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POST-HARVEST TECHNOLOGY ADOPTION AND INCOME PATTERNS OF TOMATO FARMERS IN NEPAL

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Abstract: A study was conducted in the Kavrepalanchok district of Nepal to analyze the post-harvest technology adoption among open field and plastic house tomato growers and assess the factors of tomato production determining the income of the farmers. Altogether fifty-six tomato growers were selected randomly following the Simple Random Sampling technique for the household survey. Primary data were collected using pre-tested interviews with tomato farmers. Data were analyzed using SPSS and Ms. Excel 2010. Descriptive statistics were used to estimate the adoption level of post-harvest technologies and a multiple linear regression model was carried out to estimate the factors of tomato production affecting the household income. Analysis of the post-harvest practices of farmers suggested that 53.85% of plastic house growers and 33.33% of open field growers harvested tomatoes in the yellow stage; 44.64% of farmers practiced grading; 88.5% plastic house tomatoes and 80.0% open field tomatoes were packed in plastic crates; only 26.49% practiced processing; more than half of the farmers had access to collection centers; the majority had a medium level of knowledge regarding different post-harvest management technologies. Among various factors, Nova variety was estimated to increase household income by 71% followed by production per unit area (48%), cost of cultivation (37%), access to processing industries (10%), and direct selling to consumers (9%). In wholesome, though NARC has recommended many post-harvest technologies, the adoption level is unsatisfactory. The unavailability of a sufficient quantity of quality fertilizers, lack of rural infrastructure facilities including roads, and inadequate technological extension were the factors hindering the adoption of post-harvest technologies in the study area.

Keywords: Post-harvest technology, Open fields, Plastic house, Household income, *Solanum lycopersicum* L., Adoption

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1. Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most consumed fresh and processed vegetable also used as an ingredient in many cooked dishes (Esguerra and Rolle, 2018) in the world which belongs to the Solanaceae family of plant genera. Tomato cultivation is one of the lucrative enterprises with high market potentialities in Nepal grown throughout the years. Open-field tomato farming is popular in the Terai region (up to 200 masl), inner Terai, and foothills (200-700 masl) during Autumn-Winter; however, off-season production in plastic houses during Summer-Rainy season is being admired in the hills which are fetching higher prices in the plains of Nepal and developing comparative advantage for income generation and livelihood improvement (Ghimire et al., 2018). It is an important contributor to agricultural GDP with figures of 16.36% in the fiscal year 2021/22. In the year 2020/21, fresh vegetables were cultivated in an area of 284,121 ha with a total production of 3,993,167 Metric tonnes and a yield of 14.05 Metric tonnes per ha. Among the fresh vegetables, the tomato was under cultivation in an area of 22,600 ha, with a total production of 432,616 Mt and a yield recorded at 19.14 Mt/ha. Kavrepalanchowk is one of the leading districts in tomato production that occupied an area of 2,639 ha producing 50,290 Metric tonnes of fresh tomatoes with a yield of 19.01 Metric tonnes per ha (MoALD, 2022).

Tomato is commonly used in a variety of dishes as raw, cooked, or processed products (Weldeslassie, 2007) ranging from ketchup, sauce, juice, puree, pasta sauce, salsa, tomato-based powders, sundried tomatoes, curries, to ready-to-eat products (Ghimire et al., 2018). The processed products are even exported to international markets at high prices. It was reported that 385,452 liters of unfermented tomato juice were exported worth 21530 thousand rupees in the fiscal year 2020/21 (MoALD, 2022). Nepal produces tonnes of tomatoes; however, a significant amount of tomatoes get lost before reaching the end consumers. The post-harvest loss in tomatoes is the result of improper handling, packaging, grading, off-road situation, use of low-level technology, lack of basic equipment and facilities at collection centers, improper marketing, and lack of qualified workers. Reducing post-harvest loss can save money, can feed more people, improve health and nutrition, and reduce pressure on natural resources (Acedo et al., 2016). Several postharvest handling techniques such as harvesting index, harvesting time, method, grading standards, and packaging materials have been developed

for tomatoes in Nepal. The study of post-harvest technology adoption covers many aspects such as the nature of the commodities, their profitability and turnover aspect, availability, actors involved in marketing structure, sociocultural factors, and value chain actors' awareness about technologies. Therefore, this study covers multiple dimensions of the post-harvest chain of tomatoes. The purpose of this paper, therefore, is to identify the available post-harvest technologies; spot the gaps for the adoption of improved technologies, and rank the constraints of technology adoption.

2. Materials and Methods

2.1. Study Area

This study took place in the Kavrepalanchok district of Nepal chosen purposively (Figure 1). It is among the seventy-seven districts of Nepal located in Bagmati Province at latitude 27°33′06.48″ North and longitude 85°38′38.04″ East. It is a leading tomato producer in Nepal both seasonal and off-season.

Figure 1. Study site location map.

2.2. Research Design and Data Collection Methods

This study employed a cross-sectional research design. It uses both primary and secondary sources of data. Structured questionnaires were used to collect data to evaluate the farmers' knowledge, perception, and practices on available postharvest technology; the constraints; and opportunities of adoption from the households growing tomatoes in open-field and plastic houses. A pilot study was conducted before conducting the main survey to track the study sites and minimize the limitations.

Furthermore, the secondary source of information was gathered through an intensive desk review of research reports and articles of Ministry of Agriculture and Livestock Development (MoALD, 2022), books and book sections of different organizations such as Food and Agriculture Organization of the United Nations (Esguerra and Rolle, 2018), newsletters and bulletins from different websites, relevant research articles from different scientific journals.

2.3. Sampling and Data Analysis

Sampling units were the households engaged in tomato production in open fields and plastic houses in the study area, whereby the head of the household or his/her representative was picked as the respondent. A total of 56 tomato farmers from the Kavrepalanchok district, 30 open-field growers, and 26 plastic house growers were selected randomly following lottery method of Simple Random Sampling techniques (Elder, 2009).

The collected data was analyzed using Microsoft Excel 2010 and Statistical Package for Social Science (SPSS) version 25. The descriptive statistics involved analysis of frequencies, percentages, means, and standard deviations based on (Aidoo-Mensah, 2018) to compute the socio-demographic characteristics of respondents, their practices and perception, constraints of post-harvest technology adoption, etc.

A functional analysis was carried out to examine the determinants of household income from tomato production using ordinary least squares (OLS) method as adopted by (Aidoo-Mensah, 2018). The Model (Equation 1) as shown below expressed household income as a function of the following independent variables – Variety Nova (X_1), Productivity(X_2), Cost of cultivation (X_3), Processing industries (X_4), and Marketing method (X_5).

$$Y=\beta_0+\beta_1X_1+ \beta_2X_2+ \beta_3X_3+ \beta_4X_4+ \beta_5X_5+\varepsilon_i \quad (1)$$

where,

Y= Household income from tomato

X_1= Variety Nova which takes the value '1' if the variety is cultivated and value '0' otherwise

X_2= Productivity (kg/ha)

X_3= Cost of cultivation (in USD ($))

X_4= Processing industries which take the value '1' if access to processing industries and value '0' otherwise

X_5= Marketing method which takes the value '1' if direct selling of tomato without the involvement of middlemen and value '0' otherwise

β_0= intercept

β_1, β_2, β_3, β_4, β_5 = Coefficients of the respective variable

ε_i =Random-error

3. Results

3.1. Demographics of Respondents

3.1.1. Age

The survey results showed that the mean age of farmers was 40.39 years, suggesting that most of the farmers were in the active age group. Further the age was categorized into three different age groups as seen in Table 1. The results of the age distribution of the respondents indicate the modal age group was the 30-65 years age bracket for both plastic houses (88.46%) and open fields (86.67%). Since the majority of the respondents are in their middle age, income from tomato production is potentially high for the area (Aidoo-Mensah, 2018).

3.1.2. Household size

The household size affects productivity as the possibility of more family labor available for the timely operation of farm activities. The research area appeared to be mildly populated since the average size of the family was 5.2 people per household, with the highest household size of 4-6 persons for both the plastic house (61.54%) and open field (73.33%) (Table 1). This family size is more as compared to the national average as indicated by the annual household survey 2015/16 in Nepal. Larger the household size, the larger the available labor pool for farm operations (Aidoo-Mensah, 2018).

3.1.3. Education

The average year of schooling was found to be 6.95 years which means the tomato-growing farmers were mostly illiterate; education helps to build a good and confident relationship with development agents thus maximizing production. The majority of the respondents had a secondary level of education for both plastic houses (57.69%) and open fields (36.67%) as shown in Table 1.

3.1.4. Farm size and livestock

The average farm holding for the plastic house growers was 7.87 ha which is less in comparison to 9.18 ha for open fields. Interestingly the area under tomato cultivation in plastic houses was more than that in an open field with figures 5.96 ha and 3.19 ha respectively. There was no big difference between them for livestock ownership (Table 2).

3.1.5. Household income

The annual household income was interestingly higher for plastic house growers (5957.2 USD) as compared to an open field (4724.3 USD). Similarly, the income from tomato cultivation was also higher for plastic tunnel growers (2779.61 USD) than for open field growers (1466.50 USD). This indicates that growing tomatoes under a plastic tunnel is more profitable than in an open field as shown in Table 2.

Table 1. Demographics of the respondents in the survey area conducted in Kavrepalanchok district in 2019

	Plastic House		Open field	
	Number	Percent	Number	Percent
1. Age category				
<30	3	11.54	4.00	13.33
30-65	23	88.46	26.00	86.67
>65	0	0	0	0
2. Household size				
<=3	5	19.23	3	10.00
4-6	16	61.54	22	73.33
7-9	3	11.54	4	13.33
>9	2	7.69	1	3.33
3. Education level				
No education	5	19.23	8	26.67
Basic education (1-8)	5	19.23	8	26.67
Secondary education (9-12)	15	57.69	11	36.67
Higher secondary education(>12)	1	3.85	3	10.00

Table 2. Means and standard deviations of farm sizes and household income as USD in the survey conducted in Kavrepalanchok district in 2019

	Plastic house (N=26)				Open field(N=30)			
	Minimum	Maximum	Mean	Std. Dev.	Minimum	Maximum	Mean	Std. Dev.
Land owned	0.5	25	7.87	6.27	0.5	70	9.18	12.89
Area under cultivation	2	48	10.12	9.21	1	68	8.16	12.13
Area under tomato cultivation	1	35	5.96	6.77	0.25	40	3.19	7.14
Livestock owned	0	1	0.81	0.40	0	1	0.90	0.31
Total income	776.72	39520.00	5957.29	7801.50	228.00	19000.00	4724.31	4817.61
Income from agriculture	760.00	18240.00	3849.75	4076.71	228.00	19000.00	2666.28	3804.24
Income from tomato	380.00	13680.00	2779.61	3445.76	76.00	19000.00	1466.50	3376.87

3.2. Farmer's Practices and Perception of Post-Harvest Management Technologies

3.2.1. Harvesting maturity

Harvesting of tomatoes depends upon factors like market, demand, and purpose. Farmers growing tomatoes in the study area were found to harvest tomatoes at four stages viz., green, yellow, light red, and red ripe stage with a majority at the yellow stage in both plastic houses i.e., 53.85%, and open fields i.e., 33.33%. For polyhouse growers, it was followed by the green and ripe stage with 19.23% each and very few i.e., 7.69% harvested at the red stage. While for open field cultivators, it was a red stage with 30.00% then a ripe stage i.e., 20.00%, and a green stage i.e., 16.67% as shown in Table 3. The result revealed that the bulk of tomatoes, i.e., nearly half of the production is sent to the distant market by picking at the yellow stage.

3.2.2. Time of harvesting

The combination of harvesting time following the harvesting stage is a determining factor for post-harvest life. The majority (30.77%) of the plastic house growers were observed to harvest tomatoes early morning before 10 am whereas 36.67% of open field growers harvested late morning between 10 am to 12 am. The harvest time is followed by late morning harvest (26.92%), harvest based on demand (23.08%), and then mid-day harvest (19.23%) in the case of the plastic house whereas, in case of the open field late morning harvest is followed by early morning harvest (30.00%), mid-day harvest (23.33%) and harvest based on demand (10.00%) (Table 3). The possible logic behind harvesting in the early morning is to sell maximum produce on the same day.

3.2.3. Harvesting practices

The method of harvesting plays a crucial role in reducing post-harvest loss. Different harvesting practices adopted by farmers were studied as shown in Table 3. Nearly half of the farmers, 50.00% plastic house and 40.00% open field growers were found to harvest tomatoes even if there is rain. This may have been because of demand even during rainy days. All of the farmers were revealed to harvest the tomato fruits with peduncles attached to the fruits. Farmers were observed to be aware of the necessity of peduncle at post-harvest life to reduce losses. Very few plastic house growers (7.69%) were found to practice pre-cooling activities while more than a quarter (26.67%) open field cultivators performed it. Similarly, even fewer (11.54% plastic house and 16.67% open field growers) cleaned the fruits before marketing. Farmers were somewhat aware of health issues related to the unsafe use of pesticides and thus 46.15% of polyhouse growers and 33.33% of open field growers used gloves; 38.46% of polyhouse growers and 40.00% of open field growers washed hands before, after harvesting (Table 3).

3.2.4. Sorting/grading practices

Sorting and grading of tomatoes are practiced only in big marts. However, these practices are a must in the Nepalese context due to the uneven shapes and sizes of the fruits. More than half of the farmers (55.36%) in the study area didn't appear to practice grading the fruits. Results showed that the most popular way of grading the tomato fruits in the study area was based on insect pest attacks for both open-field tomato growers (26.67%) and plastic house growers (19.23%) (Figure 2). These results are in line with (Khatun and Khandoker, 2014) where the authors discussed about majority of farmers sorting their tomatoes based on size of the fruit and disease infected.

Table 3. Harvesting practices of tomatoes at farmers' field in the survey conducted in Kavrepalanchok district in 2019

S.N.	Harvesting Practices	Plastic House		Open field	
		Frequency	Percent	Frequency	Percent
1	Harvesting stages				
	Green	5	19.23	5	16.67
	Yellow	14	53.85	10	33.33
	Red	2	7.69	9	30.00
	Ripe	5	19.23	6	20.00
2	Harvesting time of day				
	Early morning (before 10 am)	8	30.77	9	30.00
	Late morning (10 am to 12 noon)	7	26.92	11	36.67
	Mid-day (12 noon to 3 pm)	5	19.23	7	23.33
	Any time based on demand	6	23.08	3	10.00
3	Harvest During Rain	13	50.00	12	40.00
4	Harvesting with Peduncle	26	100.00	30	100.00
5	Pre-cooling practices	2	7.69	8	26.67
6	Cleaning practices	3	11.54	5	16.67
7	Use Gloves	12	46.15	10	33.33
8	Wash hands before and after harvesting	10	38.46	12	40.00

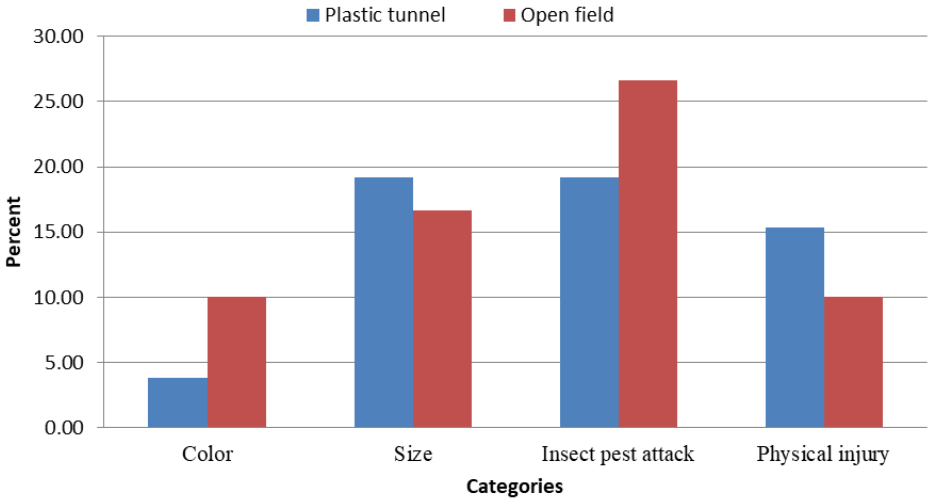

Figure 2. Sorting and grading practices in tomato.

3.2.5. Packaging practices

Doko, a locally woven bamboo basket is the most widely used packing material in rural regions of Nepal. However, its use is not limited to rural areas. The research identified that plastic crates are the most used packaging material by both plastic house growers (88.5%) and open field growers (80.0%). A negligible number of farmers was identified to pack their harvest in doko and polythene bags as shown in Table 4. Farmers of the study area were found to adopt the improved technologies by prioritizing plastic crates for ensuring damage-free fruits. Plastic crates are among the common packaging materials used in most developing countries (Paltrinieri, 2017). The use of plastic crates is recommended due to less damage. These findings are in parallel with (Bhattarai, 2018).

Different aspects of packaging practice largely determine the probability of damage during transportation. Farmers in the study area were observed to lag in practicing those aspects. More than half of the farmers, 61.5% plastic house farmers, and 46.7% open field farmers practiced packaging to full level, increasing the chances of damage. However, more open-field growers (33.3%) were found to put something at the base compared to plastic house growers (11.5%). Similarly, only 11.5% of plastic house growers compared to 16.7% of open field growers practiced cleaning the packaging materials as shown in Table 4. A wholesome majority of farmers to some aspect did know about packaging practices.

3.2.6. Management of the leftover tomatoes

Waste tomatoes with poor quality are either sold at lower prices if consumers wish to buy them or used for processing, or thrown away. The study on the management of waste tomatoes showed that the majority of the farmers 73.1% plastic house growing farmers and 86.7% open field farmers threw the unsold tomatoes in open pits. Very few, around 10% of farmers were found to bury in pits and a negligible number were identified to sell at a low price (Figure 3). Burying the waste products in pits is a time-consuming task; furthermore selling at a low price still needs transportation facilities which may lead to loss. Thus, farmers may have preferred to throw the waste in open pits.

3.2.7. Processing practices

Farmers in the study area were tested for their knowledge of processing practices. Only 26.79% of the producers practiced processing the tomatoes, remaining 73.21% did no processing practices. Some processed products; ketchup, sauce, pickle, and dry tomatoes were the parameters of the study. In the case of plastic house tomato growers, they were found to know very well about picking practices (34.6%) compared to drying (15.4%), ketchup (3.8%), and sauce (3.8%). Interestingly open field farmers also had good knowledge of pickling (30.0%) compared to drying (13.3%), sauce (10.0%), and ketchup (6.7%) (Figure 4). The results suggest that farmers in the study area were well-known about pickling and drying as these practices are traditional ones common among almost all farmers.

Table 4. Packing practices for tomato fruits in the field survey conducted in Kavrepalanchok district in 2019

S.N.	Packing Practices	Plastic House	Open field
1	Packaging materials		
	Doko	3(11.5)	5(16.7)
	Plastic crates	23(88.5)	24(80.0)
	Polythene bag	0(0.0)	1(3.3)
2	Mixed damage with good quality	5(19.2)	4(13.3)
3	Pack to the full level	16(61.5)	14(46.7)
4	Put something at the base	3(11.5)	10(33.3)
6	Cleaning packing materials before packing	3(11.5)	5(16.7)

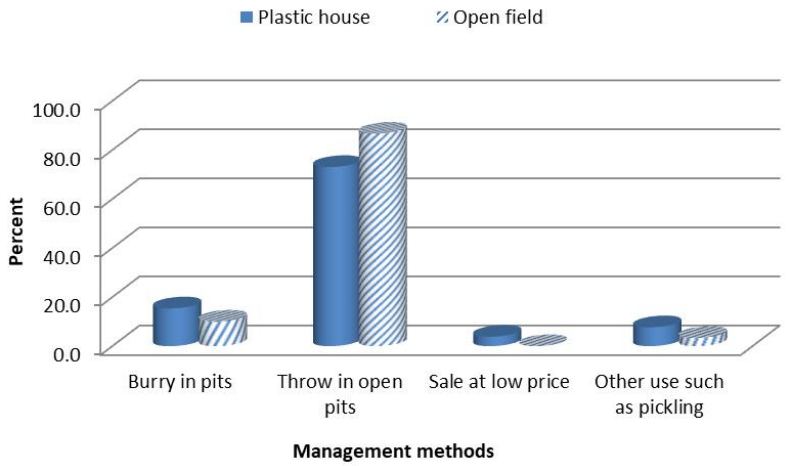

Figure 3. Management of leftover tomatoes.

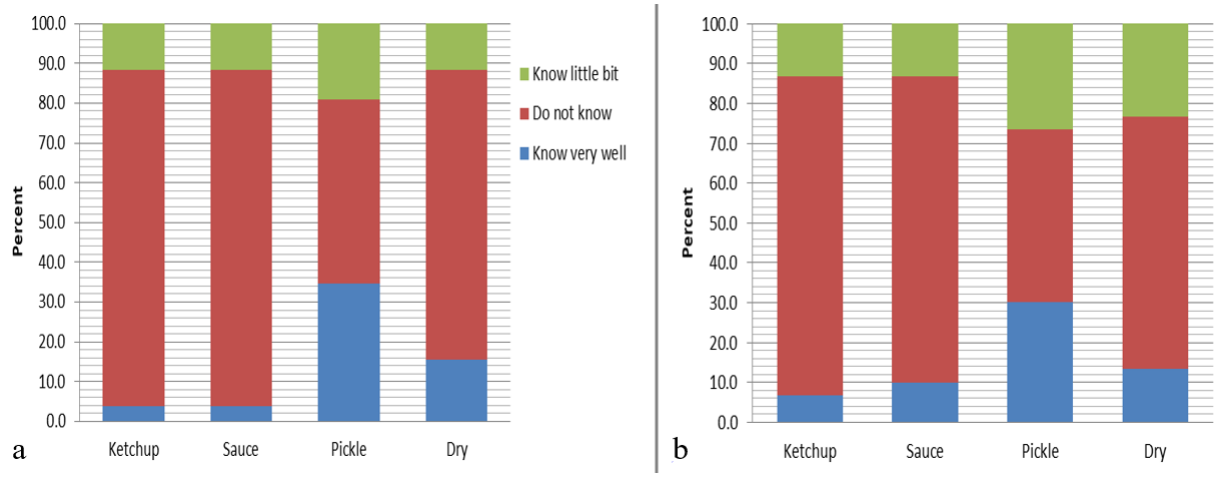

Figure 4. Level of processing knowledge: a) Plastic house and b) Open field.

3.2.8. Post-harvest management infrastructures

The study investigated if there was an involvement of middlemen in the supply chain of tomatoes. Interestingly, more than half of the producers; 73.1% and 60.0% plastic house producers and open field producers used to sell their produce to the middlemen. This lessens the net return of producers. The availability of infrastructures such as cold stores and collection centers minimizes post-harvest loss. Table 5 shows the frequency of tomato growers with access to such infrastructures. A few farmers, 11.5% and 13.3% plastic house and open field farmers, respevtively, had access to the cold store. Similarly, half (50.0%) of the plastic house producers and slightly more than half (60.0%) open field producers sent their products to the collection center. The majority of plastic house producers (61.5%) and open field producers (53.3%) had access to the good road for transporting tomatoes; 30.8% and 30.0% to poor roads; and the remaining 7.7% and 16.7% to the poor road. Wholesome the study area had good roads for transportation.

Farmers were investigated for their level of knowledge of different post-harvest management technologies (Table 6). The level of knowledge was categorized into high, medium, and low. The majority of plastic house farmers were found to have a medium level of knowledge about all three technologies i.e., high-yielding varieties (38.46%), production package (46.15%), and insect pest management (50.00%) except machinery equipment for which they had very low knowledge (53.85%). These findings are in parallel with the open field farmers, maximum of whom also had a medium level of knowledge about high-yielding variety (66.67%), production package (63.33%), and insect pest management (63.33%) except machinery equipment (33.33%). For both field conditions, a high level of knowledge was revealed in the production package. Adoption of machinery for cultivation seemed to be lagging in the areas as none had a high level of knowledge about the use of machinery; more than half (53.85% of plastic house growers and 66.67% open field growers) were found to have a low level of knowledge. Results show that farmers had more knowledge about methods of production compared to other post-harvest management technologies.

Table 5. Post-harvest management infrastructures in Kavrepalanchok district in 2019

S.N.	Infrastructures	Plastic House	Open field
1	Marketing method		
	Middlemen	19 (73.1%)	18 (60.0%)
	Direct selling	7 (26.9%)	12 (40.0%)
2	Cold store availability	3 (11.5%)	4 (13.3%)
3	Collection center	13 (50.0%)	18 (60.0%)
4	Condition of Road		
	Fair	2 (7.7%)	5 (16.7%)
	Poor	8 (30.8%)	9 (30.0%)
	Good	16 (61.5%)	16 (53.3%)

Table 6. Post-harvest management technologies in Kavrepalanchok district in 2019

	Level of knowledge					
	Plastic House			Open field		
Post-harvest management technologies	High	Medium	Low	High	Medium	Low
High yielding variety	34.62%	38.46%	26.92%	13.33%	66.67%	20.00%
Production package	46.15%	46.15%	7.69%	33.33%	63.33%	3.33%
Machinery equipment	0	46.15%	53.85%	0	33.33%	66.67%
Insect pest management	19.23%	50.00%	30.77%	3.33%	63.33%	33.33%

Table 7. Income pattern model

S.N.	Explanatory Factors	Standard Coefficients Beta	Std. Error	t	Sig.	95.0% Confidence Interval for B	
						Lower Bound	Upper Bound
	(Constant)		0.270	1.038	0.300	-0.262	0.824
1	Variety Nova (yes =1 otherwise 0)	0.71	1.510	15.921	0.000***	21.012	27.080
2	Production per unit area	0.478	0.000	10.579	0.000***	0.000	0.000
3	Cost of cultivation	0.366	0.001	7.937	0.000***	0.006	0.010
4	Access to processing industries (yes =1 otherwise 0)	0.101	0.910	2.213	0.030**	0.186	3.841
5	Marketing method (direct selling=1, otherwise 0)	0.097	0.424	2.176	0.030**	0.071	1.776

ANOVA Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1017.309	5	203.462	91.89	.000
2	Residual	110.709	50	2.214		
	Total	1128.018	55			

***=significant at 1%, **=significant at 5%, *=significant at 10%.

3.3. Determinants of Household Income from Tomato

The model (Table 7) represents a relationship between various factors of tomato production and household income. The study showed a positive and significant relationship between income and the Nova variety as a 1% increase in the use of the Nova variety increases the income of the household by 71%. Similarly, production per unit area and cost of cultivation increase the income by 48 and 37 times respectively. The farmers who had access to processing industries tended to earn 10% more than those without access. Processing is one of the value-added activities which enhance the ways of utilization of farm products. The farmers who sold their products directly to the consumers earned 10 times more than those selling via middlemen.

3.4. Constraints of Post-Harvest Technology Adoption at Farm Level

The adoption of post-harvest technologies is still lagging among Nepalese farmers; possible causes for this were studied. Farmers were asked to rank a list of factors that may have affected the rate of adoption of technologies. The results suggested that nearly three-quarters of the farmers (69.64%) agreed with the unavailability of fertilizers being the foremost constraint. Whereas, nearly half (44.64% and 41.07%) agreed that poor topography and poor extension visit affected the technology adoption. About 30% of the respondents said that small-scale production, unavailability of seeds, and loans were the reasons; while around 20% felt a lack of training, incentive and support, social networking, and irrigation

as the ones. Few, 12.5%, and 17.86% expressed that lack of information and unavailability of chemical pesticides influenced the adoption respectively as shown in Table 8. The study revealed that the untimely availability of fertilizers is the major constraint that is affecting the farmers to keep pace with the improved post-harvest technologies.

Table 8. Constraints of post-harvest technology adoption at the farm level in Kavrepalanchok district in 2019

S.N.	Status of technology adoption factors	Degree of response*
1	Poor Extension visit	23(41.07)
2	No training taken in the relevant field	12(21.43)
3	No Incentive and support	15(26.79)
4	Not able to get Information about the Usefulness of information	7(12.5)
5	No Social Networking	12(21.43)
6	Small Scale of production of less than 5 ropani	18(32.14)
7	Poor Topography or off-road	25(44.64)
8	Unavailability of inputs	(0)
	Seed	17(30.36)
	Fertilizer	39(69.64)
	Chemical Pesticides	10(17.86)
	Irrigation	16(28.57)
	Loan	17(30.36)

*If yes 1 otherwise 0.

4. Discussion

Post-harvest loss, both qualitative and quantitative occurs at all the stages in the supply chain of perishables from harvesting, through handling, packing, storage and transportation to final delivery of the fresh produce to the consumer (Paltrinieri, 2017). Post-harvest technologies lengthen the time period that a commodity can be put on use. Harvesting at right stage largely determines the post-harvest life of a fruit. However, harvesting of tomato fruits largely depends upon the purpose of fruit utilization and market distance. The fruit is harvested at the green stage if the market is distant and at pink stage if the market is near. (JICA, 2016) suggested that the ripe stage in which the majority of the fruit surface is red is suitable for home or table use while the full ripen stage, where the fruit develops maximum color and turns soft, is best for processing. Farmers in the study area were found to harvest mostly at yellow stage targeting the distant market. Thus, it can be suggested that both green and yellow stages are fine for distant market.

Serrano and Rolle (2018) in one of the studies has discussed that harvesting of the tomato needs to be carried out in dry weather and cool temperatures, hence in the early morning. This aligns with the present study where the farmers were observed to harvest at early morning. It is not wise to harvest at the time of rain and after immediate rain but the farmers in the study area were found to do so which needs an attention. Harvesting should be done with peduncle for long durability. Cent percent of farmers were found to follow this in the study area.

Balemi et al. (2005) found that the tomatoes must be picked with clean hands and twisted gently off a plant and not be squeezed or damaged by fingernails. Tomatoes must be gently placed in the container and not thrown in or dropped. Containers must be clean nylon net bags, plastic buckets, or wood/plastic crates. These findings are in parallel with the present study where majority of farmers are using plastic crates.

Tomato can be graded according to shape, color and texture separating the damaged, rotten, burst tomatoes. Ghimire et al. (2018) mentioned that good quality tomatoes are generally preferred by buyers, thus sorting/grading is a necessary operation and grading based on size i.e. small and large is highly recommended. In contrast, the present study concluded that grading based on insect pest attacks is the most popular one in the Kavrepalanchok district.

According to Paltrinieri (2017), packaging is one of the important aspects of reducing post-harvest loss as it protects the product from mechanical injuries, tampering, and contamination from physical, chemical, and biological sources. Some common packaging materials used in most of the developing countries include plastic crates, wooden crates, cardboard boxes, nylon sacks, bamboo basket, woven palm baskets, jute sacks, and polythene bags. In rural Nepal, bamboo woven doko and dhaki are still popular in rural Nepal but plastic crates and locally available wrapping/cushion materials likes newspaper, paddy straw are recommended due to less damage (Bhattarai, 2018). The findings of present study match with the recommendations. The majority of farmers are replacing traditional doko and dhaki with plastic crates. Bhattarai (2018) also mentioned that the crates must not be filled with the fruits completely, some space must be left from the surface such that something can be placed in the surface to avoid bruising and damage. In parallel to these findings, very few farmers were found to pack to full level.

The tomato can be processed into different forms like ketchup, sauce, juice, paste, and puree. Very few farmers of the study area practiced processing the tomatoes into ketchup, sauce, pickle and dry tomatoes. The present study shows that access to processing industries directly affects the household income of the tomato growers. Thus, there must be a good communication between the industry and the producers (USAID, 2014).

Adhikari (2006) mentioned that as tomato can be

produced all year round due to diversity in the climate, long time storage is not practiced in Nepal. Small growers and retailers can store for 5-10 days in zero energy storage. Free movement of fresh air needs to be maintained which helps to remove ethylene gas. During storage, temperature and relative humidity management are vital. The current findings show that very few cold store and collection center are available for storage in the study area.

The household income is catalysed by a number of factors. Among various factors, variety of the tomato, production per unit area, cost of cultivation, access to processing industries, and marketing method were revealed to determine the income of a household from tomato cultivation in the study area. Though some researches such as (Aidoo-Mensah, 2018) have been done for knowing the extent of impact of various factors on household income, yet there are rooms for more researches especially in case of Nepal.

5. Conclusion

Tomato is a year-round vegetable crop in Nepal gaining popularity because of its flexibility in its use. Keeping an eye upon the high demand for tomatoes all months around, off-season production under plastic houses has gained fame in hilly regions of Nepal. Plastic house production is one of the foremost examples of technology adoption by farmers. Farmers are slowly adopting improved technologies whether during cultivation or after cultivation i.e., during the post-harvest life of tomatoes. The study shows that income generation through tomato cultivation in plastic houses is more profitable than in the open field. Among the various factors determining the income from tomatoes; the variety of tomatoes, production per unit area, cost of cultivation, access to processing industries, and marketing method had a positive and significant relationship. This indicates that considering these factors can significantly increase the income of a household. Overviewing the constraints of technology adoption, unavailability of fertilizers, poor topography, and poor extension visits are the top three factors determining the extent of technology use.

Author Contributions

The percentage of the author(s) contributions is present below. All authors reviewed and approved final version of the manuscript.

	S.M.	T.D.
C	50	50
D	50	50
DCP	50	50
DAI	50	50
L	50	50
W	50	50
CR	50	50
SR	50	50
PM	50	50

C=Concept, D= design, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

The research was done under the supervision and monitoring of the Department of Horticulture at Tribhuvan University. The study was approved by Tribhuvan University (protocol code: 2019/15 and date: March 15, 2019).

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