

## Original Research Article

### **An Investigation on Post-Harvest Losses of Lemon Farmers in Moulvibazar District, Bangladesh: Aspects of Practices, Determinants, and Problems**

#### **ABSTRACT**

**Aims:** Lemon is a popular citrus fruit in Bangladesh. Post-harvest management is very important to make lemon production profitable. The current study was carried out to measure the post-harvest practices of lemon farmers, to identify the determinants or factors influencing post-harvest losses of lemon at farm levels, and the associated problems of lemon farmers.

**Study Design:** This article is about investigating the determinants or factors influencing post-harvest losses of lemon farmers and is placed on empirical analysis. It was also conducted to determine the practices and problems regarding post-harvest of lemon at the farm levels.

**Place and Duration of Study:** The study was conducted in five intensive lemon growing villages of Sreemangal Upazila in the Moulvibazar district of Bangladesh purposively selected as they signify the top lemon (e.g. local, bilati, china varieties) producing areas of Moulvibazar district. The study period was the harvesting season of lemons from April to May 2019.

**Methodology:** The relevant data were collected using structured questionnaires via face-to-face interviews with 160 lemon farmers that were selected using simple random sampling. The socio-demographic characteristics and practices of lemon farmers were measured by using descriptive statistics. The farm-level determinants of post-harvest losses of lemon in the survey areas were identified using a multiple linear regression model, and the Problem Faced Index (PFI) was generated to assess the severity of the particular problem of lemon farmers in the study areas.

**Results:** From descriptive statistics results, it is found that farmers in the study area harvested their lemons under mature green conditions (67.6 percent) to reap the benefits of a longer life span, and 59.5 percent of them use the bamboo basket for packaging and transportation purposes. Lemon farmers were using manual vans (48.7 percent) and motor driving rickshaws (25.3 percent) to carry their products in the market. From the multiple linear regression model, it is shown that the key determinants of post-harvest losses in the study area were total production, labor, transportation, storage, distance, market place, and lemon farmers' farming experience. Lack of storage facilities was the greatest severe problem for lemon farmers, after overproduction and supply of lemon in the peak season, lack of quality seed, high input prices, disease infection, insect infestation, and so on.

**Conclusion:** Therefore, this study highlights developing suitable storage facilities, convenient transportation, scientific harvesting methods, and a fair price policy to reduce lemon post-harvest losses at the farm levels.

**Keywords:** Lemon, Farmers, Practices, Determinants, Problems, Moulvibazar District, Bangladesh.

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## 1. INTRODUCTION

Post-harvest losses in the agricultural distribution chain are a great problem in both emerging and industrialized nations. According to Madrid ~~[1](2011)~~, a considerable percentage of freshly cultivated crops is lost after harvest for a variety of causes around the world. Based on the season of production and the type of the commodities, losses in underdeveloped nations range from 20 to 40 percent, whereas from manufacturing retail warehouses to food service facilities, post-harvest losses in developed regions are projected to be between 12 and 20 percent ~~[1](Madrid, 2011)~~.

The horticulture sector suffers losses greatly after harvest, especially in developing countries. Fruits and vegetables, as horticultural crops, hold a significant role in maintaining food and nutritional security ~~[2](Parfitt et al., 2010)~~. Post-harvest losses of fruits and vegetables relate to the quantitative and qualitative losses that occur along the food chain, from farm to fork ~~[3](Hodges et al., 2011)~~. Post-harvest losses not only affect the accessibility of food but also the amount of money that might be received by marketing them; hence, in regards to quantity, they are related to food security ~~[4](FAO, 2010)~~. Fruit and vegetable losses account for 40 to 50 percent of global losses, with 54 percent occurring during cultivation, handling, storage, and post-harvest, and 46 percent occurring during distribution, processing, and consumption for a complete loss of US\$750 billion each year ~~[5](FAO, 2013)~~. Post-harvest losses of fruits and vegetables, for example, are reported to reach 20-40% in emerging nations ~~[6](Ngowi & Selejio, 2019)~~ and for several fruits such as apples, banana, avocado, citrus, papaya, and grapes such losses were reported to be 14, 20-80, 43, 20-95, 40-100, and 53 percent, respectively in underdeveloped nations ~~[7, 8](Rejabi et al., 2015; Kughur et al., 2015)~~ whereas in Bangladesh it is assumed to be 20-25% ~~[7, 8](Mollah et al., 2018)~~. For perishable fruits and vegetables, these losses could be as high as 40%. In both rich and emerging nations, poor packing, a lack of quantity planning, and excessive handling by producers, merchants, and consumers are all major causes of post-harvest losses ~~[9](Lebersorger & Schneider, 2014)~~. However, owing to poor storage and food-management technologies, particularly post-harvest losses in emerging countries are significantly higher ~~[10](Salami et al., 2010)~~. Also, biological, mechanical, chemical, psychological, physical, environmental, and physiological elements are among the considerations of post-harvest losses of fruits and vegetables ~~[11](Kereth et al., 2013)~~. Furthermore, the perishable nature of these crops is one of the causes of these substantial losses ~~[12](FAO, 2011)~~. Although post-harvest losses may arise at any point along the distribution chain, it is necessary to include the entire distribution chain when calculating losses. Farmers can determine post-harvest losses as a percentage of total produced quantity by quantifying post-harvest losses in absolute terms for produce lost after harvest ~~[13](Weinberger et al., 2008)~~.

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Bangladesh has a comparative advantage due to the accessibility of inexpensive labor, proximity to the international market, ideal meteorological conditions, and diverse agroecology in the production of numerous fruits and vegetables, which provide a source of livelihood and income for many people. Lemon is a very important citrus among many types of citrus fruits produced in Bangladesh. In terms of international trade, it is one of the most valuable fruits, and it is grown all over the world. Approximately 10% of the world's citrus is

exported as fresh fruit including in Bangladesh. The potentiality of citrus fruit export has greatly increased due to the globalization of international trade and the founding of the World Trade Organization (WTO). As a result, citrus fruits growers faced increased competition on the international market. Lemons grow well in regions where there is adequate rainfall or irrigation to support growth and where cold temperatures are not severe enough to harm the tree. Some regions of Moulvibazar in Bangladesh are home to some of the world's most important fruits, notably the citrus-growing region. The future for lemon production in Moulvibazar is promising, as the improved weather and soil conditions, and the region are expanding into a seasonal fruit center with huge potential for creating a food manufacturing sector. In comparison to other districts in Bangladesh, this area currently contributes more than 65 percent of the country's citrus fruits, including lemon. In 2018-19, fruits were grown on 11031 acres of land in the Moulvibazar district, yielding 56908 metric tons whereas lemons were grown on 872 acres, yielding 9894 metric tons [14]. (BBS, 2020). Generally, 4.52 percent to 5.82 percent citric acid can be found in abundance in lemons. And lemon is used in a variety of delectable dishes such as salads, beverages, desserts, shampoo, medication purposes, soap, and so on. As the demand for Bangladeshi lemon grows, it is more important than ever to understand lemon farmers' post-harvest methods, the factors that influence post-harvest losses at the farm level, and the problems that these farmers face. Exporters need to guarantee that the quality of lemon meets the appropriate criteria to meet the demands of various importing countries. But in Bangladesh, like many other emerging nations, suffers from post-harvest losses in their distribution networks. Due to post-harvest losses, a significant amount of the cultivated products never reaches the consumers. A multitude of determinants affect losses, ranging from growth circumstances to consumer handling. Because of the absence of proper storage and marketing opportunities, as well as periodic oversupply, growers were compelled to sell their tireless products at less and unacceptable rates in the market. Even though these determinants have been well-documented in the literature and several methodologies to reduce these losses have been developed, they have not yet been successful. This was owing to a lack of focus on the factors that contribute to fruits and vegetables post-harvest losses in Bangladesh and elsewhere. According to Klink [15] (2015), the causes would be the foundation for any improvement approach aimed at increasing rates of achievement in minimizing post-harvest losses in emerging nations. As a result, good harvest management is important for minimizing post-harvest losses and improving nutritional quality, food security, and employment opportunities. It is essential to lessen post-harvest losses and preserve quality in existing supply to meet demand. Huge numbers of fruits, particularly lemons, have decayed and are being lost in our investigation region.

The empirical literature on post-harvest losses of lemon at farm levels is extremely limited in Bangladesh, especially in the Moulvibazar district. However, the available literature concentrates in Bangladesh on other perishable agricultural goods like fish, bananas, pineapples, brinjal, and tomatoes. Besides, several surveys in the different parts of the world investigated socio-demographic factors that influence fruits and vegetables post-harvest losses [16, 17, 18, 19, 20, 21, 22, 23, 24]. (Babalola *et al.*, 2010; Molla *et al.*, 2010; Ayandiji & Adeniyi, 2011; Aideo *et al.*, 2014; Mebratie *et al.*, 2015; Hossain *et al.*, 2017; Kikulwe *et al.*, 2018; Christian *et al.*, 2019; Kulwijila, 2021). Only a few research have used economic models to analyze the impact of various socio-demographic factors on fruits and vegetables post-harvest losses at the farmer and marketing levels in different countries [20, 21, 25, 26,

27, 28, 29](Mbuk *et al.*, 2011; Khatun *et al.*, 2014; Adde *et al.*, 2015; Umar *et al.*, 2015; [Mebratie *et al.*, 2015; Adisa *et al.*, 2015; Kaysar *et al.*, 2016; Hossain *et al.*, 2017; and Tadesse *et al.*, [30](2018). Thus, according to the literature assessment, no study has evaluated the determinants that affect post-harvest losses of lemon at the farm levels in the Moulvibazar district of Bangladesh. This study, therefore, identified practices regarding post-harvest of lemon farmers, analyzed determinants that impact post-harvest losses of lemon at farm levels, and measure the associated problems of lemon farmers in the Moulvibazar district of Bangladesh. The findings of the study are intended to contribute to our understanding of the determinants that influence post-harvest losses in lemons at the farm levels, along with aid in the formulation of suitable policies and approaches for handling post-harvest losses. Therefore, the present study was carried out with the following specific objectives (a) to identify practices regarding post-harvest of lemon farmers; (b) to analyze determinants that impact post-harvest losses of lemon at farm levels, and (c) to measure the associated problems of lemon farmers.

## 2. MATERIAL AND METHODS

### 2.1 Selection of the Study Area and Sample

—The current study was carried out in the Sreemangal Upazila of the Moulvibazar district of Bangladesh including five villages namely Sadar, Mohajirabad, Khakiachara, Radhanagar, and Dilbornagar were intensively lemon (local, bilati, china varieties) grown areas compared to other parts of Bangladesh. For the selection of sample farmers, the respondents were chosen based on simple random sampling. A sample size of 160 was considered for this study, with 32 people chosen from each selected village. In this study, the selection of respondents was on the basis of two criteria: farmers whose farms are above 6 years and have at least 1 to 5 years of lemon cultivation experience and marketed their lemons in the local and distant markets.

### 2.2 Methods of Data Collection and Analysis

Relevant information on post-harvest losses of lemon at the farm level was collected from the above areas through structured questionnaires via face-to-face interviews during the harvesting season of lemon from April to May 2019. Along with primary data, secondary data were also gathered from different publications like government reports, published articles, different organizations, and web searching. Then the collected data were precise, assembled, and analyzed by means of MS Excel and SPSS. The following analytical techniques were used to measure the practices, farm-level determinants of post-harvest losses of lemon farmers, and the severity of the particular problem of lemon farmers in the survey areas.

### 2.3 Analytical Techniques

#### 2.3.1 Determinants of farm-level post-harvest losses of lemon

The determinants of post-harvest losses of lemon at the farm level were investigated using functional analysis. At the farm level of the study area, post-harvest losses were characterized as a function of many socio-demographic parameters such as the farmer's age, educational background, total lemon production, farming experience, selling price, and so on. Khatun *et al.* [26](2014), Adisa *et al.* [31](2015), Kaysar *et al.* [29](2016), Hossain *et al.* [21](2017), and Tadesse *et al.* [30](2018) also conducted the same

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functional analysis to measure the impact of socio-demographic factors on post-harvest losses of tomato, yam, brinjal, fruits, and potato. In this investigation, the following multiple linear regression function was used:

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_{12} X_{12} + \mu_i \dots \dots (i)$$

Where,

- Y = Post-harvest losses of lemon at farm level (kg/acre)
- X<sub>1</sub> = Age of the farmers (years)
- X<sub>2</sub> = Education of the farmers (number of schooling)
- X<sub>3</sub> = Total production of lemon (kg)
- X<sub>4</sub> = Farming experience of farmers (years)
- X<sub>5</sub> = Selling price (Tk./kg)
- X<sub>6</sub> = Weather condition dummy which takes the value '1' if the weather during harvesting was favorable and value '0', otherwise
- X<sub>7</sub> = Labor dummy which takes the value '1' if the labor availability during harvesting was adequate and value '0', otherwise
- X<sub>8</sub> = Transportation dummy which takes the value '1' if the transportation facility during harvesting was adequate and value '0', otherwise
- X<sub>9</sub> = Storage dummy which takes the value '1' if the storage facility during harvesting was adequate and value '0', otherwise
- X<sub>10</sub> = Training dummy which takes the value '1' if the farmer received training about lemon production and value '0', otherwise
- X<sub>11</sub> = Distance dummy which takes the value '1' if the distance from farm to market was favorable and value '0', otherwise
- X<sub>12</sub> = Market place dummy which takes the value '1' if the market place was favorable and value '0', otherwise
- α = Constant term,
- β<sub>1</sub>, β<sub>2</sub>...β<sub>12</sub> = Co-efficient of the respective independent variables, and
- μ<sub>i</sub> = Error term.

### 2.3.2 Problem Faced Index (PFI) of farmers

The problem faced index was designed to assess the importance of each lemon farmer's problem. Respondents were given four options for each of the selected problems: 'severe problem', 'moderate problem', 'little problem', and 'no problem'. Alternative responses received scores of 3, 2, 1, and 0 accordingly. PFI was calculated using the following formula to determine the score for a certain problem:

$$PFI = (P_s \times 3) + (P_m \times 2) + (P_l \times 1) + (P_n \times 0) \dots \dots \dots (ii)$$

Where,

- PFI = Problem Faced Index,
- P<sub>s</sub> = Number of respondents who faced the severe problem,
- P<sub>m</sub> = Number of respondents who faced the moderate problem,
- P<sub>l</sub> = Number of respondents who faced the little problem,
- P<sub>n</sub> = Number of respondents who faced no problem.

### 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. According to the findings, all 160 respondents were men, accounting for 100 percent of the total, and there were no dependent female lemon producers in the study locations. It demonstrates that males account for the majority of lemon output, which could be due to cultural attitudes such as a female's incapacity to participate in cultivation in the research location. 48.75 percent of the respondents were between the ages of 41 and 50, followed by 26.88 percent between the ages of 31 and 40, and 12.5 percent between the ages of 51 and 60. Meanwhile, only 7.5 percent were between the ages of 20 and 30, with the remaining 4.37 percent being over the age of 61. This indicates that the agricultural sector in the study area has a large labor force. Furthermore, 28.13 percent of the respondents had no formal education, while 52.5 percent had received elementary school, 11.88 percent had obtained secondary education, 5.61 percent had acquired higher secondary education, and 1.88 percent had received a bachelor's degree. The majority of lemon farmers (42.5 percent) had 11-15 years of farming experience, 36 respondents (22.5 percent) had 6-10 years of farming experience, 35 respondents (21.88 percent) had 16-20 years of farming experience, 18 respondents (11.25 percent) had 1-5 years of farming experience, and the remaining 3 respondents (1.87 percent) had more than 21 years of farming experience. 48 lemon farmers (30.0 percent) had farms that were less than one acre in size, 66.87 percent of the 107 respondents had farms that were between one and five acres in size, and 5 respondents (3.13 percent) had farms that were larger than five acres. With 98 respondents (61.25 percent) producing less than 5000 kg from below 1-acre size farms, 33.75 percent of the 54 respondents have between 5001-10000 kg yield from 1-5 size farms, and the minority of lemon farmers with 8 respondents (5.0 percent) producing more than 10001-above kg yield from above 5 acres of farms.

**Table 1. Socio-demographic characteristics of the lemon farmers (n = 160)**

Socio-demographic characteristics	Explanation	Frequency (n)	Percentage (%)
Gender	<b>Gender of the respondents</b>		
	Male	160	100
	Female	0	0
Age	<b>Age of the respondents (in years)</b>		
	20-30	12	7.5
	31-40	43	26.88
	41-50	78	48.75
	51-60	20	12.5
	Above 60	7	4.37
Education	<b>The highest educational level of the respondents</b>		
	Uneducated (0)	45	28.13
	Primary (Grade 1–5)	84	52.5
	Secondary (Grade 6–10)	19	11.88
	Higher Secondary (Grade 11-12)	9	5.61

	Bachelor (13-16) and above	3	1.88
<b>Experience</b>	<b>Experience of the respondents (in years)</b>		
	1-5	18	11.25
	6-10	36	22.5
	11-15	68	42.5
	16-20	35	21.88
	21-above	3	1.87
<b>Farm size</b>	<b>Farm size of the respondents (acres)</b>		
	Below 1	48	30
	1-5	107	66.87
	Above 5	5	3.13
<b>Yield</b>	<b>Yield from the farm of the respondents (kg)</b>		
	Below 5000	98	61.25
	5001-10000	54	33.75
	10001-above	8	5

Source: Authors estimation, (2020)

### 3.2 Technologies and Practices Regarding Post-harvest of Lemon Farmers

Lemon growers have their procedures and methods for minimizing post-harvest losses. Table 2 demonstrates the existing post-harvest procedures and technology for lemons among the research area's respondents. Harvesting periods in the research area varied based on the maturation stage of the various cultivars and to a lesser extent, the desire to gain additional benefits depending on market conditions. They discovered that marketing done early and late is more profitable. Lemons were gathered in the majority of cases early in the morning during the day (Table 2). Harvesting may occur late in the afternoon, depending on the need for selling or an agreement with beparies from afar. Concerned growers said that the majority of their lemons are collected in the morning (31.2%), then in the afternoon (28.5%). This outcome is consistent with the findings of a litchi study conducted by Molla *et al.* [17](2010) in Bangladesh. On the same day or the next morning, the picked lemons were transported from the orchards to local selling stations. The lemons were then packed and despatched as soon as possible to distant markets. In the research locations, farmers who are active in harvesting were observed to follow some indigenous post-harvest practices. Lemons were gathered at various phases of development. The majority of the fruit was picked in mature green condition (67.6%), followed by half-ripe (19.0%), and fully mature (13.4%). According to Molla *et al.* [17](2010), color was the most important parameter for harvesting selection among fruit size, color, and dots on the fruit skin. According to their research, the majority of responders (70-100%) harvested their litchi when the fruit skin had reached 75-100% color. Fruits could also be picked at 50% color attainment on fruit skin for distant marketing in Bangladesh, according to some of the participants (20-30%).

Farmers in the research area used a variety of packaging materials, with the bamboo cage accounting for 59.5 percent of the total. This outcome is congruent with the results of a litchi

study conducted by Molla *et al.* [17](2010) in Bangladesh, which found that the most common packaging methods were bamboo baskets lined with litchi leaves and covered with gunny sheets. Farmers must keep their lemons in a specific location after harvesting, with 67.8% of farmers keeping their lemons under the shade of the trees and the morning was the most popular selling time for lemons (49.8%), followed by afternoon (29.5%).

Farmers transported lemons in manual vans (48.7%), and motor driving rickshaws (25.3%), as these two vehicles, are highly popular and abundant even in these study locations, and 41.7 percent of lemon farmers preferred morning time to transport their lemons in the market, followed by afternoon (37.8%). Molla *et al.* [17](2010) discovered that litchi growers generally used a manually operated tricycle, locally known as a van, and another locally made tricycle powered by a shallow-engine, locally known as Nosimon, for long-distance marketing in Bangladesh, whereas for large volumes, both growers and intermediaries (bepari) used bus and truck. This contradicts the findings of Dessalegn *et al.* [32](2016), who found that fruit is supplied by trucks, often from afar, but that these vehicles lack the essential ventilation to handle perishable items like fruit. Fruit is also transported over short distances using a cart and employees. Regardless of how they are carried, fruits are prone to heat accumulation and mechanical damage. According to Wasala *et al.* [33](2014), 24% of farmers manually carry complete banana bunches to the sales point in Sri Lanka. Farmers gathered their lemons entirely with their hands (100%). In the survey regions for lemon harvesting, no knives, scissors, or other equipment were detected. Farmers classify lemons based on appearance (43.8%), half-ripe (28.3%), fully ripe (15.7%), and physical damage after harvest (12.2%). 45.6 percent of farmers in the survey areas sorted their lemons on the basis of half-ripening conditions, whereas 41.7% sorted their lemons by size. These findings contradict those of Molla *et al.* [17](2010), who found that damaged, pest-infested, disease-infected litchis were the most commonly used foundation for sorting in their Bangladesh research regions.

Most of the time, fruits are often packed tightly in packaging material. This method speeds up the ripening process and reduces the shelf life of the fruit. From Table 2, it found that the bamboo basket (57.8%) was the most widely used packaging material in the study area, followed by the plastic crate (28.2%), jute sack (9.6%), and other packing materials e.g. plastic sack (4.4%), has a capacity of 35 to 50 kg and does not require any cushioning to absorb shocks during transit. As a result, it wounds lemons that are packed with it, contributing to the post-harvest losses. These findings are consistent with Molla *et al.* [17](2010) findings for litchi in Bangladesh, but they are inconsistent with Dessalegn *et al.* [32](2016) findings in Ethiopia, where they found that 93.5, 16.1, and 3.2% of respondents reported wooden boxes, sack, and plastic box as their fruit packaging materials, respectively. Similarly, Seid *et al.* [35](2013) reported, that sacks are the most frequent fruit packaging material in Ethiopia's South Wollo zone. Mangoes and bananas are likewise transported without being packed, instead of being spread out on the truck. Fruit spoilage is increased when fruits are transported without packaging material because they are more susceptible to mechanical damage during loading and unloading, as well as while traveling on a bumpy road. According to Ekanayake and Bandara [36](2002), post-harvest losses of bananas in Sri Lanka amounted to 30% and were mostly due to the absence of proper packaging methods for transport from the field gate to the consumer. Therefore, current packaging materials and practices must be improved to reduce lemon post-harvest losses.



**Table 2: Post-harvest practices of lemon farmers**

Items	% of respondents	Items	% of respondents
<b>Time of harvesting from the field</b>		<b>Manual van</b>	<b>48.7</b>
Morning (6.00 am - 11.00 am)	31.2	Motor driving van	9.8
Afternoon (12.00 pm - 3.00 pm)	28.5	Motor driving rickshaw	25.3
Evening (4.00 pm - 6.00 pm)	27.5	Pick up or truck	11.8
Any time of the day	12.8	<b>Time of transportation</b>	
<b>Point of harvesting</b>		Morning (6.00 am - 11.00 am)	41.7
Fully mature	13.4	Afternoon (12.00 pm - 3.00 pm)	37.8
Mature green	67.6	Evening (4.00 pm - 6.00 pm)	11.3
Half ripe	19.0	Any time of the day	9.2
<b>Types of material used for packaging</b>		<b>Means of harvesting</b>	
Plastic crates	11.3	Hand	100
Bamboo cage	59.5	<b>Basis of grading</b>	
Plastic sack	11.5	Looking good	43.8
Jute sack	9.5	Fully ripen	15.7
Plastic net bag	8.3	Half ripen	28.3
<b>Place of harvested fruits</b>		Physical damage	12.2
Under the shade of the trees	67.8	<b>Basis of sorting</b>	
Placing in a room	28.2	Size	41.7
Placing in the open sky	4.2	Color (Half ripening condition)	45.6
<b>Time of selling</b>		Disease/insect	12.7
Morning (6.00 am - 11.00 am)	49.8	<b>Packaging materials for marketing</b>	
Afternoon (12.00 pm - 3.00 pm)	29.5	Jute sack	9.6
Evening (4.00 pm - 6.00 pm)	12.2	Plastic sack	4.4
Any time of the day	8.5	Bamboo basket	57.8
<b>Means of transportation</b>		Plastic crate	28.2
<b>Headload</b>	<b>4.4</b>		

Source: Authors estimation, (2020)

### 3.3 Determining Factors of Farm-level Post-harvest Losses of Lemon

To investigate the impact of different farmer characteristics on lemon post-harvest losses at the farm level, a multiple linear regression analysis was used. Table 3 presents the determining factors of post-harvest losses of lemon in the study areas. The summary of the overall model suggests that the model is good enough to explain the association between the dependent and the independent variables. The logarithmic regression model's coefficients of multiple determination ( $R^2$ ) were observed to be 0.76, implying that variations in the 12 independent variables included in the regression model explained 76 percent of the variation in total post-harvest losses at the farmer level. The substantial F-value also means that the coefficients of the independent variables are significantly different from zero, showing that the model is well-fit. The significance of the F value at the 1% level indicates that the explanatory variable included in the model accounts for the majority of the variation in the lemon post-harvest losses at the farm level.

Twelve independent variables (5 continuous and 7 dummies) were inserted into the model to assess their quantitative effect on the proportion of post-harvest losses of lemon out of which

seven were found to have a statistically significant impact. It was hypothesized that the factors like age, education, total production, farming experience, training, and transportation have a negative effect on post-harvest losses on lemon which indicate that with the increase in age, education, total production, farming experience, training, and transportation facilities, the post-harvest losses will decrease while factors like adverse weather, inadequate labor, inadequate storage, distance, market place, and sales price have a positive effect on post-harvest losses indicates with the increase of adverse weather, inadequate labor, inadequate storage, unfavorable distance, market place, and sales price during marketing, the post-harvest losses will be increased.

Total production, labor, transportation, storage, distance, and market place are determinants that significantly affect the post-harvest losses of lemon but the farming experience of farmers had a negative significant influence. At the 1% level, the coefficient of total production was a significant and positive link with total post-harvest losses, showing that a 1% increase in the overall production of lemon would result in a 7.141 percent increase in post-harvest losses, assuming all other factors remained equal. These findings are in line with Christian *et al.* [23](2019) that total production was statistically significant with post-harvest losses in navel fruit in South Africa. Their study showed that the more the production of navel the more the post-harvest losses. The farming experience of farmers was found significant but negative at a 10 percent level, meaning that increasing farming experience by 10% would reduce post-harvest lemon loss by 10.086 percent. As a result, farmers with more years of experience appeared to be better at handling procedures, resulting in lower post-harvest losses. These findings are consistent with conclusions drawn by Kulwijila [24, 28](2021), Umar *et al.* (2015), and Mebratie *et al.* [20](2015), who discovered that experience influenced significantly but negatively post-harvest losses of grape in Tanzania, kinnow fruit in Pakistan, and banana in Ethiopia.

Among the dummy variables, it is surprising to know that labor dummy, storage dummy, distance dummy, and transportation dummy were found negative while the market place was found positively significant at a 5 percent level. This implied that with increasingly inadequate labor, transportation facilities, and storage facilities in a unit, post-harvest losses of lemon will decrease by 0.004, 0.035, and 0.039 units. The reason could be that labor is available for production but not always available for handling post-harvest losses or it could be that the labor available did not have the requisite skills in the basic processing of lemon. This result is congruent with the finding stated by Hossain *et al.* [21](2017) on the post-harvest losses of major fruits in different hill regions of Bangladesh. They found in their study that the labor dummy, market demand dummy, and transportation dummy had a significant but negative effect. Again, if the distance between farm and market is favorable to the farmer by a unit, the post-harvest loss will also decrease by 0.737 units. This finding is also consistent with the result stated by Woldu *et al.* [12](2015) on the assessment of post-harvest handling practices and losses of bananas in Ethiopia. They found that in their study that market distance and number of days of storage had a significant and expected relationship with the proportion of post-harvest losses of bananas. The results in Table 3 also show that the increase of market place by a unit would increase the post-harvest losses of lemon by 2.401 units. The findings support those of Kulwijila [24](2021) and Aidoo *et al.* [19](2014), who found that unreliable markets influenced grape losses in Tanzania and tomato losses in Ghana, respectively. The unreliable market increased the number of grapes positively way, implying that the better the probabilities of obtaining a market for grapes and tomatoes at the

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correct period of fruit maturity, the lower the mean percentage losses; all other parameters remained constant. As a result, farmers who have a stable market are more likely to harvest and sell their grapes and tomatoes at the right time, avoiding post-harvest losses.

**Table 3: Estimated values of coefficients and related statistics of regression model for post-harvest losses of lemon at farmers' level**

Regression variables		Regression coefficient	t-statistic	p-value	Standard error	Formatted: Font: Bold, Highlight
Intercept	$\alpha$	11.582***	4.541	0.000	22.142	Formatted: Highlight
Age of the farmers (years)	$X_1$	0.212	5.294	0.920	3.292	Formatted: Font: Bold, Highlight
Education of the farmers (schooling years)	$X_2$	0.0835	5.404	0.109	15.631	Formatted: Font: Bold, Highlight
Total production (kg)	$X_3$	7.141***	4.684	0.001	4.895	Formatted: Highlight
Farming experience of farmers (years)	$X_4$	-10.086*	2.426	0.078	8.642	Formatted: Font: Bold, Highlight
Selling price (Tk./kg)	$X_5$	1.095	1.998	0.614	6.586	Formatted: Highlight
Weather dummy	$X_6$	0.913	1.241	0.741	6.395	Formatted: Font: Bold, Highlight
Labor dummy	$X_7$	-0.004**	-1.583	0.047	6.363	Formatted: Highlight
Transportation dummy	$X_8$	-0.035**	-3.851	0.002	5.291	Formatted: Font: Bold, Highlight
Storage dummy	$X_9$	-0.039**	-1.738	0.045	4.568	Formatted: Highlight
Training dummy	$X_{10}$	1.557	0.916	0.231	8.693	Formatted: Font: Bold, Highlight
Distance dummy	$X_{11}$	-0.737**	-0.874	0.039	7.547	Formatted: Highlight
Market place dummy	$X_{12}$	2.401*	0.958	0.074	5.626	Formatted: Highlight
Number of observations			160			
$R^2$			0.76			
F (160, 12)			22.483***			

Source: Authors estimation, (2020)

Note: \*\*\*, \*\*, and \* denote 1%, 5% and 10% level of significance, respectively.

### 3.4 Problems Faced by Lemon Farmers

Table 4 shows the problems that lemon farmers face in the study area. The ten problems identified by the respondents were rated according to their severity. The observed PFI ranged from 216 to 445, compared to a possible range of 0 to 480. Based on PFI, the most severe problem for lemon farmers was a lack of storage facilities, followed by overproduction and supply during the peak season, a lack of quality seed, high input prices, disease infection, insect infestation, and so on. Our findings support the findings of Devkota *et al.* [33](2014), who argued that the absence of cold storage and insufficient packing facilities had a substantial impact on fruit post-harvest losses in Nepal. Similarly, Zenebe *et al.* [34](2015) and Dessalegn *et al.* [32](2016) identified storage conditions and transportation methods are both key factors in the post-harvest losses of bananas and fruits in Ethiopia. Furthermore, Usall *et al.* [37](2016) emphasized cold storage in their study of physical treatments for post-harvest disease prevention of fresh fruits and vegetables. This type of

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storage helps to preserve the physical integrity of fruits and vegetables while also lowering the risk of microbial contamination.

**Table 4: Rank of problems faced by lemon farmers**

Problems	The extent of problems faced				PFI	Rank
	High problem (3)	Medium problem (2)	Little problem (1)	No problem (0)		
Absence of storage facilities	133	19	8	0	445	1
Overproduction and supply in the peak season	118	33	9	0	429	2
Lack of quality seed	122	27	8	3	428	3
High prices of inputs	114	39	7	0	427	4
Infected by diseases	101	56	3	0	418	5
Infested by insect	93	51	16	0	397	6
Lack of technical support	98	35	22	5	386	7
Lower prices of output	74	52	24	10	350	8
Damage due to different reasons	47	53	51	9	298	9
Shortage of labor during harvesting	18	63	36	43	216	10

Source: Authors estimation, (2020)

#### 4. CONCLUSION AND RECOMMENDATIONS

Determining the processes and reasons for lemon post-harvest losses is critical to improving lemon post-harvest management and, as a result, increasing lemon growers' profitability in Bangladesh. Each year, a large amount of harvested lemon damage is documented at the farm level in Bangladesh, some of which is because of complete damage and some of which is due to partial damage. The highest prevalence of complete and partial damage occurs during the sorting and grading of lemons from the farm to the rural and urban market, followed by storage and transportation stages. Post-harvest factors that influence the superiority of lemons after harvest include the total production, labor, transportation, storage, distance, market place, and farming experience of farmers. Therefore, to reduce post-harvest losses, farmers can use a variety of post-harvest technologies and techniques, such as modes of transportation, packaging, grading, sorting, and so on. Farmers, on the other hand, must work extremely hard during peak periods to obtain a higher profit margin because the price is considerably lower than the profit margin. In addition, the absence of storage facilities, overproduction, and supply of lemon in the peak season, lack of quality seeds, high prices of inputs, infection by diseases, and infestation by the insect, resulted in a large financial loss in lemon production every year.

The following policies/suggestions should be implemented to minimize the post-harvest losses of lemon at the farm level in the study area:

- To improve the efficiency and knowledge of farmers and traders, an adequate training program on various post-harvest operations such as handling, grading, packaging, and carrying should be offered.
- Storage facilities should be developed to ensure that their product is sold at a reasonable price. Private entrepreneurs should step up to create storage facilities in key fruit-producing areas as well as other wholesale and retail markets places. Facilities for storing unsold fruits at the market for one to two days should be established.
- The establishment of various feeder roads should be used to develop the transportation and communication infrastructure. Farmers and intermediaries will be able to move fruits from the farm to a local market or a larger market where they will expect to acquire a higher price for their lemon.
- Proper pre-harvest management to reduce losses due to good plant quality, following a good set of practices, employing trained workers, proper harvesting and packing methods, loadings, and so on.
- A detailed assessment of post-harvest losses must be conducted throughout the whole production and marketing chain in order to identify important gaps and corrective actions.
- Developing a post-harvest infrastructure support base will improve safety, quality maintenance, on-time supply, and reduce handling costs and losses.
- Providing appropriate post-harvest information to the farmers and they should be increasingly relying on that post-harvest information management to stay on top of market demands, as well as labeling and traceability standards. Also, to remain competitive resource-poor farmers in international markets, infrastructure facilities, and local skills must be created.

#### **ETHICAL APPROVAL**

This article is original and contains unpublished materials. The corresponding author confirms that both authors have read and approved the manuscript and no ethical issues are involved.

#### **COMPETING INTERESTS DISCLAIMER:**

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly used products in our area of research and country. There is no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge.

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#### **Authors' Contributions**

**Maimuna Begum:** Planned, collected, scrutinized, and tested the data; and organized the draft manuscript.

**Maimuna Begum and Bibi Marium:** Jointly harmonized, reviewed, supervised the draft manuscript, and approved the final manuscript. Also contributed to the literature search, and data interpretation, and reviewed the draft manuscript.

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#### ACRONYMS, ABBREVIATIONS

BBS	: Bangladesh Bureau of Statistics
FAO	: Food and Agriculture Organization
et al.	: Et alia (l.) and others
etc.	: Etcetera
i.e.	: That is
e.g.	: For example
Kg.	: Kilogram
Tk.	: Taka (Bangladeshi Currency)
%	: Percentage