This study aims to analyze the supply chain of potatoes and determine the factors affecting postharvest losses of potatoes at the producer level of Bangladesh. Data were collected through a face-to-face interview schedule from a sample of total 60-30 farmers, 6 wholesalers, 5 aratadars, 5 retailers, and 14 consumers in Sirajdikhan and Sadar Upazila of Munshiganj district. Descriptive statistics (percentages, frequencies, etc.) and multiple linear regression analysis were used for this study. The result shows that channel 4 is the longest marketing chain in the study area which includes the marketing actors – farmers, aratadars, wholesalers, retailers, and consumers. In the supply chain of potatoes, the amount of postharvest loss is 6.6% for the producer’s level, 5.3% for the wholesale level, 1.10% for the aratadar level, and 2.1% for the retailer level in the study area. The regression model reveals that age and amount of production have a significant positive relationship, while experience has a significant negative relationship with the postharvest losses of potatoes. The study also shows that lack of storage facility (48.94%) and poor packaging system (32.73%) are the major reasons for occurring postharvest losses of potatoes. The farmers and intermediaries suggested that it is necessary to identify the maturity stage of potatoes at harvesting time (70%), improve the cold storage facility (56.67%), and improve the loading and unloading system (56.25%), etc. for reducing postharvest losses of potato.

Keywords: Bangladesh, Postharvest Loss, Potato, Supply Chain.

I. INTRODUCTION

As an agro-based country, the potato is one of the most important agricultural crops in Bangladesh [1]-[5]. It is not only used as a vegetable but also as a cash crop [6], [7]. After rice and wheat, potato is cultivated as the third most important food crop in the world in terms of human consumption [8]-[11]. In the Indian sub-continent, the cultivation of potatoes was probably started during the 17th century [11]-[13] and in Bangladesh, it was introduced in the late 19th century [9], [14]–[18]. Production of potatoes has been increased day by day due to the geographical suitability [3], [19]-[21] and the demand of lower-income people of Bangladesh [17], [22]-[24]. According to BBS [25], 9655 MT potato was produced and per acre, potato yield was 3376 Kg in the fiscal year (FY) 2018-2019 in Bangladesh. For this tremendous production, Bangladesh was ranked sixth among other countries in potatoes production [26]. As rice and wheat are the main food crops of Bangladesh; however, their production is not sufficient to meet the increasing requirements of the growing population. Bangladesh imports 10 million food grains during FY 2017-18 [27]. An adequate supply of potatoes stabilizes the vegetable market all-round the year [16]. Otherwise, the government of Bangladesh wants to promote eating potatoes instead of rice, to reduce continuous pressure on rice [28], [29]. Not only the production of potato but also its many-fold uses (making gum, starch for adhesives, for processing ink, dyes, toys, soap, leather processing, and production for bioethanol, etc.) has increased over the last few years in Bangladesh [6], [30]-[32].

Though the diversified use and huge production of potatoes, the producers are faced with many problems. Sometimes a long supply chain and middlemen are the obstacles to potato price instability [32]. In Bangladesh, about 81% of the total potatoes produced are harvested from January to April but only 28% of those potatoes are demanded during this period. Thus, it creates a surplus of 53% of ware potatoes, which have to be used or stored over the next 6 months [9], [33]. Some losses occur during post-harvest operations which are called post-harvest losses [34]. There are post-harvest losses of potatoes at different levels such as – losses at the farm level (harvesting loss, curing loss, sorting loss, pre-storage loss), losses at the storage level (home storage loss, cold-storage loss), losses at handling and transporting, etc. There are many factors that are responsible for postharvest losses. Potato is characterized as a perishable

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product. Due to its perishable characteristics and bulkiness, proper and effective post-harvest technology is critical to the entire supply chain system of the potato [33].

However, most of the studies on potatoes are conducted from the value chain perspective in Bangladesh, and there are few scientific studies on the supply chain of potatoes through which potatoes reached from producer to ultimate consumer in the study area. It will also help to identify the causes of price variation or the rising price of potatoes and its probable solution. In Bangladesh, there is a lack of authentic data on postharvest losses of potatoes at different levels of postharvest operations [35]. And it helps to assess the quantitative losses and identify factors responsible for such losses. The present study is helpful to potato producers and to other supply chain actors (wholesalers, aratdars, retailers, and consumers) for increasing the return rather than losses from the production of potatoes. This may also enable policymakers, administrators, industrialists as well as researchers to carry out improvements in postharvest technologies that aim at minimizing the postharvest losses of potatoes. So, the study is aimed to analyze the supply chain of potatoes, determine the factors affecting postharvest losses at the producer level, and lastly, give some suggestions for reducing postharvest losses of potatoes in some selected areas of Bangladesh.

II. RESEARCH METHODOLOGY

A. Selection of Sample and Sample Technique

This study was conducted in the Munshiganj district of Bangladesh due to the availability of potato producers and traders in the study area. To fulfill the objective of the study, data were collected through a purposive sampling technique with a face-to-face interview schedule. 30 potato farmers were selected from the Batka, North Rangamalia, South Rangamalia, Ghatar char, and Bashaila villages of Sirajdikhan Upazila of Munshiganj district. A total of 30 actors-6 wholesalers, 5 aratdars, 5 retailers, and 14 consumers were selected from Sadar Upazila. In addition, two hats such as Bujarhati hat and the Bashaila hat were chosen from Sirajdikhan Upazila of Munshiganj district for the study.

B. Data Collection and Analysis of Data

Interview schedules were prepared on the basis of specific objectives of this study and schedules were pre-tested and finally prepared after careful modifications. Before taking actual interviews, the whole academic purpose of the study was clearly explained to the sample farmers, traders, and consumers. The analysis was done using SPSS.

C. Analytical Technique

Descriptive statistics like percentages, means, frequencies, etc. were used for the study. In addition to descriptive statistics, a multiple linear regression model of the following form was used to determine factors affecting postharvest losses of potatoes.

\[ L_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_n X_n + u \]  

where, \( L_i \) = Postharvest losses of potato measured in Kg for the \( i \)th household, and \( X_1, X_2, \ldots, X_n \) are the independent variables affecting postharvest losses. Specifically, for farmers, the following model was considered.

\[ L_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + u \]  

where,

\[ L_i \] = Postharvest losses of potato in Kg; \( X_1 \) = Educational level; \( X_2 \) = Type of storage facility; \( X_3 \) = Experience of household head in years; \( X_4 \) = Amount of production in Kg; \( X_5 \) = Age of the household head in years; \( D_1 \) = Dummy variable for the type of storage facility; \( D_1 = 1 \) if storage is rented, \( D_1 = 0 \) if storage is owned; \( u \) = Disturbance term; \( \beta_0 \) is a constant term (intercept) and \( \beta_1, \beta_2, \beta_3, \beta_4, \beta_5 \) are the coefficients to be estimated.

III. RESULTS AND DISCUSSION

A. Actors Involved in Potato Supply Chain

The study expresses that there is a movement of potatoes from the point of producers to the point of ultimate consumers through some actors such as farmers, wholesalers, aratdars, retailers, and consumers forming a chain of the potato market in the study area.

From Fig. 1, it is found that the potato in Munshiganj district is moved through the following channels:

Channel 1: Farmer → Consumer
Channel 2: Farmer → Wholesaler → Consumer
Channel 3: Farmer → Wholesaler → Retailer → Consumer
Channel 4: Farmer → Aratdar → Wholesaler → Retailer → Consumer
Channel 5: Farmer → Aratdar → Wholesaler → Consumer
Channel 6: Farmer → Aratdar → Retailer → Consumer

We see from fig. 1, channel 4 is the longest supply chain in which the major marketing actors are the farmer, wholesaler, aratdar, retailer, and consumer. Potato producers are the prime actor and play an important role in the potato supply chain. In the study area, the producers used to hand over potatoes to the market actors, such as wholesalers (58.27%), aratdars (34.09%), and consumers (1.04%) either at the markets or at the farmyard. The wholesaler purchase potato from the farmers (58.27%) and aratdars (50.35%) in the local market and sell it directly to retailers (53.92%) and consumers (40.78%) in the same market. And the aratdars sell potatoes to wholesalers (50.35%) and retailers (48.55%) in the study area. The retailers purchased potatoes from the wholesalers (53.92%) and aratdars (48.55%), and retailers sell his 97.90% quantity directly to the ultimate consumers at their retail shops. Most of the retailers are independently organized having fixed shops in the study area. There are some retailers who have no permanent shop usually use an open marketplace for their sales. Consumers are the last user of the potato supply chain. They purchase potatoes from farmers, wholesalers, and/or retailers. Only 1.04% of consumers directly purchase from the farmer in the study area (Fig. 1).
Fig. 1. Supply chain actors of potato in Munshiganj district (Source: Author’s estimation, 2019).

B. Postharvest Losses of Different Actors Associated with Potato Supply Chain

Potato is characterized as a perishable food item, and it contains a high amount of moisture which is about 75% [33]. Potatoes undergo a lot of physical and physiological changes during the whole process of harvesting, storage, handling, transportation, and marketing, resulting in a deterioration of quality and loss of weight [9], [35]. We can also understand it from Fig. 1.

Fig. 2. Postharvest losses of different actors in the potato supply chain (Source: Author’s estimation, 2019).

Fig. 2 represents the amount of postharvest losses of different intermediaries in the potato supply chain. The amount of postharvest loss of producers is 6.60% which is the highest loss of potato among the potato supply chain actors in the study area. However, the wholesaler has 5.30%, the aratdar has 1.10% and the retailer has a 2.1% postharvest loss of potatoes in the study area.

C. Major Reasons for Occurring Postharvest Losses of Potato

The major reasons for occurring postharvest losses of potatoes are considered in this study. The major reasons for postharvest losses of potatoes include lack of storage facilities, rain at harvesting time, poor packaging system, loading and unloading problem, poor arrangement during transportation, etc. in the study area.

Fig. 3. Major reasons for occurring postharvest losses of Potato (Source: Author’s estimation, 2019).

Fig. 3 shows that the highest (48.94%) amount of loss occurs for lack of storage facility in the study area. Most of the growers store potatoes in the home following the traditional method. They use an earthen floor and/or Macha.
(bamboo or wooden made platforms) for storing potatoes and they don’t use any other extra storehouse to store the potato due to extra cost in the study area. Hossain & Miah [35] reported that there is a high amount of postharvest losses of home stored and cold-stored potatoes in Bangladesh. In Peru, postharvest losses of traditional storage of potatoes are very high [36].

About 32.73% loss occurs due to a poor packaging system in the study area. Packaging is an important postharvest handling step for long-distance transportation and storage of vegetables. Good packaging must cope with long-distance transportation, multiple handling, and changed conditions of storage, transport, and marketing [37]. Kader [38] stated that the level of postharvest loss could be greater due to the use of contaminated field packages, dirt water for washing produce before packing, decaying, rejected produce lying around the packing area, and unhealthy produce contaminating healthy ones in the same package. However, 17.63% loss occurs for rain at harvesting time, 0.506% loss occurs for loading and unloading problems and 0.203% loss occurs for poor arrangement during transportation in the selected areas.

D. Producer Level Determinants of Postharvest Loss

Analysis of factors affecting postharvest losses of potatoes at different stages of the supply chain identified factors constraining postharvest losses of potatoes. The analysis was done for the producer level. A multiple linear regression model was employed to identify the determining factors. Hence, multicollinearity detection tests were performed using appropriate test statistics. In the model, the maximum VIF (1.720) indicates no serious multicollinearity as it is away from the threshold VIF of 10 [39].

Five explanatory variables were hypothesized to determine the postharvest losses of potatoes at the producer level. However, three explanatory variables are the age of the producer, experience of the producer, and amount of production were found to be significant at 5%, 10%, and 1% respectively which affect the postharvest losses of potatoes. Among them, the age of the producer and the amount of production had a positive relationship, and experience had a negative relationship with the postharvest losses of potatoes (table 1). Here, R² = 0.733 which indicates that 73.3% of the variance of the postharvest loss of potatoes is explained by the variance of its independent variables (age, education level, experience, amount of production, type of storage facility). Age is a significant variable determining postharvest losses of potatoes and has a positive relationship with postharvest loss. The possible reasons for it could be when people have a longer age, they can’t do the work efficiently. Their physical condition is another obstacle that may increase postharvest loss.

However, there is a negative effect of educational level on potato postharvest loss. If the producers are educated, they are able to take different training programs and know the benefit to use modern cultivation tools and techniques. An educated farmer has the capacity to properly maintain, handle, and reduce the loss. Besides, experience is one of the significant variables determining postharvest losses of potatoes. It has a negative relationship with postharvest loss. With more experience in what they have been doing over a long time horizon, they may have the potential to use a technique that may reduce postharvest loss, and also they are believed to be wise in resource use as compared to their fellow farmers.

There is a significant and positive relationship between the amount of production and postharvest losses of potatoes. The possible reasons could be when the producer produces a larger amount, the amount of postharvest loss will be increased relatively. The type of storage facility at harvesting time is found to positively affect postharvest loss. The implication is that if the producer sells their production at the harvesting period, then the postharvest loss will become low. When the producer doesn’t sell all of the amounts and stores some amount, then the amount of postharvest loss will be increased. This loss will have occurred for several reasons like inadequate electricity supply, traditional storing method, improper loading and unloading system, etc.

E. Suggestions to Improve Postharvest Loss of Potato

Suggestions about postharvest losses of potato from different supply chain actors are very important to identify the improvement of the postharvest situation in the supply chain of potato. The suggestion for reducing postharvest loss differs from person to person in the study area.

1) Suggestions made by the producers to reduce postharvest loss of potatoes

Fig. 4 shows that 70% of farmers suggested that to reduce the postharvest loss, maturity assessment at harvesting time is very important. The first step in the postharvest handling process is assessing maturity. Picking the potato at the appropriate maturity stage help to reduce the loss. About 56.67% of farmers suggested that to improve the cold storage facilities which are very effective in reducing the amount of loss. Cold storage is helpful in lengthening the timeframe for the marketing of potatoes. It is mentioned to careful handling is very useful to reduce the amount of postharvest loss by 40% of farmers.

Using modern technology in the harvesting period is suggested by 36.67% of producers. Modern technology has a great impact to avoid injury and reduce postharvest loss. About 30% of producers suggested that transportation facilities should be improved to reduce the postharvest losses of potatoes. Besides, controlled fertilizer and pesticide price is very important to reduce postharvest loss of potato which is suggested by 16.67% of farmers. A good combination of

Fig. 4. Suggestions made by producers to reduce postharvest loss of potato
(Source: Author’s estimation, 2019).

Assessment of maturity stage at harvesting time
Increasing cold storage facility
Avoid careless handling
Using modern technology at harvesting period to avoid...
Improve transportation facility
Controlled fertilizer and pesticide price

0.00% 20.00% 40.00% 60.00% 80.00%
fertilizer and pesticide help to reduce insect and pest attack. And as a result, less damage has occurred.

### TABLE I. FARM-LEVEL DETERMINANTS OF POSTHARVEST LOSS OF POTATO

| Variables                  | Coefficient | Standard error | t-value | P-value | VIF |
|----------------------------|-------------|----------------|---------|---------|-----|
| Age                        | 0.2908*     | 8.518          | 2.141   | 0.043   | 1.655 |
| Educational level          | -0.062      | 17.152         | -0.056  | 0.563   | 1.006 |
| Experience                 | -0.234*     | 12.489         | -1.695  | 0.103   | 1.720 |
| Amount of production       | 0.782***    | 0.009          | 5.880   | 0.000   | 1.591 |
| Type of storage facility   | 0.084       | 187.907        | 0.622   | 0.540   | 1.650 |
| Constant                   | -183.137    | 331.172        | -0.553  | 0.585   | -     |

R²= 0.733

Note: * indicates significant at 10% level; ** indicates significant at 5% level; *** indicates significant at 1% level; VIF (Variance Inflation Factor) is a measure of the amount of multicollinearity in a set of multiple regression variables [40].

2) Suggestions made by the traders to reduce postharvest loss of potato

Fig. 5 shows that 56.25% of traders want to improve the loading and unloading problem. In the time of loading and unloading, the loss occurs. About 43.75% of traders stated that ensuring proper shorting and grading helps to reduce postharvest loss. It is suggested to upgrade the packaging system to reduce postharvest loss by 18.75% of traders and to increase cold storage facility by 31.25% of traders. About 43.75% of traders stated that to reduce the postharvest loss of potatoes, transportation facilities should be improved.

| Suggestions                  | Improvement |
|------------------------------|-------------|
| Improve transportation facility | 43.75%      |
| Increasing cold storage facility | 31.25%      |
| Upgrading the packaging system | 18.75%      |
| Ensure proper sorting and grading | 43.75%      |
| Improving loading and unloading problem | 6.25%      |

Fig. 5. Suggestions made by traders to reduce postharvest loss of potato. (Source: Author’s estimation, 2019).

IV. CONCLUSIONS

Potato is a source of nutrients and also a source of cash income for farmers. A large number of people are involved in the supply chain of potatoes. Expanded potato cultivation can upgrade the living standard of the actors in the supply chain. Based on the findings of the study, it can be concluded that considerable scope exists to increase productivity and reduce the amount of postharvest losses of potatoes. Moreover, there is a scope to develop the supply chain of potatoes. However, the farmers and actors could certainly be benefited financially if the production and supply system of potatoes are well developed. And a well-developed supply system is helpful to reduce the postharvest loss of potatoes. Government intervention in potato marketing is necessary to ensure a fair price. The numbers of middlemen need to be reduced by eliminating unnecessary actors from the chain so that farmers can get a fair price to cover their costs and make a profit. After the harvesting period, storage of potatoes is very crucial for the potato cultivators, because they do not get a reasonable price at the harvesting period. Storage of a huge amount of potato at the household level is quite impossible. For this reason, national and regional potato storage capacity should be enhanced by establishing more cold storage. Besides, an adequate supply of inputs such as fertilizers, seed, irrigation, etc. has to be ensured to the farmers. The constraints encountered by actors also need to be effectively addressed that would greatly help in reducing post-harvest losses of potatoes.

CONFLICT OF INTEREST

The authors declare that they do not have any conflict of interest.

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