Development of a hot water treatment plant suitable for banana

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Abstract: Banana is a year round fruit in Bangladesh. After harvesting, banana is attacked by postharvest disease caused by some fungi. The quality and quantity losses of banana occur due to disease attacks and lack of proper postharvest handling. Fungus can be destroyed or made inactive by chemical or heat treatment. Most of the chemicals are hazardous to human health. Heat treatment technology is simple and is a non-chemical method to kill or inactivate pest and to control fungus. A hot water treatment plant was designed and developed with local materials for treating banana fruits. Overall dimensions of the hot water treatment plant were 1600 mm×926 mm×1566 mm and operated by an electrical motor of 0.38 kW. Water was heated by the six electric immersion heaters of 2,000 W of each. The capacity of the plant was 350 kg h^{-1}. The price of the hot-water treatment plant was Taka 1,00,000 (US$ 1300) and treatment cost was Taka 0.55 kg^{-1} ($0.007). The effective combinations of temperatures and exposure periods of *BARI Kola 1* and *Sabri Kola* were found to be 55°C for 5 min. When the banana fruits were treated with hot water, the shelf-life of the fruits was found to increase by 30% and the postharvest loss reduced by 70% over those of untreated bananas. The break-even point of the plant was 70 h yr^{-1}. Banana fruits treated by the plant can be profitable to traders when the annual use of the plant exceeds 70 h. Payback period of the plant was estimated to be 26 d. Therefore, there is a good opportunity of farmers and traders to increase income and generate employment using the hot water treatment plant.

Keywords: Hot-water treatment plant, banana, temperature, exposure period, break-even point and payback period

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1 Introduction

Banana (*Musa sapientum* L) is one of the important tropical fruits, with a global annual production of about 107 million metric tons in which Asia contributes 62 million tons (FAO, 2011). Bangladesh produces 4.39 million tons of fruits annually from 0.15 million ha of land. Of these, mango, banana, jackfruit, pineapple, papaya, litchi and guava are the major fruits. Among the fruits, banana ranks first in terms of area coverage (0.06 million ha) and second in terms of production (0.80 million tons) in Bangladesh (BBS, 2011). Interest in heat treatments waned with the development of chemical fumigants, which could be applied cheaply and easily. Today, with the increasing cost of developing new chemicals and regulatory restrictions on existing ones, interest in heat disinfestations has been revived (Couey, 1989).

Heat treatment technologies are currently a relatively simple, non-chemical alternative to methyl bromide that can kill quarantine pests (insects and fungi) in perishable commodities and control some postharvest diseases. Heat treatments do not pose significant health risks from chemical residues and, as a result, are more appealing to consumers than methyl bromide fumigation (Couey, 1989). In most cases, heat treatments are performed in the country of origin before a product is exported. The temperature, duration, and application method is both

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cultivar and commodity specific and must be very precise to kill pests without damaging the commodity. Fruit responses to heat varies depending on the condition of the fruit prior to treatment (Mitcham et al., 1994), the commodity concerned, the temperature and duration of treatment, as well as the mode of heat application (i.e., hot air vs. water temperature ranged from 45°C to 49°C for times of five to 40 min). If not properly applied, heat treatments (as well as methyl bromide treatments) may result in commodity damage, which typically is manifested as browning fruit surfaces, uneven ripening, and breakdown of the fruit flesh. However, beneficial effects of heat treatment include reduced susceptibility to chilling injury in avocados and persimmons (Lay-Yee, 1994).

Hot water is an effective heat transfer medium and, when properly circulated through the load of fruit, quickly establishes a uniform temperature profile (Couey, 1989). Hot water immersion also has the additional benefit of controlling postharvest microbial diseases such as anthracnose and stem end rot (Couey, 1989; McGuire, 1991). Acedo et al. (2001) found that dipping bananas in water at 47°C to 52°C effectively inhibited anthracnose and finger rot development when fruits were artificially infected. The use of hot water treatment to suppress microbial development and spoilage also promoted desirable colour (mixed yellow and green to yellow) and retention of firmness characteristics when measured by a fruit depression meter (Hassan, 2000).

Disease severity in banana fruit was significantly reduced by hot water treatment at 50°C ± 2°C for 5 min. Fruit dipped in hot water was found to develop desirable colour and firmness characteristics (Hassan et al., 2004). Bananas were treated by hot water at 50°C for 5 min to minimize bruising and control crown rot (Kader, 2005). Banana is a perishable fruit. It is attacked by several fungi, which causes disease. Anthracnose disease is one of them that occupies in banana fruit. Anthracnose disease, which developed in fresh banana, is retarded through hot water treatment. Objective of the study is undertaken to develop a hot water treatment plant to reduce the postharvest loss of banana and test the efficacy of the plant for treating banana.

2 Material and methods

A hot-water treatment plant was fabricated with locally available materials in the workshop of the Division of Farm Machinery and Post-harvest Process Engineering, Bangladesh Agricultural Research Institute, Gazipur in 2011-2012.

The hot water treatment plant is designed with the following consideration:

- The capacity of the plant should be half a ton per hour
- It should be portable
- Fabrication cost should be minimum
- Water temperature should be auto controlled

2.1 Development of the hot water treatment plant

2.1.1 Determination of the size of the plant

Length (L) of the plant: The plant size was determined based on the available crate size and capacity of the plant. Length of the plant was determined according to the width of the crate. Three crates were used at the same time in operation. Length of it was designed on the width of four crates for attaining the desired capacity.

$$L = 4\times \text{width of crate} = 4\times 0.37 = 1.48 \text{ m}$$

Width (w) of the plant: Width of the plant was calculated by the addition of the roller pipe length and shaft of the roller on the side.

$$w = Lr + Lrs \times 2$$

where, Lr = roller pipe length, m; Lrs = roller shaft length, m.

Roller pipe length was taken little bit than plastic crate length due to clearance between the wall of the plant and loaded plastic crate for easy movement. Crate length was 0.54 m, so roller pipe length was taken 0.605 m. Roller shaft length was taken 0.0775 m.

$$w = 0.605 + 0.0775 \times 2 = 0.76 \text{ m}$$

Height (H) of the plant: The plant height was determined on the basis of height of plastic crate (h_c), height of roller (h_r) and free space (h_f) so that water could not over flow at full load condition.

$$H = h_c + h_r + h_f = 0.30 \text{ m} + 0.08 \text{ m} + 0.12 \text{ m} = 0.50 \text{ m}$$

2.1.2 Motor power calculation

The electric motor was designed to produce power required to rotate the rollers at desired speed and convey the plastic crates loaded with bananas from feeding end to the delivery end. Motor power was calculated from the following formulaes (Equation (1), Equation (2), Equation (3) and Equation (4)):

$$P_m = Pc/\eta \quad (1)$$

where, P_m = rated power of motor, W; P_c = power required to move loaded crate, W; η = overall power transmission efficiency, %.

$$\eta = \eta_1 \eta_2 \eta_3 \eta_4 \quad (2)$$

where, η_1 = power transmission efficiency of belt pulley, %; η_2 = power transmission efficiency of gear (there were 4 sets of gear and pinion), %; η_3 = power transmission efficiency of chain sprocket (there were 22 sets of chain and sprockets), %; η_4 = power transmission efficiency of nylon bush bearing (there were 22 sets of bush bearing), %.

$$Pc = F \times V \quad (3)$$

where, F = force required to move loaded crate, N; V = velocity of plastic crate, m s^{-1}.

$$F = f(m - v\rho)g + h\rho g \times A \quad (4)$$

where, f = coefficient of friction of plastic crate surface with the surface of roller; m = mass of plastic crate with banana, kg; v = volume of water displaced by the crate with banana, m^3; ρ = mass density of water, 1,000 kg m^{-3}; g = gravitational force, m s^{-2}; h = height of centre of gravity of plastic crate from water surface, m; A = projected area of front side of crate, m^{-2}.

The power requirement of the driving motor becomes 128 W. Since the lowest capacity motor available in the market is 380 watts. Therefore, 380W electric motor was selected to operate the roller.

2.1.3 Determination of heater calculation

The electric immersion heaters were designed so that within 2 h time the heater can warm up the quantity of water (466 L) up to desired temperature of 55°C.

Electric energy was calculated from the following formulae (Equation (5)):

$$Q = MS\Delta T \quad (5)$$

where, Q = eat, J; M = weight of water, kg; S = specific heat of water, 4,200 J kg^{-1} $°C^{-1}$; ΔT = difference between temperature ($T_2 - T_1$), °C; T_1 = initial water temperature, °C; T_2 = desired water temperature, °C.

2.1.4 Calculation of number of heaters

Calculation of number of heaters (Equation (6) and Equation (7))

$$\text{Power,} \quad P = \frac{Q}{t} \quad (6)$$

where, P = power, W; t = required time, s.

$$\text{Number of heaters} = \frac{P}{CE} \quad (7)$$

where, C = capacity of heater, W; E = efficiency of heater, %.

The plant was made of available materials such as MS sheet, MS angle bar, MS pipe etc (Figure 1). SS sheet was not used due to higher cost. MS sheet was used to reduce cost. Corrosion of mild steel was prevented by painting the surface. Power was transmitted to the conveyor roller with the use of gear box, pinion, chain sprocket, belt and pulley, self-centered and bearing, etc.

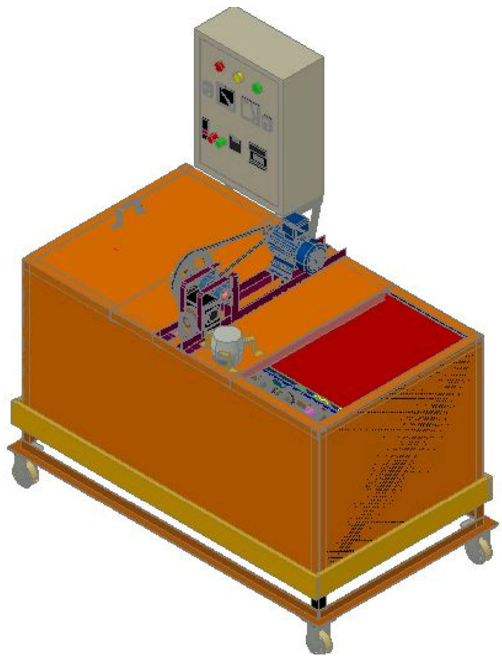

Figure 1 Isometric view of the hot water treatment plant

The main functional parts of the plant were: 1) rectangular tank; 2) roller type conveyor assembly; 3) water heating system; 4) power transmission assembly; and 5) stirring assembly. Orthographic views of the plant are shown in Figure 2.

2.2 Description of the main functional

2.2.1 Rectangular water tank

Rectangular water tank was made of MS sheet and MS angle bar, which was welded to a separate frame of MS angle bar. The tank had conveyor rollers, stirring plate, sensor and water.

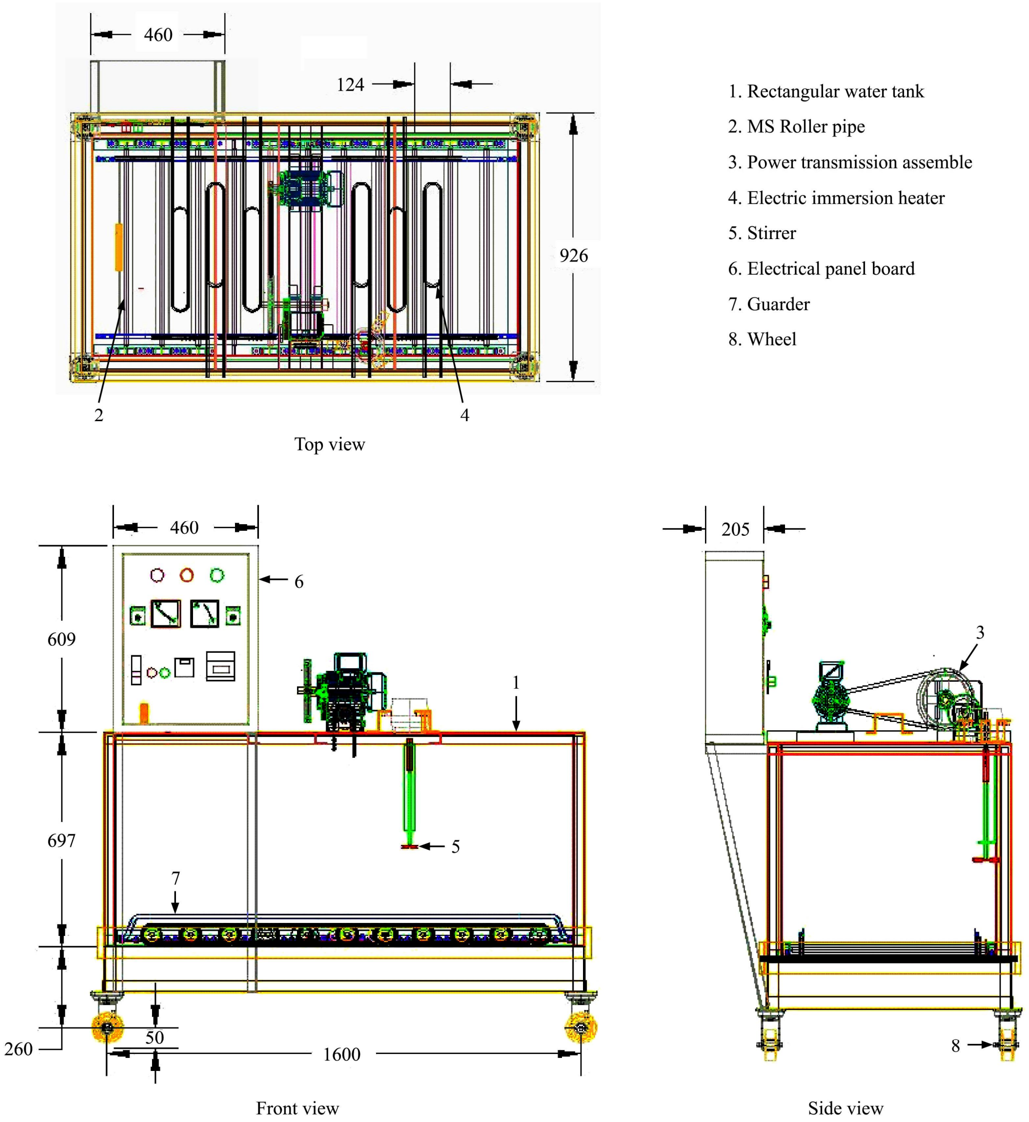

Figure 2 Orthographic views of the plant

2.2.2 Roller type conveyer assembly

Conveyer was an important part of the plant, which included rectangular frame, MS pipe, metal bush, fibre bush, shaft, chain, sprocket, clamp etc. A rectangular frame was made of MS angle bar, which contained rollers. The rollers were fabricated with MS pipe, metal bush and shaft. Both ends of each pipe were blinded with metal bush, and the shaft was connected and welded with the metal bush. Sprocket was welded on the shaft of the roller. The other end of the shaft was inserted into the fibre bush to rotate. The fibre bush was fixed on the frame by mean of MS clamp with nut-bolts. Eleven pipes were set in similar way to the frame and spaced at 150 mm apart to move plastic crates easily. Rollers were linked with each other by chain sprocket. The ends of each pipe were connected to the end of other pipe by sprocket alternately for transmitting power to each point. Power was transmitted to roller from motor by chain sprocket. It was placed on the inside bottom of the water tank. It was used to convey the plastic crates from one end of the plant to the other.

2.2.3 Power transmission system

Power transmission system included motor, pulleys, pinions, gear box, self-center bearings, and chain sprocket. A single-phase electric motor was used as the power source. Electric motor revolution per minute (r min^{-1}) was stepped down from 1,400 r min^{-1} to 420 r min^{-1} by belt-pulley of 170 mm and later from 420 to 1.1 r min^{-1} by a group of gear and pinion. Shafts of driven pulley were attached with the self center bearings those fixed on the frame of MS angle bar. Power was transmitted to the roller from shaft by chain sprocket. The power transmission unit was set on the middle portion of the plant. The following equation was used to calculate the dimension of pulley, pinion and sprocket and to obtain the required rotational speed in the rotary shaft and roller conveyor (Equation (8)).

$$\frac{D_1}{D_2} = \frac{N_2}{N_1} \tag{8}$$

where, D_1 = diameter of the driver pulley, mm; D_2 = diameter of the driven pulley, mm; N_1 = r min^{-1} of the driver pulley; N_2 = r min^{-1} of the driven pulley.

2.2.4 Water heating system

It was one of the essential parts of the plant to warm up water in the tank to the desired temperature at a particular period. It included dry heaters, magnetic contactor, digital thermostat valve, sensor, etc. The six heaters (2,000 W, 220 V) were placed horizontally at 20 mm from the bottom of the tank. They were fixed on the longitudinal sides at about 25 cm interval. Their connecting ends were covered with the light and cheap wood frame to protect from breaking and human safety.

Thermocouple/sensor was placed on the centre of the length of the plant vertically so that end of it dipped in the water. The heaters and sensor were connected with the electric panel board. The panel board was connected to a three phase electric line for balancing load. Panel board was kept with a stand made of MS angle bar, which was attached to the tank. Desired temperature of water was maintained by a digital thermostat valve through switch on-off of the heaters.

2.2.5 Stirrer

Stirrer was made of two blades and was rotated at 420 r min^{-1} by an electrical motor. It was fitted vertically inside the water tank below 250 mm from the top surface of the tank by a small frame. The fruits were placed in plastic crates of size 600 × 300 × 28 mm and immersed in the hot water. The stirring action helped in prevention of accumulation of heat around the heating coils and helped in the rotation of the fruits so that all the sides of the fruit were subjected to get uniform heat stress.

2.3 Working principle of the plant

The water tank was filled with fresh water. The matured green banana was passing across the hot water. The desired temperature (55°C) of banana treatment is set on the digital thermostat valve. The immersion water heaters and stirrer are started through switch on from the electric panel board. When water attains the desired temperature, the heaters are stopped automatically by the thermostat valve. The motor was started and conveyor was run at the same time. Banana hands are washed before feeding in the plant. Washed bananas are put inside the plastic crates having capacity of 14-17 kg. The crates of fruits are then submerged on a conveyor roller at 2 min interval. They are moved slowly from one end of the hot-water tank to the other by 5.30 min. When the alarm bell rang, treated banana crates are picked up from the other end at same intervals. This process is continued until the desired amount of bananas was treated. Finally the treated bananas are carried to the drying place to dry.

When fruit was treated more than 5 min by this plant, loaded crate was submersed inside the hot water and hold the crate by the holding tool at input end of the plant for desired heating exposure time subtract then 5 min, later it released to run other end.

2.4 Labour required

In total four labours are required for operating the plant. One labour for each of the following operation such as gathering the hands of banana near the plant, putting the crate on the roller, picking up the crate from other end and bringing them to drying place.

2.5 Estimation for fabrication of hot water treatment plant

The fabrication cost of the plant was calculated including cost of materials, labour, overhead, incidental expenses and manufacturing. Overhead cost included power consumption, machine depreciation, house rent etc.

2.6 Laboratory test

30 kg of green matured *BARI Kola 1* and same quantity of *Sabri Kola* were harvested from orchard of Farm Machinery and Postharvest Process Engineering Division. The maturity stages of *BARI Kola 1* and *Sabri Kola* were 130 and 110 d after emergence of flowering, respectively. Moisture contents at harvest of *BARI Kola 1* and *Sabri Kola* were 75.48 and 71.52% (wb),

respectively. They were washed and put into plastic crates. Later (after 2-3 h of harvest), they were treated through warm water at 55°C±1°C for 5 min. Water heating time, water temperature, quantity of bananas, and travelling time, etc were recorded.

2.7 Quality of banana

Weight, colour and firmness of treated and untreated banana fruits were measured immediately after immersion, 4, 6 and 8.5 d after storage period for *BARI Kola 1*. The same parameters were measured immediately after immersion, 3, 7 and 9.5 d after storage period for *Sabri Kola*. Decay data was recorded at 9, 9.5, 10.5 and 11.5 d after storage period for *BARI Kola 1* and at 10, 10.5, 10.5, 11.5 and 12.5 d after storage period for *Sabri Kola*.

2.7.1 Shelf-life

Shelf life (days) of banana fruit of each treatment was recorded during the period of storage. It was calculated from the date of harvesting to last edible stage. Edible stage of ripe banana was measured when it became very soft, observed black spot of anthracnose disease on the peel surface and detached finger from hand.

2.7.2 Incidence and severity of postharvest disease of banana

The sample of treated and untreated banana was not inoculated. But disease was identified by experienced observation. Generally, anthracnose disease is developed naturally at room temperature (22°C) and relative humidity (79%). Disease incidence and disease severity were recorded at stage of S_4 = full ripe (9 to 10 d after storage period), S_5 = edible stage (9.5 to 10.5 d after storage period), S_6 = 1 d after edible stage and S_7 = 2 d after edible stage. Disease incidence was calculated by the following formula (Equation (9)):

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected fruits}}{\text{Total number of fruits assessed}} \times 100 \tag{9}$$

Data on disease severity (DS) was indexed on a scales, where, 0 = no disease symptom on the fruit surface area, 1 = 1%-10% disease area, 2 = 11%-20% disease area, 3 = 21%-30% disease area and 4 = 31% and over disease area (Illeperuma and Jayasuriya, 2002). Disease severity was expressed according to the following Equation (1) 0 given by Singh (1984).

$$\text{Disease severity (\%)} = \frac{\Sigma(\text{Severity rating} \times \text{number of fruits in that rating}}{\text{Total in number of fruits assessed} \times \text{highest scale}} \times 100 \tag{10}$$

2.8 Economic analysis

Economic analysis of the hot water treatment plant was done. Cost analysis included the operating cost of the plant. Operating cost of the plant included the fixed cost and variable cost.

Fixed cost

Fixed cost of the plant included annual depreciation, interest on investment, and shelter. Capital consumption included depreciation and interest.

Capital consumption (CC) (Equation (11))

$$CC = (P - S)CRF + Sxi \tag{11}$$

where, P = Purchase price, Tk; S = Salvage value, Tk; CRF = Capital recovery factor (Equation (12))

$$CRF = \frac{i(1+i)^L}{(1+i)^L - 1} \tag{12}$$

where, i = Rate of interest; L = Life of hot water treatment plant, yr.

Shelter

T = 0.5% of purchase price of the hot water treatment plant, Tk.

Total fixed cost per year (Equation (13))

$$FC = CC + T \tag{13}$$

Variable Cost

In calculation of variable cost, the following relations were assumed

Labour cost per hour/L_b=Tk man-h^{-1}

Electricity cost per hour/ E=Lit h^{-1}

Repair and maintenance (R&M) cost per year = 3.5% of purchase price of the hot water treatment plant

Total variable cost (Equation (14))

$$VC = L_b + E + R\&M \tag{14}$$

Annual cost/operating cost (Equation (15))

$$AC = FC + VC \tag{15}$$

2.9 Break-even point (BEP)

Break-even point is the level at which an investment neither incurs a loss nor produce a profit. For mechanization, it is defined as the use level at which the machine must be operated. Fixed cost and variable cost were calculated the above mentioned equation.

3 Results and discussion

3.1 Fabrication of hot water treatment plant

The plant is suitable for treatment of banana at different temperatures (53°C to 57°C) for particular exposure times (3 to 3 min). The plant was tested with and without specimen in the laboratory during 2011-2012. The performance results of the plant are described in Table 1.

Table 1 Performance results of the hot water treatment plant in the workshop

Performance parameters	Results
Initial temperature of water/°C	34
Working temperature of water/ °C	55
Time for reaching 55°C of water/h	2
Roller speed/r min^{-1}	1.6
Capacity of electric heaters/kW	2
Treating exposure time/min per crate	5
Weight of the plant/kg	235
Price/Taka (US$)	100,000 (1300)
Quantity of bananas/kg	210
Temperature fluctuation range/°C	±1
Total treating time, minutes	36
Capacity of the plant/kg h^{-1}	350
Plant utilization factor	0.68
Power consumption for water heating from (ambient) 34°C to 55°C/ kWh	11.2
Power consumption for treating of 210 kg fruits/kWh	3.9

It was observed that the capacity of the plant was 350 kg h^{-1} for banana, which was lower than theoretical value owing to low holding capacity of plastic crate for banana. Low holding capacity of the plastic crate was might be due to elongated and curve shape of the banana hands. Banana hands could not be put uniformly inside the plastic crate that left a lot of internal space among them. Banana fruits were treated at 55°C for 5 min successfully. The heating time of water was different due to fluctuation of voltage. Traveling speed of a crate was 0.28 m min^{-1} that was lower than designed speed. This was due to the frictional losses of chain sprocket and between bush and shaft of roller. In unloaded condition, fluctuation of temperature was increased by 1°C due to error of the digital thermostat valve while temperature was decreased by 1°C at loaded condition because of heat loss by convection through opening sides and absorption of heat by banana fruits. Power consumption for treating 1 kg of fruits was 0.072 kWh, the cost of which was Taka 0.40. The price of the plant was Taka 100000 (US$ 1300).

3.2 Profitability analysis

3.2.1 Treatment cost of hot water treatment

The treatment cost of hot water treatment plant (HWTP) is shown in Table 2. Profitability analysis revealed that the method of banana treatment incurred fixed and variable costs. The lion share of cost was estimated for variable cost for the method. Fixed cost included two cost items namely capital consumption and shelter, whereas variable cost included labour, electricity, R&M, and materials. The treatment cost of the plant was found to be 0.55 Tk kg^{-1}. It was also found that payback period of the plant was 26 d.

Table 2 Treatment cost of hot water treatment

Cost item	Taka
Fixed cost (FC)	
1. Capital consumption (CC)/ Tk yr^{-1}	17,857.00
2. Shelter (T)/ Tk yr^{-1}	460.00
Sub-total / Tk yr^{-1}	18,317.00
Tk h^{-1}	9.16
Variable cost (VC)	
Labour/ Tk h^{-1}	150.00
Electricity/Tk h^{-1}	30.00
R&M/ Tk h^{-1}	1.38
Materials/ Tk h^{-1}	1.25
Sub-total	182.63
Total cost (FC+VC)/ Tk h^{-1}	191.79
Capacity of the plant	350
Treatment cost (Total cost/capacity)/ Tk kg^{-1}	0.55

3.2.2 Payback period of the plant

Total fixed cost/ Tk yr^{-1} = 18317

Yearly use of the plant = 250 d = 250 d×8 h d^{-1} = 2000 h

Fixed cost/ Tk h^{-1} = 9.16

Variable cost/ Tk h^{-1} = 182.63

Total cost/ Tk h^{-1} = 191.79

Capacity of the plant/ kg h^{-1} = 320

Purchase price of untreated green banana/Tk kg^{-1} = 15

Treatment cost/ Tk kg^{-1}= 0.60

Total cost of treated green banana/ Tk kg^{-1} = 15.60

Selling price of treated green banana/ Tk kg^{-1} = 17.00

Net profit/ Tk kg^{-1} = 1.40

Profit per hour = 1.4 Tk kg^{-1} × 350 kg h^{-1} = 448 Tk h^{-1}

Profit per day = 448 Tk h^{-1} × 8 h d^{-1} = 3584 Tk d^{-1}

Payback period of the plant =price of the plant /profit per day=92000 Tk./3584 Tk. d^{-1}=25.67 = 26 d^{-1}

3.2.3 Break-even point

Figure 3 shows the break-even point (BEP) of hot water treatment plant for banana fruits. It was observed that BEP of the plant was 70 h yr^{-1}. Therefore, banana treated by the plant could be profitable to traders when the annual use of the plant exceeds 70 h.

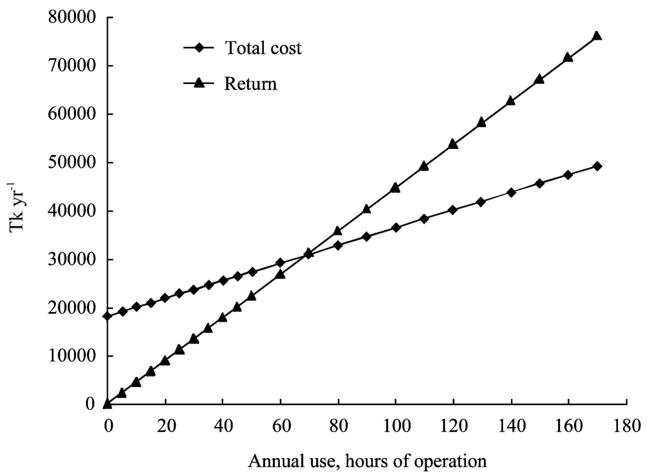

Figure 3 Break-even point of hot water treatment plant for banana

3.3 Shelf-life

The maximum shelf-life of treated *Sabri Kola* was found 13 d and the minimum 9.5 d in untreated *BARI Kola 1* followed by treated *BARI Kola 1* and untreated *Sabri Kola*. The shelf-lives of treated banana for both the varieties increased than those of untreated fruits. It occurred due to slowing down of enzyme activity and eliminated the disease incidence by applying the heat treatment. The difference of shelf-life for *BARI Kola 1 and Sabri Kola* was obtained due to varietal effects.

3.4 Disease incidence and severity

Banana fruits under all treatments of *BARI Kola 1* and *Sabri Kola* showed a progressive disease incidence and severity during and after full ripening stages (S_5 = edible stage, S_6 = 1 d after edible stage and S_7 = 2 d after edible stage) at 22°C and 79% Rh (Figure 4 and Figure 5).

The minimum value was recorded in treated *Sabri Kola* proceed by treated *BARI Kola 1*. The reason was that the fungi of the surface of fruits were destroyed and inactive through hot water treatment. The postharvest loss (disease severity) of *BARI Kola 1* and *Sabri Kola* was saved by 27.5% and 95% over the untreated fruits at S_7, respectively. Hassan et al. (2004) reported that disease severity in banana fruit was significantly reduced by hot water treatment at 50°C ± 2°C for 5 mins.

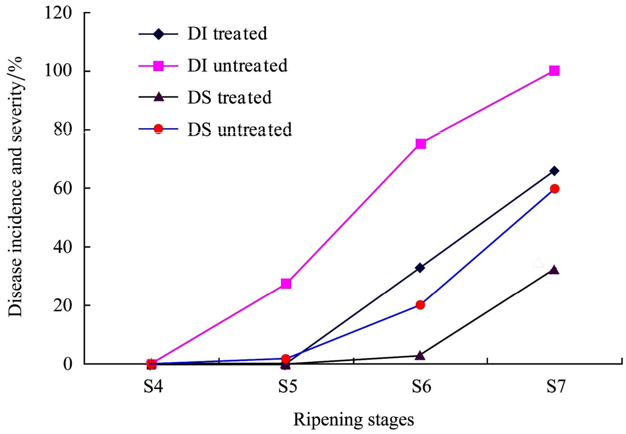

Figure 4 Effect of ripening stages of *BARI Kola 1* on disease incidence and severity

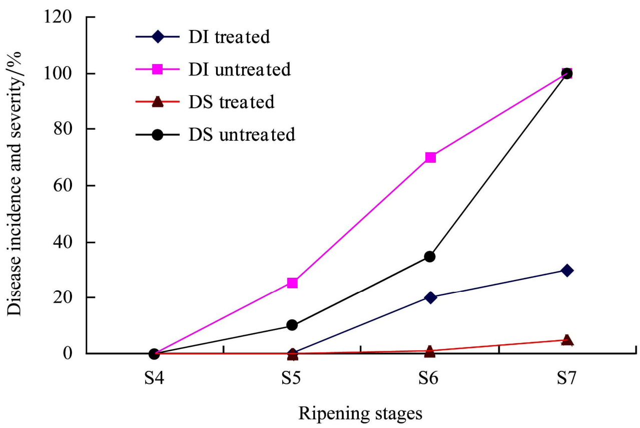

Figure 5 Effect of ripening stages of *Sabri Kola* on disease incidence and severity

4 Conclusions

The hot water treatment plant was designed and developed for treating banana fruits. It was tested with *BARI Kola 1* and *Sabri Kola* treating them at 55°C for 5 min. The capacities of the plant were 350 kg h^{-1} for both the varieties. Break-even point of the hot water treatment plant was 70 h yr^{-1}. Payback period of the plant was found to be 26 d. Treatment cost of the hot water treatment plant was found 0.55 Tk kg^{-1}. The hot water treatment can increase the shelf-life (30%) and reduce the postharvest loss (70%). Hot water treatment plant may be used for treating mango, papaya, guava etc. However, for different fruits the temperature and treatment time should be adjusted for optimum treatment. It is expected that the plant may be profitable for mango, papaya, guava etc.

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