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EFFECT OF SMOKING AS POST-HARVEST TREATMENT ON THE RIPENING AND QUALITY OF BANANA (*Musa* sp)

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ABSTRACT
The application of smoke is a traditional practice to trigger the ripening process of banana. This experiment was conducted to investigate the effects of different post-harvest treatment on the physiochemical properties of banana fruits. This experiment was laid out in a Completely Randomized Design (CRD) with three replications, which constituted the seven treatments *viz*. control, low density polyethylene bag, as well as 12, 18, 24, 30 and 36 hours exposed to smoke. The results indicated that smoke treatment increased physiological weight loss and pulp weight during storage whereas decreased firmness, peel weight and dry matter content. Chemical parameters such as moisture, total soluble solid, and total sugar showed an increasing trend during the storage period, whereas acidity and vitamin C increased initially up to 5 days and declined thereafter during the ripening of the banana. Smoking for 18 hours resulted in uniform ripening with yellow coloration within 5 days, whereas untreated control fruits remained green for 5 days and ripened within 8 days after storage. The present study concludes that smoke treatment is a simple but quick means of banana ripening. Exposer of banana fruits to smoke for 18 hours produced better quality and improved the shelf life.

Keywords: Banana, ethylene, fruit ripening, shelf life, sugar

INTRODUCTION
Banana (*Musa* sp.) is an important fruit all over the world due to its auspicious flavor, nutritious value and medicinal properties. After rice, wheat and maize, it ranks as the fourth-most significant staple food in the world. Banana ranked top on the list of fruits in Bangladesh, with an annual production of 826.15 thousand MT from 49.45 thousand ha of land (BBS 2021). It is the only fruit crop that is available around the year and the most-consumed fruit than any other fruit. The banana fruit is perishable and a significant portion of it is spoiled. After harvest, the fruit undergoes significant physiological changes that contribute to its perishability (Momen *et al*. 1993). Normally bananas are harvested at a mature stage and fruits are not generally allowed to ripen on the plant. After harvesting, fruits need a few days to ripen naturally. Fruits' skin cracks, ripens unevenly and doesn't develop a pleasing color or aroma when they ripen naturally, which lowers their marketability (Khader *et al*. 1990). To solve this problem, people frequently utilize harmful artificial substances such ethanol, glycol, calcium carbide, acetylene, ethylene, propylene, 2-chloroethyl phosphonic acid, and ethrel, which can lead to major health issues like heart disease,

skin illness, lung failure, and kidney failure (Siddiqui and Dhua 2010). In many developing countries inexpensive traditional and biological methods such as smoking and keeping with hay and banana leaves are practiced (Gomasta and Mondoal 2016). Generally, people in Bangladesh use smoking from burning rice husks, wood litter, etc. to ripen banana. Due to the presence of both acetylene and ethylene in the smoke, it is commonly accepted that this practice accelerates the ripening of banana (Saranada 1990). However, most people are unaware of how smoking affects fruit quality and how it varies over time. Poor exterior color development and uneven ripening are both caused by improper smoke treatment (Kulkarni *et al.* 2011). However, a few studies have been carried out on evaluating the effects of different durations of smoking on the quality of banana. Therefore, the present study was conducted to evaluate the effects of different duration of smoking treatments on the physio-chemical properties of banana fruits.

MATERIALS AND METHODS

Fruit materials and treatments: Banana (*Musa* Sp.) cv. Amritsagar were collected at mature green stage from the research field near Hajee Mohammad Danesh Science and technology University (HSTU), Dinajpur and immediately moved to the laboratory of the department of Horticulture, HSTU. Healthy fruit with uniform size and shape were selected, washed in clean water and then air dried. The experiment was set in Completely Randomized Design (CRD) with three replications. The seven treatments were as follows; T_0= control, T_1= fruit covered with low density polyethylene (LDPE) bag, T_2= 12 hours, T_3= 18 hours, T_4= 24 hours, T_5= 30 hours and T_6= 36 hours exposed to smoke. The traditional earthen chambers were used for ripening. Rice husk was burnt in the outer combustion unit next to the chamber. Through the pipes, the smoke was brought into the chamber's lower section. After treatment, the samples were placed in plastic crates at ambient conditions. To measure the physical and chemical parameters ten fruits were arbitrarily chosen for each treatment and replication at 2, 5 and 8 days after storage.

Data collection

Physical parameters: The pulp and peel weight were recorded by using a monoplane electronic balance and expressed in gram (g). Physiological weight loss was estimated using the following formula: Percent weight loss=Initial weight (g)-Final Weight(g)/Initial weight(g) ×100. With the help of a pressure tester by using a 5/16 plunger, firmness of fruits was determined and expressed in kg cm^{-2}. Moisture and dry matter content was determined according to AOAC (1980).

Peel color change: Daily peel color change were recorded at storage and ripening stage by using standard banana ripening chart of Dadzie (1997). The standard banana ripening chart consists of 7 color plates. Where: 1 = green; 2 = green with yellow tracks; 3 = more green than yellow; 4 =more yellow than green; 5 = yellow with green tips; 6 = all yellow, and 7 = yellow flecked with black spots.

Chemical parameters: Using the Erma Hand Refractometer (0–32° Brix), total soluble solids were calculated and represented in Brix. The method of Ranganna (1997) was used to measure titratable acidity, total sugar, and vitamin C.

Ripening period and shelf life: Based on the variations in color and firmness of the bananas, the ripening period was calculated. The number of days till the fruit reached its fully mature stage was noted (Color stage 4). After ripening, the shelf life (days) was recorded. When the fruits began to spoil, the fruits had reached the end of its shelf life.

Statistical analysis: The experimental data were analyzed using IBM SPSS statistics 22 program. The significant differences between the treatment means were calculated using Tukey's test. Statement of statistically significant differences between the experimental treatments at the probability level of $P<0.05$.

RESULT AND DISCUSSION

Physical characteristics: The different smoking treatments significantly influenced the fruit physiological weight loss (PWL), pulp and peel weight, dry matter, firmness and color (Table 1 and 2). Physiological weight loss (PWL) of banana fruits gradually increased with the advancement of storage period. The highest PWL (5.61%) was measured on 8th days in 36 hours smoking treated fruits whereas the minimum PWL (5.31%) was observed at low density polyethylene (LDPE) covered fruit. Some external and internal factors i.e., temperature, relative humidity and peel permeability regulate the rate of PWL (Duan *et al.* 2007). An upsurge in PWL in bananas could be due to increase temperature by smoking treatment (Abraham *et al.* 2021). The result of this study indicated a continuous rise in pulp weight during the storage period. At 8th days after storage (DAS) the pulp weight was increased by 41.75% due to application of 18 hours smoking comparing to control. Oppositely, the peel weight of LDPE covered fruit and 18 hours smoke treated fruits decreased from 49.35 to 49.03 and from 25.06 to 24.91 g, respectively after 8 DAS. Whereas in control fruits, the peel weight decreased from 35.84 to 35.06 g after 8 DAS. The weight of pulp increased than peel because of the transpiration rate of peel was higher than pulp. Similar results were reported by previous author who found a higher pulp to peel ratio in bananas ripened with smoking (Mebratie *et al.* 2015). Also, on the storage time the dry matter content gradually decreased (Table 2). The dry matter content was reduced by 4.42% in fruits exposed to 36 hrs smoking at 8 DAS compared to the untreated control. The early softening of smoke treated fruit might be cause of enhanced ripening. The loss of firmness was higher in 36 hours smoking (3.13 to 0.25 kg cm^{-2}) and the untreated fruits were found to be highly firm during storage (3.56 to 2.50 kg cm^{-2}). These outcomes were also consistent with banana (Mebrati *et al.* 2015).

Table 1. Effect of smoking treatments on physiological weight loss (PWL), weight of pulp and weight of peel on banana at different storage time

Treatments	Storage time (day)								
	PWL (%)			Weight of pulp (g)			Weight of peel (g)		
	2	5	8	2	5	8	2	5	8
T_0	1.17c	4.21a	5.31c	93.09g	94.65g	94.36g	35.84c	35.95c	35.36c
T_1	1.53a	4.55a	5.29c	142.4c	144.1c	143.3c	49.35a	49.61a	49.03a
T_2	1.50ab	4.26a	5.35bc	124.2d	124.8d	124.9d	40.25b	40.26b	39.33b
T_3	1.16c	4.56a	5.36bc	158.3a	162.0a	162.0a	25.06e	25.03e	24.91e
T_4	1.22bc	4.26a	5.43b	113.2e	116.4e	116.4e	25.28e	25.28e	24.60e
T_5	1.30abc	4.36a	5.59a	104.7f	104.5f	103.1f	27.87d	28.25d	28.29d
T_6	1.16c	4.22a	5.61a	151.6b	154.6b	154.3b	28.50d	28.55d	27.99d
LSD	0.28	1.55	0.07	4.28	5.84	5.28	1.56	1.61	1.16
CV %	12.25	20.09	3.85	1.90	2.55	2.31	2.65	2.72	1.99

Means followed by same letter(s) within each column didn't significantly different (Tukey's test, $p \leq 0.05$). T_0= Control, T_1= Low density polyethylene bag, T_2= 12, T_3= 18, T_4= 24, T_5= 30 and T_6= 36 hours smoking.

Fruit color was increased with the storage period of banana. Color development was faster with the smoking treatment as compared to control. The highest color score (7.00) attained at 36-, 30- and 24-hours smoking treatment at 8 DAS. The lowest value (4.00) was found in control and

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LDPE treatment at 8 DAS. It was probably due to the higher amount of ethylene production from smoking. There is an interconnection between and ethylene and chromoplast development at the ripening stage which is occurred due to the carotenoid pathway being under positive control of ethylene (Klee and Giovannoni, 2011). Smoking likely produces more ethylene when it is burned, which accounts for the quicker coloration that has been observed (Mebratie *et al.* 2015).

Table 2. Effect of smoking treatments on dry matter, firmness, and color on banana at different storage time

	Storage time (day)								
	Dry matter (%)			Firmness (kg/cm^2)			Color		
Treatments	**2**	**5**	**8**	**2**	**5**	**8**	**2**	**5**	**8**
T_0	29.47a	29.87a	27.80a	3.56a	3.37a	2.50a	1.00 c	2.00 d	4.00 c
T_1	29.11a	28.31bc	27.62a	3.35a	3.24a	1.41b	1.00 c	3.00 c	4.00 c
T_2	30.17a	28.72b	27.80a	3.50a	2.44b	1.02c	2.00 b	4.00 b	6.00 b
T_3	30.14a	28.29bc	27.26ab	3.19a	0.56d	0.31d	2.00 fb	4.00 b	6.00 b
T_4	30.48a	28.77b	26.72b	3.30a	0.95c	0.32d	3.00 a	5.00 a	7.00 a
T_5	30.10a	28.12bc	26.97ab	3.37a	0.46d	0.34d	3.00 a	5.00 a	7.00 a
T_6	30.29a	27.48c	26.57b	3.13a	0.43d	0.25d	3.00 a	5.00 a	7.00 a
LSD	1.35	0.80	0.81	0.49	0.21	0.11	0.7	0.58	0.21
CV %	2.54	1.59	1.68	8.37	7.56	7.16	20.03	8.22	2.02

Means followed by same letter(s) within each column didn't significantly different (Tukey's test, $p \leq 0.05$). T_0= Control, T_1= Low density polyethylene bag, T_2= 12, T_3= 18, T_4= 24, T_5= 30 and T_6= 36 hours smoking.

Quality characteristics: The moisture content, total soluble solid (TSS), acidity, vitamin C and total sugar of banana fruit was significantly influenced by using different smoking treatments (Figure 1). The moisture content of smoking treated fruits gradually increased during storage and reached a maximum of 73.43% in 36 hr smoking treatment at 8 DAS. Control fruits showed minimum moisture content of 72.2% on 8 DAS. Moisture content of fruit increased due to an upsurge in sugar content resulting in starch hydrolysis to sugar (Mohapatra *et al.* 2010). The TSS content of fruits significantly increased with storage period (Figure 1). The TSS in all smoke fruits showed higher value than the control fruit. The highest TSS content (22.17%) was recorded in 18 hr and lowest (12.37%) were recorded in control at 8 DAS. Due to an increase in water soluble sugar content brought on by the starch hydrolysis, pulp moisture content increased. The conversion of starch into water soluble sugars could be the attribute cause of raising TSS during storage (Dadzie 1997). Titratable acidity increased from the initial value in all the treatment reaching a peak and declining later during the ripening process. The titratable acidity increased by 69% in 18 hours smoking at 5 DAS compared to control. The decrease in acidity later during ripening may be due to use of organic acid in respiratory process (Mahajan *et al.* 2010). Vitamin C content of fruits decreased in banana fruit during storage. Control fruit showed highest ascorbic acid degradation from 6.48 to 5.05 mg/100g whereas 18 hours smoking treated fruit displayed lowest degradation from 8.47 to 7.2 mg/100g. Due to the oxidation of ascorbic acid in ripened fruit, the amount of vitamin C decreased. According to the chemistry of ripening, vitamin C levels drop as temperatures rise (Njoku *et al*, 2011). In this study, the total sugar of treated and

controlled bananas increased gradually. Highest total sugar content 27.67% was recorded in T_3 and lowest 12.15% was recorded in control at 7 DAS. The total sugar was increased by 53.68% and 56.09% in 18 hr smoking at 5 and 8 days, respectively over the control. Due to the conversion

of complex starch to simple sucrose such as glucose and fructose by the enzymatic activities as well as the conversion of polysaccharides to soluble solids, the initial rise of total sugar content increased and reduction of total sugar due to its utilization in respiration process. The results were in conformity with the Subbaiah *et al*. (2014).

Ripening period and Shelf life: There were significant differences of ripening period and shelf life by using different types of smoking treatment (Figure 2). The shortest ripening period (3 days) was observed in 36 hours smoking whereas the highest ripening period (8 days) was observed in control. The fruit treated with smoke ripened quickly due to the influence of exogenous ethylene and the high temperature produced by smoking, which may boost the physico-chemical changes (Mebratie *et al.* 2015). Shelf life was improved by 25% upon exposure of 18 hours smoking in comparison to the untreated control (natural ripening). The findings of the current experiment were confirmed by Mebratie *et al.* 2015.

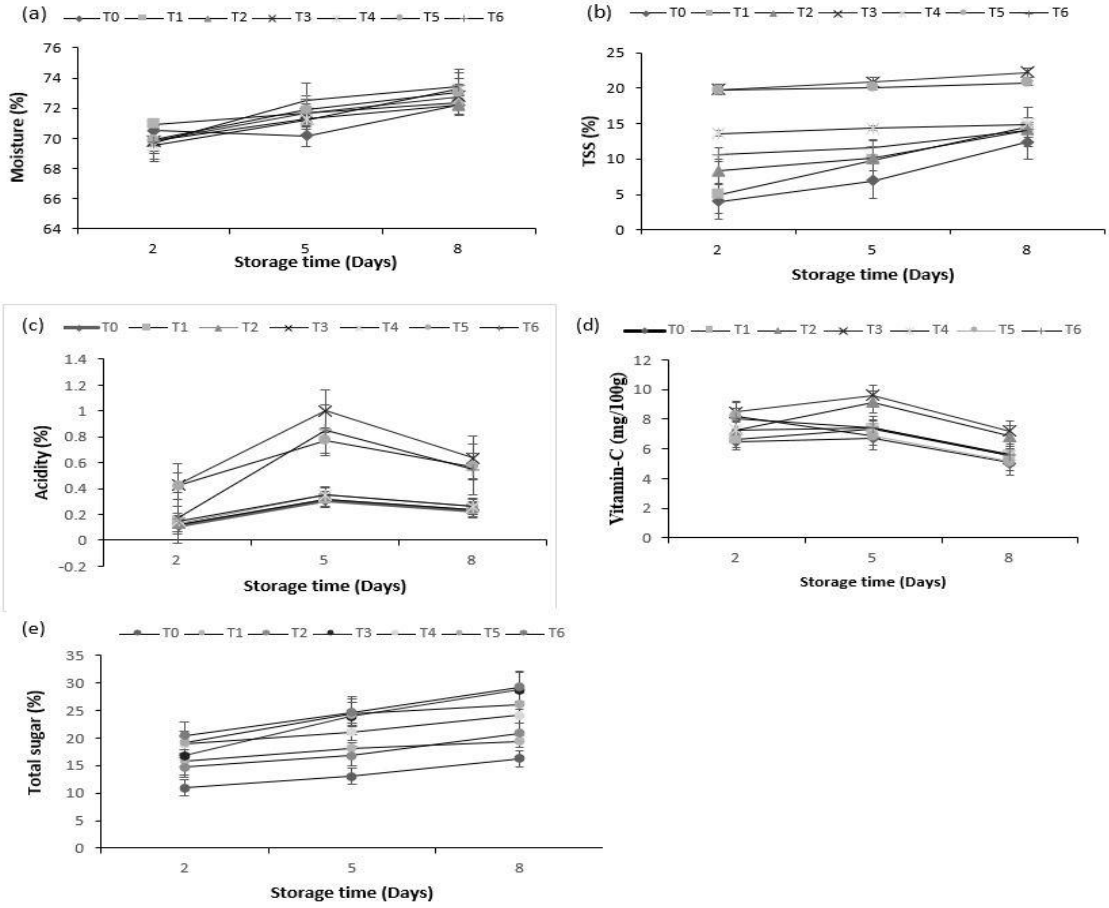

Figure 1: Effect of smoking treatments on (a) moisture, (b) TSS, (c) acidity, (d) vitamin-C and (e)

total sugar on banana at different storage time. Vertical bar indicates LSD at 5% level of significance. T_0= Control, T_1= Low density polyethylene bag, T_2= 12, T_3= 18, T_4= 24, T_5= 30 and T_6= 36 hours smoking.

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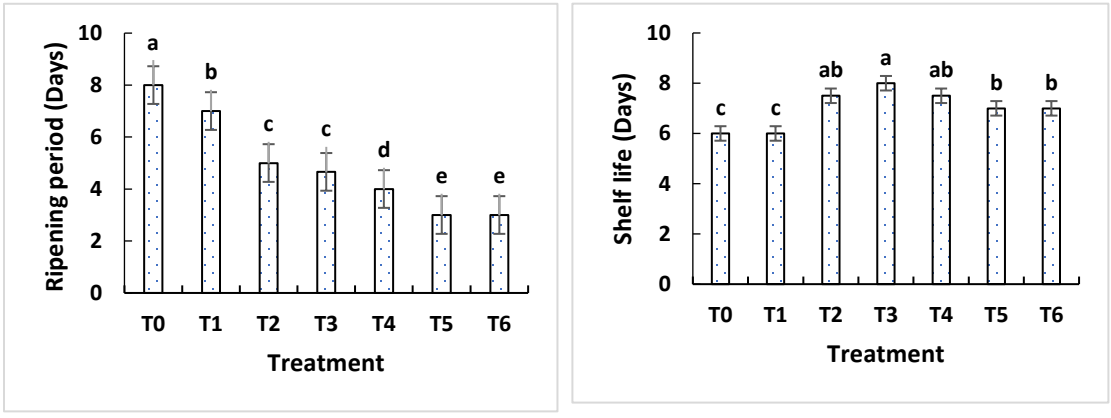

Figure 2: Effect of smoking treatments on ripening period and shelf life on banana at different storage time. Vertical bar indicates LSD at 5% level of significance. T_0= Control, T_1= Low density polyethylene bag, T_2= 12, T_3= 18, T_4= 24, T_5= 30 and T_6= 36 hours smoking.

CONCLUSION

From the present study it could be concluded that the fruits treated with smoking for 18 hours ensure faster and uniform ripening under ambient conditions after 5 DAS compared to control (8 days). The ripening stage, the smoking for 18 hours treated banana fruits improved physio-chemical properties such as PWL, softness, TSS and total sugar (%) compared to non-treated fruits. The consequence of the study of safe ripening agents benefits for health and is also commercially beneficial to traders due to early availability and less post-harvest loss.

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