# Post Harvest Losses and Technical Efficiency of Potato Storage Systems in Bangladesh

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**This study was carried out with the support of the**

NFPCSP

**National Food Policy Capacity Strengthening Programme**

USAID FROM THE AMERICAN PEOPLE

June 2009

This study was financed under the Research Grants Scheme (RGS) of the National Food Policy Capacity Strengthening Programme (NFPCSP). The purpose of the RGS was to assist in improving research and dialogue within civil society so as to inform and enrich the implementation of the National Food Policy. The NFPCSP is being implemented by the Food and Agriculture Organization of the United Nations (FAO) and the Food Planning and Monitoring Unit (FPMU), Ministry of Food and Disaster Management with the financial support of EU and USAID.

# EXECUTIVE SUMMARY


1. Appropriate and efficient post-harvest technology and marketing are critical to the entire production-consumption system of potato because of its bulkiness and perishability. Unlike in temperate regions, in Bangladesh the potato is harvested in the beginning of summer. Due to inadequate cold storage facilities to hold the produce for longer periods, large quantities are spoiled before they could be consumed. Consumers are also unable to develop a habit of consuming more potatoes because potato stocks disappear from the market within a few months of harvesting and in the later part of the year the relative prices of potato are high. Therefore, it needs both short and long-term storage of potato. After harvesting, a series of operations need to reach in the consumers' table termed as post-harvest operations. During these operations, some losses occur called post-harvest losses. Therefore, it is necessary to quantify the post-harvest losses of potatoes in different post-harvest operations like harvesting, cleaning, grading, bagging, transportation, processing and storage. Also it is important to assess the technical efficiency of cold storage systems for policy making regarding food security of Bangladesh. The objectives of the study were (i) to find out different storage systems of potato in Bangladesh; (ii) to quantify post-harvest losses of potato at different post-harvest operations and to identify the factors responsible for post-harvest losses; (iii) to measure the technical efficiency of cold storage for storing of potatoe; and (iv) to make some policy guidelines for reducing post-harvest losses and to increase storage systems of potato for food security.

2. Six major potato growing districts namely Comilla, Jessore, Munshiganj, Bogra, Rajshahi and Thakurgaon were selected for this study. A total of 940 respondents were randomly selected for collecting primary data and information. Among total respondents, 300 potato farmers, 40 cold storage managers, 360 potato traders (60 *Bepari*s (big trader), 60 *Faria*s (petty trader), 60 *Aratdar* (commission agent), 60 *Paiker*s (wholesaler), and 120 retailers), and 120 potato consumers (60 households and 60 restaurant owners) were randomly interviewed using four sets of pre-tested interview schedules.

3. Disposal pattern of potato at farm level was calculated. About 2.92% potato was used for family consumption, 0.52% was gifted to relatives or others, 62.04% was sold during harvesting period, 12.73% potato was stored in cold storage as seed and another 23.04% (cold storage 19.70% and home storage 3.34%) was stored as table potato and sold it later when price became high. Average harvesting loss in all areas was found to be 5.65% of total production. Harvesting loss comprised insect damage (1.21%), rotten

loss (1.40%), cutting loss (1.14%), potato remained under soil during harvesting (0.89%), and other losses (1.02%) such as off size, green potato etc. Farmers stored 3.34% of potato in traditional storage for a period of 3 to 4 months. In this period the storage loss was found to be 7.35%. Total pre-storage loss (harvesting, curing, cleaning and sorting) at farm level was 8.15% and total postharvest loss was found to be 15.50 including farm level storage loss.

4. Cold storage users use two chains to avail the facility of storing potato in cold storage such as through agent and without agent. In Comilla and Munshigonj, cold storages were over loaded (103%) but in other study areas capacity utilization was below the capacity limit. The average capacity utilization in all areas was 93.49%. The average loss in cold storage during nine months storage period was 3.82% of total potato stored. This loss included the weight loss (57%), spoilage loss (34%) and other loss (9%) caused due to sprouting, shrinkage, cold injury etc. Load shading, storing of unsorted potato, overload of storage bag are the main problems in cold storage operation.

5. Two different types of potato marketing were identified- traditional stored and cold stored potato marketing. In the case of traditional stored potato, *Bepari* and *Faria* bought potatoes from farmer. The share of purchasing potato by *Bepari* (60.9%) was higher than the *Faria* (36.2%). *Bepari* bought a large amount of potatoes from farmers and directly sold to *Paiker* (38.9%), retailers (26.2%) and *Aratdar* (21.6%). Similarly, *Faria* bought potatoes directly from farmers and mostly sold them to *Bepari* (25.8%) and a small portion (10.4%) to retailer through *Aratdars*. *Paiker* bought a major portion of potato directly from *Bepari* (38.9%) and a very small amount from farmers (2.1%). They also bought a good amount of potatoes (20.9%) from *Faria* and other *Beparis* through *Aratdars*. *Paikers* sold their entire potatoes directly to the retailers. Retailers sold their whole quantity (100%) of potatoes to consumers. For cold stored potato marketing, *Bepari* and *Paiker* bought potatoes from cold storage (farmer/Stockiest). The share of purchasing potato by *Bepari* (73.2%) was higher than the *Paiker* (24.4%). *Paiker* also bought some potatoes (1.8%) from *Bepari*. *Aratdar* bought all of his potatoes of *Bepari*) from *Bepari* and sold 42.1% to the *Paiker* and 29.3% to the retailer. *Paiker* sold maximum amount (68.1%) of potato to retailer and a very small quantity to directly to consumer (0.2%). Retailer sold his whole quantity of (100.0%) but 99.8% of the channel of potatoes to the consumers. The average loss at traders' level for traditional and cold stored potatoes were 11.95 and 9.61%, respectively.

6. Average post-harvest losses in the household and restaurant levels were 3.24, and 4.52%, respectively of purchased potato. This loss comprised rotten loss and processing loss. Total losses of traditional stored potatoes including consumers' loss were found to be 27.65% where for cold stored potatoes it was 23.11%. Total losses excluding consumer losses for traditional stored and cold stored potatoes were found to be 24.61 and 19.90%, respectively.

7. A number of variables included in the Cobb Douglas Production models for estimating the coefficients of post-harvest losses of potato in cold storage. For post-harvest loss in clod storage, the coefficients of electricity and relative humidity in the cool room were negative and significant at 5% level. The influence of outside temperature on potato losses was positively significant at 5% level. The coefficients of pre-cooling time, good bag used, maturity of stored potato, and number of bag per stack were found negatively significant at 10% level.

8. The estimated maximum, minimum and mean technical efficiencies of cold storages were 99, 73 and 91%, respectively. Total nine independent variables were used in the model and out of them, five were found significant. The coefficients of daily maximum outside temperature and percent of good bag used for packing and storage of potato were both significant at 1% level. Electricity supply and relative humidity inside the store were found to be positive and significant at 5% level. Maturity of stored potato was found significant at 10%. The coefficients of other variables such as pre-cooling period, number of inversion during storage, and storage period were insignificant but they had positive responses on the production of good potato. The increase of mangers' experience would reduce the inefficiency of the model as well as increase the production of good potato. Training and type of storage floor were positively significant at 10% level. The coefficient of the type of power supply and age of cold storage had some positive effects on the inefficiency model but these were found insignificant. This model is recommended for efficient management of cold storage in Bangladesh.

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# Acronyms

| | |
|---|---|
| BADC | Bangladesh Agricultural Development Corporation |
| BBS | Bangladesh Bureau of Statistics |
| BARI | Bangladesh Agricultural Research Institute |
| FAO | Food and Agricultural Organization |
| GDP | Gross Domestic Product |
| ha | Hectare |
| kg | Kilogram |
| km | Kilometer |

# 1. Introduction

## 1.1 World Potato Production

Potato (*Solanum tuberosum* L.) is one of the most important food crops grown in more than 100 countries in the world (www.npcspud.com/history.htm). Over one billion people consume potato worldwide and it is the staple diet of half a billion people in developing countries. Potato ranks fourth in the world (325.30 million tons) and third in Bangladesh (8.0 million tons) with respect to food production. Because of the dry matter, edible energy and edible protein content, potato is considered nutritionally a superior vegetable as well as a versatile food item not only in our country but also throughout the world. Potato is a pershable comodoty and contains about 75% water. Nutritionally, the potato is the best known for its carbohydrate content (approximately 26 grams in a medium potato). It is a high energy food contains about 80 kcal per 100 grams of fresh potato. The potato contains vitamins and minerals that have been identified as vital role to human nutrition, as well as an assortment of phytochemicals, such as carotenoids and polyphenols. The fiber content of a potato with skin (2 g) is equivalent to that of many whole grain breads, pastas, and cereals (Potato in India , 1992).

World's potato production is increasing steadily. Until the early 90's, most potatoes were grown and consumed in Europe, North America and former Soviet Union. Since then, there has been a dramatic increase in potato production in Asia, Africa and Latin America. In the early 60's potato production was less than 30 million tons and increased to more than 165 million tons in 2007. FAO data show that in 2005, for the first time, the developing countries potato production exceeded that of developed countries. The comparative potato productions of developed and developing countries during 1991-2007 are shown in Fig. 1.1. In 2007, world's potato production was 325.30 million tons in which the share of developed and developing countries were 49 and 51%, respectively (www.potato2008.org/eng/world/index.html). Per capita potato consumption is the highest in Europe and the lowest in Africa. The world's per capita potato consumption in different regions of the world is given in Fig. 1.2. Africa, Asia and Latin America consume less potato than world's average consumption. Now the production trend of potato in the developing countries is increasing day by day.

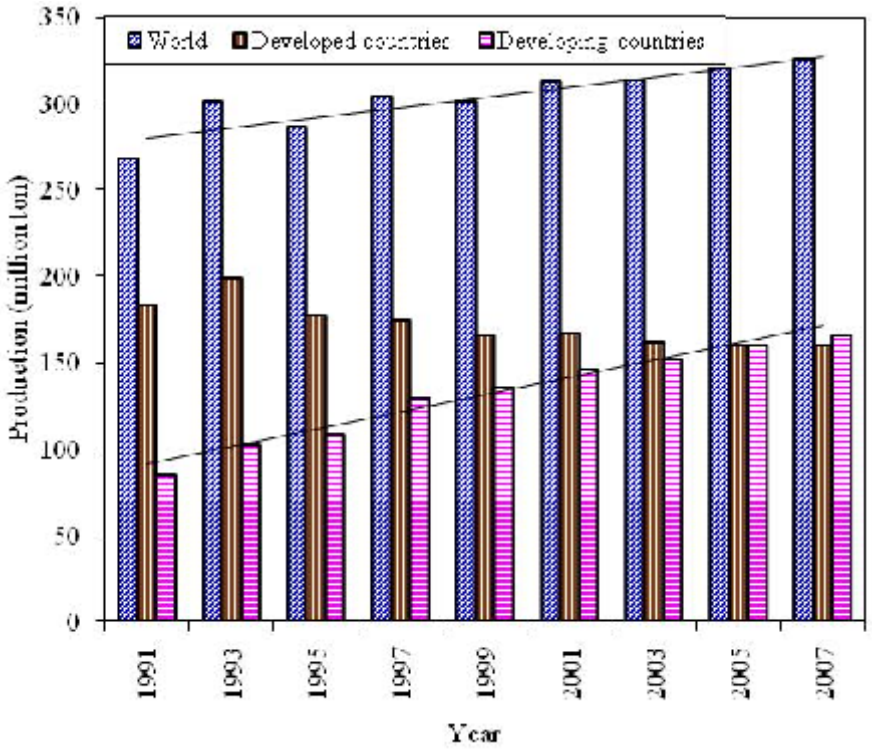



**Fig. 1.1 World potato production from 1991 to 2007 (*Source*: www. potato2008.org/ eng/world/index.html)**

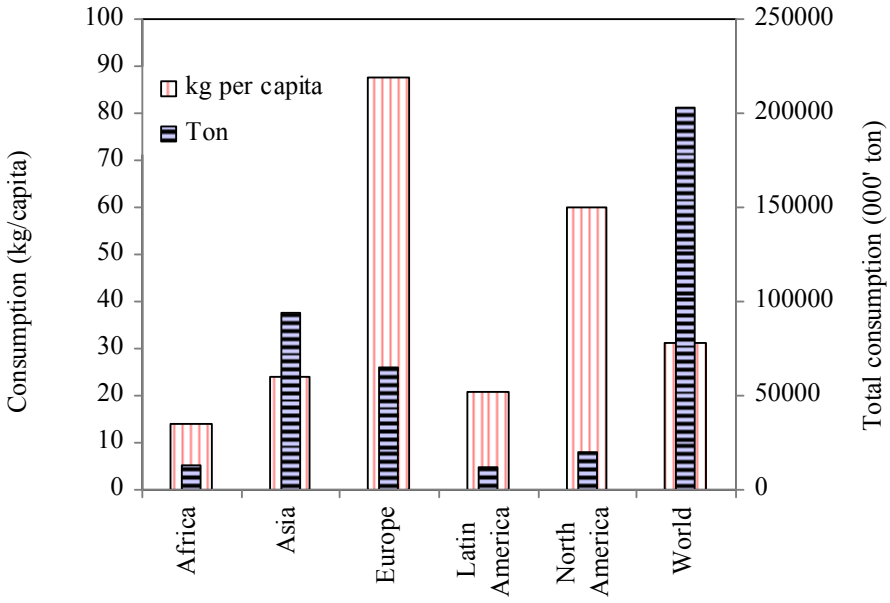



**Fig. 1. 2 Annual per capita potato consumption in different regions of the world (*Source*: www. potato2008.org/eng/world/index.html)**

### 1.2 Potato in Bangladesh

Potato was introduced in this subcontinent in the sixteenth century. It was grown then in small plots as a vegetable. Potatoes have been grown in Bangladesh since at least the 19th century. By the 1920s, the first commercial production of the crop was established in the country (Islam, 1983). Agronomic research on potato dates late 1950s when limited variety trials were started by the Bangladesh Agricultural Research Institute (BARI). Research expended through the 1960 to include fertilizer applications, seed degeneration, mulching, planting techniques and storage (Ahmad, 1977). In 1967-1968 the Bangladesh Agricultural Development Corporation (BADC) launched a project for the multiplication and distribution of high quality seed potatoes (Ahmad, 1977). Now, potatoes have become an increasingly an import crop in Bangladesh. From 1955 to 1985 the annual area planted to potatoes increased from 25,900 to 111,300 ha with an average annual growth rate of 10% (Scott, 1985). The expansion of production over the same period has been even stronger rising from 0.12 to 1.16 million tons at an average annual growth rate of 23% (Scott, 1985). The area and production of potato from 1971-1972 to 2005-2006 is shown in Fig. 1.3. For the introduction and adaptation of HYV potatoes and production technology, the area and production of potato sharply increased after nineties. Still now the area and production of potato is following increasing trend.

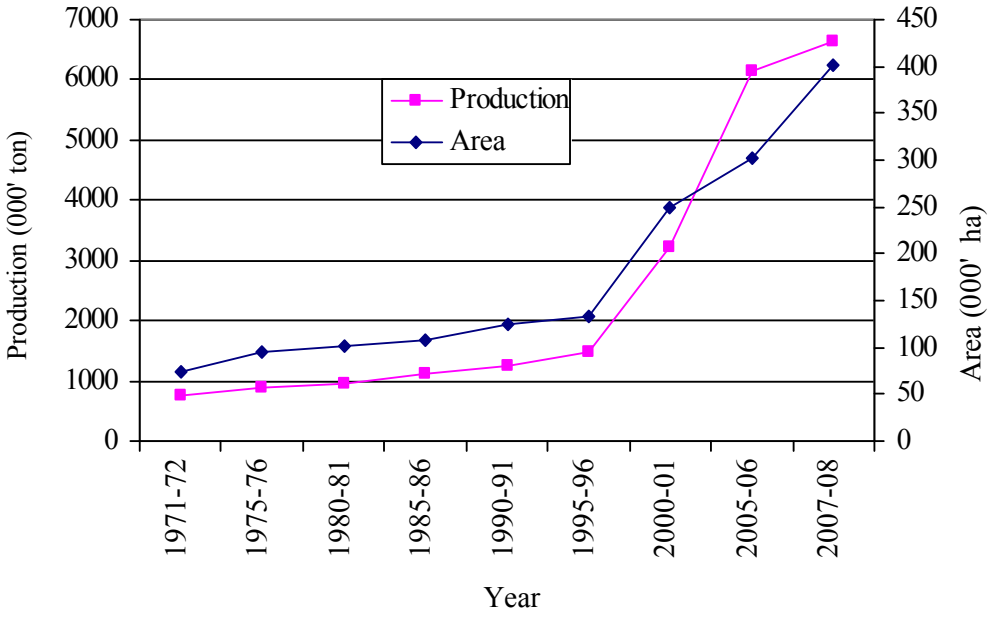



**Fig. 1.3 Trend of area and production of potato in Bangladesh from 1971-1972 to 2007-2008 (*Source*: BBS, 2008)**

Nowadays, potato has emerged as a major food crop in Bangladesh and is being cultivated throughout the country. The total production of potato is 6648 thousands tons from the area of 400 thousands hectares (BBS, 2008). Though Bangladesh has become a major potato producer in the SAARC countries, the status of this crop has remained vegetable in the country. The time has come now for all of us to understand and appreciate the role of potato that can play an important role in the present food situation of Bangladesh. One of the major problems faced by developing countries in general and Bangladesh in particular, is the ever increasing population. As per the current trend, the population in Bangladesh is expected to be around 172.9 million by the year 2020. In order to further increase agricultural production, the only option is to grow high productivity crops, like potato. We have been relying heavily on the major cereal crops- rice, wheat and maize to feed the ever increasing population in our country. Such an over dependence on cereals should be reduced gradually if we have to ensure food security, in the decades to come. Potato can help to widen the food supply base and thereby help to minimize the risk of serious food shortages in the tropics and sub-tropics. Potato, one of the most productive crops can play a significant role in ensuring foods security (http://agmarknet.nic.in/profile-potato.pdf). A developing country like Bangladesh needs not only the quantity of food but sufficient quantity and quality of a balanced nutritious food. It is a proven fact that if the food available provides balanced nutrition, the quantity of food intake is relatively low, e.g. in developed countries, where people consume balanced food and their dietary intake is relatively low in quantity. Whereas, in the developing countries the food availability is not well balanced, the quantity of dietary intake is higher because people tend to eat much cereals (mainly rice) to compensate for the poor nutrition. This results in greater demand for food and higher pressure on the limited land available to produce required quantity of food (Azimuddin *et al.*, 2009).

Potato is one of the main commercial crops grown all over the country. In Bangladesh, potato is mainly consumed as vegetable. Various other food items (*Singara, Samucha, Chop*, chips etc.) are also made from potato. Adequate supply of potato stabilises the vegetable market all round the year (Moazzem and Fujita, 2004). Recently, the government has been trying to diversify food habits and encourage potato consumption to reduce pressure on rice. So, potato is becoming an important food for food security in Bangladesh. In 2008, about 8 million metric tons of potatoes have been produced from 0.5 million hectares of land in Bangladesh. It is reported in different newspapers that

thousands of tons of potatoes are going to rot due to lack of adequate cold storage facility (http://en.ce.cn/World/Asia-Pacific/200805/06/t20080506_15373277.shtml). If this loss can be minimized, it will reduce the food shortage of Bangladesh to a great extent. Hence, potato may prove to be a useful tool to achieve the nutritional security of the nation.

### 1.3 Post-harvest Technology of Potato

Reducing post-harvest losses is one of the efficient approaches in the improvement of potato farmers' livelihood (Yang, 2000). The actual situations in the rural areas of Asian developing countries indicate that need for low-cost technology to produce, process and add-value, while maintaining quality of its products. Research on both technology and improvement in infrastructure is critical in reaching this goal (Skerritt and Greg, 2001). With respect to the role of post-harvest technology in the development of Asian economies, Tsubota (1999) noted that post-harvest technologies become more complex along with economic development. Technologies are generally more agricultural production and product-oriented during the early stages of economic development. In this phase, technologies are not sophisticated and post-harvest enterprises are small-scale, and post-harvest chains are short and simple. Technologies and systems become more complex with development, and at present, many Asian countries are somewhere in the middle stage (Tsubota, 1999). A broad range of potato products are processed and marketed mostly by small-scale producers or traders using less sophisticated technologies, while a few large enterprises use more advanced technologies in processing plants or treatment facilities to process produce for upstream markets.

In developing countries, post-harvest processing of potato is the major practice for adding value to this crop through traditional processing or modern technology. Most of the processing is done on a commercial basis as a business. Recently many potato chips industries have established in Bangladesh. There are other indigenous postharvest practices used for processing of potato in rural and peri-urban areas. These processing technology increases the income of the rural people. This greater enhance the use of potatoes during the harvesting season and reduce the pressure of storage of potato in cold storage. This may also enhance more consumption of potato as alternative food rather than cereals. The integration of traditional practice and modern technology also help both the farmers and the processing industries which tend to generate more jobs. Potato fries and chips can be processed using the traditional indigenous practices, varies from place to

place. In the hilly areas, the traditional practice is the major way of keeping the potato as staple. The technologies used for the traditional practices are simple, in most case, are still by manual or facilitated by very simple machines. Industrial processing with modern technology can be applied to potato starch processing, food processing, and manufacturing of alcohol, synthetic rubber, cellulose, rayon, perfume, glucose, amylose, and sugar syrup. New technology has developed in the developed countries to process potato into starch or modified starch for textile, foundry, iron-casting, electronic, paper-making, pharmaceutical, rubber and chemical industries (Tsubota, 1999).

The development of an agro-processing of agricultural commodities can generate employment in several ways. First, there is employment in the processing industries themselves. Second, there is employment in wholesale and retail trade, bringing raw materials from farms to processors and finished products from processors to consumers. Third, agro-processing can generate more employment by increasing the demand for the agro-commodity. This stimulates more farm production than would have been the case without agro-processing, creating more farm work. Finally, expansion of agro-processing creates employment in related industries, such as suppliers of machinery and other inputs to the processing enterprises (Lin and Zhang, 2003; Yang, 2000). The amount of employment generated from agro-processing also depends on the size of enterprise. Large-scale enterprises typically use more mechanized, capital intensive processing technology, which increases the amount of raw material processed per worker employed. Small-scale or household enterprises typically use more labor-intensive methods. For a given amount of raw material processed, the more labor-intensive enterprises will generate more employment, although each worker is less productive.

### 1.4 Post-harvest Loss of Potato

Potato is a living entity that is capable of respiring, transpiring (release water) and reproducing. Respiration is a key metabolic process that tubers undergo and this process allows the release of energy through the breakdown of stored carbon compounds, which in this case is starch. During this process the tuber generates heat, which becomes an important consideration for storage and transportation of potatoes. The need for refrigeration or cool temperatures during the post harvest life of the potato is to slow down the process of respiration and thereby maintain tuber quality. The potato tuber is also roughly made up of 75% water and 25% starch, and therefore is capable of losing the

internal water if subjected to low external vapor pressure or relative humidity (CIP, 2009). When potatoes lose excessive moisture they shrink and may become unmarketable. Sprouting will significantly increase water loss in stored and transported potatoes. Sprouting will also diminish the nutritive quality of the potato. Therefore, sprout inhibitors are required after potatoes pass their dormant phase (Shetty, 1998). Major causes of postharvest losses of potato are water loss, mechanical damage, physiological damage, diseases damage and insect damage (www.fao.org/docrep/008/a0185e/a01850c.htm). These losses occur during harvesting, sorting and cleaning, handling and packing, transportation, storage, distribution or marketing and processing.

Potato should be stored in a suitable environment to prevent weight loss, rot, shrinkage, sweetening, discolour and sprouting (Gottschalk and Christenbury, 1998). Additionally, seed potato needs to be stored to maintain its dormancy before planting to the next season. Storage losses are mainly caused by the processes like respiration, sprouting, evaporation of water from the tubers, spread of diseases, changes in the chemical composition and physical properties of the tuber. These processes are influenced by storage conditions. (Gottschalk, 1999). However, the storability of potatoes is already determined before the beginning of storage, by such factors as cultivar, growing techniques, diseases before harvesting, and maturity of potatoes at the time of harvesting, damage to tubers during lifting, transport and filling of the store (Rastovesky, 1987; Burton *et al*., 1992). Good storage should prevent excessive loss of moisture, development of rots, and excessive sprout growth. It should also prevent accumulation of high concentration sugars in potatoes, which results in dark-coloured processed products. Temperature, humidity, carbon dioxide and air movement are the most important factors during storage (Harbenburg *et al*., 1986; Maldegem, 1999).

The potato is a semi-perishable commodity. Appropriate and efficient post-harvest technology and marketing are critical to the entire production-consumption system of potato because of its bulkiness and perishability. Unlike in temperate regions, in Bangladesh the potato is harvested in the beginning of summer (Hussain *et al*., 2006). Due to inadequate cold storage facilities to hold the produce for longer periods, large quantities are spoiled before they could be consumed. Consumers are also unable to develop a habit of consuming more potatoes because potato stocks disappear from the market within a few months of harvest and in later part of the year relative prices of potato are high (Hussain *et*

*al*., 2006). Therefore, there is a need for both short and long term storage of potato. After harvesting, a series of operations need to reach in the consumers' table termed as post-harvest operations. During these operations, some losses occur called post-harvest losses (Ritenour, 2003). There are about 300 cold storages in Bangladesh with a capacity of 2.2 million tons. In the year 2008, about 27.5% of total production of potato was stored in the cold storage including seeds (Rashid, 2008). The rest were stored by the farmers using their traditional storage systems.

Post-harvest losses of vegetables are high as 20-50% in developing countries (Rashid, 2008). In India post-harvest losses of potato are 17% and in Pakistan these losses ranged 15-40% (Iqbal, 1996; Ilangantileke *et al*., 1996). But, in Bangladesh data on post-harvest losses of potato at different post-harvest operations are lacking. Therefore, it is necessary to quantify the post-harvest losses of potatoes in different post-harvest operations like harvesting, cleaning, grading, bagging, transportation, processing and storage.

### 1.5 Technical Efficiency of Cold Storage

The measurement of technical inefficiency has received renewed attention since the late eighties from an increasing number of researchers, as the frontier approaches to efficiency measurement have become more popular.

Frontier production functions were introduced and have been widely applied by different researchers. The stochastic frontier production function was independently proposed by Aigner *et al.* (1977), Meeusen *et al.* (1977) and Battese and Corra (1977), and there have been a vast range of applications in the literature. The model was originally defined for the analysis of cross-sectional data but various models to account for panel data have been introduced by Pitt and Lee (1981), Cornwell *et al.* (1990), Kumbhakar (1990), and Kumbhakar *et al.* (1991).

Cobb-Douglas stochastic production frontier approach is widely used for estimating the technical efficiency of crop production systems. Krasachat (2003) investigated the technical efficiency in rice farms in Thailand. In this study, the data envelopment analysis (DEA) approached and farm-level cross-sectional survey data of Thai rice farms in 1999. A Tobit regression was used to explain the likelihood of changes in inefficiencies by farm-specific factors. The empirical findings indicated a wide diversity of efficiencies from farm to farm and also suggested that the diversity of natural resourced has had an

influence on technical efficiency in Thai rice farms. A study was conducted to estimate technical efficiency obtained from both Data Envelopment Analysis (DEA) and stochastic frontier approach using household survey data for rice farming households in Vietnam. Technical efficiency was modeled as a function of household and production factors. The results from the deterministic, semi-parametric and parametric approaches indicated that among other things, technical efficiency was significantly influenced by primary education and regional factors. In addition, scale efficiency analysis indicated that many farms in Vietnam were operating with less than optimal scale of operation, especially in the central region (Vu, 2009).

Bakhsh and Ahmad (2006) estimated the technical efficiency in potato production by employing the Cobb-Douglas stochastic production frontier approach in Pakistan. The results indicated that potato farmers were 84% technically efficient, implying significant potential in potato production that can be developed. By shifting the average farmer to the production frontier, the average yield would increase from 8.33 tons per acre to 9.92 tons per acre using the available resources. Hossain *et al*. (2008) estimated the technical efficiency of potato production in Bangladesh. This study was carried out in three potato growing areas viz. Munshigonj, Bogra and Jessore covering 75 potato growers to measure technical efficiency and economic performance of potato production. The estimated results showed that the average level of technical efficiency among the sample farmers was 75%. This implies that given the existing technology and level of inputs the output could be increased by 25%. Training on the potato production, extension linkage and quality seed played a significant role in the technical efficiency of the potato production.

Cobb-Douglas production frontier model is not only used for crop production but also widely used for estimating the technical efficiency of various industries. Battese *et al.* (1993) and Battese *et al.* (1996) studied the frontier production function, considering four years of panel data for each of four districts of Pakistan and a modified Cobb-Douglas production frontier in which the models for the technical inefficiency effects of different industries in Pakistan. Battese and Coelli (1995) proposed a stochastic frontier production frontier for panel data, which has firm effects assumed to be distributed as truncated normal random variables, which are also permitted to vary systematically with time and in which the inefficiency effects are directly influenced by the number of variables. By using the same model, Taymaz and Saatci (1997) estimated the stochastic production frontier for

Turkish textile, cement and motor vehicle industries. A frontier production function studied by Ajibefun *et al.* (1996) applied time-varying inefficiency model using eleven years of data on rice production in prefectures in Japan. They suggested that the traditional average response function, which does not account for the technical inefficiency of production, is not an adequate representation of the data. Tzouvelekas *et al*. (1999) investigated the relative contribution of technical efficiency, technological change and increased input use to the output growth of the Greek olive-oil sector using a stochastic frontier production function approach applied to panel data. Technical efficiency was studied for manufacturing industries in Bangladesh using the stochastic frontier production function. Jafrullah (1996) studied the technical efficiency of 19 four-digit manufacturing industries of Bangladesh and concluded that the manufacturing industries of Bangladesh analyzed were not highly technical but efficient. Baten *et al*. (2006) investigated the technical efficiency of selected manufacturing industries of Bangladesh using a stochastic frontier production function approach. In this paper a feasible Cobb-Douglas stochastic frontier production function time-varying technical inefficiency effects, was estimated. Two alternative distributions were used to model the random inefficiency term: a truncated normal distribution and a half-normal distribution. The estimated average technical efficiency for four groups of industries of Bangladesh over the reference period was 40.22% of potential output for the truncated normal distribution, whereas it was 55.57% of potential output for the half-normal distribution.

Cold storage is a one type of agro-industry for storing fresh agricultural produce especially for potato storage. Cold storage has some characteristics of industries such as fixed establishment, machinery, workers, administration, input (potato). But it differs from industry in the sense that it does not change inputs into outputs of a different nature and the input-out system is not continuous. On the other hand, cold storage possesses some characteristics of biological production systems e.g. input seed (tuber), output (production) also tuber.

Different physical and biological factors are associated with cold storage to produce good quality of potato after storage of certain period. These inputs are social, financial, physical, environmental and biological. So, the management of a cold storage is a complex and difficult task. To estimate the efficiency, all of the factors are to be considered. It is necessary to identify the factors those have direct or indirect influence on the efficiency of

cold storage system. Therefore, the storage efficiency or technical efficiency of cold storage is needed to access to identify its lacking so that its efficiency can further be improved. The present study was, therefore, designed to measure technical efficiency of potato storage system in cold storage.

# Objectives

(i) To find out different storage systems of potato in Bangladesh.

(ii) To quantify post-harvest losses of potato at different post-harvest operations and to identify the factors responsible for post-harvest losses.

(iii) To measure the technical efficiency of cold storage for storing of potatoes.

(iv) To make some policy guidelines for reducing post-harvest losses and to increase storage systems of potato for food security.

# 2. Methodology

## 2.1 Selection of Study Areas

Six major potato growing districts namely Jessore, Comilla, Munshigonj, Bogra, Rajshahi and Thakurgaon were selected for this study. Two upazillas from each district including sadar upazillas were selected for field data collection. Sadar upazillas were selected for each of the district because most of the cold storages and big markets are situated in the district towns. The study sites were selected with the consultation of relevant agricultural offices. The list of the study areas is given in Table 2.1.

**Table 2.1. Selected study areas for primary data collection**

| District | Upazilla | District | Upazilla |
|---|---|---|---|
| 1. Jessore | i. Sadar | 4. Bogra | i. Sadar |
| | ii. Bagherpara | | ii. Shibgonj |
| 2. Comilla | i. Sadar | 5. Rajshahi | i. Sadar |
| | ii. Chandina | | ii. Poba |
| 3. Munshigonj | i. Sadar | 6. Thakurgaon | i. Sadar |
| | ii. Tongibari | | ii. Peergonj |

## 2.2 Sampling Technique and Sample Size

A total of 940 respondents were randomly selected for collecting primary data and information for the present study. Among total respondents, a total of 300 potato growing farmers taking 25 farmers from each upazilla were selected for interview irrespective of farm size (e.g. landless, small, medium, large, etc.).

A total of 40 cold storage managers were interviewed taking 6 to 8 managers from each district. On the other hand, a total of 360 potato traders taking 60 *Bepari*s (big trader), 60 *Faria*s (petty trader), 60 *Aratdar* (commission agent), 60 *Paiker*s (wholesaler), and 120 retailers were interviewed for gathering data and information regarding potato marketing and post-harvest losses. Interviews were also held with potato consumers both at household level and restaurant level for assessing post-harvest losses of potato. Hence, a total of 120 potato consumers at household level, taking 20 consumers from each upazilla, were randomly selected and interviewed. Again, 120 restaurant owners/managers taking 20 from each upazilla, were selected and interviewed for the study. The selected respondents and sample size are shown in Table 2.2.

**Table 2.2 Selected respondents of the study**

| Sl. No. | Respondent category | | No. of respondent | | |
|---|---|---|---|---|---|
| | | | Each Upazilla | Each district | Total |
| 1 | Cold storage manager | | - | 6-8 | 40 |
| 2 | Potato farmer | | 25 | 50 | 300 |
| 3 | Trader | (i) *Bepari* | 5 | 10 | 60 |
| | | (ii) *Faria* | 5 | 10 | 60 |
| | | (iii) *Aratdar* | 5 | 10 | 60 |
| | | (iv) *Paiker* | 5 | 10 | 60 |
| | | (v) Retailer | 10 | 20 | 120 |
| 4 | Consumer | (i) Restaurant owner/manager | 10 | 20 | 120 |
| | | (ii) Household | 10 | 20 | 120 |
| **Total sample size** | | | | | **940** |

### 2.3 Method of Data Collection

Four sets of pre-tested interview schedules were used for collecting data and information from potato farmers, potato traders (intermediaries), and potato consumers. Data and information were collected by both enumerators and MS students with the direct supervision of PI (Principal Investigator) and CI (Co-Principal Investigator) of the project. Enumerators were scientific assistant of local agricultural research station and senior scientific assistant of Agricultural Economic Division of BARI. PI and CI collected cold storage level data and information from the study areas. Secondary data were gathered from BBS, journal articles, research reports, and internet etc. Metrological data were received from the Metrological Stations from relevant districts or nearby districts.

### 2.4 Method of Estimation of Different Post-harvest Losses

Field data from different respondents (farmers, cold storage managers, traders and consumers) were collected on quantity basis and post-harvest losses obtained at different operations as well as different levels. The sampled potato farmers were asked through direct interviewing what quantity of potatoes they produced during 2008-09. Regarding post-harvest losses, farmers were asked how much quantity of potato was lost during each operation (harvesting, curing, sorting etc.). For example, during harvesting, 18 kg of potatoes were cut and the total production was 60 maunds[1] or 2400 kg. Thus the cutting loss was estimated as (18 × 100/2400) 0.75%. Similarly, other harvesting losses were estimated in terms of total production.

[1] 1 maund= 40 kgs

Farm level storage loss was estimated on the basis of the quantity of potato stored during the storage periods (3-4 months). Different types of storage losses were estimated similarly in terms of quantity of potato stored. In cold storage, potatoes were stored for maximum of nine months. Losses were estimated what quantity of potato lost during storage period in terms of total quantity of potato stored. During the total storage of period, percentage of storage loss was estimated as quantity of potato lost during storage period divided by quantity of potato stored multiplied by 100. Traders' levels losses were estimated the quantity potato lost during one week of trading in terms of potato bought in the same period. During interviewing, the traders (*Bepari, Faria, Paiker Aratdar* and retailer) were asked what quantity of potato bought and sold in one week. The different types of losses occurred during marketing of potato were estimated in terms of quantity bought in one week. Then the losses at different levels of traders at different marketing operations (transportation, handling etc.) were estimated in terms of quantity bought. Losses at consumers' level were also estimated on the basis of quantity lost in one week in terms of quantity bought in one week.

Post-harvest losses were also estimated for different types of losses such as weight loss, rotten or spoilage loss, insect damage, physical injury etc. The characteristics of different types of losses were explained to the respondents and they are asked to quantify the losses. Then the individual losses were calculated in term of total quantity and expressed in percentage. For the calculation of the total loss in terms of percentage it should be noted that the total cannot be taken as a sum to the percentages at each loss stage. Thus, if the preharvest loss, storage loss, losses in *Bepari*, *Faria*, *Aratdar*, *Paiker*, retailer and consumer levels were $z_1$, $z_2$, and $z_3$, .....,$z_8$, then total loss will be calculated as follows: $z_1 + (100 - z_1) \times z_2/100 + [100-(100-z_1) \times z_2/100] \times z_3/100 +$ .....

**2.5 Identification of Factors Affecting Post-harvest Loss of Potato**

The post-harvest loss of potato is likely to be influenced by different factors. In order to determine the influence of different factors on post-harvest loss of potato at cold storage level, the Cobb-Douglas production model was used for estimating the coefficients of these factors. The functional form of the Cobb-Douglas multiple regression model is as follows.

$$Y = aX_1^{b1}X_2^{b2}\ldots\ldots\ldots\ldots\ldots\ldots X_n^{bn}e^{ui}$$

For the purpose of the present empirical equation the Cobb-Douglas production function was converted into the following logarithmic (double log) form with the variables specified below.

$$LnY_c = Lna + b_1LnX_1 + b_2LnX_2 + b_3LnX_3 + b_4LnX_4 + b_5LnX_5 + b_6LnX_6 + b_7LnX_7 + b_8LnX_8 + b_9LnX_9 + b_{10}LnX_{10} + b_{11}LnX_{11} + U_i$$

Where,

$Y_c$ = Post-harvest loss in cold storage (kg)

$X_1$ = Electricity supply (h)

$X_2$ = Outside temperature (°C)

$X_3$ = Relative humidity in the cool room (%)

$X_4$ = Pre-cooling time (h)

$X_5$ = Good bag used (%)

$X_6$ = Capacity utilization (%)

$X_7$ = Inversion of bag (No.)

$X_8$ = Maturity of stored potato (%)

$X_9$ = Storage period (month)

$X_{10}$ = Bag per stack (No.)

$X_{11}$ = Floor type (wood = 1, other = 0)

$X_{11}$ = Age of cold storage (year)

$b_1, b_2 \ldots\ldots\ldots\ldots\ldots\ldots b_n$ = Coefficient of the representative variables

$U_i$ = Error terms.

**2.6 Model Description**

In this study we have considered the Stochastic Frontier Model to measure the technical efficiency of selected cold storage in Bangladesh. The framework assumes the existence of a best practice frontier corresponding to fully efficient operation in the industry under investigation. This frontier defines the maximum level of output that can be obtained from any vector of resource inputs in the absence of uncertainty. The stochastic component of the frontier consists of two types of disturbance or error terms. The first is a regular symmetric disturbance that represents statistical noise in a typical regression. The second disturbance or error term, which is firm specific, is a one-sided deviation from this idealized frontier, and is referred to as technical inefficiency. The greater the amount by

which the realized production falls short of the stochastic frontier, the greater the level of technical inefficiency.

Stochastic frontier model has been developed to provide maximum likelihood estimates of a wide variety of stochastic frontier production and cost functions. The stochastic frontier production functions of Battese and Coelli (1992; 1995) and notes the many special cases of these formulations which can be estimated (and tested for). The stochastic frontier production function was independently proposed by Aigner *et al*. (1977) and Meeusen and Broeck (1977). The original specification involved a production function specified for cross-sectional data which had an error term which had two components, one to account for random effects and another to account for technical inefficiency. This model can be expressed in the following form:

$$Y_i = x_i\beta + (V_i - U_i) \qquad i = 1,.....,N$$

Where, $Y_i$ is the production (or the logarithm of the production) of the i-th firm; $x_i$ is a $k\times1$ vector of (transformation of the) input quantities of the i-th firm; $\beta$ is a vector of unknown parameters; the $V_i$ are random variables which are assumed to be independently and identically distributed (iid) $N(0,\sigma_V^2)$, and independent of the $U_i$ which are non-negative random variables which are assumed to account for technical inefficiency in production and are often assumed to be iid.

This original specification has been used in a vast number of empirical applications over the past two decades. The specification has also been altered and extended in a number of ways. These extensions include the specification of more general distributional assumptions for the $U_i$, such as the truncated normal or two-parameter gamma distributions; the consideration of panel data and time-varying technical efficiencies; the extension of the methodology to cost functions and also to the estimation of systems of equations; and so on. A number of comprehensive reviews of this literature are available, such as Forsund *et al*. (1980), Schmidt (1986), Bauer (1990) and Greene (1993).

The following Cobb-Douglas stochastic frontier model was used to measure the technical efficiency of cold storage.

$$LnY_i = \beta_0 + \beta_1 LnX_{1i} + ..... + \beta_n LnX_{ni} + Vi - Ui$$

Where, Y = Quantity (good potato) of cold storage output (tons)

$X_1$ = Availability of electricity in 24 hours (hour)

$X_2$ = Outside maximum temperature ($^oC$)

$X_3$ = Storage relative humidity (%)

$X_4$ = Duration of pre-cool period (hour)

$X_5$ = Good quality gunny bags used (%)

$X_6$ = Capacity utilization (%)

$X_7$ = Inversion during storage (number)

$X_8$ = Maturity potatoes stored (%)

$X_9$ = Duration of storage period (month)

The following inefficiency model was used to measure the inefficiency effect of different variables related to manager's and cold storage inherent characteristics.

$$U_i = \delta_0 + \delta_1 Z_{1i} + \delta_2 Z_{2i} + ..... + \delta_n Z_{ni} + W_i$$

Where, $Z_1$ = Length of manager's experience (year)

$Z_2$ = Training received (Received =1, Other = 0)

$Z_3$ = Level of education (schooling year)

$Z_4$ = Power source (PDB=1, REB=0)

$Z_5$ = Age of the cold storage (year)

### 2.7 Description of Variables used in the Model

#### 2.7.1 Dependent variable

Cold storage output (Y) may be described by two ways. The first one is the quantity of good quality potato which is ultimately delivered by the cold storage authority to its client. The second one is the percentage of good quality potato received by the owner of potato. The second definition is used in this study because of policy concern. The ratio of observed stock (OS) and initial stock (IS) is multiplied by hundred will be the percent of good quality delivered potato. This can be expressed mathematically as follows.

$$\text{Percent of cold storage output (Y)} = \frac{\text{Observed stock (OS)}}{\text{Initial stock (IS)}} \times 100$$

#### 2.7.2 Independent variables

The quantity of quality potato is likely to be influenced by the availability of electricity, storage temperature maintained, storage humidity, outside day temperature of the cold

storage, duration of pre-cool period, percent of low quality gunny bags used, percent of immature potatoes stored, number of inversion, capacity utilization of cold storage, type of platform for stacking potato bags, number of gunny bags per stack, percent sorted and graded potato and duration of storing period. A brief description of these variables is given below.

***Availability of electricity*:** Electricity is an important input in cold storage. Cooling machine is operated by electric power. If electricity supply is interrupted, the temperature in the cold storage may increase. Due to increase in temperature, potato respiration and microbial activity may also increase which will enhance spoilage of potato. During load shedding, potato store chamber becomes dark and loading, unloading, bag checking, inversion, etc. works are hampered.

***Storage temperature***: Storage temperature is the most important factor for potato storage. Standard temperature for cold storage of potato is 2-4$^{o}$C. If storage temperature increases over the desired temperature then potatoes deteriorate rapidly. The main work of a cold storage is to maintain the desired storage temperature throughout the storage period.

***Relative humidity:*** Humidity is another important factor for potato storage. If humidity decreases, then weight loss of potato increases. On the other hand, if humidity increases, then condensation takes place and potato may deteriorate. Standard relative humidity for cold storage of potato is 90-95%.

***Outside temperature:*** Outside temperature also influences the storage temperature. If outside temperature becomes high then cold storage temperature tends to become high and sometimes it increases above the desired temperature. Also more energy is required to stabilise the storage temperature. Therefore, outside temperature has an influence in potato storage. Average maximum temperature of the hottest month of the year (generally May) is considered in this case. This temperature has been collected from the secondary source (Metrology Department/BARI)

***Duration of pre-cool period:*** Pre-cooling is the intermittent cooling of potatoes between the outside temperature and the cool chamber temperature. If outside potatoes are put directly into the cool chamber, then they may suffer from cool shock or cool injury which may the cause of deterioration.

***Low quality gunny bags used:*** New, disease free and perforated gunny bags are good packages for potato storage. Old bags may be contaminated with insect and microorganisms. Used bags of flour, sugar etc. restrict proper aeration in the bagged potato.

***Immature potatoes stored:*** Due to thin skin and tender tissue, immature potatoes are susceptible to spoilage and injury and they rot more rapidly than matured potatoes. Immature potatoes come to cold storage at an early stage of loading generally in the month of February.

***Number of inversion:*** Inversion i.e. the fact of turning bags upside down in several times during storage period of potato bags that allows proper cooling and aeration of bagged potato. Therefore, improper inversion may influence the spoilage of potato in storage.

***Capacity utilization:*** Each cold storage has its own design capacity. If the quantity stored exceeds this capacity, the storage temperature may increase and stored potatoes may not be uniformly cooled. This may enhance the deterioration of the potatoes.

***Type of platform:*** This is used for stacking potato bags on it. The stacking platform should be such that it does not absorb moisture from the potato or it does not condense the vapour from the storage air. It should also allow air ventilation under the stacked bags and be sufficiently strong to carry the load. Wooden platforms are suitable for this stacking.

***Number of gunny bags per stack*****:** The number of bags per stack increases the weight of potatoes on the lower bags. Continuous weight for several months may smash partially the potatoes at the bottom of the pile. This may also restricts the aeration of potatoes.

***Duration of storing period:*** There is a positive correlation of storage period with storage loss. If the storage period is prolonged, potato deterioration increases.

### 2.7.3 Inefficiency variables

It is expected that both managers' behavior/characteristics and the inherent characteristics of the cold storage are responsible for the efficient use of cold storage. The variables are: length of manager's experience, level of education, relevant training, number of

employees (full time and part time), power source (REB or PDB), and age of the cold storage. A brief description of these variables is given below.

***Length of experience***: The experience of managers enhances the management of the cold storage. A manager can take correct and timely decisions based on his past experience.

***Training received:*** Training increases the skills of a person. More training make more efficient managers.

***Level of education****:* The level of education increases the skills, understanding and outlook of a person. Since cold storage is a modern technology of storage system, higher levels of education help to understand technical matters more easily.

***Number of employees****:* Sufficient number of employees ensures the timely operation of the cold storage system such as loading, unloading, checking, inversion etc.

***Power source:*** Power supply sometimes depends on power sources. Generally load shedding of REB (Rural Electrification Board) is more frequent than the PDB (Power Development Board).

***Age of the cold storage*****:** Machine efficiency decreases with its age. Generally, new buildings and new machine performs better than old ones.

# 3. Results and Discussion

### 3.1 Socio-economic Characteristics of Potato Farmers

#### 3.1.1 Age and family size

The socio-economic characteristics of the sampled potato farmers in the study areas are presented in Table 3.1. Most of the farmers (40-46%) in Comilla, Jessore, Rajshahi, Bogra and Thakurgaon were relatively young and falling in the age group of 30-40 years. But in Munshigonj the highest age group of farmers (40%) was in the age range of 41-50 years followed the young farmers (36%) in the age range of 30-40 years. The higher number of old farmers (above 50 years) was engaged in potato farming than the youth group (below 30 years) in all study areas except Thakurgaon where the share of both old and youth farmers were the same (16%). About one fifth of the old (above 50 year) farmers were engaged in potato farming in Munshigonj and Comilla areas because many young farmers of these places had been working in foreign countries. Average share of below 30 years, 30-40 years, 41-50 years and age above 50 years of the sampled potato farmers of all study areas were 9.0, 42.7, 31.6, and 16.7%, respectively.

The average family size of the sampled potato farmers of all study areas was found to be 5.91 which is slightly higher than average of Bangladesh and there were no significant difference of the family sizes among the study areas. Similar results were presented by Zahid and Uddin (1990) for the rural areas of Bangladesh.

#### 3.1.2 Level of education

Most of the farmers in Comilla (66%) and Munshigonj (50%) areas completed primary level education (up to Class V) and the farmers of Jessore (30%), Rajshahi (38%), Bogra (34%) and Thakurgaon areas completed secondary level education (Class VI-VII). The highest level of illiterate farmers were found in Munshigonj (32%), followed by Jessore (26%) and the lowest level were in Comilla, Rajshahi, Bogra and Thakurgaon (10%). The notable number of higher educated farmers (22%) of Thakurgaon was engaged in potato farming because relatively young farmers cultivated potato commercially in this area. The level of literacy in all areas was found higher (83.7%) than the average in Bangladesh. Most of the sampled potato farmers (63.4%) in the study areas reached the primary and secondary education. Similar results were reported by Zahid and Uddin (1990) for the rural areas of Bangladesh. Generally, during primary and secondary schooling, the fathers

or guardians of the sampled potato farmers gave the charge of their family and lands to their elder sons and thus they could not further continue their higher education. Sometimes they forced to leave schools and engaged in family earning due to economic crisis.

**Table 3.1 Socio-economic characteristics of the sampled potato farmers in the study areas**

| Land type | Comilla | Jessore | Munshi -gonj | Rajshahi | Bogra | Thaku - rgaon | All area |
|---|---|---|---|---|---|---|---|
| Number of respondents | 50 | 50 | 50 | 50 | 50 | 50 | 300 |
| **A. Age (%)** | | | | | | | |
| Below 30 years | 8 | 4 | 2 | 10 | 14 | 16 | 9.0 |
| 30-40 years | 44 | 46 | 36 | 46 | 44 | 40 | 42.7 |
| 41-50 years | 28 | 40 | 40 | 28 | 26 | 28 | 31.6 |
| Above 50 years | 20 | 10 | 22 | 16 | 16 | 16 | 16.7 |
| **B. Family size** | 5.67 | 6.06 | 5.78 | 6.14 | 6.10 | 5.72 | 5.91 |
| **C. Education (%)** | | | | | | | |
| No schooling | 10 | 26 | 32 | 10 | 10 | 10 | 16.3 |
| Primary | 66 | 18 | 50 | 36 | 26 | 18 | 35.7 |
| Secondary | 18 | 22 | 16 | 38 | 34 | 38 | 27.7 |
| Higher secondary | 6 | 30 | 2 | 4 | 18 | 12 | 12.0 |
| Degree and above | - | 4 | - | 12 | 12 | 22 | 8.3 |
| **D. Land type (ha)** | | | | | | | |
| 1. Own land | 0.75 | 1.11 | 0.70 | 1.07 | 0.96 | 2.27 | 1.14 (64.8) |
| 2. Rent in | 0.01 | 0.08 | 0.12 | 0.04 | 0.51 | 0.08 | 0.14 (7.9) |
| 3. Rent out | 0.04 | 0.04 | - | 0.05 | 0.10 | 0.15 | 0.06 (3.4) |
| 4. Mortgage in | 0.18 | 0.13 | 0.95 | 0.10 | 0.07 | 0.37 | 0.30(17.0) |
| 5. Mortgage out | 0.03 | - | 0.00 | 0.02 | - | 0.02 | 0.01 (0.6) |
| 6. Home | 0.09 | 0.12 | 0.08 | 0.16 | 0.08 | 0.09 | 0.10 (5.7) |
| 7. Garden | 0.03 | 0.02 | 0.09 | 0.03 | 0.04 | 0.08 | 0.05 (2.8) |
| 8. Pond | 0.08 | 0.07 | 0.14 | 0.05 | 0.13 | 0.05 | 0.08 (4.5) |
| 9. Fellow | - | - | - | - | 0.01 | 0.01 | - |
| **10. Farm size** | **1.06** | **1.49** | **2.08** | **1.41** | **1.77** | **2.78** | **1.76** |
| 11. Potato area | 0.38 (35.8) | 0.38 (25.5) | 1.60 (77.3) | 0.72 (68.3) | 0.70 (39.5) | 0.88 (31.7) | 0.81 (46.0) |

*Note: Farm size = 1 + 2 – 3 + 4 – 5 + 6 + 7 + 8 + 9*
*Figures in the parenthesis indicate percent of farm size*

### 3.1.3 Land holdings

Potato farmers are the key players in producing potatoes. They are also responsible for distributing potatoes because marketing channels start from them. Their socio-economic conditions depend on their farm or land size. The average farm size of potato farmers in the study areas are shown in Table 3.1. Average farm size of all potato farmers was 1.76 ha. They possessed on an average 1.14 ha of crop land that was 64.8% of their farm size. It is interesting to note that the highest crop land owned by the farmers of Thakurgaon and the lowest in Munshigonj but the farmers of Munshigonj cultivated the highest area (77.3%) of potato land. The farm size of potato farmers in Thakurgaon was found to be the highest and the lowest in Comilla. This might be due to higher density of population in Comilla than Thakurgaon. But the potato cultivated area in Munshigonj (77.3%) was the highest and the lowest in Thakurgaon (46%). The reason was that the potato farmers of Munshigonj cultivated more potato even taking rent in of lands from other farmers. The soil and agro-climate of Munshigonj is favourable in potato cultivation than those of Thakurgaon. On the other hand, some of the land owners of Munshigonj live in the capital city for service and business purposes and they gave rent out of their land to the potato farmers. No land remained fellow in the study areas except a very small area of land (0.01 ha) in Bogra and Thakurgaon. This indicates that the potato farmers of Bogra and Thakurgaon were less efficient in land use compare to other study areas.

### 3.1.4 Household income

Average income of potato farmers in the study areas during 2008-2009 was Taka 203,110 (Table 3.2). The highest annual income of potato farmers was observed in Thakurgaon and the lowest was in Jessore. The farmers of Thakurgaon owned more land than those of other study areas. Income from crop sector was dominated in all study areas. The share of average contribution of crop sector in total income of potato farmers in all areas was 64.64%. Again, the contribution of crop sector in Thakurgaon was the highest (90.32%) and the lowest in Comilla (47.41%). The reason was that the potato farmers of Thakurgaon possessed more crop land than Comilla and the incomes from livestock, fish, and business sectors in Comilla area were higher than Thakurgaon. The contribution of livestock and fish in the household income were not found significant. This means that the potato farmers in the study areas did not reared livestock and fish commercially. Some of the family members in all areas engaged in some sorts of services except Munshigonj.

**Table 3.2 Annual household income of potato farmers in the study areas**

(Figures in Taka)

| Particulars | Comilla | Jessore | Munshi -gonj | Rajshahi | Bogra | Thaku – rgaon | All area |
|---|---|---|---|---|---|---|---|
| 1.Crop | 72,586 (47.41) | 62,480 (65.68) | 130,600 (57.44) | 144,490 (58.75) | 100,900 (53.24) | 276,699 (90.32) | 131,293 (64.64) |
| 2. Livestock | 6,924 (4.52) | 7,120 (7.48) | 3,440 (1.51) | 7,100 (2.89) | 8,484 (2.89) | - | 5,530 (2.72) |
| 3. Fish | 9,370 (6.12) | 5,250 (5.52) | 4,600 (2.02) | 13,540 (5.51) | 12,320 (5.51) | 1,160 (0.38) | 7,707 (3.79) |
| 4. Business | 33,140 (21.64) | 12,000 (12.61) | 44,720 (19.67) | 62,020 (25.22) | 48,140 (25.22) | 9,020 (2.94) | 34,840 (17.15) |
| 5. Service | 18,192 (11.88) | 1,680 (1.77) | - | 10,000 (4.07) | 9,400 (4.07) | 17,848 (5.83) | 9,520 (4.69) |
| 6. Other | 12,904 (8.43) | 6,600 (6.94) | 44,000 (19.35) | 8,776 (3.57) | 10,270 (3.57) | 1,640 (0.54) | 14,221 (7.00) |
| Total income | 153,11 6 (100) | 95,130 (100) | 227,360 (100) | 245,926 (100) | 189,514 (100) | 306,366 (100) | 203,110 (100) |

### 3.2 Economics of Potato Cultivation

#### 3.2.1 Cost of production

Average cost of potato cultivation per hectare of land in the study areas is given in Table 3.3. It is observed from the table that the share of variable cost in the total cost in all areas was 92.45%. Variable cost in Rajshahi was found to be the highest and Thakurgaon was the lowest. The variable costs were invested in four months period. Potato farmers in all areas spent a little amount (2.31% of total cost) for applying organic fertilizer (manure) in the crop field. On the other hand, they used enough chemical fertilizers (35.23% of total cost) to boost up the potato production. It is reported that potato farmers, especially in Munshigonj areas use excessive chemical fertilizer for potato production (Azimuddin *et al*., 2009). The share of cost of pesticide used in potato field was 7.78%. This pesticide was mainly fungicide used for controlling of late and early blight of potato. Average labour cost for potato cultivation was 14% of total cost. Labour included all types of labour employed e.g. for land preparation, seed planting, weeding, earthing up, harvesting etc. Average fixed cost in all study areas was 7.55%. Fixed cost included rental value of land and interest in total investment.

**Table 3.3 Average cost of potato cultivation in the study areas**

(Figures in Tk/ha)

| Cost head | Comilla | Jessore | Munshi -gonj | Rajshahi | Bogra | Thaku –rgaon | All area |
|---|---|---|---|---|---|---|---|
| **A. Variable cost** | **148386 (92.06)** | **198575 (92.60)** | **195882 (92.02)** | **239004 (93.27)** | **172551 (92.85))** | **113307 (91.89** | **177951 (92.45)** |
| 1. Land preparation | 8538 (5.30) | 7349 (3.45) | 11995 (5.63) | 9069 (3.54) | 5432 (2.92) | 10315 (8.37) | 8783 (4.86) |
| 2. Seed | 39268 (24.36) | 39209 (18.28) | 58226 (27.35) | 72770 (28.40) | 49381 (26.57) | 35725 (28.97) | 49097 (25.66) |
| 3. Manure | 1616 (1.00) | 6411 (2.99) | - | 1252 (0.49) | 3941 (2.12) | 8987 (7.29) | 3701 (2.31) |
| 4. Fertilizer | 57121 (35.44) | 92791 (43.27) | 80145 (37.65) | 97224 (37.94) | 69880 (37.60) | 24038 (19.49) | 70200 (35.23) |
| 6. Pesticide | 10517 (6.53) | 16166 (7.54) | 12738 (5.98) | 20611 (8.04) | 17490 (9.41) | 11352 (9.21) | 14812 (7.78) |
| 7. Irrigation | 3303 (2.05) | 5670 (2.64) | 2883 (1.35) | 9299 (3.63) | 5488 (2.95) | 3641 (2.95) | 5047 (2.60) |
| 8. Labour | 28023 (17.39) | 30979 (14.45) | 29895 (14.04) | 28779 (11.23) | 20939 (11.27) | 19249 (15.61) | 26311 (14.00) |
| **B. Fixed cost** | **77973 (7.94)** | **102591 (7.40)** | **103090 (7.98)** | **120858 (6.73)** | **88449 (7.15)** | **59869 (8.11)** | **92138 (7.55)** |
| i. Rental value of land | 5600 (3.47) | 6300 (2.94) | 7500 (3.52) | 5800 (2.26) | 5000 (2.69) | 4500 (3.65) | 5783 (3.09) |
| ii. Interest on operating cost | 72373 (4.46) | 96291 (4.46) | 95590 (4.46) | 115058 (4.46) | 83449 (4.46) | 55369 (4.46) | 86355 (4.46) |
| **C. Total cost (A+B)** | **161177 (100)** | **214443 (100)** | **212880 (100)** | **256236 (100)** | **185843 (100)** | **123309 (100)** | **192315 (100)** |

*Interest 14% for 4 months: Figures in the parenthesis indicate percent of total cost*

### 3.2.2 Productivity and profitability

The productivity or yield of potato in all areas was 23.12 ton/ha which is higher than the national average yield of 16.0 ton/ha (BBS, 2008) but close to the average farm level yield (22.25 ton/ha) of Comilla and Munshigonj (Azimuddin *et al*., 2009). Average gross return, gross margin and net return in all the study areas were Taka 346,800, 168,849 and 154,485 per hectare respectively (Table 3.4). Average benefit cost ratio (BCR) in all study areas was 1.80 over total cost and 1.95 over variable cost and it was highest in Thakurgaon (2.35) due to lower labour cost. The estimated BCR was lower but close to the result presented by Hossain *et al*. (2008) 2.40 and Hoque *et al*. (2006) 2.41. Also average BCR for potato production in Comilla and Munshigonj was presented by Azimuddin *et al*. (2009) 1.58 which is lower than that of the present study.

**Table 3.4 Profitability of potato cultivation in the study areas**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| A. Variable cost Tk./ha) | 148386 | 198575 | 195882 | 239004 | 172551 | 113307 | 177951 |
| B. Total cost (Tk./ha) | 161177 | 214443 | 212880 | 256236 | 185843 | 123309 | 192315 |
| C. Yield (ton/ha) | 24.26 | 22.28 | 24.74 | 25.36 | 22.76 | 19.32 | 23.12 |
| D. Gross return (Tk./ha) | 363900 | 334200 | 371100 | 380400 | 341400 | 289800 | 346800 |
| E. Gross margin(Tk./ha) | 215514 | 135625 | 175218 | 141396 | 168849 | 176493 | 168849 |
| F. Net return (Tk./ha) | 202723 | 119757 | 158220 | 124164 | 155557 | 166491 | 154485 |
| G. BCR over total cost | 2.26 | 1.66 | 1.74 | 1.48 | 1.84 | 2.35 | 1.80 |
| H. BCR over variable cost | 2.45 | 1.68 | 1.89 | 1.59 | 1.98 | 2.56 | 1.95 |

*Note: E = D-A, F = D – B: BCR = Benefit Cost Ratio*

### 3.3 Disposal Pattern of Potato

Disposal pattern of potato at farm level is shown in Table 3.5. The highest quantity of potato produced per farm family was in Munshigonj and the lowest in Jessore areas. This might be due to higher area and yield in Munshigonj area than those of Jessore (Tables 3.1 and 3.4). Average potato production per farm was 17,643 kg. About 2.92% of the potatoes were used for family consumption by the potato farmers and 0.52% was gifted to relatives or others. A major portion (62.04%) of the potatoes was sold during the harvesting period. Another 12.73% of the potatoes was stored in cold storage as seed for planting in the next season. The remaining 23.04% was stored as table potato and sold later when prices became high.

About 14.49% of the potatoes was traditionally stored in house and the remaining 85.51% was stored in cold storage (Table 3.6). A big variation of storage of potatoes was observed. In Comilla, 37.13% of potato was stored traditionally but in Rajshahi this amount was only 7.87%. This variation may be due to the fact that distance and availability of cold storage in Comilla (17) was less than in Rajshahi (24). Most of the potato farms and cold storages were concentrated in Sadar and Poba Upazilla of Rajshahi district. But in Comilla cold storages were scattered over the district. Most of the potatoes were sold at farm gate to wholesalers (*Paiker*) 43.72% and big traders (*Bepari*) 42.33%. A small quantity was sold to petty traders (*Faria*) 11.33%. In Comilla, Munshigonj and Bogra, farmers did not sell their potatoes directly to retailer but a small quantity of potatoes was sold in Jessore, Rajshahi and Thakurgaon directly to the retailers.

**Table 3.5 Disposal pattern of potato at farm level in the study areas**

(Figures in kg)

| Particulars | Comilla | Jessore | Munshi -gonj | Rajshahi | Bogra | Thaku - rgaon | All area |
|---|---|---|---|---|---|---|---|
| Family consumption | 192 (1.62) | 289 (3.02) | 450 (1.46) | 324 (1.16) | 264 (2.61) | 235 (1.52) | 292 (2.92) |
| Gift to others | 85 (0.71) | 71 (0.74) | 96 (0.31) | 112 (0.40) | 82 (0.81) | 110 (0.71) | 93 (0.52) |
| Used as seed | 1796 (15.14) | 620 (6.47) | 3074 (9.96) | 4084 (14.62) | 1420 (14.05) | 2490 (16.06) | 2247 (12.73) |
| Stored for sale | 4500 (37.93) | 1637 (17.08) | 10248 (33.20) | 4268 (15.28) | 1683 (16.66) | 2054 (13.25) | 4065 (23.04) |
| Sale | 5292 (44.60) | 6969 (72.70) | 17000 (55.07) | 19148 (68.54) | 6655 (65.87) | 10613 (68.47) | 10946 (62.04) |
| Production (per farm) | 11865 (100) | 9585 (100) | 30869 (100) | 27936 (100) | 10104 (100) | 15501 (100) | 17643 (100) |

*Note: Figures in the parentheses indicate percent of total production*

**Table 3.6 Quantity of potato stored and sold at farm level in the study areas**

(Figures in kg )

| Particulars | Comilla | Jessore | Munsh-igonj | Rajshahi | Bogra | Thaku - rgaon | All area |
|---|---|---|---|---|---|---|---|
| **A. Quantity stored (as table potato)** | **4500 (100)** | **1637 (100)** | **10248 (100)** | **4268 (100)** | **1683 (100)** | **2054 (100)** | **4065 (100)** |
| 1. Home storage | 1671 (37.13) | 446 (27.24) | 530 (5.17 | 336 (7.87) | 294 (17.47) | 260 (12.66) | 589 (14.49) |
| 2. Cold storage | 2829 (62.87) | 1191 (72.76) | 9718 (94.83) | 3932 (92.13) | 1389 (82.53) | 1794 (87.34) | 3476 (85.51) |
| **B. Quantity sold to** | **5292 (100)** | **6969 (100)** | **17000 (100)** | **19148 (100)** | **6655 (100)** | **10613 (100)** | **10946 (100)** |
| 1. Big trader (*Bepari*) | 2486 (46.97) | 2065 (29.63) | 5589 (32.88) | 4252 (22.21) | 3069 (46.12) | 4977 (46.89) | 4633 (42.33) |
| 2. Wholesaler (*Paiker*) | 2701 (51.04) | 3033 (43.52) | 8728 (51.34) | 12296 (64.22) | 2345 (35.24) | 2633 (24.81) | 4786 (43.72) |
| 3. Petty trader (*Faria*) | 105 (1.98) | 962 (13.80) | 2683 (15.78) | 2380 (12.43) | 1241 (18.64) | 2213 (20.85) | 1240 (11.33) |
| 4. Retailer | - | 909 (13.04) | - | 220 (1.14) | - | 790 (7.45) | 287 (2.62) |

*Note: Figures in the parentheses indicate percent of total quantity*

### 3.4 Postharvest Losses of Traditionally Stored Potatoes

#### 3.4.1 Post-harvest loss at farm level

Potatoes are semi perishable commodity, which contain more than 70% of moisture. Thus, they undergo a lot of physical, chemical and physiological changes during the whole process of harvesting, curing, storage, handling, transportation and marketing, resulting in a deterioration of quality and loss in weight. The post-harvest losses of potato at different stages of post-harvest operations at farm level in the study areas are shown in Table 3.7. Average harvesting loss of all areas was found to be 5.65% of total production. Average harvesting loss comprised of insect damage (1.21%), rotten loss (1.40%), cutting loss (1.14%), potato remained under soil during harvesting (0.89%), and other losses (1.02%) such as off size, green potato etc.

**Table 3.7 Average loss of potato at farmers' level at different post harvest operations in the study area**

(Figures in kg )

| Particulars | Comilla | Jessore | Munshi-gonj | Rajsha-hi | Bogra | Thaku-rgaon | All area |
|---|---|---|---|---|---|---|---|
| **A. Production** | **6985.6** | **9585.2** | **30868.8** | **27855.2** | **10104.3** | **15501.3** | **16816.7** |
| 1. Harvesting loss | 415.08 **(5.94)** | 527.19 **(5.50)** | 1707.04 **(5.53)** | 1735.38 **(6.23)** | 539.57 **(5.34)** | 832.42 **(5.37)** | 950.15 **(5.65)** |
| a. Insect damage | 69.30 (0.99) | 99.64 (1.04) | 395.12 (1.28) | 467.96 (1.68) | 103.06 (1.02) | 192.21 (1.24) | 203.48 (1.21) |
| b. Rotten loss | 99.20 (1.42) | 120.77 (1.26) | 487.73 (1.58) | 353.76 (1.27) | 138.43 (1.37) | 232.52 (1.50) | 235.43 (1.40) |
| c. Cutting loss | 93.60 (1.34) | 117.89 (1.23) | 299.43 (0.97) | 328.69 (1.18) | 127.31 (1.26) | 133.31 (0.86) | 191.71 (1.14) |
| d. Remain under soil | 81.03 (1.16) | 91.06 (0.95) | 197.56 (0.64) | 295.27 (1.06) | 66.68 (0.66) | 128.66 (0.83) | 149.67 (0.89) |
| e. Other loss | 71.95 (1.03) | 97.79 (1.02) | 327.21 (1.06) | 289.69 (1.04) | 104.07 (1.03) | 145.71 (0.94) | 171.53 (1.02) |
| 2. Curing loss | 58.68 (0.84) | 71.89 (0.75) | 188.30 (0.61) | 256.27 (0.92) | 67.69 (0.67) | 224.77 (1.45) | 147.98 (0.88) |
| 3. Sorting loss | 118.06 (1.69) | 167.74 (1.75) | 546.38 (1.77) | 440.11 (1.58) | 167.73 (1.66) | 196.87 (1.27) | 201.80 (1.62) |
| **B. Pre-storage losses (1+2+3)** | 591.68 **(8.47)** | 766.82 **(8.00)** | 2441.72 **(7.91)** | 2431.76 **(8.73)** | 774.99 **(7.67)** | 1254.06 **(8.09)** | 1370.56 **(8.15)** |
| **4**. Home storage loss | 584.69 (8.37) | 662.33 (6.91) | 2278.12 (7.38) | 2008.36 (7.21) | 2526.07 (7.18) | 1092.84 (7.05) | 1236.03 (7.35) |
| **C. Total loss (B+4)** | 1176.38 **(16.84)** | 1429.15 **(14.91)** | 4719.84 **(15.29)** | 4440.12 **(15.94)** | 1500.48 **(14.85)** | 2346.89 **(15.14)** | 2606.59 **(15.50)** |

*Figures inside the parentheses indicate percent of total production*

Potatoes in all the study areas were harvested manually using country ploughs or spades. No mechanical harvester for harvesting potatoes was observed. The harvesting of potato in Bangladesh is found to be 5.65%, which is higher than the result presented Meyhuay (2007) for Costa Rica (3%). This variation may due to that in Bangladesh, potato is generally harvested by manually using spade or plough. But, in Costa Rica, potato is normally harvested by mechanical harvester.

Harvested potatoes are cured in the shade to adjust to the environment and heel injuries normally caused during harvesting, handling and transportation from field to the farmer's home. Different methods of curing were practiced in different study areas. In Munshigonj, potatoes were peeled in the field and covered with straw for about a week. Then the peel was broken, potatoes were sorted, bagged and carried to home, market or cold storage. Harvested potatoes were carried directly to home and spread in shed and kept for a week for curing. This is the proper method of curing and observed to follow in Comilla and Jessore areas. In Rajshahi, Bogra and Thakurgaon (Northern part of Bangladesh) potatoes were bagged from the field and the bag kept in the shade at home for several days for curing. Sometimes, potatoes were bagged from the field and transported directly to the market or cold storage without curing. This may cause heat stress in the potato and deteriorate it rapidly. In other areas potatoes were spread on the floor and kept in the shade for one to two weeks. After curing, potatoes were sorted and sometimes graded and bagged. Average curing and sorting losses were found to be 0.88 and 1.62%, respectively. The average pre-storage loss in all study areas was 8.15% including harvesting loss, which was about 1.40 tons per farm house. Harvesting loss of potato is reported to range between 1 to 6% in India (http://agmarknet/nic.in/profile-potato.pdf).

About 97% of sampled farmers stored potatoes in home following traditional methods. Rest of the sampled farmers sold their whole quantity of potatoes in the harvesting season. In the traditional method, farmers stored potatoes at home by stacking them on the earthen floor of dwelling houses or stacking them on bamboo or wooden made platforms (*Macha)* for better aeration. Farmers did not store potato in separate store house to avoid extra storage cost. In the traditional method generally bulk potatoes are stored for three to four months. Height of bulk storage potato varied from 15 cm to 1.0 m. Farmers did not care for height of the pile. They only considered available space and quantity of potato to be stored. During storage period, they frequently checked their home stored potatoes to sort

out rotten ones and diseased ones which otherwise would cause damage to the whole quantity of stored potatoes. In this method, farmers cannot maintain proper temperature and humidity that cause large-scale damage due to rot by disease, insect damage and weight loss. During three to four months of storage period about 7.35% potato was lost. Traditional storage loss was quantified as 1.23 tons per farm, on average. Meyhuay (2007), referred to in CIP, (2009) reports that traditional home storage loss of potato in Peru for a period of one, two and three months were 4.0, 10.5 and 15.2%, respectively. Average total farm level loss in all study areas was 15.50% or 2.60 tons per farm house for three months of storage period. This result agreed well with the present study for three months of storage period. Rhoades (1984) reported that post harvest loss of traditional storage of potato was as high as 29% for only two months storage in Sri Lanka.

### 3.4.2 Marketing of traditionally stored potatoes

After the harvest of potatoes in March, there are several options for the farmers: (1) to sell them immediately, (2) to sell them after drying (curing) for two weeks, (3) to sell them after storage at home for 2–3 months, and (4) to store them in cold storages. The advantage of option (2) over (1) is that by drying during a sufficient time, the skin of potato becomes thick and suitable for long-term storage in cold storages. Farmers sometimes choose option (3) for getting a higher price without utilizing cold storages, but 2–3 months is the physical limit for traditional storage at home.

The majority of the farmers, especially large and medium category farmers generally sells harvested potatoes in their homestead and receives cash from traders immediately. Landless tenants and small category farmers (with less than 0.20 ha), on the other hand, sometimes sell their small amount to traders who are waiting in the nearby market (primary market), for obtaining a slightly higher price and receive cash payment on the spot. When collecting potatoes at the farm gate *Beparis* (big traders) themselves bargain the price with the farmers, but thereafter, the actual operations such as weighing, bagging and carrying are usually conducted by their hired laymen. In the harvesting period, traders and their assistants work for day and night moving around wider areas for maximum collection of potatoes within a short period of time. Since potato the harvest season is very short, traders usually become specialized in their job on a full-time basis for storing part of the collected potatoes in cold storages and sell them later gradually over the whole year. The other part of potatoes is sold immediately and transported another town. Some

*Paikers* (wholesaler) in rural areas store a part of purchased potatoes in local cold storages. Some farmers store potatoes in cold storages themselves, although some store only seed potatoes but also non-seed potato for getting extra profit (Moazzem, and Fujita, 2004). In other cases, potatoes were stored in farm houses traditionally for about three months. These potatoes are marketed up to the months of May and sometimes June when cold stored potato have not yet come out in the market.

### 3.4.3 Characteristics of marketing intermediaries

The marketing intermediaries in the potato marketing were farmers, cold storage managers and traders (*Bepari* (big trader), *Faria* (petty trader), *Aratder (*commission agent*), Paiker* (wholesaler) and retailer) and consumers (households and restaurant owners/managers). Characteristics of the respondents are given below.

***Farmers*:** Farmers are referred as potato growers in this study. Most farmers grow potatoes on their own land. But there are some farmers who grow potatoes on leased land. All farmers in the study areas do not grow potatoes. Some farmers grow potatoes for their own consumption and sell the excess amount in the potato harvesting season. But, some farmers grow potatoes commercially, store both seeds and table potato in cold storage to get higher return in the off season. Farmers sell their potatoes to *Bepari, Faria,* and retailer. Some large category farmers store seeds and table potato in the cold storage.

***Faria* (petty trader):** *Farias* are small non-licensed traders who operate in the primary market and sometimes in the secondary markets. They are one of the basic key players in the traditional potato marketing systems. Most of the *Farias* usually run their business independently. They have no fixed business premises. They are generally landless or small farmers having no full-time work on the farm. *Farias* generally buy small amount of potatoes from farmer either at farm gate or in the primary markets and sell those to the *Beparies* and retailers in the primary markets. In the secondary market, they purchase small amount of potatoes from *Beparies* and sell them to retailers and consumers.

***Bepari* (big trader):** Beparies are relatively big and non-licensed traders in the market premises. Some of them have fixed establishments in the market places with adequate keeping and short time storage facilities. They generally purchase large amount of potatoes from farmers at farmyard and primary market and a small amount from *Farias*. They had permanent staff/labour for running their business. They sell large amount of potatoes *Paikers* and retailers through *Arathdars* (commission agents). Sometimes they

sell little amount of potatoes to *Faria* at secondary market. They also store potato in the cold storage for higher profit.

***Paiker* (wholesaler):** *Paikers* are also big traders generally operates between *Bepari* and retail trader in secondary market. They have fixed establishments in the market places with adequate keeping and short time storage facilities. They had permanent staff/labour for running their business. They purchase large amount of potatoes from *Bepari* directly or through *Arathdars*. *Paikers* also purchase potato from nearby cold storage. They sell large amount of potatoes to retailers and big consumers like restaurant owners. They also store potato in the cold storage for higher profit.

***Aratdars* (commission agents):** Aratdars are basically commission agents of a big or wholesale market (secondary market). They have fixed establishments in the market places with adequate weighing, bagging and keeping facilities. They have permanent staffs. Apart from potato trading most of the wholesalers are engaged in trading of other vegetables. They facilitate *Beparies* to sell large amount of potato to *Paikers*, retailers, and a small amount to *Faria*. They charge fixed commission at Taka 0.40-0.50 per kg from *Beparies*.

***Retailer*:** The retailers have fixed permanent shop or place in the market. In the shop they have temporary keeping facility of potato with other commodities. They purchase small amount of potato from farmers (harvesting season), *Arath* and *Faria* from the local market. They run their business with other commodities and sell their products to the consumer at retail price.

***Cold storage manager*:** The cold storage manager is the key person of the cold storage in the study areas. Cold storage owners are wealthy persons often residing in the capital city. They often communicate with the manager over telephone and inform him of administrative and financial decisions regarding the cold storage management system. The technical side depends mainly on the manager. The manager works with the help of other technical staff like a foreman and operator. He deals with customers regarding potato storage. He also deals with the administrative and financial matters with the help of an accountant.

***Restaurant owner/Manager*:** Restaurant owners play a vital role in supplying readymade foods to various consumers both in primary and secondary markets. They use several items in cooking readymade foods. One of the important food ingredients for most of the food items is potato. Generally, a big restaurant owner purchases 5 to10 bags (400-800 kg) of potato per week from a *Paiker*, whereas a small restaurant owner purchases between 5 to 20 kg of potatoes generally from retailers for their purposes.

### 3.4.4 Marketing channels traditionally stored potatoes

The marketing chain refers to the sequential arrangements of various marketing intermediaries involved in the movement of products from producers to consumers. In the chain of potato marketing in Bangladesh, the product moves from the producers-sellers to ultimate consumers through a number of market intermediaries. In the context of Bangladesh, the work of different intermediaries often overlaps. For example, wholesaler (*Bepari/Paiker*) sometimes performed retail business. In the present study, different marketing chains of potato were identified. The marketing channel of traditionally stored potatoes is illustrated in Fig 3.1. *Bepari* (Big trader) and *Faria* (Petty trader) bought potatoes from farmers. The share of the cases where potatoes were purchased by *Beparis* (60.9%) was higher than the one by *Farias* (36.2%). *Bepari*, *Paiker* and *Faria* play a crucial role in the process of traditionally stored potato marketing in the study areas. *Bepari* bought a large amount of potatoes from farmers and directly sold to *Paiker* (38.9%), retailers (26.2%) and again retailer (21.6%) through *Aratdar*. Similarly, *Faria* bought potatoes directly from farmers and mostly sold them to *Bepari* (39.2%) and a small portion (6.6%) to retailer through *Aratdars*. *Paiker* bought a major portion of potato directly from *Bepari* (38.9%) and a very small amount from farmers (2.1%). They also bought a good amount of potatoes (20.9%) from *Faria* and other *Beparis* through *Aratdars*. *Paikers* sold all their potatoes directly to the retailers. Retailers sold their whole quantity (100%) of potatoes to consumers. Thus consumers bought 100% of farmers' potatoes from retailer through a number of chains.

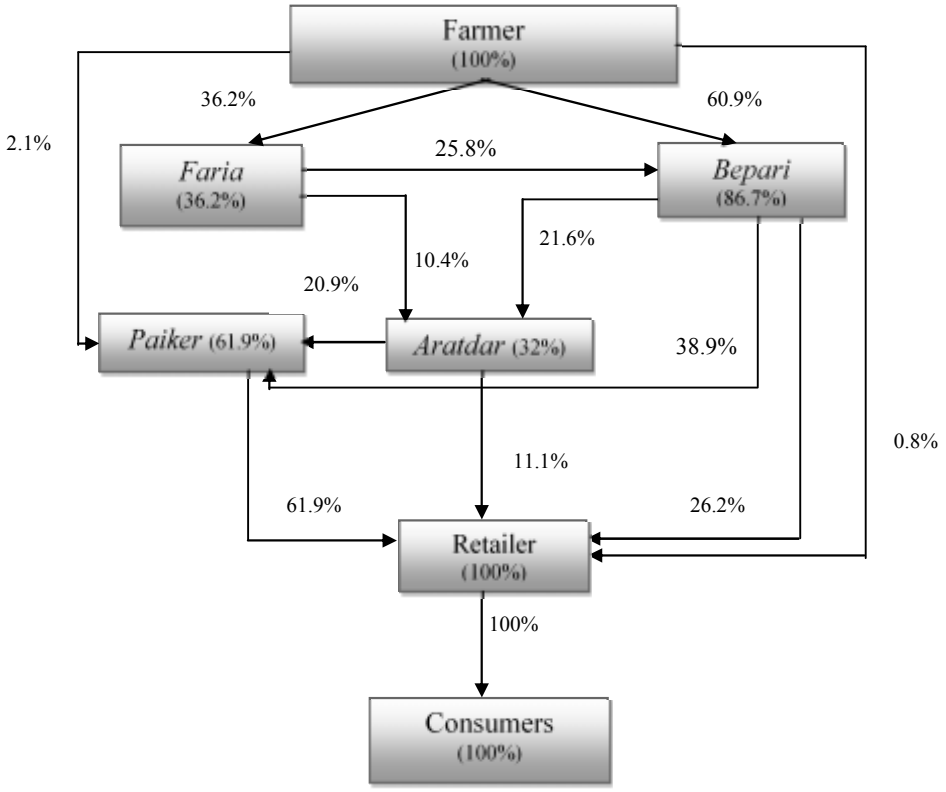



**Fig 3.1 Flow diagram of traditional stored potato marketing at farm level**

The following major marketing channels of traditional stored/non-stored potato were identified:

1. Farmer → Retailer → Consumer
2. Farmer →*Faria*→ *Bepari*→ Retailer → Consumer
3. Farmer →*Faria*→ *Aratdar* → Retailer → Consumer
4. Farmer →*Faria*→ *Aratdar*→ *Paiker* → Retailer → Consumer
5. Farmer →*Bepari*→ *Aratdar*→ Retailer → Consumer
6. Farmer →*Bepari*→ *Paiker* → Retailer → Consumer
7. Farmer →*Bepari*→ *Aratdar*→ *Paiker* →*Retailer* → Consumer

### 3.4.4.1 Quantity traded and loss at *Bepari's* level

*Bepari* bought traditional stored potato from farmers and *Faria*. About 50% potatoes were bought from farmers and 50% were bought from *Farias* (Table 3.8). The quantity of potatoes bought varied among the study areas. *Bepari* bought 70% potato from farmer in

Comilla and for Rajshahi this figure was 32.35%. About 68.65% of potatoes were bought from *Faria* in Rajshahi and 30% potatoes were bought in Comilla. *Beparis* sold their potatoes to *Paikers* (55.65%) and retailers (2.95%) directly or through *Aratdars* (41.4%). These figures also varied for different study areas.

**Table 3.8 Transaction and loss of traditional stored potatoes at *Bepari's* level in the study areas**

(Figures in kg)

| Particulars | Comilla | Jessore | Munshi-gonj | Rajshahi | Bogra | Thakur-gaon | All areas |
|---|---|---|---|---|---|---|---|
| **A. Quantity bought from** | **32285 (100)** | **19780 (100)** | **19620 (100)** | **18510 (100)** | **20650 (100)** | **16220 (100)** | **21179 (100)** |
| Farmer | 26735 (70.00) | 12230 60.00 | 4370 (40.46) | 4830 (32.35) | 8850 (52.64) | 5700 (42.94) | 10453 (49.73) |
| *Faria* | 5550 (30.00) | 7550 (40.00) | 15250 (59.54) | 13680 (68.65) | 11800 (47.36) | 10520 (57.06) | 10725 (50.27) |
| **B. Quantity sold to** | **31578 (100)** | **19262 (100)** | **19159 (100)** | **18027 (100)** | **20192 (100)** | **15871 (100)** | **20678 (100)** |
| *Aratdar* | 11700 (37.75) | 9400 (49.73) | 7385 (39.18) | 5598 (31.75) | 9460 (47.70) | 6820 (44.08) | 8393 (41.40) |
| *Paiker* | 18100 (58.41) | 9300 (49.21) | 10600 (56.23) | 11483 (65.24) | 9550 (48.16) | 8650 (55.91) | 11281 (55.65) |
| Retailer | 1190 (3.84) | 200 (1.06) | 865 (4.59) | 519 (2.95) | 820 (4.14) | - | 599 (2.95) |
| **C. Quantity lost** | 707.0 **(2.19)** | 518.2 **(2.62)** | 461.0 **(2.35)** | 483.1 **(2.61)** | 458.4 **(2.22)** | 348.7 **(2.15)** | 499.8 **(2.36)** |
| Weight loss[1] | 293.8 (0.91) | 174.0 (0.88) | 145.2 (0.74) | 157.3 (0.85) | 150.7 (0.73) | 136.2 (0.84) | 175.8 (0.83) |
| Rotten loss | 155.0 (0.48) | 112.7 (0.57) | 113.8 (0.58) | 125.9 (0.68) | 123.9 (0.60) | 111.9 (0.69) | 127.1 (0.60) |
| Handling loss | 203.3 (0.76) | 156.3 (0.79) | 153.3 (0.69) | 131.5 (0.71) | 121.8 (0.59) | 76.2 (0.47) | 137.6 (0.65) |
| Transportation loss | 54.9 (0.35) | 75.2 (0.38) | 66.7 (0.34) | 68.5 (0.37) | 61.0 (0.30) | 24.3 (0.15) | 59.3 (0.28) |

*Note: Figures in the parentheses indicate loss as percentage of total quantity bought*

[1]Weight loss is the reduction of moisture from the tubers

In the period of buying and selling some potatoes were lost at *Bepari's* level. The quantity of loss was about 500 kg i.e. 2.36% of bought quantity. It may be clearly said that post-harvest loss to *Bepari* was 23.60 kg per ton of purchased potato. This loss comprised weight loss (0.83%), rotten loss (0.60%), handling loss (0.65%) and transportation loss (0.28%). Among these losses, weight was the highest (0.83%) and transportation loss was the lowest (0.28%). The reason might be that weight loss was the continuous loss of water from the living tuber by respiration and transpiration. But transportation loss was the

lowest as potatoes were transported from one place to another by well packed gunny bags (not bulk condition).

### 3.4.4.2 Quantity traded and loss at *Faria's* level

Marketing and loss of traditional stored potato by *Faria* in the study areas are shown in Table 3.9. *Farias* bought a small quantity (compared to *Bepari*) of potato from a single source (farmer). They sold these potatoes directly to *Beparis* (58.50%) and retailer through *Aratdar* (32.80%). Quantities of potatoes sold to the buyers varied from place to place. For *Bepari*, it was the highest quantity in Comilla and the lowest in Bogra.

**Table 3.9 Transaction and loss of traditional stored potatoes at *Faria's* level in the study areas**

(Figures in kg)

| Particulars | Comilla | Jessore | Munshi-gonj | Rajshahi | Bogra | Thakur-gaon | All areas |
|---|---|---|---|---|---|---|---|
| **A. Quantity bought from** | **530 (100)** | **460 (100)** | **515 (100)** | **440 (100)** | **380 (100)** | **410 (100)** | **456 (100)** |
| Farmer | 530 (100.0) | 460 (100.0) | 515 (100.0) | 440 (100.0) | 380 (100.0) | 410 (100.0) | 456 (100.0) |
| **B. Quantity sold to** | **514 (100.0)** | **448 (100.0)** | **504 (100.0)** | **429 (100.0)** | **372 (100.0)** | **399 (100.0)** | **444 (100.0)** |
| *Bepari* | 322 (62.65) | 256 (57.30) | 301 (59.78) | 258 (60.06) | 206 (55.31) | 222 (55.73) | 260 (58.50) |
| *Aratdar* | 184 (35.72) | 177 (39.54) | 192 (38.15) | 163 (37.93) | 160 (43.15) | 10 (2.44) | 146 (32.80) |
| **C. Quantity lost** | 16.0 (**3.01**) | 12.4 (**2.69**) | 10.7 (**2.08**) | 10.8 (**2.46**) | 8.4 (**2.20**) | 11.3 (**2.75**) | 11.6 (**2.50**) |
| Weight loss | 5.7 (1.08) | 3.9 (0.84) | 3.5 (0.68) | 3.5 (0.79) | 2.8 (0.73) | 3.5 (0.86) | 3.8 (0.80) |
| Rotten loss | 4.0 (0.75) | 3.3 (0.71) | 3.1 (0.61) | 2.9 (0.66) | 2.4 (0.64) | 3.1 (0.76) | 3.1 (0.70) |
| Handling loss | 4.1 (0.77) | 3.1 (0.68) | 2.6 (0.50) | 2.4 (0.55) | 1.9 (0.50) | 2.7 (0.65) | 2.8 (0.60) |
| Transportation loss | 2.2 (0.41) | 2.1 (0.46) | 1.5 (0.29) | 2.0 (0.46) | 1.3 (0.33) | 2.0 (0.48) | 1.8 (0.40) |

*Note: Figures in the parentheses indicate percentage loss of total quantity bought*

During buying and selling, about 2.50% potatoes in the form of weight loss (0.80%), rotten loss (0.70%), handling loss (0.60%) and transportation loss (0.40%). Weight loss was observed higher than rotten loss followed by handling and transportation loss Table (3.9).

### 3.4.4.3 Quantity traded and loss at *Aratdar's* level

*Aratdars* bought potatoes from *Beparis* and *Farias* in the study areas (Table 3.10). About 56.36% potatoes were bought from *Beparis* and rest quantity from *Farias* (43.64%). Again, *Arartdar* sold their potatoes to *Paikers* (84.02%) and retailers (15.98%). *Aratdars are* commission agents in the process of potato marketing.

During buying and selling about 1.55% of potatoes were lost. The whole loss occurred due to weight loss. Other losses such as rotten loss, handling and transportation loss did not occur because in *Arat* only packed potatoes were transacted. Potatoes were sold as volume basis (bag) rather than weight basis. No bag was opened during selling or buying.

**Table 3.10 Marketing and loss of traditional stored potatoes at *Aratdar's* level in the study areas**

(Figures in kg)

| Particulars | Comilla | Jessore | Munshi-gonj | Rajshahi | Bogra | Thakur-gaon | All areas |
|---|---|---|---|---|---|---|---|
| **A. Quantity bought from** | **11538 (100.0)** | **8466 (100.0)** | **11450 (100.0)** | **7210 (100.0)** | **12040 (100.0)** | **12113 (100.0)** | **10469 (100.0)** |
| *Bepari* | 7600 (65.87) | 6200 (72.23) | 5050 (44.10) | 3360 (46.60) | 7580 (62.96) | 5613 (46.34) | 5900 (56.36) |
| *Faria* | 3938 (34.14) | 2266 (26.77) | 6400 (55.90) | 3850 (53.40) | 4460 (37.04) | 6500 (53.66) | 4569 (43.64) |
| **B. Quantity sold to** | **11367 (100.0)** | **8323 (100.0)** | **11292 (100.0)** | **7105 (100.0)** | **11852 (100.0)** | **11901 (100.0)** | **10307 (100.0)** |
| *Paiker* | 9310 (81.90) | 7074 (85.00) | 9230 (81.74) | 6337 (89.20) | 8653 (73.01) | 10279 (86.37) | 8660 (84.02) |
| Retailer | 2057 (18.10) | 1248 (15.02) | 2062 (18.26) | 1478 (20.80) | 3199 (26.99) | 1622 (13.63) | 1647 (15.98 ) |
| **C. Quantity lost** | 171 (**1.48**) | 143 (**1.69**) | 158 (**1.38**) | 105 (**1.46**) | 188 (**1.56**) | 212 (**1.75**) | 162 (**1.55**) |
| Weight loss | 171 (1.48) | 143 (1.69) | 158 (1.38) | 105 (1.46) | 188 (1.56) | 212 (1.75) | 162 (1.55) |

*Note: Figures in the parentheses indicate percentage loss of total quantity bought*

### 3.4.4.4 Quantity traded and loss at *Paiker's* level

Quantity of potato potatoes traded and loss of traditional stored potatoes at *Paiker's* level in the study areas are shown in Table 3.11. *Paikers* bought potatoes from different sources such as farmers, *Beparis* and *Aratdars*. Large quantities of potatoes were bought from *Beparis* (77.93%) followed by *Aratdars* (21.98%). A small quantity of potatoes was

bought from farmers (0.09%). These quantities varied from place to place. The highest quantity of potato was bought in Rajshahi and the lowest quantity in Comilla area. The whole quantities (100%) were sold to the retailers.

About 2.07% of potatoes were lost during buying and selling processes. The highest loss was obtained for weight loss (0.74%) and the lowest for transportation. The highest loss was observed in Jessore area (2.94%) and the lowest in Comilla area (1.16%).

**Table 3.11 Transaction and loss of traditional stored potatoes at *Paiker's* level in the study areas**

(Figures in kg)

| Particulars | Comilla | Jessore | Munshi-gonj | Rajshahi | Bogra | Thakur-gaon | All areas |
|---|---|---|---|---|---|---|---|
| **A. Quantity bought from** | **10410 (100)** | **22300 (100)** | **34520 (100)** | **47760 (100)** | **33840 (100)** | **29740 (100)** | **29762 (100)** |
| Farmer | 18 (0.17) | 28 (0.13) | 20 (0.06) | 30 (0.06) | 32 (0.09) | 25 (0.08) | 26 (0.09) |
| *Bepari* | 2760 (26.51) | 15820 (70.94) | 28960 (83.89) | 43340 (90.75) | 27640 (81.68) | 20640 (69.40) | 23194 (77.93) |
| *Aratdar* | 7632 (73.31) | 6452 (28.93) | 5540 (16.05) | 4390 (9.19) | 6168 (18.23) | 9075 (30.51) | 6543 (21.98) |
| **B. Quantity sold to** | **10289 (100.0)** | **21644 (100.0)** | **33712 (100.0)** | **46733 (100.0)** | **33427 (100.0)** | **28970 (100.0)** | **29146 (100.0)** |
| Retailer | 10289 (100.0) | 21644 (100.0) | 33712 (100.0) | 46733 (100.0) | 33427 (100.0) | 28970 (100.0) | 29146 (100.0) |
| **C. Quantity lost** | 121 (**1.16**) | 656 (**2.94**) | 808 (**2.34**) | 1027 (**2.15**) | 413 (**1.22**) | 770 (**2.59**) | 616 (**2.07**) |
| Weight loss | 58.3 (0.56) | 189.6 (0.85) | 283.1 (0.82) | 363.0 (0.76) | 189.5 (0.56) | 270.6 (0.91) | 221.2 (0.74) |
| Rotten loss | 25.0 (0.24) | 173.9 (0.78) | 231.3 (0.67) | 257.9 (0.54) | 91.4 (0.27) | 232.0 (0.78) | 162.7 (0.55) |
| Handling loss | 22.9 (0.22) | 171.7 (0.77) | 193.3 (0.56) | 234.0 (0.49) | 84.6 (0.25 ) | 154.6 (0.52) | 139.4 (0.47) |
| Transportation loss | 14.6 (0.14) | 120.4 (0.54) | 100.1 (0.29) | 171.9 (0.36) | 47.4 (0.14) | 113.0 (0.38) | 91.8 (0.31) |

*Note: Figures in the parentheses indicate percentage loss of total quantity bought*

### 3.4.4.5 Quantity traded and loss at retailers' level

Retailer is the last intermediary in potato marketing. Retailers handled comparatively small quantities of potatoes for a comparatively long time. They bought potatoes from many sources: farmers (2.22%), *Beparis* (49.86%), *Paikers* (46.75%), and *Aratdars* (4.23%) (Table 3.12). Retailers bought potatoes where they received the cheapest price because they wanted to make a high profit using their small capital. Retailers bought small

quantities of potatoes from nearby farmers in the primary market. They bought large quantities of potatoes from *Beparis* followed by *Paikers*. They also bought small quantities from nearby *Arats*. It was observed that retailers bought potatoes from *Aratdars* only in Comilla area. In Jessore area, retailers bought most of the potatoes from *Beparis* (98.18%) and a small quantity from farmers (1.82%). Quantities of potato bought varied from one area to another. Retailers sold all their potatoes to the consumer.

**Table 3.12 Marketing and loss of traditional stored potatoes at retailer's level in the study areas**

(Figures in kg)

| Particulars | Comilla | Jessore | Munshi-gonj | Rajshahi | Bogra | Thakur-gaon | All areas |
|---|---|---|---|---|---|---|---|
| **A. Quantity bought from** | **338 (100)** | **660 (100)** | **625 (100)** | **622 (100)** | **279 (100)** | **766 (100)** | **555 (100)** |
| Farmer | 14 (4.14) | 12 (1.82) | 14 (2.24) | 10 (1.61) | 8 (2.87) | 5 (0.65) | 10 (2.22) |
| *Bepari* | 70 (20.71 ) | 648 (98.18) | 200 (32.00) | 240 (38.59) | 246 (88.17) | 165 (21.54) | 262 (49.86) |
| *Paiker* | 113 (33.45) | - | 411 (58.57) | 412 (42.14) | 25 (5.00) | 595 (70.71) | 259 (46.75) |
| *Aratdar* | 141.00 (41.71) | - | - | - | - | - | 23.50 (4.23) |
| **Quantity sold to** | **327 (100.0)** | **638 (100.0)** | **600 (100.0)** | **602 (100.0)** | **268 (100.0)** | **741 (100.0)** | **536 (100.0)** |
| Consumer | 327 (100.0) | 638 (100.0) | 600 (100.0) | 602 (100.0) | 268 (100.0) | 741 (100.0) | 536 (100.0) |
| **C. Quantity lost** | 11 (**3.23**) | 22 (**3.30**) | 25 (**4.04**) | 20 (**3.15**) | 11 (**3.85**) | 25 (**3.25**) | 19 (**3.47**) |
| Weight loss | 5.2 (1.53) | 8.3 (1.25) | 10.5 (1.68) | 8.3 (1.33) | 3.8 (1.37) | 11.9 (1.56) | 8.1 (1.45) |
| Rotten loss | 2.9 (0.86) | 6.5 (0.98) | 7.7 (1.23) | 5.7 (0.92) | 3.4 (1.22) | 6.4 (0.84) | 5.6 (1.01) |
| Handling loss | 1.6 (0.46) | 4.1 (0.62) | 4.1 (0.65) | 3.5 (0.57) | 2.0 (0.73) | 3.7 (0.48) | 3.2 (0.59) |
| Transportation loss | 1.3 (0.38) | 3.0 (0.45) | 3.0 (0.48) | 2.1 (0.33) | 1.5 (0.53) | 2.8 (0.37) | 2.3 (0.42) |

*Note: Figures in the parentheses indicate percentage loss of total quantity bought*

During marketing about 3.47% of potato was lost at the retailer's level. This loss was found higher than for other intermediaries because retailers bought potatoes in packed bags and sold them as bulk. Also some of the potatoes were kept in bulk in the shop and the weight loss became higher than that of bagged potato. Usually consumers select the potatoes they are going to buy and do not buy any defective potatoes.

### 3.4.5 Postharvest loss of traditionally stored potato at consumers' level

In Bangladesh potatoes are mainly consumed as a vegetable. Other uses of potatoes are potato chips, potato *Dal* (rural food) and preparation of different types snacks. It is one of the ingredients of curry and is used for preparation of many foods like *singara*, *samucha, alupuri* etc. Potato is mainly consumed at household level and restaurant level. At these levels, a notable amount of potatoes are lost during processing for final food preparation. There are debates among scientists about the recognition of household level loss as post-harvest loss. In this study, an attempt has been made to quantify the post-harvest loss at consumers' level. Before the preparation of food, it is necessary to process the potato into a desirable form. Peeling, cutting, slicing, smashing etc. are the methods used for potato processing.

Table 3.13 shows the loss of traditional stored potato at household and restaurant levels in the study areas. The average quantity of potatoes purchased in a week in all study areas was 3.28 kg. Average post-harvest losses at the household level was 3.24% of purchased potatoes. The highest loss was found in Bogra (4.38%) followed by Jessore (4.06%) and the lowest was in Rajshahi (2.40%). This loss comprised rotten loss and processing loss. Rotten loss was the loss experienced when part of inside the tuber was found rotten although outside of the tuber was sound. Consumer level loss of potato included the loss occurred during peeling, cutting slicing etc. In all study areas, the processing loss was found higher (2.46%) than the rotten loss (1.08%). Similar losses were observed at restaurant level in all the study areas. But the loss of potato (4.52%) at the restaurant level was found to be higher than the household level (3.54%). This might be due to that for household level, small quantities of potato were purchased and much care taken at the time of purchase avoiding possible defective tubers. But in the case of restaurant, bulk quantity of potatoes (an average of 63 kg) is purchased at a time and there is less possibility for sorting and rejecting the defective potatoes. Sometimes, bagged potatoes are purchased and there is no chance for sorting. Again, at household level a few tubers were cut for cooking and care was taken during peeling and cutting to avoid possible loss. But at restaurant level, a large number of tubers are cut at a time and it is not always possible to take much care during peeling and cutting. As a result losses become higher at restaurant level than at the household level.

**Table 3.13 Post-harvest loss of traditional stored potato at household and restaurant levels in the study areas**

| Particulars | Comilla | Jessore | Munshi -gonj | Rajshahi | Bogra | Thaku - rgaon | All area |
|---|---|---|---|---|---|---|---|
| **Household:** | | | | | | | |
| Potato bought in a week (kg) | 3.60 | 3.45 | 3.75 | 2.90 | 3.20 | 2.80 | 3.28 |
| Total loss (kg) | 0.13 **(3.61)** | 0.14 **(4.06)** | 0.12 **(3.20)** | 0.09 **(2.40)** | 0.14 **(4.38)** | 0.10 **(3.57)** | 0.12 **(3.54)** |
| (i) Rotten loss (kg) | 0.06 (1.57) | 0.02 (0.49) | 0.05 (1.23) | 0.02 (0.640 | 0.04 (1.11) | 0.04 (1.43) | 0.04 (1.08) |
| (ii) Processing loss (kg) | 0.07 (2.04) | 0.12 (3.57) | 0.07 (1.97) | 0.05 (1.76) | 0.10 (3.27) | 0.06 (2.14) | 0.08 (2.46) |
| **Restaurant:** | | | | | | | |
| Potato bought in a week (kg) | 80 | 100 | 60 | 40 | 50 | 45 | 63 |
| Total loss (kg) | 3.44 **(4.30)** | 5.10 **(5.10)** | 2.82 **(4.70)** | 1.68 **(4.20)** | 2.30 **(4.60)** | 1.91 **(4.24)** | 2.88 **(4.52)** |
| (i). Rotten loss (kg) | 1.81 (2.26) | 1.53 (1.53) | 1.64 (2.73) | 0.98 (2.44) | 0.67 (1.33) | 0.95 (2.10) | 1.26 (2.07) |
| (ii) Processing loss (kg) | 1.63 (2.04) | 3.57 (3.57) | 1.18 (1.97) | 0.70 (1.76) | 1.64 (3.27) | 0.96 (2.14) | 1.61 (2.46) |

*Note: Figures in the parentheses indicate percentage loss of total quantity bought*

### 3.5 Post-harvest Losses of Cold Stored Potatoes

#### 3.5.1 Description of cold storage

All cold storages have permanent establishment such as land, building with office room, cool chamber, pre-cool chamber, machine room, curing shed, etc. There are several permanent staff like a manager, accountant, foreman, machine operator and supervisor. These staffs get a fixed monthly salary. Loading, unloading, inversion, etc. are carried out by contact labours. These labours are engaged in works through an intermediary called 'Labour Member'. The labour member generally makes contact with the cold storage owner to accomplish the necessary works during the storage period. He received payment from the cold storage owner on a bag basis for loading, unloading and inversion. He then pays wages to the labours on a daily basis.

Generally two types of clients store potatoes in cold storage such as farmers and traders. Traders buy potato from farmers during harvesting season, store in the cold storage to get good price in off season. In the study areas about 66% of the sampled farmers and 46% of sampled traders stored potatoes in cold storage. Cold storage users use two chains to avail

the facility of storing potato in cold storage: through an agent or without an agent. The storage cost differs between the chains. The cost of keeping potatoes in cold storage varies from one cold storage to another and it was almost same for all type of cold storage users (farmers and traders). The quantity of potatoes in a bag varies from user to user. Cold storage authorities generally allow 85 kg per bag.

**Table 3.14 Capacity utilization, storage loss and other related factors of cold storages**

| Particulars | Comilla | Jessore | Munshi-gonj | Rajshahi | Bogra | Thaku-rgaon | All area |
|---|---|---|---|---|---|---|---|
| Available cold storage* | 17 | 9 | 69 | 24 | 36 | 7 | 27 |
| Storage capacity (ton) | 5773 | 4467 | 8468 | 10000 | 9837 | 8017 | 7904 |
| Capacity utilization (ton) | 5975 (103.51) | 3774 (84.56) | 8722 (103.07) | 8920 (89.22) | 8534 (86.75) | 7415 (92.51) | 7389 (93.49) |
| Good potato obtained (ton) | 5715 (95.65) | 5519 (95.57) | 8399 (96.26) | 8624 (96.68) | 8255 (96.73) | 7119 (96.08) | 7107 (96.19) |
| Loss during storage (ton) | 285 **(4.35)** | 725 **(4.43)** | 310 **(3.61)** | 322 **(3.31)** | 537 **(3.28)** | 539 **(3.92)** | 444 **(3.82)** |
| Availability of electricity in 24 hours | 17.83 | 18.67 | 18.37 | 18.86 | 20.00 | 18.83 | 18.78 |
| Store temperature ($^{o}$C) | 2.01 | 2.31 | 2.32 | 2.27 | 2.25 | 2.31 | 2.25 |
| Storage RH (%) | 81.33 | 83.00 | 81.13 | 82.43 | 82.71 | 80.00 | 81.78 |
| Max.outside temp. ($^{o}$C) (April-May) | 33.00 | 37.80 | 35.00 | 35.70 | 32.70 | 31.6 | 34.33 |
| Pre-cool period (h) | 14.00 | 20.00 | 17.00 | 18.00 | 18.86 | 18.00 | 17.65 |
| Good bag used (%) | 75.00 | 76.00 | 75.63 | 75.57 | 73.43 | 75.83 | 75.23 |
| Matured potato stored (%) | 87.00 | 89.50 | 88.13 | 90.71 | 90.14 | 88.17 | 88.98 |
| Number of inversion of bag during storage | 5.17 | 5.33 | 4.25 | 4.14 | 5.29 | 3.50 | 4.60 |
| Number of bag per stack | 5.83 | 5.67 | 6.38 | 6.29 | 5.86 | 6.00 | 6.02 |
| Maximum storage period (month) | 9.50 | 8.17 | 9.75 | 9.43 | 9.42 | 9.33 | 9.30 |

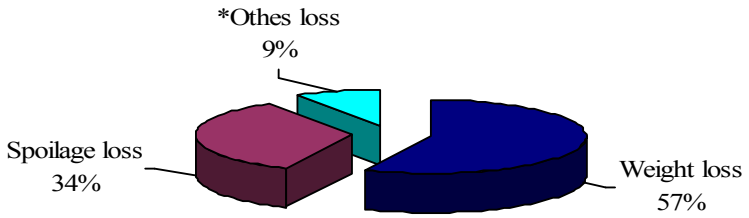
*Note: Figures in the parentheses indicate percentage*
**Government cold storages were not included in this study*

### 3.5.2 Capacity utilization, related factors and storage loss

Capacity utilization, storage loss and other related factors of cold storages are shown in Table 3.14. The highest number of cold storages were found in Munshigonj (69) and the lowest in Thakurgaon (7). The number of cold storages in Comilla, Jessore, Rajshahi and Bogra were 17, 9, 24, and 36 respectively. The average capacity of cold storages in all areas was 7,904 tons of potato. The highest size of cold storages was found in Rajshahi

(10,000 tons) followed by Bogra (9,837 tons), Munshigonj (8,468 tons) and Thakurgaon (8,017 tons), whereas the lowest capacity of cold storages was observed in Comilla (5,773 tons) and Jessore (4,467 tons). It is observed from the Table 3.11 that in Comilla (103.51%) and Munshigonj (103.07%) cold storages were loaded above their capacity. But in other study areas capacity utilization of cold storages was below the capacity limit. The average capacity utilization in all areas was 93.49% which is below the design capacity of the cold storages.

After nine months (March-November) storage, 96.19% of the stored potatoes were found to be in good condition. The average potato loss in cold storage during storage of nine months period was 3.82% of total potato stored. This loss comprised the weight loss (57%), spoilage loss (34%) and other loss (9%) caused due to sprouting, shrinkage, cold injury etc. (Fig. 3.2). Weight loss in the present study was 2.15% which is very close to the result presented by Islam *et al*. (2008): between 1.2 to 2.38% in Bangladesh. It is also quite close to the result presented by Meyhuay (2007): between 1 to 4%.




*Other loss included sprouting, shrinkage etc.

**Fig. 3.2. Components of cold storage losses of potato**

The electric power supply in all study areas was in an alarming situation. Average electricity supply in the study areas was 18.78 hours per day i.e. the cold storage remained without power supply for about five hours. Most of the cold storages had their own generator for supply of electricity during load shedding time but most of them were used only for lighting. Most of the generators were not able to generate sufficient power for the operation of the cooling machine due to low capacity and low voltage of electricity. The

storage temperatures in all selected cold storage were below 3.0°C those were within the recommended range of temperature (2-4°C) for storing of potato in cold storage. But the clients of cold storage (farmer and stockiest) informed that the cold storage managers did not give the correct information regarding temperature. According to their (clients) opinion, temperature in the cold storage remained higher than the recommended temperature.

The relative humidities of all cold storages were 80-83% which are below the desirable value (>90%). Most cold storages did not measure the temperature and relative humidity in the storage chambers but the gauged it from the panel board. Average pre-cool period of all the studied cold storages was 17.65 hour which was below the required minimum pre-cool period (24 hours). Potato should be stored in the cold storage in good quality bag. Yet, low quality bags were used in about 25% of the cases for packing of stored potato. The low quality bag included very old bags and used bags of flour and spices. During the storage period, these bags disrupted ventilation and made potatoes susceptible to insect and pest such as rats. Immature potatoes deteriorate rapidly and suffer from heat or cold stresses. The maturity of cold stored potato in all cold storages was 88.98%. Generally, early harvested potatoes are immature. Bags in the cold storages were inverted several times for uniform cooling. The average number of inversion in the studied cold storages was 4.60 times. The minimum and maximum inversions recorded were three and six times respectively.

The number of bags (layer) per stack ranged from 5 to 7 and the average figure was 6.02. The maximum storage period started from the middle of February and ended in mid December. The customer had to pay for a fixed amount of money as rent to the cold storage. He could take the potatoes out from the cool chamber at any time but rent remained fixed.

### 3.5.3 Economics of Cold Storage Operation

Mainly two aspects of cost are involved in cold storage operations in the form of variable cost and fixed cost (Table 3.15). The variable cost was found to be the highest cost component, and accounted for 84.67 % while fixed cost was 15.33% of total cost. Among the variable costs, electricity ranked the highest (43.86%). The next cost component was labour (18.13%) followed by staff salary (14.28%). The cost for using cooling gas was the lowest

(0.72%) variable cost component. These costs were found similar in all study areas. Fixed cost comprised of interest on invest (1.80%), taxes (1.10%), insurance (1.69%), depreciation on shade and building (3.35%), and depreciation on machinery (7.21%). The total cost was the highest in Rajshahi (Tk. 9,713,496) and the lowest was in Jessore (Taka 5,497,907). The average cost in all areas was Taka 7,996,320.

**Table 3.15 Annual costs of cold storage operations in the study areas**

(Figures in Taka)

| Particulars | Comilla | Jessore | Munshi-gonj | Rajshahi | Bogra | Thaku-rgaon | All area |
|---|---|---|---|---|---|---|---|
| **A. Variable cost** | **5287950 (84.38)** | **4532001 (82.43)** | **7684125 (84.87)** | **8271713 (85.16)** | **7931084 (85.06)** | **6914600 (85.14)** | **6770246 (84.67)** |
| 1. Electricity bill | 2650000 (42.29) | 2225000 (40.47) | 4037500 (44.59) | 4380000 (45.09) | 4142857 (44.43) | 3561667 (43.86) | 3499504 (43.86) |
| 2. Fuel and oil | 266667 (4.26) | 366667 (6.67) | 245625 (2.71) | 259428 (2.67) | 597571 (6.41) | 200000 (2.46) | 322660 (4.04) |
| 3. Cooling gas | 40617 (0.65) | 32833 (0.60) | 72125 (0.80) | 64143 (0.66) | 55228 (0.59) | 78600 (0.97) | 57258 (0.72) |
| 4. Repair and maintenance | 225000 (3.59) | 166667 (3.03) | 400000 (4.42) | 212857 (2.19) | 235714 (2.53) | 241667 (2.98) | 246984 (3.09) |
| 5. Staff salary | 1040000 (16.60) | 860000 (15.64) | 1070500 (11.82) | 1617143 (16.65) | 1001429 (10.74) | 1262333 (15.54) | 1141901 (14.28) |
| 6. Labor wages | 1017333 (16.23) | 881667 (16.04) | 1795875 (19.84) | 1684571 (17.34) | 1835428 (19.68) | 1525333 (18.78) | 1450035 (18.13) |
| 9.Miscellaneous | 48333 (0.77) | 39167 (0.71) | 62500 (0.69) | 53571 (0.55) | 62857 (0.67) | 45000 (.55) | 51905 (0.65) |
| **B. Fixed cost** | **978854 (15.62)** | **965906 (17.57)** | **1369781 (15.13)** | **1441783 (14.84)** | **1393323 (14.94)** | **1206803 (14.86)** | **1212575 (15.33)** |
| 1. Interest on investment | 134507 (2.15) | 199872 (3.64) | 163500 (1.81) | 171982 (1.77) | 166240 (1.78) | 109379 (1.35) | 144080 (1.80) |
| 2. Taxes | 78652 (1.26) | 109800 (2.00) | 93619 (1.03) | 72057 (0.74) | 78662 (0.84) | 96190 (1.18) | 88163 (1.10) |
| 3. Insurance | 105759 (1.69) | 90640 (1.65) | 153683 (1.70) | 165434 (1.70) | 158622 (1.70) | 138292 (1.70) | 135405 (1.69) |
| 4. Depreciation on building | 210460 (3.36) | 180374 (3.28) | 305828 (3.38) | 329214 (3.32) | 315657 (3.39) | 275201 (3.34) | 269456 (3.35) |
| 5. Depreciation on machinery | 449476 (7.17) | 385220 (7.01) | 653151 (7.21) | 703096 (7.24) | 674142 (7.23) | 587741 (7.26) | 575471 (7.21) |
| **C. Total cost (A+B)** | **6266804 (100)** | **5497907 (100)** | **9053906 (100)** | **9713496 (100)** | **9324407 (100)** | **8121403 (100)** | **7996320 (100)** |
| D. Gross return | 13714167 | 18115000 | 18625000 | 24374286 | 17947186 | 24520000 | 20194062 |
| E. Net return (D-C) | 7447363 | 12617093 | 9571094 | 14660790 | 8622779 | 16398597 | 11552953 |
| **F. BCR** | **2.19** | **3.29** | **2.06** | **2.51** | **1.92** | **3.02** | **2.50** |

*Note: Figures inside the parentheses indicate percent of total cost*

The highest gross return was obtained from potato storage in Thakurgaon (Tk. 24,520,000) followed by Rajshahi (Taka 24,374,286) and Munshigonj (Taka 18,625,000). The lowest

gross return was obtained from Comilla (Taka 13,714,167). The average gross return in all areas was Taka 20194062. The net return in all study areas followed the same trend of gross return and the average net return was found to be Taka 11,552,953. The average benefit cost ratio (BCR) in all study areas was 2.50. The BCR in Thakurgaon (3.02**)** was the highest and the lowest BCR (1.92) was in Bogra. The BCRs of cold storages are close to the findings of Islam *et al.* (2008) for several storages in Rangpur district. These results indicated that cold storage of potato in all study areas is a profitable business.

### 3.5.4 Problems of Cold Storage Operation

Problems of cold storage operations in the study areas are shown in Table 3.16. Several problems were encountered in the study areas. Load shedding was found to be the number one recurrent problem in cold storage operation. Respondents in all study areas faced severe load shedding problem. During cold storage loading period and in high temperatures (March to May), it was very difficult to cool down the air in the cold storage.

**Table 3.16 Respondents perceptions on problems of cold storage operation in the study areas**

(Figures in percentage)

| Particulars | Comilla | Jessore | Munshi-gonj | Rajshahi | Bogra | Thaku-rgaon | All area |
|---|---|---|---|---|---|---|---|
| 1. Load shedding | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 2. Storage used above capacity | 100 | 100 | 100 | 100 | 100 | 80 | 96.7 |
| 3. Bags used above capacity | 60 | 60 | 80 | 40 | 60 | 40 | 56.7 |
| 4. Potatoes not properly sorted | 40 | 60 | 40 | 60 | 80 | 40 | 53.3 |
| 5. Poor quality bags | 60 | 40 | 40 | 60 | 60 | 40 | 50.0 |
| 6. Potatoes not cured properly | 20 | 40 | 20 | 80 | 60 | 40 | 43.3 |
| 7. Immature potatoes stored | 20 | 20 | 20 | 20 | 40 | 20 | 23.3 |
| 8. Cut and infected potatoes stored | 20 | 20 | 20 | 20 | 20 | 20 | 20.0 |
| 9. Loans not properly time disbursed | 20 | - | 20 | 20 | 20 | - | 13.3 |
| 10. Other problems | - | - | - | 20 | 20 | 20 | 10.0 |

Most of the cold storage had their own generator but the capacity of the generator was not sufficient to operate cooling machine. Hundred percent of the respondents in all areas except Thakurgaon (80%) thought load shedding in cold storage was one of the major problems. All the cold storages stored potato on a volume (number of bags) basis, not weight basis. The standard weight of each bag filled with potatoes is 80 kg. But practically no bag was found below 85 kg. Therefore, each of the bag weighed at least 6% more than its capacity and thus the storage capacity of the cold storage became over loaded. Farmers and traders had no enough time and not interested to spend money for sorting and grading potatoes at storage time. Immature, pest and disease infected, off size, dirty potatoes were mixed together and bagged for storage. As a result, these infected potatoes caused spoilage of other good potatoes. About 53% respondents thought it was a problem for the storage of potatoes. The perceptions of 50% of the respondents were that one of the causes of spoilage of potato was the use of poor quality bag. About 43% respondents thought that if potato was not properly cured and these were susceptible to insect and disease attack due to its tender skin. Due to tender cells immature potatoes deteriorate rapidly. Twenty percent farmers in all study areas said that storage of cut and infected potatoes damage the surrounding potatoes by spreading the rot. Sometimes cold storage owner provided loan to the traders to purchase and storage of potato. About 13% respondent thought if bank loans are not disbursed in time, it hampers potato storage.

### 3.5.5 Marketing of Cold Stored Potato

The process of cold stored potato marketing started from the cold storage in and around urban areas and continued through certain channels until the potato reached the final consumers. A number of intermediaries were involved in the marketing systems. Some of the big farmers stored potatoes in the cold storage to sell them during off season at a higher price. It was found that *Beparis* and *Paikers* were important middlemen in the process of potato marketing. Some of the *Beparis* and *Paikers* bought potatoes in the harvesting season and stored them in cold storage. These *Beparis* and *Paikers* then became potato stockist. When the market price of potato became high (traditional stored potato quantities diminished in the market), they brought out potatoes from cold storage and sold it to another *Bepari* and *Paiker*. Sometimes, they directly sold potatoes to *Aratdars* or retailers.

The marketing channel of cold stored potato is shown in Fig 3.3. *Beparis* and *Paikers* bought potatoes from cold storage (farmer/stockiest). The share of *Beparis* purchasing potatoes from cold storage was higher that the share of *Paikers* (73.2% against 24.4%). *Paikers* also bought some potatoes (1.8%) from *Bepari*. *Aratdars* bought all their potatoes from *Beparis* and sold 42.1% of their stock to *Paikers* and 16.1% to retailers. *Paikers* sold the majority of their potato stock (68.1%) to retailers and a very small quantity directly to consumers (0.2%). Retailers sold their whole stock (100.0%) of potatoes but 99.8% of the channel to the consumers.

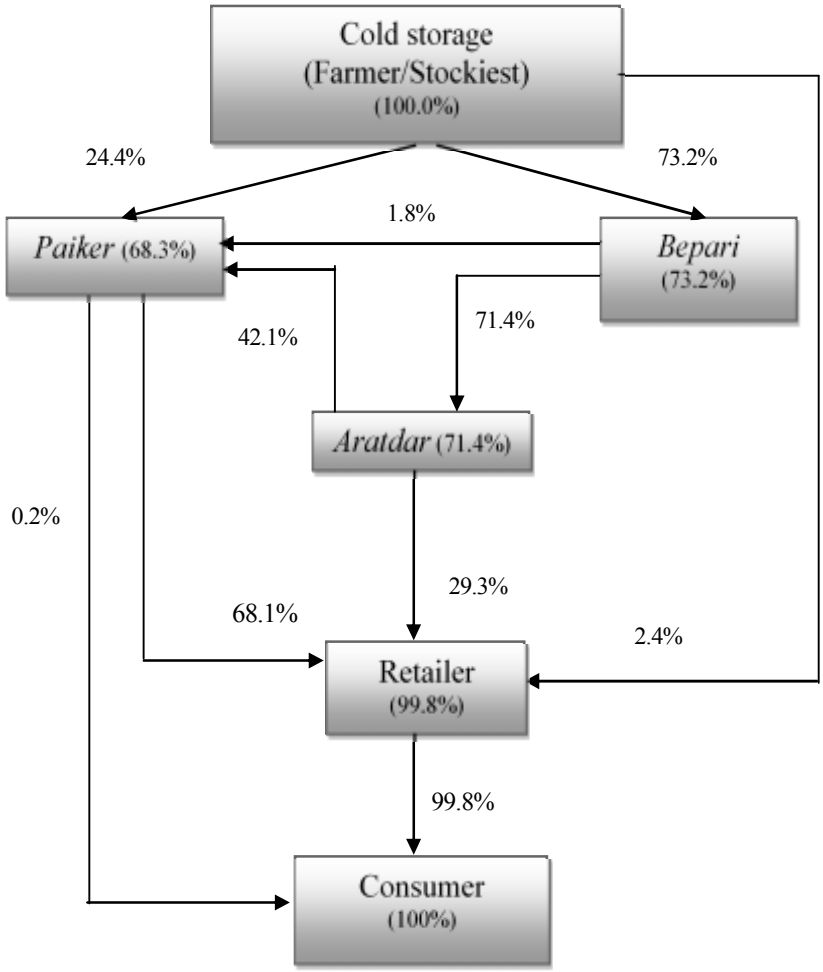



**Fig. 3. 3 Flow diagram of marketing of cold stored potato**

The following major channels were identified in the study areas for cold stored potato marketing:

1. Cold storage → Retailer→Consumer
2. Cold storage → *Bepari*→ *Aratdar*→Retailer→Consumer
3. Cold storage→*Bepari* →*Aratdar*→*Paiker*→ Retailer → Consumer
4. Cold storage→*Bepari* →*Paiker*→ Retailer → Consumer
5. Cold storage→P*aiker* →Retailer → Consumer

**3.5.5.1 Quantity traded and loss at *Bepari* level**

The quantity of potatoes traded by *Beparis* and loss occurred during potato transaction at *Bepari* level in the study areas are shown in Table 3.17. The average quantity of potatoes *Beparis* purchased in one week was 25,849 kg. *Beparis* bought all their potatoes from cold storage either from farmer or stockiest (another *Bepari* or *Paiker*). Large quantities of potatoes were sold by *Beparis* to *Aratdars* (75.73%) and then *Paikers* (21.15%). A small amount (3.13%) of potatoes was sold to the retailer. The highest quantity of potato sold to *Aratdar* was in Munshigonj and the lowest quantity (1.90%) was sold to the retailer in Jessore.

The average total loss of potato in all areas was 2.82% of total bought potato. The shares of different types of potato loss were weight loss (1.00%), rotten loss (0.80%), handling loss (0.62%) and transportation loss (0.40%). The average loss of cold stored potatoes (2.82%) marketed by *Beparis* was a little higher than that of traditional stored potato (2.36%). The reason might be that moisture loss and rotten loss of cold stored potato was higher than those of traditional stored potato. Traditional stored potatoes were kept in an ambient condition for a long time (2-3 months) and it was dried with the ambient air. On the other hand, cold stored potatoes remained for a longer time (3-9 months) in a low temperature (2.2$^{o}$C) and high relative humidity (>80%). When they brought out from cold storage into the ambient condition (generally at high temperature and low relative humidity), their moisture loss became high.

**Table 3.17 Quantity traded and loss of cold stored potatoes at *Bepari*'s level in the study areas**

(Figures in kg)

| Particulars | Comilla | Jessore | Munshi-gonj | Rajshahi | Bogra | Thakur-gaon | All areas |
|---|---|---|---|---|---|---|---|
| **A. Quantity bought from** | **23151 (100)** | **35813 (100)** | **40198 (100)** | **25077 (100)** | **18300 (100)** | **12457 (100)** | **25849 (100)** |
| Cold storage (Stockiest) | 23151 (100) | 35813 (100) | 40198 (100) | 25077 (100) | 18300 (100) | 12457 (100) | 25849 (100) |
| **B. Quantity sold to** | **22570 (100)** | **35050 (100)** | **38835 (100)** | **24500 (100)** | **17760 (100)** | **12002 (100)** | **25120 (100)** |
| *Aratdar* | 15840 (70.17) | 23870 (68.10) | 36895 (95.00) | 17575 (71.73) | 12950 (72.93) | 9748 (62.25) | 19379 (75.73) |
| *Paiker* | 5600 (24.81) | 10515 (30.00) | 990 (2.55) | 6125 (25.00) | 4060 (22.86) | 5360 (34.23) | 5442 (21.15) |
| Retailer | 1130 (5.00) | 665 (1.90) | 950 (2.45) | 800 (3.27) | 750 (4.22) | 550 (3.52) | 807 (3.13) |
| **C. Quantity lost** | 581 **(2.51)** | 763 **(2.13)** | 1363 **(3.39)** | 577 **(2.30)** | 540 **(2.95)** | 455 **(3.65)** | 729 **(2.82)** |
| Weight loss | 224.6 (0.97) | 300.8 (0.84) | 454.2 (1.13) | 218.2 (0.87) | 192.1 (1.05) | 142.0 (1.14) | 258.5 (1.00) |
| Rotten loss | 173.6 (0.75) | 186.2 (0.52) | 377.9 (0.94) | 180.6 (0.72) | 151.9 (0.83) | 128.3 (1.03) | 206.4 (0.80) |
| Handling loss | 108.8 (0.47) | 164.7 (0.46) | 325.6 (0.81) | 107.8 (0.43) | 129.9 (0.71) | 107.1 (0.86) | 161.1 (0.62) |
| Transportation loss | 74.08 (0.32) | 111.02 (0.31) | 205.01 (0.51) | 70.21 (0.28) | 65.88 (0.36) | 77.23 (0.62) | 103.40 (0.40) |

*Note: Figures in the parentheses indicate percentage loss of total quantity bought*

### 3.5.5.2 Quantity traded and loss at *Aratdars'* level

*Aratdars* in all study areas bought potatoes from a single source i.e. from *Beparis* (Table 3.18). These potatoes were sold to *Paikers* and retailers. About 83.18% of potatoes were sold to *Paikers* and remaining 16.82% were sold to retailers. The highest quantity (90%) was sold to the *Paikers* of Bogra area and the lowest quantity was sold to the retailers of the same area.

The average loss for all areas was found to be 1.66% of total bought quantity. This loss was due to the weight loss, rotten loss, handling loss, and transportation loss. The highest loss was found in Jessore (2.21%) and the lowest loss was in Rajshahi area. A higher loss (1.66%) was found for cold stored potato than that of traditional stored potato (1.55%). This may be due to that cold stored potato was kept in higher humidity (>80% ) than the traditional stored potato with lower humidity (40-70%). When cold stored potatoes were taken out from the cold storage the weight loss became higher.

**Table 3.18 Quantity traded and loss of cold stored potatoes at *Aratdar's* level in the study areas**

(Figures in kg)

| Particulars | Comilla | Jessore | Munshi-gonj | Rajshahi | Bogra | Thakur-gaon | All areas |
|---|---|---|---|---|---|---|---|
| **A. Quantity bought from** | **11080 (100)** | **10839 (100)** | **19719 (100)** | **10970 (100)** | **11540 (100)** | **9270 (100)** | **12242 (100)** |
| *Bepari* | 11080 (100) | 10839 (100) | 19719 (100) | 10970 (100) | 11540 (100) | 9270 (100) | 12242 (100) |
| **B. Quantity sold to** | **11080 (100)** | **10839 (100)** | **19719 (100)** | **10970 (100)** | **11540 (100)** | **9270 (100)** | **12242 (100)** |
| *Paiker* | 9280 (84.98) | 7980 (75.14) | 16740 (86.00) | 8445 (78.04) | 10155 (89.99) | 7480 (82.02) | 10014 (83.18) |
| Retailer | 1640 (15.02) | 2640 (24.86) | 2725 (14.00) | 2375 (21.96) | 1130 (10.01) | 1640 (17.98) | 2025 (16.82) |
| **C. Quantity lost** | 160 (**1.44**) | 219 (**2.02**) | 254 (**1.29**) | 150 (**1.37**) | 255 (**2.21**) | 150 (**1.62**) | 198 (**1.66**) |
| Weight loss | 70.9 (0.64) | 82.4 (0.76) | 116.3 (0.59) | 70.2 (0.64) | 85.4 (0.74) | 51.0 (0.55) | 80.0 (0.65) |
| Rotten loss | 37.7 (0.34) | 61.8 (0.57) | 53.2 (0.27) | 35.1 (0.32) | 73.9 (0.64) | 43.6 (0.47) | 53.3 (0.44) |
| Handling loss | 35.5 (0.32) | 34.7 (0.32) | 51.3 (0.26) | 24.1 (0.22) | 57.7 (0.50) | 38.9 (0.42) | 41.6 (0.34) |
| Transportation loss | 15.5 (0.14) | 40.1 (0.37) | 33.5 (0.17) | 20.8 (0.19) | 38.1 (0.33) | 16.7 (0.18) | 28.2 (0.23) |

*Note: Figures in the parentheses indicate percentage loss of total quantity bought*

### 3.5.5.3 Quantity traded and loss at *Paikers'* level

The quantity of potatoes traded by *Paikers* and the loss of cold stored potatoes at *Paikers'* level in the study areas is illustrated in Table 3.19. *Paikers* bought 2298 kg (13.59%) potatoes from *Bepari* and 14617 kg (86.41%) potatoes from *Aratdars* in each week. *Paikers* sold most of the potatoes (91.04%) to retailers and small amounts (8.96%) directly to the consumer. Generally big consumers like restaurant owners bought potato from the *Paikers* at a comparatively lower price.

During buying and selling about 1.52% loss of potato was found. This loss was the combination of weight loss (0.59%), rotten loss (0.45%), handling loss (0.31%) and transportation loss (0.17%). Total loss was found to be the highest in the Jessore area (2.02%). Among the loss components, transportation loss was lowest and no transportation loss was found in Rajshahi area.

**Table 3.19 Quantity traded and loss of cold stored potatoes at *Paiker's* in the study areas**

(Figures in kg)

| Particulars | Comilla | Jessore | Munshi-gonj | Rajshahi | Bogra | Thakur-gaon | All areas |
|---|---|---|---|---|---|---|---|
| **A. Quantity bought from** | **9560 (100)** | **16980 (100)** | **26200 (100)** | **12900 (100)** | **21550 (100)** | **14300 (100)** | **16915 (100)** |
| Bepari | 1430 (14.96) | 3055 (17.99) | 1690 (6.45) | 895 (6.94) | 4850 (22.51) | 1870 (13.08) | 2298 (13.59) |
| Aratdar | 8130 (85.04) | 13925 (82.01) | 24510 (93.55) | 12005 (93.06) | 16700 (77.49) | 12430 (86.92) | 14617 (86.41) |
| **B. Quantity sold to** | **9445 (100)** | **16630 (100)** | **25755 (100)** | **12778 (100)** | **21250 (100)** | **14040 (100)** | **16650 (100)** |
| Retailer | 8500 (89.99) | 14300 (85.99) | 24305 (94.37) | 10907 (85.36) | 20179 (94.96) | 12759 (90.88) | 15158 (91.04) |
| Consumer | 957 (10.01) | 2379 (14.01) | 1475 (5.63) | 1889 (14.64) | 1086 (5.04) | 1304 (9.12) | 1516 (8.96) |
| **C. Quantity lost** | 115 (**1.20**) | 350 (**2.06**) | 443 (**1.69**) | 124 (**0.96**) | 300 (**1.39**) | 260 (**1.82**) | 257 (**1.52**) |
| Weight loss | 44.0 (0.46) | 115.5 (0.68) | 165.1 (0.63) | 61.9 (0.48) | 120.7 (0.56) | 103.0 (0.72) | 99.5 (0.59) |
| Rotten loss | 32.5 (0.34) | 91.7 (0.54) | 133.6 (0.51) | 41.3 (0.32) | 94.8 (0.44) | 78.7 (0.55) | 76.1 (0.45) |
| Handling loss | 20.1 (0.21) | 81.5 (0.48) | 89.1 (0.34) | 20.6 (0.16) | 49.6 (0.23) | 61.5 (0.43) | 52.2 (0.31) |
| Transportation loss | 18.2 (0.19) | 61.1 (0.36) | 55.0 (0.21) | - | 34.5 (0.16) | 17.2 (0.12) | 29.3 (0.17) |

*Note: Figures in the parentheses indicate percentage loss of total quantity bought*

### 3.5.5.4 Quantity traded and loss at retailer's level

Retailer was the last intermediary of the potato marketing system. Retailers bought potatoes from *Paikers* and *Aratdars* and also directly from cold storage. The share of quantity bought from *Paikers*, *Aratdars* and cold storage were 82.30, 15.11 and 2.59%, respectively. Retailers sold his whole quantity of potatoes to the consumer (Table 3.20).

Post-harvest loss also occurred during the marketing of potatoes by retailers. This loss occurred due to the weight loss, rotten loss, handling loss and transportation loss. The highest loss was found in Bogra (4.08%) and the lowest loss was in Rajshahi (3.36%). The average of loss of all areas was found to be 3.61% of total potato bought. The post-harvest loss of cold stored potato was higher than that of traditional stored potato (3.47%) by the retailer.

**Table 3.20 Transaction and loss of cold stored potatoes at retailer's level in the study areas**

(Figures in kg)

| Particulars | Comilla | Jessore | Munshi-gonj | Rajshahi | Bogra | Thaku-rgaon | All areas |
|---|---|---|---|---|---|---|---|
| **A. Quantity bought from** | **420 (100)** | **520 (100)** | **640 (100)** | **480 (100)** | **320 (100)** | **400 (100)** | **463 (100)** |
| Cold storage | 10 (2.38 ) | 12 (2.31) | 20 (3.13) | 8 (1.67) | 10 (3.13) | 12 (3.00) | 12 (2.59) |
| Aratdar | 65 (15.48) | 75 (14.42) | 90 (14.06) | 80 (16.67) | 50 (15.63) | 60 (15.00) | 70 (15.11) |
| Paiker | 345 (82.14) | 433 (83.27) | 530 (82.81) | 392 (81.67) | 260 (81.25) | 328 (82.00) | 381 (82.30) |
| **B. Quantity sold to** | **405 (100)** | **501 (100)** | **618 (100)** | **464 (100)** | **307 (100)** | **385 (100)** | **447 (100)** |
| Consumer | 405 (100) | 501 (100) | 618 (100) | 464 (100) | 307 (100) | 385 (100) | 447 (100) |
| **C. Quantity lost** | 15 (**3.47**) | 19 (**3.66**) | 22 (**3.36**) | 16 (**3.42**) | 13 (**4.08**) | 15 (**3.67**) | 17 (**3.61**) |
| Weight loss | 0.3 (1.23) | 0.2 (1.18) | 0.2 (1.26) | 0.3 (1.30) | 0.5 (1.64) | 0.3 (1.22) | 0.3 (1.31) |
| Rotten loss | 0.3 (1.03) | 0.2 (1.12) | 0.2 (1.05) | 0.2 (0.98) | 0.4 (1.36) | 0.3 (1.08) | 0.3 (1.10) |
| Handling loss | 0.2 (0.72) | 0.2 (0.82) | 0.1 (0.76) | 0.2 (0.76) | 0.2 (0.58) | 0.2 (0.79) | 0.2 (0.74) |
| Transportation loss | 0.1 (0.49) | 0.1 (0.54) | 0.1 (0.29) | 0.1 (0.38) | 0.2 (0.50) | 0.2 (0.58) | 0.1 (0.46) |

*Note: Figures in the parentheses indicate percentage loss of total quantity bought*

### 3.5.2 Post-harvest Loss of Cold Stored Potatoes at Consumers' Level

Post-harvest losses of cold stored potatoes at household and restaurant levels in the study areas are given in Table 3.21. It is observed from the table that quantities of potatoes that have been in cold storage bought by households (2.79 kg) and restaurants (43.28 kg) were fewer than those that had been stored traditionally. The reason might be that the price of cold stored potato was higher than that of traditional stored. But the patterns of losses were similar. Loss at restaurant was higher than the loss occurred in household level. Again, the processing loss was higher than the rotten loss for both household and restaurant levels.

**Table 3.21 Post-harvest loss of cold stored potato at house hold and restaurant levels in the study areas**

| Particulars | Comilla | Jessore | Munshi -gonj | Rajshahi | Bogra | Thaku - rgaon | All area |
|---|---|---|---|---|---|---|---|
| **Household:** | | | | | | | |
| Potato bought in a week (kg) | 2.68 | 3.07 | 2.88 | 2.55 | 2.80 | 2.75 | 2.79 |
| Total loss (kg) | 0.095 **(3.62)** | 0.097 **(3.06)** | 0.092 **(3.17)** | 0.078 **(3.29)** | 0.088 **(3.12)** | 0.094 **(3.46)** | 0.092 **(3.28)** |
| (i) Rotten loss (kg) | 0.03 (1.23) | 0.03 (0.98) | 0.04 (1.42) | 0.02 (0.87) | 0.03 (1.09) | 0.04 (1.31) | 0.03 (1.15) |
| (ii) Processing loss (kg) | 0.06 (2.39) | 0.06 (2.08) | 0.05 (1.75) | 0.06 (2.42) | 0.06 (2.03) | 0.06 (2.03) | 0.06 (2.14) |
| **Restaurant:** | | | | | | | |
| Potato bought | 53.00 | 40.40 | 40.50 | 42.25 | 39.00 | 44.50 | 43.28 |
| Total loss (kg) | 2.93 **(5.53)** | 1.65 **(4.09)** | 1.94 **(4.79)** | 2.14 **(5.06)** | 1.75 **(4.48)** | 1.98 **(4.44)** | 2.05 **(4.73)** |
| (i) Rotten loss (kg) | 0.90 (1.69) | 0.30 (0.74) | 0.23 (0.56) | 0.23 (0.550 | 0.21 (0.53) | 0.32 (0.72) | 0.35 (0.80) |
| (ii) Processing loss (kg) | 2.04 (3.84) | 1.35 (3.35) | 1.71 (4.23) | 1.91 (4.51) | 1.54 (3.95) | 1.66 (3.72) | 1.70 (3.93) |

Note: Figures in the parentheses indicate percentage loss of total quantity bought

### 3.6 Comparison of Traditional and Cold Stored Losses

Total Post-harvest losses of traditional stored and cold stored potatoes are shown in Table 3.22 and Table 3.23, respectively. Total postharvest loss was calculated on actual basis rather than apparent losses. For each of the loss item, actual loss was estimated as total quantity (100%) minus apparent loss. Total losses of traditional stored potatoes including consumers' loss were found to be 27.65% where for cold stored potatoes it was 23.11%. Total losses comprised pre-storage loss, storage loss, losses at traders' level and consumers' level. Variations of traditional stored and cold stored potatoes were mainly due to the storage losses. In the case of traditional stored potatoes, average storage loss was found to be 7.35% for three months of storage period. On the other hand, average storage loss for cold storage was 3.82% for about nine months storage period. Traders' level loss (11.95%) of traditional stored potato was found to be higher than that of cold stored potato (9.61%). This was due to that traditional stored potatoes were affected by continuous spoilage at higher temperature. Consumers' level losses for both traditional and cold stored potatoes were almost same.

**Table 3.22 Post-harvest losses of traditional stored potatoes at different levels in the study areas**

(Figures in percentage)

| Particulars | Comilla | Jessore | Munsh-igonj | Rajs-hahi | Bogra | Thakur-gaon | All areas |
|---|---|---|---|---|---|---|---|
| **A. Farmer** | **16.84** | **14.91** | **15.29** | **15.94** | **14.85** | **15.14** | **15.50** |
| 1. Pre-storage | 8.47 | 8.00 | 7.91 | 8.73 | 7.67 | 8.09 | 8.15 |
| 2. Home storage | 8.37 | 6.91 | 7.38 | 7.21 | 7.18 | 7.05 | 7.35 |
| **B. Trader** | **11.07** | **13.24** | **12.19** | **11.83** | **11.05** | **12.49** | **11.95** |
| 1. *Bepari* | 2.19 | 2.62 | 2.35 | 2.61 | 2.22 | 2.15 | 2.36 |
| 2. *Faria* | 3.01 | 2.69 | 2.08 | 2.46 | 2.20 | 2.75 | 2.50 |
| 3. *Aratdar* | 1.48 | 1.69 | 1.38 | 1.46 | 1.56 | 1.75 | 1.55 |
| 4. *Paiker* | 1.16 | 2.94 | 2.34 | 2.15 | 1.22 | 2.59 | 2.07 |
| 5. Retailer | 3.23 | 3.3 | 4.04 | 3.15 | 3.85 | 3.25 | 3.47 |
| **C. Consumer*** | **3.96** | **4.58** | **3.95** | **3.3** | **4.49** | **3.905** | **4.03** |
| 1. Household | 3.61 | 4.06 | 3.20 | 2.40 | 4.38 | 3.57 | 3.54 |
| 2. Restaurant | 4.30 | 5.10 | 4.70 | 4.20 | 4.60 | 4.24 | 4.52 |
| **D. Total loss** ** **excluding processing** | **25.03** | **25.11** | **24.65** | **24.81** | **23.37** | **24.73** | **24.61** |
| **E. Total loss including processing** | **28.00** | **28.54** | **28.19** | **27.29** | **26.81** | **27.67** | **27.65** |

* *Average of household and restaurant*

** Total loss was calculated on the basis of actual loss basis shown in Section 2.6 in Materials and Method.

Post-harvest losses excluding consumer losses for traditional stored and cold stored potatoes were found to be 24.61 and 19.90% of the total potatoes, respectively. Post-harvest losses of potato in different countries were reported as Colombia 25%, Costa Rica 24%, Dominican Republic 20% and United States 24% (Meyhuay, 2007). These cited losses agreed with the findings in this study. Post-harvest loss at farm level was reported 24% in Bihar and 21% in UP, India (ASET, 2003). Eltawil *et al.* (2006) reported that post-harvest loss at farm level stored potato was 20-30% in India. Another study shows that the post-harvest losses of potato in India were 17% and in Pakistan these losses ranged from 15 to 40% (Iqbal, 1996; Ilangantileke, 1996). Postharvest losses of potato in India were lower than those of present study. This may due to the variations of postharvest practices, climatic conditions and varieties. Post-harvest loss of potato in Iran was 30% (Shahbaz,

2009). In Bangladesh, post-harvest losses of fruits and vegetables are high as 20-50% (Rashid, 2008; Miaruddun and Chowdhury, 2009). Average post-harvest loss of potato was reported by Roy (2009) as 25%. The findings in this study is supported by the above reports.

**Table 3.23 Post-harvest losses of cold stored potatoes at different levels in the study areas**

(Figures in percentage)

| Particulars | Comilla | Jessore | Munshi-gonj | Rajshahi | Bogra | Thakur-gaon | All areas |
|---|---|---|---|---|---|---|---|
| **A. Farmer** (pre-storage) | **8.47** | **8.00** | **7.91** | **8.73** | **7.67** | **8.09** | **8.15** |
| **B. Cold storage** | **4.35** | **4.43** | **3.61** | **3.31** | **3.28** | **3.92** | **3.82** |
| **C. Trader** | **8.62** | **9.87** | **9.73** | **8.05** | **10.63** | **10.76** | **9.61** |
| 1. *Bepari* | 2.51 | 2.13 | 3.39 | 2.30 | 2.95 | 3.65 | **2.82** |
| 2. *Aratdar* | 1.44 | 2.02 | 1.29 | 1.37 | 2.21 | 1.62 | **1.66** |
| 3. *Paiker* | 1.20 | 2.06 | 1.69 | 0.96 | 1.39 | 1.82 | **1.52** |
| 4. Retailer | 3.47 | 3.66 | 3.36 | 3.42 | 4.08 | 3.67 | **3.61** |
| **D. Consumer*** | **4.58** | **3.58** | **3.98** | **4.18** | **3.80** | **3.95** | **4.01** |
| 1. House hold | 3.62 | 3.06 | 3.17 | 3.29 | 3.12 | 3.46 | 3.28 |
| 2. Restaurant | 5.53 | 4.09 | 4.79 | 5.06 | 4.48 | 4.44 | 4.73 |
| **E. Total loss excluding processing** | **19.96** | **20.45** | **19,58** | **18.95** | **19.84** | **20.83** | **19.90** |
| **F. Total loss including processing** | **23.43** | **23.29** | **22.78** | **22.35** | **22.88** | **23.96** | **23.11** |

* *Average of household and restaurant*

** Total loss was calculated on the basis of actual loss basis shown in Section 2.6 in Materials and Method.

### 3.7 Factors Affecting Post-harvest Loss of Potato in Cold Storage

Factors affecting postharvest loss of potato in cold storage are shown in Fig. 3.24. In cold storage, several mechanical, environmental, biological and socio-economic factors are associated with the postharvest losses of stored potatoes. These factors were identified by stepwise regression method. For post-harvest loss in cold storage, the coefficients of electricity and relative humidity in the cool room were negative and significant at 5% level, implying that 1% increase of electricity and relative humidity, keeping other factors constant, would result in a decrease of post-harvest loss by 1.99% and 0.22%, respectively.

**Table 3.24 Estimated values of coefficients and related statistics of Cobb Douglas Production model for post-harvest loss of potato in cold storage**

| Regression variable | | Regression coefficient | t-statistic | p-value | Standard error |
|---|---|---|---|---|---|
| Intercept | a | 0.6346** | 1.2282 | 0.0431 | 1.5756 |
| Electricity | $X_1$ | -1.9988** | -0.7919 | 0.0465 | 1.5242 |
| Temperature | $X_2$ | 9.7336** | 1.1308 | 0.0269 | 6.7336 |
| Relative humidity | $X_3$ | -0.21844** | -0.9684 | 0.03429 | 0.2255 |
| Pre-cooling time | $X_4$ | -0.4641* | -0.0886 | 0.0542 | 1.2382 |
| Good bag used | $X_5$ | -2.3539* | -0.6182 | 0.0854 | 3.8074 |
| Capacity utilization | $X_6$ | 0.1157 | 0.1101 | 0.9132 | 1.0516 |
| Inversion of bags | $X_7$ | -2.3539 | -0.6183 | 0.5424 | 3.8074 |
| Maturity of stored potato | $X_8$ | -1.4180* | -0.8649 | 0.0960 | 1.6395 |
| Storage period | $X_9$ | 1.0696 | 0.8879 | 0.3837 | 1.2046 |
| Bag per stack | $X_{10}$ | 0.6849* | 1.9686 | 0.0611 | 0.3479 |
| Floor type | $X_{11}$ | -0.1792 | -0.3011 | 0.7660 | 0.5953 |
| Age of cold storage | $X_{12}$ | 0.1302* | 0.6466 | 0.0584 | 0.2013 |
| Number of observations | 40 | | | | |
| $R^2$ | 0.6725 | | | | |
| F (40,12) | 2.0481** | | | | |

*'***', '**' and '*' denote 1%, 5% and 10% level of significance*

The influence of outside temperature was found positive and significant at 5% level. These indicated that for increase in temperature 1%, the post-harvest loss would increase by 9.73%. Coefficients of pre-cooling time, good bag used, maturity of stored potato and number of bag per stack were found negative and significant at a 10% level only. This implied that for 1% increase of pre-cooling time, good bag used, maturity of stored potato and number of bag per stack, post-harvest loss of potato would reduce by 0.46, 2.35, 1.42 and 0.68%, respectively. Other variables such as capacity utilization in cold storage, inversion of bag, storage period, floor type and age of cold storage were found not to have a significant effect on the post-harvest loss of potato in cold storage. Coefficients of multiple determination ($R^2$) of the logarithmic regression model was found 0.67 which revealed that 67% of the variation in post-harvest loss at farmers level can be explained by the explanatory variable included in the model. The F-value of the model is significant at

5% level implying that the variation in post-harvest loss depends mainly upon the explanatory variables included in the model.

### 3.8 Technical Efficiency of Cold Storage

The estimated technical efficiencies of selected cold storages and their frequency distributions are shown in Table 3.25. The maximum, minimum and mean efficiencies were 99%, 73% and 91%, respectively. Among the 40 cold storages studied, the efficiencies of three were below 80%, from 80 to 90% efficiencies for 14 cold storages, 94% for seven and 16 cold storages had the efficiencies from 95 to 99%.

**Table 3.25 Frequency distribution and descriptive statistics of the technical efficiency of cold storage**

| Level of technical efficiency | Frequency | Cumulative % |
|---|---|---|
| 0.73 | 1 | 2.50% |
| 0.77 | 2 | 7.50% |
| 0.81 | 0 | 7.50% |
| 0.86 | 5 | 20.00% |
| 0.90 | 9 | 42.50% |
| 0.94 | 7 | 60.00% |
| More | 16 | 100.00% |
| Total | 40 | 100.00% |
| Maximum | 0.99 | |
| Minimum | 0.73 | |
| Mean | 0.91 | |
| Range | 0.27 | |
| Standard deviation | 0.068 | |
| Standard error of mean | 0.108 | |

The Cobb Douglas Stochastic Frontier Production Function model was used to estimate the technical efficiency of cold storage and results have been presented in Table 3.26. A total of nine independent variables were used in the model and out of them, five were found to be significant. The coefficients of daily maximum outside temperature and percent of good bag used for packing and storage of potato were both significant at 1% level. The elasticities of maximum ambient temperature and good bag were -2.09 and 1.53, respectively. It implies that the good potato output would increase by 2.09 and 1.53% if the maximum ambient temperature was decreased and use of good quality bags was increased by 1%.

**Table 3.26 Maximum Likelihood Estimates of the Cobb Douglas Stochastic Frontier Production Function for estimation of technical efficiency of cold storage**

| Variables | Parameters | Coefficients | Standard error | t-ratio |
|---|---|---|---|---|
| Intercept | $\beta_0$ | 10.40924*** | 1.09243 | 9.52852 |
| Supply of electricity in 24 hours (h) | $\beta_1$ | 0.84641** | 0.37257 | 2.27184 |
| Outside max. temperature (°C) | $\beta_2$ | -2.08796*** | 0.81382 | -2.56563 |
| Relative humidity in cool room (%) | $\beta_3$ | 0.69560** | 0.33290 | 2.08949 |
| Pre-cooling time (h) | $\beta_4$ | 0.05549 | 0.09475 | 0.58560 |
| Good bag used (%) | $\beta_5$ | 1.52552*** | 0.42558 | 3.58460 |
| Capacity utilization (%) | $\beta_6$ | -0.06642 | 0.84422 | -0.07867 |
| Inversion of bag (number) | $\beta_7$ | 0.05925 | 0.33927 | 0.17463 |
| Maturity of stored potato (%) | $\beta_8$ | 0.49355* | 0.36711 | 1.64442 |
| Storage period (month) | $\beta_9$ | -0.09807 | 0.33309 | -0.29441 |
| Sigma-squared | $\sigma^2$ | 0.13780*** | 0.07533 | 2.82920 |
| Gamma | $\gamma$ | 0.99998*** | 0.00129 | 77.0039 |
| Log likelihood function | -12.22191 | | | |

** indicates significant (p<0.1), ** indicates significant (p<0.05) and *** indicates significant (p<0.01)*

Electricity supply and relative humidity inside the store were found to be positive and significant at 5% level. Hence, the elasticities of electricity supply and relative humidity were 0.85 and 0.69, respectively. For additional 1% increase of the supply of electricity and increase of the relative humidity, the good potato production would increase by 0.85 and 0.69%, respectively. The maturity of stored potatoes was found significant at 10% and its elasticity was 0.49. Output of good potato would increase by 0.49 percent if additional matured potato could be stored. The coefficients of other variables such as pre-cooling period, number of inversion during storage, and storage period were insignificant they had positive responses on the production of good potato.

The estimated value of variance ($\sigma^2$) was significantly different from zero which indicated good fit and correctness of specified distributional assumption. The high value of gamma ($\gamma$) (0.99) indicated the presence as well as dormancy of inefficiency effect over random error.

***Inefficiency effect***

The estimated coefficients of technical inefficient model (Table 3.27) showed that the experience of cold storage manager was negatively significant on inefficiency model at a 5% level. So, as one would expect, the increase of managers' experience would reduce the inefficiency of the model as well as increase the output of good potato. Training and the type of storage floor were positively significant at 10% level. Training and wooden floor decrease the inefficiency of cold storage thus increases the output of good potato. The coefficient of the type of power supply and age of cold storage had some positive effects on the inefficiency model but these were found insignificant.

**Table 3.27 Maximum Likelihood Estimates of the Cobb Douglas Stochastic Frontier Production Function for estimation of technical inefficiency of cold storage**

| Coefficients | Notation | Coefficient | standard -error | t-ratio |
|---|---|---|---|---|
| Intercept | $\delta_0$ | 1.18848 | 0.88624 | 1.34105 |
| Manager's experience (yr) | $\delta_1$ | -0.06406** | 0.24172 | -2.65039 |
| Training | $\delta_2$ | -0.74572* | 0.55283 | -1.74892 |
| Type of power supply (Wood = 1, other =0) | $\delta_3$ | 0.32464 | 0.44148 | 0.73533 |
| Floor type (Wood = 1, other = 0) | $\delta_4$ | -0.31874* | 0.21955 | -1.65179 |
| Age of cold storage (year) | $\delta_5$ | 0.00153 | 0.07350 | 0.02077 |

** indicates significant (p<0.1), ** indicates significant (p<0.05) and *** indicates significant (p<0.01)*

# 4. Key Findings

This research shows the post-harvest losses of potato in different post harvest operations. Different potato storage systems and marketing channels have been identified. Variables responsible for postharvest losses have been identified and their coefficients have been estimated. The technical efficiency of potato cold storage has been estimated.

Disposal pattern of potato at farm level was calculated. About 2.92% potato was used for family consumption, 0.52% was gifted to others, 62.04% was sold during harvesting period, 12.73% potato was stored in cold storage as seed and another 23.04% was stored as table potato either in home or in cold storage. Average harvesting loss in all areas was found to be 5.65% of total production. Harvesting loss comprised insect damage (1.21%), rotten loss (1.40%), cutting loss (1.14%), potato remained under soil during harvesting (0.89%), and other losses (1.02%). Pre-storage and home storage losses of potatoes were 8.15 and 7.35%, respectively.

The average capacity utilization in all areas was 93.49%. The average loss in cold storage during nine months storage period was 3.82% of total potato stored. This loss included the weight loss (57%), spoilage loss (34%) and other loss (9%) caused due to sprouting, shrinkage, cold injury etc. Load shedding, storing of unsorted potatoes, overload of storage bags are the main problems in cold storage operation.

Two different types of potato marketing systems were identified- traditional stored and cold stored potato marketing. In the case of traditional stored potatoes, the marketing channel comprised farmer *Bepari* (big trader), *Faria* (petty trader) *Paiker* (wholesaler), *Aratdar (*commission agent), retailer and consumer. For cold stored potato marketing channel composed of Stockiest/farmer, *Bepari*), *Faria, Paiker, Aratdar*, retailer and consumer. The average loss at traders' level for traditional and cold stored potatoes was 11.95 and 9.61%, respectively.

Average post-harvest losses in the household and restaurant levels were 3.24, and 4.52%, respectively of purchased potato. This loss comprised rotten loss and processing loss. Total losses of traditional stored potatoes including consumers' loss were found to be 27.65% whereas for cold stored potatoes, it was 23.11%. Total losses excluding consumer

losses for traditional stored and cold stored potatoes were found to be 24.61 and 19.90%, respectively.

A number of variables included in the Cobb Douglas Production models for estimating the coefficients of post-harvest losses of potato at farmers, traders and cold storage levels. The output elasticities of curing, sorting, storage, insect damage, rotten, cutting of tubers (during harvest), potato under soil were positively significant at 1% level. The coefficients of weight loss, rotten loss, handling and transportation losses at traders' level were positively significant at 1% level. In the case of post-harvest loss in clod storage, the coefficients of electricity, relative humidity, outside temperature, pre-cooling time, good bag used, maturity of stored potato, and number of bag per stack were found significant. The estimated mean technical efficiency of cold storages was 91%. A total of nine independent variables were used in the model and out of them, five were found significant. The coefficients of daily maximum outside temperature, good bag used, electricity supply, relative humidity, maturity of stored potato was found significant at different levels. The increase of mangers' experience and training and wooden floor would reduce the inefficiency of the model as well as increase the production of good potato. This model is recommended for efficient management of cold storage in Bangladesh.

# 5. Conclusions

Disposal pattern of potato at farm level was examined. Average harvesting loss in all areas was found to be 5.65% of total production. Pre-storage and home storage losses of potatoes were 8.15 and 7.35%, respectively. The average capacity utilization in all areas was 93.49%. The average loss in cold storage during nine months storage period was 3.78% of total potato stored. Load shedding, storing of unsorted potato, overload of storage bag are the main problems in cold storage operation.

The average loss at traders' level for traditional and cold stored potatoes were 11.95 and 9.61%, respectively. Average post-harvest losses in the household and restaurant levels were 3.24, and 4.52%, respectively of purchased potato. This loss comprised rotten loss and processing loss. Total losses of traditional stored potatoes including consumers' loss were found to be 31.50% whereas for cold stored potatoes, it was 25.59%. Total losses excluding consumer losses for traditional stored and cold stored potatoes were found to be 27.47 and 21.58%, respectively.

A number of variables included in the Cobb Douglas Production models for estimating the coefficients of post-harvest losses of potato at farmers, traders and cold storage levels. The identified variables at farm level were curing, sorting, storage, insect damage, rotten, cutting of tubers, and loss of potato that remained under soil. The variable at traders' level were weight loss, spoilage, handling and transportation. In the case of post-harvest loss in cold storage, the variables were of electricity supply, relative humidity, outside temperature, pre-cooling time, good bag used, maturity of stored potato, and number of bag per stack. The estimated mean technical efficiencies of cold storages was 91%. Total nine independent variables were used in the model and out of them, five were found significant. The coefficients of daily maximum outside temperature, good bag used, electricity supply, relative humidity, maturity of stored potato was found significant at different levels. The increase of mangers' experience and training and wooden floor would reduce the inefficiency of the model as well as increase the production of good potato. This model is recommended for efficient management of cold storage in Bangladesh.

# 6. Policy Implications and Recommendations

1. Potato is a perishable commodity which cannot be stored at farmers' home for long periods of time. The present study revealed that the highest post-harvest loss (7.35%) occurred in the traditional storage system where potatoes cannot be stored more than three months. In order to reduce this post-harvest loss, more cold storage needs to be established at farm level.

2. Potato is generally harvested in Bangladesh by spade or country plough. Harvesting by ploughing leaves some potatoes in the soil while spade harvesting potato means many potatoes are cut and damaged. In order to reduce this loss, low cost mechanical harvesters may be introduced for proper harvesting of potatoes so that the farmers can use this harvester within their financial capacity and reduce harvesting loss.

3. Load-shedding is the main problem of cold storage operation. Continuous electricity with the right voltage should be supplied so that cooling machines can be operated as and when necessary to maintain a proper temperature in the cold storage. Given the country's current difficulties in providing adequate electricity to all end users, special and separate electric connections may be established for cold storage. Given that it is perishable agricultural produce such as potatoes which is stored in cold storage, the electricity charge of cold storage may be considered in the agricultural category (like the BADC cold storage).

4. The awareness of the farmers, traders and cold storage personnel needs to be increased they use adequate methods to store potatoes. They may be provided adequate training so that they can produce, handle and store potatoes properly.

5. Presently most of cold storages have no separate cool chambers for seed and table potato storage. Seed potatoes and table potatoes should be stored at different temperatures (seed potatoes at 2-4$^{o}$C and table potatoes at 3-5$^{o}$C). Separate chambers should be made for seed and table potatoes.

6. Market infrastructure should be developed in terms of quick transportation, proper storage and other physical facilities to reduce postharvest loss of potato as well as fresh

fruits and vegetables. Potato should be packed in 50 kg bags and transported in covered van to reduce handling and transportation losses.

7. Postharvest processing machinery and technology should be developed and demonstrated intensively at farmers' level for the minimization of postharvest losses of foods so that just after harvesting, the bulk quantity of potato may be processed to different types of food items. This will enhance the adoption of food potato at the farm levels and reduction of pressure on rice.

8. Traditional storage systems may be improved through research and development so that the farmers can store potato comparatively longer period (3-6 months) with lower storage loss.

9. Government should take necessary steps so that market price of potato remains uniform all round the year and all over the country. This may be possible through price control mechanism of the government.

# 7. Areas of Further Research

This research quantified the post-harvest losses of potato at different levels and its causes have been identified. Also a set of recommendations has been forwarded to reduce the post-harvest losses of potato. The following research may be conducted to reduce the postharvest losses of foods to attain food security.

1. Assessment of the post-harvest loss of perishable such as fruits, vegetables, pulses, oilseeds, livestock and fisheries.
2. Studies on the improvement of local storage systems for fresh produce
3. Standardization of storage packages for storage, handling, transportation and marketing of potato.
4. Research on development of summer potato by some interventions such as conventional breeding, biotechnology and tissue culture
5. Studies on the invention and popularization of potato foods for the rural and urban people.

# Acknowledgments

This research has been carried out with the financial and technical support of National Food Policy Capacity Strengthening Programme (NFPCSP) jointly being implemented by the Ministry of Food and Disaster Management, Government of the Peoples' Republic of Bangladesh, and Food and Agriculture Organization (FAO) of the United Nations funded by the USAID and European Union, and the authors gratefully acknowledge these organizations/agencies. The authors are also grateful to their TAT members namely Dr. Marie Jo A. Cortijo, Prof. Dr. Rezaul Karim Talukdar and Professor Dr. Ferdous Alam for their suggestions, valuable comments, and encouragement throughout the study period. The authors are grateful to the Head of Machinery Repair and Maintenance Division as well as the authority of Bangladesh Agricultural Research Institute for providing physical facilities to carry out this research.

# References


Ahmad, K. U. 1977. Report on Potato Production in Bangladesh. International Potato Course: Production, Storage and Seed Technology. Report of Participants. International Agricultural Center, Wageningen, The Netherlands.

Aigner, D.J., Lovell, C.A.K. and Schmidt, P. 1977. Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*. 6:21-37.

Ajibefun, I.A., Battese, G.E., and Kada, R.1996. Technical efficiency and technological change in the Japanese rice industry: a stochastic frontier analysis. *Centre for Efficiency and Productivity Analysis Working Papers*, University of New England, Australia.

ASET. 2003. Estimation loss of horticulture produce due to non-availability of post-harvest and food processing facilities in Bihar and UP. ASET, New Delhi. Socio-Economic Research, Planning Commission, Government of India.

Azimuddin, M., Alam, Q. M. and Baset, M.A. 2009. Potato for food security in Bangladesh. *International Journal of Sustainable Crop Production*. 4(1):94-99.

BBS. 2008. Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh (28 th Edition, March 2009).

Bangladesh: Campaign to popularize potato food item. http://www.freshplaza.com/index_sector.asp?sector=8, accessed on 24 April 2009.

Bakhsh, A. K. and Ahmad, B. 2006. Technical efficiency and its determinants in potato production, evidence from Punjab, Pakistan. *The Lahore Journal of Economics*. 11 (2): 1-22.

Baten. M. A., Rana, M., Das, S. Khaleque M. A. 2006. Technical efficiency of some selected manufacturing industries in Bangladesh: a stochastic frontier analysis. *The Lahore Journal of Economics*. 11 (2): 23-41.

Battese, G.E. and Corra, G.S. 1977. Estimation of a production frontier model: with application to the pastoral zone of Eastern Australia. *Australian Journal of Agricultural Economics*. 21: 169-179.

Battese, G.E. and Coelli, T. J. 1992. Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India. *Journal of Productivity Analysis.* 3. 153-169.

Battese, G.E., Malik S.J. and Broca, S. 1993. Production functions for wheat farmers in selected districts of Pakistan: an application of stochastic frontier production function with time-varying inefficiency effects. *Pakistan Development Review.* 32: 233-268.

Battese, G.E. and Coelli, T.J. 1995. A Model for Technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*. 20: 325-332.

Battese, G.E., Malik S.J. and Gill, M.A. 1996. An investigation of technical inefficiencies of production of wheat farmers in four districts of Pakistan. *Journal of Agricultural Economics*. 47: 37-49.

Bauer, P.W. 1990. Recent developments in the econometric estimation of frontiers. *Journal of Econometrics*. 46: 39-56.

Burton, W.G., van Es, A. and Hartmans, K. J. 1992. The physics and physiology of storage. *In*: *Harris, P.M. (eds) The potato crop*: The scientific bases for improvement. Chapman & Hall, London.

CIP. 2009. International Potato Centre. Potato. http://www.cipotato.org/potato. Accessed on 24 September 2009.

Cornwell, C., Schmidt, P. and Sickles R. C. 1990. Production frontier with cross-sectional and time-series variation in efficiency levels. *Journal of Econometrics.* 46: 185-200.

Eltawil, M. A., Samuel, D. V. K. and Singhal, O. P. 2006. Potato storage technology and store design aspects. *Agricultural Engineering International the CIGR Ejournal*. 8(11):1-18.

FAO. Major Causes of Crop Losses. www. fao.org/ docrep/008/a0185e/a01850c.htm, accessed on 24 May 2009.

Forsund, F. R., Lovell, C.A.K. and Schmidt, P. 1980. A Survey of frontier production functions and of their relationship to efficiency measurement. *Journal of Econometrics*. 13: 5-25.

Greene, W. H. 1993. The econometric approach to efficiency analysis. In Fried, H. O., Lovell, C.A.K. and Schmidt, S.S. (Eds), *The Measurement of Productive Efficiency*, Oxford University Press, New York, 68-119.

Gottschalk, K. and Christenbury, G. D. 1998. A model for predicting heat and mass transfer in filled pallet boxes. Paper (Paper No. 983157) presented at the ASAE Annual International Meeting in Orlando, Florida on 12-16 July, 1998.

Gottschalk, K. 1999. Ventilation of potato storage piles. *Landtechnik*. 54: 338-339.

Harbenburg, R.E., Watada, A.E. and Wang, C.Y. 1986. The commercial storage of fruits, vegetables and florist and nursery stocks. U.S. Department of Agriculture: 66-68.

History of Potato. www.npcspud.com/history.htm, accessed on 26 June 2009.

Hossain, M. A., Hasan, M. K. and Naher, Q. 2008. Assessment of technical efficiency of potato producers in some selected areas of Bangladesh. J Agric Rural Dev. 6(1&2): 113-118.

Hoque, M. A., Hasan, M. K., Islam, M. R., Siddique, M. S. J. and Rahman, M. F. 2006. Effect of cut seed size and spacing on yield and profitability of potato. Bang J Agric Environ. 2(1): 9-15.

Hussain, M. S., Rahman, M. M., Rashid, M. H., Farid, A. T. M., Qauyum, M. A., Ahmed, M. Alam, M. S. and Uddin, M. S. 2006. Edited Bengali *Krishi Projukti Hatboi* (Handbook of Agro-technology). Bangladesh Agricultural Reassert Institute, Gazipur-1701, Bangladesh.

Iqbal, M. 1996. Type and extent of post-harvest losses in horticultural commodities. *In*: Proceedings of National Conference on Post-harvest Technology. 10-12 September 1996, Quetta, Pakistan.

International Year of the Potato 2008. www. potato2008.org/eng/world/index.html, accessed on 30 August 2009.

Ilangantileke, S. G., Khatana, V. S., Singh, J. P. and Kumar, D. 1996. Improved rustic storage in South Asia. Program Report, International Potato Centre (CIP), South and West Asia Regional Office, New Delhi, India.

Islam, M. A. 1983. Report on Potato Production in Bangladesh. International Potato Course: Production, Storage and Seed Technology. Report of Participants. International Agricultural Center, Wageningen, The Netherlands.

Islam, M. M., Kabir, H. M., Satter, M. A. and Kabir, M. S. 2008. Management practices in some selected cold storage in Bangladesh. *j. innov. dev. strategy*. 2(3): 48-54.

Jafrullah, M. 1996. Technical efficiencies of some manufacturing industries of Bangladesh: An application of the stochastic frontier production function approach. *The Bangladesh Development Studies*. Vol. XXIV (1 & 2) 22-31.

Krasachat, W. 2003. Technical efficiencies of rice farms in Thailand: a nonparametric approach. Paper presented to the 2003 Hawaii International Conference on Business, Honolulu, June 18-21, 2003.

Kumbhakar, S.C. 1990. Production frontiers, panel data and time-varying technical efficiency. *Journal of Econometrics*. 46: 201-211.

Kumbhakar, S. C., Ghosh, S. and McGuckin, J. T. 1991. A generalized production frontier approach for estimating determinants of inefficiency in U.S. dairy farms. *Journal of Business and Economic Statistics*. 9: 279-286

Lin, S. L. and Zhang, G. 2003. China Agriculture Development Issue Report. China Development Press, 2003.

Maldegem, J. P V. 1999. State of the art techniques for the potato storage. Abstract, Global Conference on Potato, New Delhi, Dec 6-11.

Meeusen, W. and van den Broeck, J. 1977. Efficiency estimation from Cobb-Douglas Production Functions with composed error. *International Economic Review*. 18: 435-444.

Meyhuay, M. 2007. Potato: Postharvest operations. Instituto de Desarrollo Agroindustrial (INDDA). ttp://www.fao.org/inpho/content/conpend/text/ch17_02.htm#TopOfPage

Miaruddun, M. and Chowdhury, M. G. F. 2009. Postharvest management of fruits and vegetables for reducing losses. Paper presented at the workshop on "Reduction of Post-harvest Agricultural Crops Losses" at Centre on Integrated Rural Development for Asia and the Pacific (CIRDAP), Dhaka on 23 November 2009.

Moazzem, K. G. and Fujita, K. 2004. Potato marketing system and its changes in Bangladesh: From the perspective of village study in Comilla district. The Developing Economics. XLII-1 (March): 63-94.

Pitt, M. M. and Lee, L. F. 1981. Measurement and sources of technical inefficiency in the Indonesian weaving industry. *Journal of Development Economics*. 9: 43-64.

Potato In India.1992. Tech Bulletin no-1, Central Potato Research Institute, Shimla.

Postharvest Profile of Potato. http://agmarknet.nic.in/profile-potato.pdf. Accessed on 24 September 2009.

Potato bumper harvest brings misery rather than smile to Bangladeshi farmers http://en.ce.cn/World/Asia-Pacific/200805/06/t20080506_15373277.shtml accessed on 24 September 2009.

Rashid, M. H. 2008. Food security during natural disasters. Paper presented at the seminar on 'Engineers' Day' organized by the Institution of the Engineers, Bangladesh on 7 May 2008, IEB Head Quarters, Ramna, Dhaka, Bangladesh.

Rastovski, A. 1987. Storage losses. *In*: Rastovski, A, Van Es, A. (eds.) *Storage of potatoes. Postharvest behavior, store design, storage practice, handling*. Pudoc. Wageningen.

Rhoades, R. E. 1984. Changing a post-harvest system: Impact of diffused light potato storage in Sri Lanka. Social Science Department, Working paper 1984-1. International Potato Centre (CIP), Lima, Peru.

Ritenour, M. A. 2003. Postharvest 101: Overview of postharvest biology. University of Florida, IRREC, USA.

Schmidt, P. 1986. Frontier production functions. *Econometric Reviews*. 4: 289-328.

Roy, K. C. 2009. Engineering Approaches to Minimize Postharvest Loss in Agriculture towards Attaining Food Security in Bangladesh. A keynote paper presented at The Institutes of Engineers, Bangladesh (IEB), Ramna, Dhaka on 12 April 2009.

Scott, G. 1985. Marketing Bangladesh's Potatoes: Present Pattern and Future Prospects. Lima: International Potato Centre**.**

Shahbaz, H. 2009. Reduction of post-harvest agricultural crops losses: Agricultural and post-harvest practices in I. R. Iran. Paper presented at the workshop on "Reduction of Post-harvest Agricultural Crops Losses" at Centre on Integrated Rural Development for Asia and the Pacific (CIRDAP), Dhaka on 23 November 2009.

Shetty, K. 1998. Handling, packaging and transportation of fresh pack potatoes in refrigerated rail cars. Potato Storage Research Facility. University of Idaho, 3806 North 3600 East, Kimberly, ID 83341. www.kimberly.uidaho.edu/potatoes/shipping .htm, accessed on 24 September 2009.

Taymaz, E. and Saatci, G. 1997. Technical change and efficiency in Turkish manufacturing industries. *Journal of Productivity Analysis.* 8: 461-475.

Skerritt, J. H. and Greg I. J. 2001. Post-harvest management: the importance of technical and economical research. Promoting Global Innovation of Agricultural Science and Technology and Sustainable Agriculture Development. ICAST.

Tsubota, K. 1999. Relation between post-harvest technologies and economic development. In Nawa Y *et al*., (Eds), Post-harvest Technology in Asia. Proceedings of the 5th IRCAS International Symposium, 1999.

Tzouvelekas, V., Giannakas, K., Midmore, P.and Mattas, K. 1999. Decomposition of olive oil production growth into productivity and size effects: A frontier production function approach. *Cahiers d'Economie et Sociologie rurales.* No.51.

Vu, L. H. 2009. Efficiency of rice farming households in Vietnam: a DEA with bootstrap and stochastic frontier application. Research Report. Department of Applied Economics, University of Minnesota, #332M, 1994 Buford Ave, St Paul, MN 55108.

Yang, Yong-Zhe. 2000. Rural Structure Reorganization and Farmer Income. China Agriculture Press, China.

Zahid, B. J.A., Uddin, J. M. 1990. Socio-economic characteristics of rural poor: A case study of two villages. *The Journal of Rural Development*. 20(1): 43-55.

# APPENDICES

# APPENDIX -1

Post-harvest Loss and Technical Efficiency of Potato Storage Systems in Bangladesh

**SURVEY SCHEDULE FOR POTATO FARMERS**

Serial No. ☐ Date: ☐

1. Location:

District:……..…Upazilla:…….……

Union/Pourashova……..…….Village…….

2. Name: ……Age:……Years, Family size:.....

3. Educational qualification:

☐ Illiteral (00), ☐ Primary (01), ☐ Secondary (02),

☐ Higher secondary (03), ☐ Above degree (04)

4. Status of cultivated and other lands:

| Type of land | Area (decimal) | Type of land | Area (decimal) |
|---|---|---|---|
| a) Own cultivated land | | f) Orchard | |
| b) Rented in land | | g) Pond | |
| c) Rented out land | | h) Homestead | |
| d) Mortgaged in land | | i) Barren land | |
| e) Mortgaged out land | | j) Other | |

5. How many years have you been working in potato cultivation?…….years

6. Have you got training on potato cultivation? ☐ Yes ☐ No.

If 'Yes', how many times?.....

7. What was the source of potato seeds? (Give tick)

☐ BARI (06), ☐ BADC/BADC dealer (05), ☐ Seed selling centre (04)

☐ Own stock (03), ☐ Neighboring farmer (02), ☐ Open market (01)

8. Technological and extension services:

| Source of technological support | DAE | BARI | BADC | NGO | Other |
|---|---|---|---|---|---|
| Type of technological support | | | | | |

9. Family income in the year 2008-09 :

| Source of income | Income (Taka) | Source of income | Income (Taka) |
|---|---|---|---|
| From crop | | From business | |
| From livestock | | From service | |
| From fishery | | From other sources | |

10. Information on potato cultivation in 2008-09:

| Potato variety | Area of land (decimal) | Total production (mound) | Price at harvest (Taka/mound) | Total value (Taka) |
|---|---|---|---|---|
| Local | | | | |
| HYV | | | | |

11. Cost of inputs for potato cultivation (Plot)

| Variety | Area (Decimal) | Land prepar a-tion | Seed | Manure | Fertili-zer | Weeding& earthing up | Insec-ticide | Irriga-tion | Other cost | Total cost |
|---|---|---|---|---|---|---|---|---|---|---|
| HYV | | | | | | | | | | |
| Local | | | | | | | | | | |

12. Disposal pattern of fresh potato in this year (kg)

| Total production | Family consumption | Given to relatives | Sold | Stored as seed potato | Stored as food potato | Other |
|---|---|---|---|---|---|---|
| | | | | | | |

13. How did you harvest potato? ☐ 01 with spade, ☐ 02 with plough

☐ 03 with machine, ☐ 04 Other (specify)

14. How much damaged potato was found during harvesting?

| Type of damage | Amount of damaged tubers (kg) | Cause of damage |
|---|---|---|
| a) Damaged by insect and vertebrate | | |
| b) Rotten potato | | |
| c) Cut potato | | |
| d) Remained in the soil (unharvested) | | |
| e) Other damage (if any) | | |

15. After harvesting, did you cure the potato ? ☐ Yes ☐ No

If 'Yes' how did you cure the harvested potato?

☐ Keep in the field as a heap, Duration ……

☐ Keep in the sun, Duration ……

☐ Keep in the shade, Duration ……

16. How much potato was lost during curing? ……..kg

17. Before selling did you sort and grade the potato? ☐ Yes ☐ No

If 'Yes' how much potato was rejected? ……..…...kg

18. Information on potato buyer and amount sold during this year (2008-09)

| Buyer | *Place of selling | Amount sold (kg) | Price (Tk/kg) |
|---|---|---|---|
| Stockiest | | | |
| Whole seller | | | |
| Bepari | | | |
| Retailer | | | |
| Consumer | | | |

*Field, home, local market, Upailla market, Whole sell market, District market, etc.

19. Last year how did you store potatoes? ☐ Traditionally ☐ Cold storage ☐ Both

20. Information on storage of potato in 'Traditional Storage' system (at home)

| Storage method | Type of potato (Food/seed) | Amount stored (kg) | Storage period | Storage cost (Taka) | Amount damaged (kg) | Causes of damage |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |

21. Is there any cold storage in your Upazilla/District ? ☐ Yes ☐ No

If 'Yes', what was the distance from your home?.....km

22. Information on storage of potato in cold storage

| Type of potato | Amount stored (kg) | Storage period | Storage cost (Taka) | | | | Amount loss (kg) | Causes of damage |
|---|---|---|---|---|---|---|---|---|
| | | | Transpo -rtation | Storage charge | Other charge ) | Total cost | | |
| Food | | | | | | | | |
| Seed | | | | | | | | |

23. How much potato damage during transportation?

| Type of transportations | Means of transportations | Distance (km) | Amount transported | Amount lost (kg) |
|---|---|---|---|---|
| Field to home | | | | |
| Home to market | | | | |
| Home to cold storage | | | | |
| Cold storage to home | | | | |
| Field to cold storage | | | | |

24. Please suggest, how can we reduce postharvest losses of potato?

……..

…….

Signature of interviewer

Name:

# APPENDIX -2

Post-harvest Loss and Technical Efficiency of Potato Storage Systems in Bangladesh

**SURVEY SCHEDULE FOR COLD STORAGE**

Serial No. ☐ Date: ☐

1. Location of cold storage:

Name of cold storage……..

District:……..…Upazilla:…….……

Union/Pourashova……..…….Village/Road……

Telephone/Mobile No…….

2. Name of interviewee: ……Age:……Years

3. (a) Relation with cold storage: Owner/Manager/Supervisior/Staff

(b) Relevant experience of cold storage management .....year

4. Educational qualification:

☐ Illiteral (00), ☐ Primary (01), ☐ Secondary (02),

☐ Higher secondary (03), ☐ Above degree (04)

5. Have you got any training on cold storage management? Yes ☐ No ☐

If 'Yes' how many times .....

6. When this cold storage was established (Year)? ……..

7. What was then the installation cost then ? Taka…….

8 What is the capacity of the cold storage? …….ton/bag

9. What is source of electricity supply? ☐ PDB ☐ REB

10. What is the frequency of electricity failure per day (24 hours)?.....hour

11. How do you operate the cooling system during electricity failure?

(a) Operating generator ☐ (b) Left without electricity ☐

12. If generator provides backup electricity, then how long do you operate the generator?

(a) Continuously (until electricity comes):…….hours (b) Break

(interval)……..hours

13. What is power capacity?.....kVA and Fuel consumption……..Litre/hour

14. Statement of monthly average operating cost (Taka)

| Sl no. | Description of cost | Monthly cost (Taka) | Remarks |
|---|---|---|---|
| 1 | Electricity bill | | |
| 2 | Generator fuel & oil | | |
| 3 | Machine servicing | | |
| 4 | Cooling gas (ammonia) | | |
| 5 | Salary of staff | | |
| 6 | Labour charge | | |
| 7 | Other cost (Telephone, tax, etc.) | | |

15. What is the source of potato storage?

☐ Own production, ☐ By purchasing, ☐ Hire basis ☐ Other

16. Do you sort/grade potato before storage? ☐ Yes ☐ No

If 'Yes', how much potato was rejected during.....kg

17. Is there any grading system before storage? ☐ Yes ☐ No

18. How much sorted/graded (by farmers/traders) potato stored ?.....kg/bag

19. How much immature potato stored?.....kg/bag

20. (i) How are potato kept in cold storage ?

(a) Gunny bags ☐ (b) Plastic bags ☐ (c) Other (specify) ☐ …….

(i) How many old bags were used for potato storage? .....quantity/percent.

21. Did you pre-cool the potato before storage? ☐ Yes ☐ No

22. If 'Yes', at what temperature and how time?.....$^{o}$C, ……hour

23. Are the bags kept directly on the floor? ☐ Yes ☐ No

If 'No', what materials do you provide below the bags (stack)?

(a) Wooden frame ☐ (b) Bamboo frame ☐ (c) Other (specify)☐ …….

24. What is layer of bags vertically in each of the stack?.....

25. When (month) do you start to store potato?.....

26. What is the last date of release of potato from cold storage?.....

27. Information on potato storage system

| Type of potato | Amount stored (Bag*) | Duration | Storage Temperature ($^{o}$C) | Relative humidity (%) | Fare (Tk/Bag) | Amount of loss (kg) | Causes of loss |
|---|---|---|---|---|---|---|---|
| Food | | | | | | | |
| Seed | | | | | | | |

*Weight per bag = ……..kg

27. Do you use any chemical during storage? ☐ Yes ☐ No

If 'Yes', what is the name of chemical?..... ……..

28. How many time do you check the bags……..

29. Do you invert the bags during storage for proper cooling? ☐ Yes ☐ No

If 'Yes', how many times?.....

30. Do you refresh the storage with fresh air? ☐ Yes ☐ No

If 'Yes', how many times?.....

31. Do you pre-heat the potato after end of storage (before delivery) ? ☐ Yes ☐ No

If 'Yes', at what temperature and how time?.....$^{o}$C, ……hour

32. What are the causes of losses of potato in cold storage?

…….

33. What are the problems of potato storage in cold storage?

…….

34. What are your suggestions to reduce the postharvest losses of potato?

……

Signature of interviewer

Name:
Date:

# APPENDIX-3

Post-harvest Loss and Technical Efficiency of Potato Storage Systems in Bangladesh

**SURVEY SCHEDULE FOR POTATO TRADERS**

Serial No. ☐ Date ☐

**Type marketed potato: Traditionally stored/ Cold storage stored**

**Type of markets**: Primary/Secondary/Tertiary

**Type or Traders:** Bepari/Faria/Aratdar/Paiker/Retailer

1. Name of market: ……..… ..Union/Pourashova ……

Upazilla……..…….. District:……

2. Name of trader: ……Age:……Years

3. Educational qualification: Year of schooling ……...Years

☐ Illiteral (00), ☐ Primary (01), ☐ Secondary (02),

☐ Higher secondary (03), ☐ Above degree (04)

4. How many years are you associated with potato trade? ……Years

5. How many potato traders are in this market?

(a) Aratder…….…….(b) Whole seller/Paiker……(c) Faria……(d) Bepari……

(e) Stockiest…….……(f) Retailer……(g) Other……

6. How much and from whom did you purchase potato last month?

| Purchased from | | Traditional storage potato | | Cold storage potato | |
|---|---|---|---|---|---|
| Person | Place | Amount (mound) | Price (Tk/mound) | Amount (mound) | Price (Tk/mound) |
| Farmer | | | | | |
| Cold storage | | | | | |
| Whole seller | | | | | |
| Bepari | | | | | |
| Faria | | | | | |
| Retailer | | | | | |

7. How much and to whom did you sell potato last week?

| Sold to | | Traditional storage potato | | Cold storage potato | |
|---|---|---|---|---|---|
| Person | Place | Amount (mound) | Price (Tk/mound) | Amount (mound) | Price (Tk/mound) |
| Cold storage | | | | | |
| Whole seller | | | | | |
| Bepari | | | | | |
| Faria | | | | | |
| Retailer | | | | | |
| Consumer | | | | | |

8. Handling of potato

| Type of handling | Amount handled | Amount lost | Causes of losses |
|---|---|---|---|
| Sorting/grading | | | |
| Weighing and bagging | | | |
| Loading | | | |
| Unloading | | | |
| Other (specify) | | | |

9. Transportation

| Mode of transportations | Distance of transported (km) | Amount transported | Amount lost (kg) | Causes of losses |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

10. In the last week how did you store potato between each lot of buying and selling?

| Method of storage | Amount Stored | Storage time (day | Storage loss (kg) | | | |
|---|---|---|---|---|---|---|
| | | | Weight | Rotten | Other | Total |
| | | | | | | |
| | | | | | | |

11. What are the problems do you face during potato business?

…….

…….

12. What are your suggestions to reduce losses of potato during different business operations?

…….

…….

Signature of interviewer

Name:

Date:

# APPENDIX-4

Post-harvest Loss and Technical Efficiency of Potato Storage Systems in Bangladesh

**SURVEY SCHEDULE FOR POTATO CONSUMERS**

**Household / Restaurant**

Serial No ☐ Date: ☐

1. Location:

District:……..…Upazilla:…….……

Union/Pourashova……..……Village…….

Name of Restaurant: .....

2. Name: …….....(owner/manager, for restaurant)

Age:……Years, Sex: Male/female

3. Educational qualification:

☐ Illiterate (00), ☐ Primary (01), ☐ Secondary (02),

☐ Higher secondary (03), ☐ above degree (04)

4. What is your family size? ……person

5. How much of potato did you buy last week ……..kg

6. To whom did you buy potato?

☐ Grower, ☐ Retailer, ☐ Faria, ☐ Bepari , ☐ Aratder, ☐

Other

7. What type of potato did you buy?

☐ Fresh potato, ☐ Cold storage potato, ☐ Traditional storage potato

8. What was the price of potato? ……..Tk/kg

9 How did you consume the potato?

(a) As vegetable …….kg (b) Other (specify) …….kg

10. How much was the loss of potato found after buying? ……...kg

11. What were the types of losses?

| Type of damage | Amount of damaged potato(kg) |
|---|---|
| a) Damaged by insect | |
| b) Rotten potato | |
| c) Cut potato | |
| d) Mechanical injury | |
| e) Other damage | |

12. Where did you store potato before consumption? …….

13. How much potato damage during temporary storage? ……kg

14. What are the main causes of loss of potato during storage?

……..

15. How much potato was lost/rejected during processing (cutting, peeling etc.) ……kg

16. Please suggest, how can we reduce postharvest losses of potato?

……..

Signature of interviewer
Name:

Date:

# APENDIX-5

## SOME SNAP SHOTS OF POSTHARVEST LOSS STUDIES OF POTATOES

Interviewing the farmers

Interviewing the traders (Faria)

Interviewing the traders (retailer)

Interviewing the cold storage manger

Curing the potato in a heap

Sorting of harvested potato

Potato bags in the field

Potato in the sun on the cold storage yard

Potato transportation by truck

Potato transportation by boat

Cold storage in Jessore

Potato in cold storage

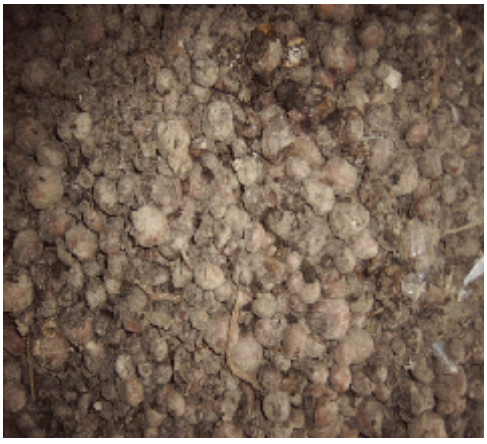
Potato bags carrying out from cold storage

Labours working in cold storage

Cold stored potato is sorting by women

Cold stored potato is sorting by men

Partially damaged cold stored potato



Fully damaged cold stored potato