Original Research Article

Determinants of post-harvest losses of pineapple: A farm-level study in Moulvibazar district, Bangladesh

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ABSTRACT

Aims: Post-harvest losses are acknowledged as one of the major reasons for fresh grain production, especially fruit production in most developing countries. Thus, the present study is highlighted the perishable nature of the food and inefficient post-harvest management are one of the key reasons for fruit (pineapple) losses in the Moulvibazar district.
Study Design: This article is about determinants of post-harvest losses study and is placed on empirical analysis. It was carried out to find out what factors influence pineapple post-harvest losses at the farm level.
Place and Duration of Study: Sreemangal, Barlekha, Kulaura, Juri, and Rajnagar Upazilas were purposefully chosen for this study because they represent the five most important pineapple producing locations in the Moulvibazar district. The study period was the harvesting season of pineapple from April to June 2019.
Methodology: Structured questionnaires were used to collect relevant information during face-to-face interviews with 320 pineapple farmers who were chosen using simple random sampling. Then the data were examined using descriptive and inferential statistics such as chi-square and factor analysis.
Results: The descriptive analysis shows that, based on the ranking of percentage, all pineapple farmers (100%) were engaged in the marketing of pineapple in order to reduce losses by exploring both direct and indirect means to sell their produce. This means that in order to avoid losses, finding a market for pineapples is important. There was a substantial link between the level of education (P=0.049), farm size (P=0.000), farm experience (P=0.021), yield (P=0.000), and post-harvest losses, as per chi-square analysis. Furthermore, according to the findings of the factor analysis, harvesting, grading, sorting, storage, packaging, transportation, and marketing are all aspects that affect post-harvest losses of pineapple at the farm level in the study area. Implementing proper storage and packaging facilities can reduce pineapple farmers' losses and make it easier for them to market their products year-round. Moreover, sorting and grading pineapple increases its price, enabling more effective marketing.
Conclusion: It has been shown that the transportation system has a substantial impact on pineapple distribution in the study area. Thus, it is logical to say that the transportation infrastructure should be upgraded in order to reduce pineapple production losses.

Keywords: Post-harvest losses, Post-harvest activities, pineapple farmers, chi-square analysis, factor analysis, Moulvibazar, Bangladesh.

1. INTRODUCTION

Fruits play a pivotal role in Bangladesh's overall economic development. In Bangladesh, fruit production, notable pineapple, is steadily increasing. The pineapple (*Ananas Comosus*) is a

prominent commercial fruit crop in Bangladesh and around the world. It is well-known as the "Queen of Fruits" because of its exceptional taste and aroma (Baruwa, 2013). Pineapple is the world's third-best vital tropical fruit, following bananas and citrus fruits (Bartholomew *et al*., 2003).

Bangladesh has a lot of fertile areas where a wide variety of tropical and subtropical fruits can be grown. The most commonly cultivated fruits in the country's agricultural territory are mango, litchi, pineapple, plum, jackfruit, guava, custard apple, lemon, wood apple, banana, golden apple, Indian berry, elephant apple, watermelon, melon, papaya, cashew nut, Indian olive, rose apple, pomegranate, tamarind, blackberry, and Indian jujube (BBS, 2020). According to the time-series research, pineapple is the fourth highest significant fruit based on total planting area as well as production in Bangladesh (Hossain & Abdullah, 2015). Pineapple is begun to be a major manufacturing product in several states, and pineapple demand is growing globally. The future of pineapple cultivation in Bangladesh is bright because, even though the fruit is grown in roughly 90 countries around the world, Pineapples from Bangladesh are much more juicy and flavorful than those from other countries. If correctly marketed, these pineapples are guaranteed to bring in a lot of money in the form of exports (Golam, 2014). Pineapple fruits have a large amount of moisture, ascorbic acid, sugar, soluble solids, and crude fiber. As a result, pineapple can be used as a dietary supplement to help maintain good health (Hemalatha & Anbuselvi, 2013). Pineapple is high in calcium, vitamin C, crude fiber, water, potassium, carbs, and a range of mineral deposits that help to digest and the maintenance of a healthy weight and a well-balanced diet. A single pineapple provides more than 130 percent of the daily vitamin needs for humans. Pineapple reduces cough and cold symptoms, protects against cancer, and improves sight, bone well-being, oral strength, circulation of blood, and control of blood pressure (Hossain *et al.,* 2015).

Pineapple growing thrives in a tropical climate. It is grown virtually everywhere in Bangladesh, particularly in steep and highland areas where there is little water stagnation. It is a very popular fruit that grows more in the rainy season due to its economic and nutritional benefits. Long periods of drought are detrimental to pineapple production. Drought affect the quality, quantity, and size of this fruit. Even though Bangladesh is not a humid country, the weather and topsoil in many of the country's regions are perfect for pineapple cultivation. Pineapples abound in Tangail, Rangamati, Chittagong, Bandarban, Dhaka, Mymensingh, Khagrachari, Sylhet, and Moulvibazar (BBS, 2020).

According to Kader *et al.* (2012), nearly one-third of the foodstuff manufactured in both developed and emerging nations is misused each year, equal to 1.3 billion tons. A lot of foodstuffs are thrown away in middle- and high-income states. According to an FAO estimate, global quantities of lost and thrown away food are larger in the lower phases of the food chain in high-income countries. However, the opposition is right in low-income nations, where more food is lost and squandered in the early phases of production (FAO, 2013). Fruit and vegetable post-harvest losses are projected to be 30-40% in developing nations after leaving the farm gate (Salami *et al.,* 2010; Aujla *et al.,* 2011), and 12 percent in industrialized countries from manufacturing to retailing, with a projected 20 percent at retailing stocks and food manufacturing locations (Madrid, 2011). The notable difference between developed and emerging nations is that underdeveloped nations lose fresher fruits and vegetable infrastructure than developed nations (Parfitt *et al.,* 2010).

According to research by Mollah *et al.,* (2018), post-harvest losses in food grains are estimated to be 15%, while losses in fruits and vegetables are believed to be 20-25% in Bangladesh. These losses might be as high as 40% for very perishable fruits and vegetables. This indicates that issues causing low productivity must be identified. In Bangladesh, the post-harvest management of horticulture products is still inadequate. Immediate action is required to enhance the current state of post-harvest management to reduce losses while maintaining quality and safety standards. In general, harvesting can occur at a variety of stages of maturity. Crop failures that cause damage or excessive heat in the ground can be decreased by correctly employing containers while harvesting and field management (Rolle, 2006).

Pineapple sales are heavily reliant on marketing. Pineapples cannot be saved until they are put away. Agricultural product marketing, unlike industrial product marketing, is not well organized. Because of this fundamental difference, agricultural product marketing requires the development of unique systems, institutions, and infrastructure. According to Yeshiwas & Tadele (2021), fruits and vegetables' average post-harvest losses in North-Western Ethiopia range from 5 to 83 percent of the market share. The most common causes of post-harvest losses are rotten, mechanical injury, poor handling, unsuitable temperature, relative humidity control, and cleanliness issues throughout handling.

In Bangladesh, particularly in the Moulvibazar district, no empirical study has been conducted yet to recognize and determine the determinants or latent factors influencing post-harvest losses among pineapple farmers. Given the above backdrop, it is necessary to understand post-harvest loss assessment and marketing practices of fruits in the Moulvibazar district. In this present investigation, we tried to explicitly estimate and determine the latent determinants or factors influencing post-harvest losses among pineapple farmers in Moulvibazar, Bangladesh. The study will help to recognize and determine the causes responsible for the losses of pineapple farmers. In turn, this will help to develop proper measures required to reduce such losses and increase the availability of pineapples for domestic consumption and export purposes. Thus, the overall objective was to recognize and determine the determinants or factors influencing post-harvest losses of pineapple farmers in Moulvibazar district, Bangladesh.

2. MATERIAL AND METHODS

2.1 Selection of the study area and sample

The research was carried out in the Moulvibazar district of Bangladesh with five regions namely Sreemangal, Barlekha, Kulaura, Juri, and Rajnagar Upazilas were purposively selected. The Department of Agricultural Extension in Moulvibazar district provided a list of registered pineapple farmers and villages. Out of 5 Upazilas, 4 villages from each Upazila were taken, and then 320 pineapple farmers were selected from a total of 20 villages using a simple random sampling technique employing structured questionnaires via face-to-face interviews with pineapple farmers primary data were collected from April to June 2019.

2.2 Data Collection Methods And Analysis

Using SPSS software, data and information from questionnaires were coded and evaluated. Descriptive and inferential statistics were applied to evaluate and show the post-harvest loss

in the study area, as well as to assess the key determinants for its loss. The socio-demographic characteristics and post-harvest activities were measured using descriptive analysis based on percentage and ranking. To investigate the strong link between the socio-demographic characteristics and post-harvest losses of pineapple farmers', inferential statistics such as chi-square analysis were applied. In addition, factor analysis was used to detect determinants of pineapple farmers' post-harvest losses. A Likert scale (of 1 to 5) was used to assess the key determinants that affect post-harvest losses of pineapple farmers (where 1 represents strongly disagree and 5 represents strongly agree). The constructs (scale items) for the factors influencing pineapple farmers' post-harvest losses were adapted from previous literature (Amanullah *et al*., 2020). Through the Kaiser-Meyer-Olkin indicator (KMO), Bartlett's Test of Sphericity, and Varimax rotation method, the accuracy of data tests were carried out to see if the data collected were adequate for factor analysis or not.

3. RESULTS AND DISCUSSION

3.1 Socio-demographic characteristics of the respondents

Table 1 shows the socio-demographic characteristics of the respondents who took part in this study. The findings revealed that there were no female farmers in the studied locations, with males accounting for 100% of the pineapple farmers. It demonstrates that males contribute a significant share of pineapple output, which could be due to cultural views such as a female's inability to participate in farming. 45 percent of the respondents were between the ages of 41 and 50, followed by 25 percent between the ages of 31 and 40, and 24 percent between the ages of 51 and 60. Meanwhile, just 5% were between the ages of 20 and 30, with the rest 1% being over the age of 61. This indicates that the agricultural sector in the studied area has a large worker force. It is indeed worth noting that 29% of the respondents had no formal education, compared to 41% who had received an elementary education, 20% who had acquired the secondary school, 9% who had completed upper secondary education, and 1% who had completed bachelor's degrees. The majority of the 152 pineapple farmers (48%) had 16-20 years of farming experience, 88 respondents (28%) had 11-15 years of farming experience, 46 respondents (14%) had 6-10 years of farming experience, 28 respondents (9%) had 1-5 years of farming experience, and The remaining 6 respondents (1%) had a farming experience of more than 21 years. 78 pineapple farmers (24%) had farms smaller than one acre, 206 respondents (65%) had farms between one and five acres, and 36 respondents (11%) had farms more than five acres. With 94 respondents (29%) producing less than 1000 kg from 1-acre size farms, 66 percent had between 10001-20000 kg yield from 1-5 size farms, and the minority of pineapple farmers (16 respondents (5%) produced more than 20001 kg to above yield from more than 5 acres of farms.

Table 1. Socio-demographic characteristics of the pineapple farmers (n = 320)

Socio-demographic characteristics	Explanation	Frequency	Percent (%)
Gender	Gender of the respondents		
	Male	320	100
	Female	0	0
Age	Age of the respondents (in years)		
	20-30	16	5
	31-40	80	25

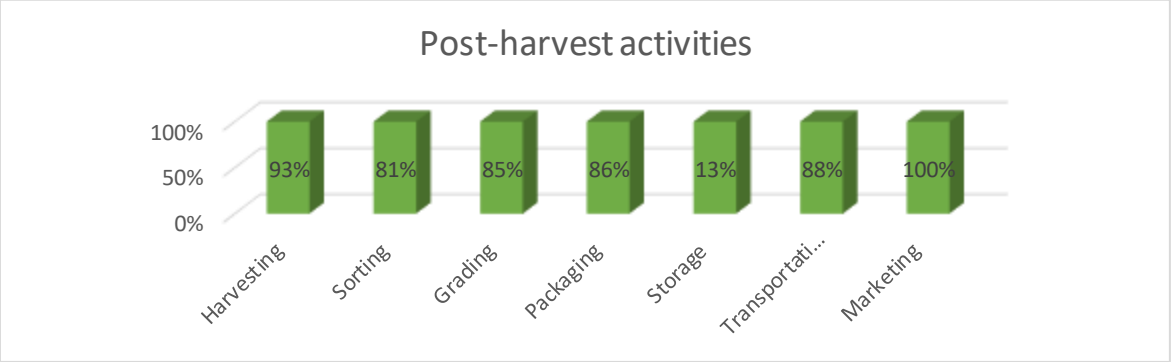
	41-50	144	45
	51-60	76	24
	Above 60	4	1
Education	The highest educational level of the respondents		
	Uneducated or no formal education (0)	92	29
	Primary (Grade 1–5)	130	41
	Secondary (Grade 6–10)	64	20
	Higher Secondary (Grade 11-12)	28	9
	Bachelor (13-16) and above	6	1
Experience	Experience of the respondents (in years)		
	1-5	28	9
	6-10	46	14
	11-15	88	28
	16-20	152	48
	21-above	6	1
Farm size	Farm size of the respondents (acres)		
	Below 1	78	24
	1-5	206	65
	Above 5	36	11
Yield	Yield from the farm of the respondents (kg)		
	Below 10000	94	29
	10001-20000	210	66
	20001-above	16	5

Source: Authors estimation, (2020)

3.2 Identifying of post-harvest activities of pineapple farmers

Figure 1 displays the activities of post-harvest that taken by pineapple farmers who took part in this study. In the study areas, pineapple harvests are often done by hand by pineapple farmers with the help of family members or hired laborers. As a result, 93 percent of pineapple producers pick their pineapples or hire someone to do so for them. Also, 81 percent of pineapple farmers sort their fruit with their family or hired workers. Furthermore, 85 percent of pineapple producers grade their fruits based on size, shape, and color. 86 percent of pineapple farmers process their fruit for market. Many pineapple farmers in the study area use bamboo-made baskets for packing pineapples, while some also use board cartons and crates. Only thirteen percent of pineapple farmers retain their fruit in storage. Eighty-eight percent of pineapple farmers transport their fruits to markets, while 100 percent of pineapple farmers participate in pineapple marketing. Pineapple farmers offer their fruit to native and regional dealers, as well as retailers and customers straight away. This suggests that pineapple farmers sell their products through a range of distribution channels. Those findings are also consistent with the results of Mahmud (2017) and he found that harvesting, transportation, grading, packaging, sorting, storage, and marketing are all part of post-harvest management.

Figure 1. Post-harvest activities of pineapple farmers in Moulvibazar district



Source: Authors estimation, (2020)

3.3 Relationship between socio-demographic characteristics and post-harvest losses of pineapples farmers

The significance of the selected variables used in this study was examined using the chi-square method. As shown in Table 2, the dependent variable was shown to be strongly linked with four variables: level of education, farming experience, farm size, and yield. Age, in contrast, had no significant relationship with post-harvest losses of pineapple farmers'.

Table 2. Chi-square test between socio-demographic characteristics and post-harvest losses of pineapple farmers

Variable	χ2	d.f	Sig	Decision
Age	18.302[a]	12	0.221	Failed to reject H_0
Level of education	24.407[a]	12	0.049*	Reject H_0
Farm size	129.454[a]	6	0.000**	Reject H_0
Farm experience	27.769[a]	12	0.021*	Reject H_0
Yield	272.539[a]	6	0.000**	Reject H_0

**Significant at 1% level of significance, * Significant at 5% level of significance.
Source: Authors estimation, (2020)

Table 2 shows that level of education (χ2=24.407, P=0.049) was significant at 0.05% level to pineapple farmers post-harvest losses. This means that, over time, the level of education has influenced the implementation of suitable farming equipment and assistance by the farming community. These results are similar to those of Alemayehu *et al*. (2018) and Amanullah *et al*. (2020), who reported a high association between education level and post-harvest losses of fruits at (P=0.021) and (P=0.046), respectively, and stated that farmers with formal education may have lower post-harvest losses than farmers with informal education. Farm size (χ2=129.454, P=0.000) was significant at 0.01% level of significance to pineapple farmers post-harvest losses. This indicates that the bigger the cultivation area, the greater the amount harvested and the smaller the chance of losses because of improper management and storage. Adisa *et al*. (2015) found that the larger the area under cultivation, the greater the harvest, and the greater the likelihood of losses due to poor management and shortage of proper storage facilities. Amanullah *et al*. (2020) also found that the bigger the area under cultivation, the higher the harvest, and the higher the likelihood of losses because of poor management and absence of proper storage.

Farm experience ($\chi 2$=27.769, P=0.021) was significant at 0.05% significance level to pineapple farmers post-harvest losses. This means that more experienced farmers have lower post-harvest losses of pineapple in the study area. This finding is consistent with Alidu *et al*. (2016) and Amanullah *et al*. (2020), who found that experience had a beneficial impact on fruit loss quantity. Furthermore, as per chi-square results, yield shows a substantial connection with post-harvest losses of pineapple farmers ($\chi 2$=272.539, P=0.000) at a 0.01% significance level. As a result of the lack of adequate storage facilities, an increase in harvested amounts results in losses. These findings are also in line with Alidu *et al*. (2016) and Amanullah *et al*. (2020), who reported a positive connection between quantity collected and quantity loss (P=0.00). However, age was not a determinant in pineapple farmers' post-harvest losses ($\chi 2$=18.302, P=0.221). According to Busari *et al*. (2015) and Amanullah *et al*. (2020), there is no noteworthy link between respondent age and fruit loss quantity (P=0.898) and (P=0.193), correspondingly. This indicates that the age of pineapple farmers in the research locations does not influence the post-harvest losses of pineapples. This may be because production restrictions and other variables can influence post-harvest losses.

3.4 Determinants of post-harvest losses of pineapple farmers

Factor analysis was applied in this study to recognize the determinants affecting pineapple farmers' post-harvest losses. The validity of the items in the questionnaire, which were linked to determinants impacting post-harvest losses, was examined using principal components analysis (PCA). Before factor analysis, the Kaiser-Meyer-Olkin (KMO) approach evaluates sample adequacy and predicts whether the data will be well factored based on correlation and partial correlation values ranging from 0 to 1, with a minimum of 0.6 (Hair *et al*., 2009). The KMO value was 0.917, indicating inter-correlations between the components, and Bartlett's test of sphericity was significant ($\chi 2$=4846.643, P<0.000) (Table 3). As a result, the data are suitable for PCA (Tabachnick & Fidell, 2014).

Table 4 shows the factor loadings, eigenvalue, and variance for the 31 items. In this study, the factors loading of un-eliminated standardized items ranged from 0.519 to 0.867. If the consistent loading value is more than 0.5, then an item is regarded reliable for the analysis (Sawyer & Levine, 1966). Low extracted variables (below 0.5) were therefore excluded from the analysis. Significant factors have eigenvalues greater than one, while inconsequential factors that have eigenvalues less than one are considered irrelevant and are thus removed. This study's total variance explained was 66.64 percent, which is acceptable. This factor solution accounts for 33.36 percent of data loss throughout the data reduction process.

Table 3. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		**0.917**
Bartlett's Test of Sphericity	Approx. Chi-Square	4846.643
	df	465
	Sig.	0.000

In this study, the primary factor or determinant influencing post-harvest losses of pineapple farmers' was identified as harvesting. This factor had a total variance of 34.733 percent and was made up of seven sub-variables. This factor had an eigenvalue of 10.42. The findings reveal that the harvesting factor is the most important factor to consider when it comes to post-harvest losses. Post-harvest losses may be reduced by employing precise harvesting techniques and trained staff during pineapple harvesting. According to Toivoen *et al.,* (2007),

harvesting fruit is an important stage since fruits are susceptible to bruise damage. Harvested fruits may become contaminated with farm spores if they are kept on the field for longer than four hours after being spread on the ground during harvesting. Picking fruits with hand compression can cause harm when the respiratory forces around the fruit reach one end for tissue breakage (Li & Thomas, 2014). It focuses on the importance of using proper picking techniques to avoid fruit injury.

Sorting was the second factor that influenced post-harvest losses, and it had a total variance of 9.822 percent, an eigenvalue of 4.794, and four sub-variables. The findings suggest that pineapple farmers should adopt fruit sorting in their fields to avoid post-harvest losses. Buyers are given an initial quality guarantee by getting rid of non-marketable and rejected fruits, with superfluous items like stones, boulders, and rubbles. Pineapple hand sorting includes visual inspection and the removal of undesired objects, and employees must be trained to identify fruit with malformations, blemishes, bugs, or infections (Nissen *et al*., 2016).

Grading was the third component, with a total variance of (5.723 percent) and an eigenvalue of (2.947). It had four sub-variables. As a result, pineapple grading by size, color, and shape, turn into extremely modest, selling out quickly on the market and avoiding post-harvest losses. Grading is a crucial component of effective marketing initiatives that should not be disregarded. Grading should be done with caution because untrained labor can cause skin irritation and microbiological contamination (Saeed & Khan, 2010). Farmers may get a lot of information from grading systems, such as scale, color, shape, fault, and inner quality. The most crucial criteria for effectively identifying and/or categorizing citrus fruits like oranges, limes, and tangerines are size and color (Londhe *et al*., 2013).

With a total variance of (4.952%), an eigenvalue of (1.717), packaging was identified as the fourth factor in this study which had four sub-variables. Packaging is one of the most important factors in reducing post-harvest losses and making vegetables and fruits more appealing to consumers. During transit, distribution, and marketing, standard packaging protects against mechanical intervention, undesirable physiological changes, and pathological degradation (Yahaya & Mardiyya, 2019). A wide range of boxes, such as corrugated fiberboard boxes, sacks made by jute, wooden boxes, bamboo bins, and clay pots are important packaging components. Kumar *et al.* (2016) found similar results when assessing losses during long-distance transportation with litchi fruit packaging. Lu *et al.* (2010) discovered that corrugated fiberboard box (CFB) packing is more suitable than typical wooden boxes in avoiding both mechanical and pathological injury to fruits such as apples. Ultimately, innovative packaging technologies may be a key component of initiatives to reduce fruit losses.

Storage was the fifth factor, with a total variance of (4.713 percent) and an eigenvalue of (1.485), and four sub-variables. Product storage, promotion, and consumption can all be done more gradually to optimize time management. Storage extends the growing season and ensures uniform fruit distribution throughout the year. Furthermore, storage is generally essential in the value chain to assure the continuous availability of processing raw materials (Znidarcic & Pozrl, 2006). In a cold storage facility, temperature control is very important. The lowest temperature is ideal for storing fresh fruits since it does not cause cold damage to the produce (Ramjan & Ansari, 2018). To prevent waste and keep up the superiority of

fresh food, appropriate storage capacity, accessibility of cold storage, and warehousing conveniences are essential (Negi & Anand, 2015).

Table 4. Factor loading of the scale items (scale ranges from 1 (strongly disagree) to 5 (strongly agree)) and Cronbach's alpha coefficient (scale items adapted from Amanullah *et al.,* 2020).

Code	Scale items	Factor loading
	Factor 1: Harvesting *(reliability (α) = 0.913)*	
Har1	Rough handling at harvest can greatly affect the quality of pineapples	0.913
Har2	The use of skilled workers at harvesting can reduce post-harvest losses of pineapples	0.890
Har3	Poor harvest techniques increase post-harvest losses of pineapples	0.852
Har4	Harvesting of pineapples in non-proper time increase the post-harvest losses	0.846
Har5	Harvesting of pineapples by hand decrease post-harvest losses	0.803
Har6	Harvesting of pineapples by shaking trees increase post-harvest losses	0.784
Har7	Lack of harvesting equipment increase the post-harvest losses of pineapples	0.838
	Eigenvalue	10.42
	Percentage of variance	34.733
	Cumulative percentage of variance	34.733
	Factor 2: Sorting: *(reliability (α) = 0.892)*	
Sort1	Sorting practices decrease the post-harvest losses of pineapples	0.895
Sort2	Sorting to remove low quality will be useful for maintaining the quality of the pineapples and decreasing the post-harvest losses	0.847
Sort3	Non-availability of skilled labor in sorting increase apple post-harvest losses	0.861
Sort4	Lack of sorting automatic machine increase the post-harvest losses	0.832
	Eigenvalue	4.794
	Percentage of variance	9.822
	Cumulative percentage of variance	44.555
	Factor 3: Grading*: (reliability (α) = 0.801)*	
Grad1	Grading of pineapples based on size increase the market value and decrease the post-harvest losses	0.846
Grad2	Grading of pineapples apples based on maturity index or color increase the market value and decrease the post-harvest losses	0.835
Grad3	Grading of pineapples based on shape increase the market value and decrease the post-harvest losses	0.763
Grad4	Non-available grading machines increase the post-harvest losses of pineapples	0.729
	Eigenvalue	2.947
	Percentage of variance	5.723
	Cumulative percentage of variance	50.278
	Factor 4: Packaging*: (reliability (α) = 0.743)*	
Pack1	Non-availability of packing materials increases the post-harvest losses of pineapples	0.841

Pack2	The use of proper packaging prevents pineapples from physical damages	0.872
Pack3	The use of wooden crates decrease the post-harvest losses during transportation	0.738
Pack4	Non-available packaging machines increase the pineapples post-harvest losses	0.719
	Eigenvalue	1.717
	Percentage of variance	4.952
	Cumulative percentage of variance	55.229
	Factor 5: Storage: ***(reliability (α) = 0.871)***	
Stor1	Non – availability of storage facility increases post-harvest losses of pineapples	0.775
Stor2	Keeping harvested pineapples under the shaded area or away from direct sunlight decreases the post-harvest losses	0.838
Stor3	Poor infrastructure of cold storage affects the quality of pineapples and increase the post-harvest losses	0.782
Sort4	Limited space of warehouses increases the post-harvest losses of pineapples	0.734
	Eigenvalue	1.485
	Percentage of variance	4.713
	Cumulative percentage of variance	59.943
	Factor 6: Transportation: ***(reliability (α) = 0.891)***	
Trans1	Using different kinds of vehicles for pineapples transferring increases the number of losses of apples	0.826
Trans2	Stored pineapples are transferred to market without quality damaged	0.852
Trans3	Pineapples' low-level packaging status during transportation affect the quality and increase the losses	0.761
Trans4	Rough loading and unloading of pineapples can greatly increase physical damage to pineapples and increase the losses of pineapples	0.682
Trans5	Without packaging, transferring pineapples to market increase the losses	0.748
	Eigenvalue	1.414
	Percentage of variance	3.457
	Cumulative percentage of variance	63.399
	Factor 7: Marketing: ***(reliability (α) = 0.815)***	
Mark1	Unstable and low market prices increase the losses of pineapples	0.856
Mark2	Lack of product specification information increase the losses of pineapples	0.847
Mark3	Lack of reliable market information increases the losses of pineapples	0.744
	Eigenvalue	1.037
	Percentage of variance	3.235
	Cumulative percentage of variance	66.635

Source: Authors estimation, (2020)

With an eigenvalue of 1.414, in this study, transportation was designated as the sixth factor. This factor, which had five sub-variables, explained 3.457 percent of the total variance. The transportation and distribution of crops are the utmost vital parts of post-harvest loss (Ramjan & Ansari, 2018). Pineapple farmers must transport their fruit in a variety of vehicles in order to minimize losses. The challenges of time and distance can only be solved by a

modern and professional transportation system. Refrigeration temperature systems must be installed in vehicles delivering fresh food in order to maintain product quality throughout the journey (Kitinoja & Thompson, 2010). Hard handling or vibration during shipment are the most common causes of mechanical damage (Aba *et al*., 2012). As a result, efficient and modern fruit transportation is essential to the successful marketing of outstanding quality and preservation.

The final factor that influences post-harvest losses of pineapple at the farm level was marketing, which had a total variance of 3.235 percent, an eigenvalue of (1.037), and three sub-variables. Horticultural produce must reach the market as soon as possible and at a period when it is most demanded by consumers. It is indeed essential to have a good marketing system in place to reduce fruit losses and to get a good return on similar products (Ramjan & Ansari, 2018). Through a wonderful and comprehensive marketing plan, it is possible to achieve a reasonable return on investment of efforts and assets at a moment while the consumer is most in need of the product (Yahaya & Mardiyya, 2019). By establishing marketing cooperatives and they have to be motivated amongst key commodity growers in major producing areas, especially in developing nations. Because due to the small size of farms in developing nations, such organizations are extremely important (Kader, 2004).

After the factor analysis, internal reliability assessments were undertaken to evaluate the internal accuracy of the seven-factor components' Cronbach's alpha and it has been shown in Table 4. The alpha in this study ranged from 0.743 to 0.913, exceeding Nunnally's (1978) minimum requirement guideline of explanatory research, which is more than 0.5. Harvesting (0.913) has the highest reliability value, indicating that the items representing each factor are internally consistent. Sorting (0.892), transportation (0.891), storage (0.871), marketing (0.851), grading (0.801), and packing were the next steps (0.743).

4. SUMMARY AND CONCLUSION

The present research has revealed that post-harvest losses of pineapple production in the Moulvibazar district of Bangladesh are very significant. Based on various percentage rankings, the survey found that maximum pineapple farmers were participating in all post-harvest activities. The study also reveals that all pineapple farmers (100%) were involved in marketing activities in order to sell their pineapples through direct or indirect methods. To avoid pineapple losses, a smart and effective marketing approach is required. There was also a link between the education level of pineapple farmers, farm experience, farm size, yield, and post-harvest losses. As a result, increasing or upgrading pineapple farmers' education, skill, and storage will reduce post-harvest losses. Harvesting, grading, transportation, packaging, sorting, storage, and marketing were all used to determine which factors caused pineapple post-harvest losses in the study area. According to the findings, pineapple farmers require appropriate storage facilities and suitable transportation infrastructure to decrease the losses. Furthermore, the three significant and required components that contribute to higher sales volume are sorting, packing, and grading and the standard packaging technique reduces the pineapple losses that pineapple farmers in the research area face. In summary, to reduce the high post-harvest loss of pineapple at the farm level in the research area and to offer superior products to consumers all year round, a continuous and long-lasting multi-stakeholder bond with liable entities is necessary. The findings of this research can assist the government in developing appropriate policies and

agricultural development for pineapple production in Bangladesh, which will benefit all stakeholders in the fruit industry. For the future, the current study suggests the following intervention areas. To ensure that consumers receive high-quality produce, a permanent selling shade/area for fruits and vegetables should be constructed. Furthermore, standard evaporative cooling storage technologies such as zero energy or cooling chambers can be employed to keep perishable horticulture crops in good condition and extend their shelf life. As a result, farmers, traders, and consumers must be instructed as soon as possible on revolutionary post-harvest management practices for fresh fruits and vegetables. Infrastructure facilities for horticultural crops, like transportation networks, proper storage facilities, and appropriate packaging systems must also be built. Simultaneously, the state and other officials should establish clear norms and standards for the accreditation of fruit and vegetable dealers.

Consent

As per international standard or university standard, respondents' written consent has been collected and preserved by the author(s).

DISCLAIMER

This article is original and contains unpublished content. The corresponding author certifies that all authors have read and approved the article and that there are no ethical concerns.

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ACRONYMS, ABBREVIATIONS

BBS: Bangladesh Bureau of Statistics
et al.: *Et al*ia (L.) and others
Etc. : Etcetera
i.e.: That is
SPSS: Statistical Package for the Social Sciences
% : Percentage