (%) in selected vegetables at various levels of supply chain.

Crops	Supply chain						F-value
	Farmer level		Retailer level		Wholesaler level		
	Mean (%)	Std. Deviation	Mean (%)	Std. Deviation	Mean (%)	Std. Deviation	
Cauliflower	6.79^{a}	6.55	23.52^{b}	17.83	2.93^{a}	4.16	64.01**
Okra	5.57^{a}	7.75	24.50^{b}	11.25	5.92^{a}	6.67	91.74**
Pea	1.41^{a}	3.54	16.92^{b}	10.98	12.29^{b}	3.15	114.01**
Potato	5.14^{ab}	6.58	12.34^{b}	10.04	0.07^{a}	0.04	47.28**
Tomato	17.71^{b}	13.35	30.10^{b}	15.80	2.73^{a}	5.07	83.32**
F-value	118.32**		81.82**		8.37**		

**Significant at the 0.01 level.

Alphabets (a,b,c) in superscript represents a non-significant difference between levels.

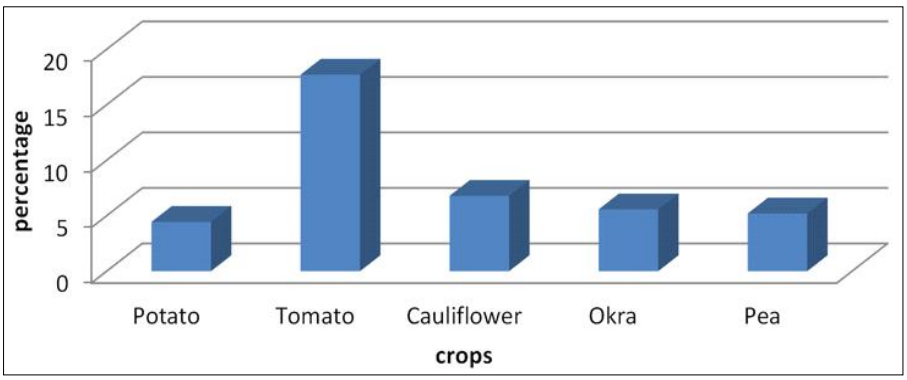

Fig 2: Graphical representation of extent of losses in selected vegetables at farm level.

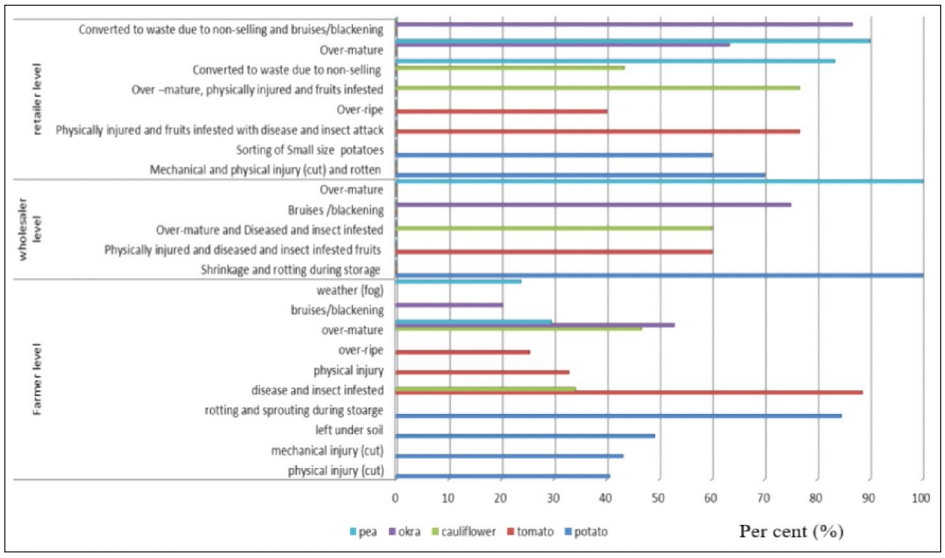

Fig 3: Graphical representation of factors affecting post-harvest losses in the supply chain.

potato digger and 50.32 per cent of the farmers used cultivator after potato digger to dig out the potatoes which were left in soil after harvesting with digger. About 41.38 per cent of farmers manually harvested potato using spade to harvest immature green potatoes so that wheat could be sown after potato. Cauliflower was harvested using sickle and other three vegetables, okra, pea and tomato, were directly pulled with hand from plant.

The characterizations of post-harvest losses in vegetables were studied in terms of qualitative analysis and observations made during the data collection. Samples were also collected from the stakeholders for assessing the visual perception for the rejection of the produce at different stages for different vegetables and data related to the same is presented in Fig 3. In potato, 43.10 per cent of the farmers reported the mechanical injury due to cut on the tuber while harvesting the crop with potato digger as well as spade. During storage of potatoes in cold stores, sprouting and rotting of potatoes was the major problem faced by the farmers. Post-harvest losses in tomato were mainly faced due to infestation of fruits with disease and insects, by 88.6 per cent of the farmers. Farmers cultivating cauliflower reported over-maturity as cause of loss followed by infestation due to disease and insects whereas delayed harvest of cauliflower, okra and pea led to the post-harvest losses. About 52.81 per cent of the okra growers reported that delayed picking of crop due to unavailability of labour resulted in over-maturity.

The wholesalers reported sprouting and rotting during storage as major cause of loss in potato. Sprouting and rotting happened due to temperature or relative humidity fluctuations in cold stores. Post-harvest losses in tomato and cauliflower were due to physical injury and infestation of fruits with insects and diseases which were carried from farm. This indicated no sorting and grading of vegetables.

Further, 75 per cent of wholesalers reported bruises/ blackening of okra as major cause of loss. In pea over-maturity of the pods was stated as the major cause of loss by 100 per cent of wholesalers. Discussion with the key informants wholesalers revealed that farmers pack the vegetables without sorting and retaining injured or diseased vegetables in the middle covering them with good quality produce.

Major causes of loss during handling at retailer level were mechanical and physical injury and rotting (70%) due to cut on potatoes during harvesting operations. Retailers handling tomato and cauliflower reported infestation of fruits and physical injury (76.67%) as the major causes of loss. Majority of retailers (86.67%) reported bruises/ blackening and non-selling of okra which was converted to waste thus leading to the loss of produce. Same trend was observed for pea. Majority of the retailers said that the process of buying was non selection basis and were buying the whole packed polythene, crate or gunny/fibre bag. Sometimes the entire vegetable purchase from wholesaler turns out to be spoiled. On the other hand consumers always prefers and selects the best quality vegetable and so rest of remined gets wasted. Shelf life of vegetables like tomato is very less and there was no facility of storage available at retailer level. Moreover, there was no prevalent use of short term storage technologies at the retailer level.

CONCLUSION

The results indicated that post-harvest losses within vegetables at all the three levels of supply chain were highest in tomato followed by okra and cauliflower. Post-harvest losses in vegetables within the supply chain were highest at retailer level followed by farmer and wholesaler level but there has been no significant difference in the loss at farmer's and retailer's level. The major post-harvest losses in almost all the vegetables being considered in the study were

attributed to the harvesting operations. The considerable losses at farmer's level were carried over into the forward supply chain. So, in order to minimize the losses at farmer's level the attention of research and extension in post-harvest operations and its forward management is suggested. It is also suggested that the low cost storage technologies should be popularized at farmer and retailer level and field level training should be imparted to farmers regarding post-harvest management techniques.

Conflict of interest

On behalf of all the authors in the article I wish to state that there is no conflict of interest among us.

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