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Research Article

Evaluation of Commercial Bleach and Packing Materials as a Management Option of Tomato (*Lycopersicon esculentum* Mill.) Rotting Disease in Eastern Ethiopia

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Abstract

Tomato is a very perishable vegetable with a short shelf-life in many parts of the world including Ethiopia. Experiments were conducted to evaluate effect of commercial bleach and packing materials as a management option of these diseases. Eight levels of storage structures integrated with three levels of washing were evaluated. Among management options the highest (68.88%) mean marketable fruits were obtained from treatments washed with bleach, rinsed in water, dried and stored in plastic boxes without plastic lining. The highest incidence (89.74%) and percent severity index (67.2%) was recorded on unwashed fruits stored in traditional basket lined with polyethylene sheet, where as the lowest was from fruits washed with bleach, rinsed in water, dried and stored with plastic box without polyethylene sheet lining. Washing of fruit with bleach, rinsing in water, drying and storing in plastic box without polyethylene sheet lining was found to be the best management option. This treatment provided the highest net profit of 1298.5 Ethiopia Birr/box with marginal rate of return of 11.6% and marginal benefit of 820.5 Birr/box. In conclusion, washing of fruits with bleach, rinsing in water, drying and storing in plastic box without polyethylene sheet lining was found to be the most effective management option. However, further studies are important to evaluat other manegement options for fruit rotting fungi.

Keywords

Bleach, Fruit Rot, *Lycopersicon esculentum*, Marketable Fruits, Packing Material

1. Introduction

Tomato (*Lycopersicon esculentum* Mill.) is originated in Central America and later spread throughout the world by explores [10]. Consumers buy tomatoes primarily for their appearance but are attracted to repeat purchases by flavor and quality [4]. Tomatoes are rich in minerals, vitamins, essential amino acids, sugars and dietary fibres. Ripe tomato fruit has high nutritive value being a good source of vitamins A, B, and C, and minerals [15]. In Ethiopia, tomato is produced mainly as a source of income and food. At present large scale production of tomato is being carried out in the Upper Awash Valley under irrigated and rain-fed conditions [9].

Nutritional values of tomato make it a widely accepted vegetable by consumers. Nevertheless, tomato is a very perishable vegetable with a short shelf-life and high susceptibility to fungal disease [2]. Post-harvest diseases destroy 10-30% of the total yield of crops [1]. The improper handling, packaging, storage and transportation may result in decay and production of microorganisms, which become

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activated because of the changing physiological state of the fruits [16]. The shelf-life of fresh tomato can be substantially increased by washing with an aqueous chlorine solution (bleach) and packaging in a container with air circulation and permeability, which decreases microbial load [11].

Hararghe is one of the important tomato producing areas in Ethiopia. Currently a lot of tomato supplied to local and export markets. However, in storage and during transportation to market, a lot of tomato is discarded due to damage by fungi. In Hararghie area the potential of bleach to reduce post harvest loss is not known. Thus, the objectives of this study were to evaluate effects of bleach and packing materials as a management option of these diseases.

2. Materials and Methods

2.1. Treatments and Experimental Designs

This experiment had two factors. Factor one was washing which had three levels: washing with bleach, rinsing in water and drying, washing by water alone and drying, and without washing. Factor two was packing method which had eight levels: bamboo basket alone, bamboo basket lined with polyethylene sheet, wooden box alone, wooden box lined with polyethylene sheet, plastic box alone, plastic box lined with polyethylene sheet, traditional basket alone, and traditional basket lined with polyethylene sheet arranged in randomized complete block design. One set of tomato fruits were washed with dilute commercial bleach (10% sodium hypochlorite), rinsed in water and air dried; the second set was washed by water alone and air dried; and the third set was unwashed. For each treatment, 100 tomato fruits were placed in each packaging structure with three replications. Then the treatments were arranged in factorial combination in RCBD giving a total of 24 treatment combinations.

2.2. Data Collected and Analysis

Experimental materials were examined at three days interval and disease incidence and severity were recorded. Disease severity was recorded by estimating the percentage of fruit area diseased using the 1-5 disease scoring scales where: 1 represents for 0-1%, 2 for 1-5%, 3 for 6-9%, 4 for 10-49% and 5 for 50-100% [5]. Disease severity scores were then converted into percentage severity index (PSI) for analysis. Data on the proportion of marketable and unmarketable fruits were collected at the time of disease assessment according to the procedure of [12] based on descriptive quality attributes such as the level of visible lesion, shriveling smoothness and shininess of the fruit.

The data's were analyzed using the Generalized Linear Model (GLM) procedures of the Statistical Analysis System [13]. Fisher's Least Significant Difference (LSD) test at α= 0.05 was used to separate significant differences between treatments means when analysis of variance indicated $P \leq 0.05$.

2.3. Cost Benefit Analysis

Cost and benefit of each treatment was analyzed partially and marginal rate of return was computed by considering the variable cost available for the respective treatment. Variable cost includes; cost of storage structures, cost of bleach, cost of polyethylene sheet, cost of water and labor for washing. Amount of marketable fruits and economic data were collected to compare the advantage of washing of fruits by sodium hypochlorite integrated with different storage structures. Economic data include input cost. The price of each plastic box, wooden box, bamboo basket, traditional basket and polyethylene sheet were 60, 120, 50, 40, 3 Birr, respectively. Cost of 800 ml sodium hypochlorite was 14 Birr, water cost was 1 Birr and labor cost for washing and other activities was 15 Birr per day. Based on obtained data, cost benefit analysis was performed using partial budget analysis.

3. Results and Discussion

Disease incidence. Washing of fruits with bleach, rinsing in water, drying and rinsing in water combined with different packing structures significantly dicreased disease incidence ($P < 0.05$) over unwashed and washed with water alone (Table 1), where as packing structures lined with polyethylene sheet resulted in segnifficantly higher disease insidene in all storage structures over storage structures without lining. The highest (89.74%) incidence was recorded in fruits which were not washed and stored with traditional basket lined with polyethylene sheet followed by fruits washed with water alone and stored with traditional basket lined with polyethylene sheet (75.93%). The lowest (29.32%) insidense was observed in fruits washed with bleach, rinsed in water, dried and stored with plastic box without plastic lining which was not segnifficantly different from fruits washed with bleach, rinsed in water, dried and stored in wooden box (32.57%) and bamboo basket (35.86%) without plastic lining.

Percent severity index (PSI). Highly significant variation ($P<0.0001$) was observed in the final PSI among treatments. Unwashed Fruits which stored with traditional basket lined with polyethylene sheet had highest (67.2%) level of final PSI. On the other hand the lowest final PSI of 23.73% and 24% were recorded on fruits washed with bleach, rinseed in water, dried and stored in plastic box and wooden box without plastic lining. However, they were not significantly different each other. Generally, any of the packing structures lined with polyethylene sheet resulted in higher severity as compared with packing structures without lining (Table 1).

Marketability of tomato fruits. Washing of tomato fruits with bleach, rinsing in water, drying and storing in different packing structures increased final marketability of tomato fruits significantly ($P<0.05$) over unwashed fruits (Table 1). Fruits washed with bleach, rinsed in water, dried and stored with plastic box and wooden box without plastic lining resulted in the highest marketable fruits of 68.88% and 64.66%, respectively. However, these are not significantly different from each other. Whereas the lowest marketable fruits were recorded in unwashed fruits and stored in traditional basket lined with polyethylene sheet (20.79%) and bamboo basket lined with polyethylene sheet (21.62%). In all situations any packing structures lined with polyethylene sheet resulted in lower marketable fruits as compared with unlined structures.

Table 1. *Effect of washing and storage structures on PSI, incidence and marketability of tomato fruit.*

Washing treatments	Storage treatments	Incidence mean (%)	PSI mean (%)	Marketable fruit mean
WBRWD	BBA	35.86 (34.33) ^{ij}	27.8 ^{k}	63.25 (79.67) ^{b}
	BBLPS	61.03 (76.33) ^{def}	41.03 ^{gh}	33.19 (30.00) ^{lijk}
	WBA	32.57 (29.00) ^{j}	24 ^{l}	64.66 (81.67) ^{ab}
	WBLPS	53.74 (64.33) ^{efg}	42.26 ^{fg}	35.46 (33.67) ^{ghi}
	PBA	29.32 (24.33) ^{j}	23.73 ^{l}	68.88 (87.00) ^{a}
	PBLPS	45.19 (50.33) ^{ghi}	38.73 ^{hi}	38.44 (38.67) ^{efgh}
	TBA	36.46 (35.33) ^{hij}	28.13 ^{k}	61.17 (76.67) ^{b}
	TBLPS	70.57 (87.00) ^{bcd}	45.2 ^{e}	34.01 (31.33) ^{hij}
WWAD	BBA	47.68 (54.67) ^{g}	32.6 ^{j}	39.22 (40.00) ^{defg}
	BBLPS	70.79 (88.67) ^{bcd}	43.4 ^{ef}	28.71 (23.33) ^{lm}
	WBA	45.57 (51.00) ^{ghi}	33.13 ^{j}	42.69 (46.00) ^{cde}
	WBLPS	70.68 (88.00) ^{cbd}	44.2 ^{ef}	30.59 (26.00) ^{jkl}
	PBA	45.57 (51.00) ^{ghi}	34.27 ^{j}	44.24 (48.67) ^{c}
	PBLPS	63.41 (79.67) ^{cde}	39.8 ^{h}	33.52 (30.67) ^{ijk}
	TBA	48.45 (56.00) ^{g}	37.07 ^{i}	35.25 (33.33) ^{ghi}
	TBLPS	75.93 (89.00) ^{b}	50.13 ^{d}	25.91 (19.33) ^{mn}
WOW (control)	BBA	46.92 (53.33) ^{gh}	40.13 ^{gh}	36.02 (34.67) ^{fghi}
	BBLPS	76.55 (90.00) ^{b}	60.17 ^{b}	21.62 (13.67) ^{no}
	WBA	48.06 (55.33) ^{g}	45.33 ^{e}	43.27 (47.00) ^{cd}
	WBLPS	72.67 (91.00) ^{bc}	49.2 ^{d}	29.10 (23.67) ^{klm}
	PBA	46.94 (53.33) ^{gh}	38.8 ^{hi}	40.38 (42.00) ^{cdef}
	PBLPS	70.44 (88.67) ^{bcd}	55.2 ^{c}	28.85 (23.33) ^{lm}
	TBA	50.80 (60.00) ^{fg}	40.8 ^{gh}	34.20 (31.67) ^{hij}
	TBLPS	89.74 (100.00) ^{a}	67.2 ^{a}	20.79 (12.67) ^{o}
Mean		55.62	40.93	38.89
LSD (0.05)		10.85	2.31	4.62
CV (%)		11.87	3.43	7.23

Means within the same column with a common letter are not significantly different ($P<0.05$). Data in parentheses are mean of non-transformed values.

Data outside the parentheses are arcsine transformed.

WBRWD= washing with bleach, rinsing in water and drying; WWAD= washing by water alone and drying; WOW= without washing; BBA= bamboo basket alone; BBLPS= bamboo basket lined with polyethylene sheet; WBA= wooden box alone; WBLPS= wooden box lined with polyethylene sheet; PBA= plastic box alone; PBLPS= plastic box lined with polyethylene sheet; TBA= traditional basket alone; TBLPS=

traditional basket lined with polyethylene sheet; and PSI= percentage severity index.

Marketable fruits and final PSI on different washing systems and packing structures had highly significant ($P < 0.0001$) and showed negative correlation (r=-0.87) (Table 2). This indicates that the observed levels of disease had a considerable adverse effect on marketability of tomato fruits. Similarly, marketable and unmarketable fruits had negative highly significant ($P < 0.0001$) correlation (r=-1). However, final PSI and unmarketable fruits had highly significant ($P < 0.0001$) positive correlation (r=0.87).

Table 2. *Correlation coefficients (r) between final marketable fruits, unmarketable fruits and PSI.*

	Marketable	Unmarketable	PSI
Marketable	1		
Unmarketable	-1***	1	
PSI	-0.87***	0.87***	1

*** refers to significant level at $P < 0.0001$; PSI, percent severity index

It is impossible and uneconomical to completely eliminate post-harvest losses; it is possible and desirable to reduce them by 50%. Minimizing post-harvest losses of food that has already been produced is more sustainable and environmentally sounds than increasing production areas to compensate for these losses [8]. Chlorine is a very common disinfectant that can be added to transport flumes or to produce cooling or wash water. Liquid sodium hypochlorite is typically used. Chlorine's used in postharvest management as an algicide, disinfectant, and sanitizer [6]. Published research on post-harvest efficacy and proper management of chlorination for specific fruits and vegetables has been largely focused on tomato [14]. [3] obtained that free chlorine concentrations of 20 or 25 mg/liter were lethal to spores of *Geotrichum candidum* (causal agents of sour rot) within 30 seconds in most in vitro tests, whereas spores of *Rhizopus stolonifer (causal agents of Rhizopus rot)* were slightly less sensitive. In the absence of chlorine, incidence averaged 57% (range, 15 to 95%) for *R. stolonifer* and 38% (range, 17 to 58%) for *G. candidum* was obtained, whereas sporadic sour rot lesions were observed among fruit that had been treated with free chlorine at 75 mg/liter.

Longevity of plastic box is more, easy to carry, easy to load and unload [7]. Material can be transported to long distance without much spoilage. The result of this study shows that washing of tomato fruits by bleach and storing in plastic box without plastic lining provides better result. This may be due to combined effect of the two treatments as sodium hypochlorite reduces microbial lode that cause fruit rot of tomato, and plastic box reduces physical damage which create injury for entering of microorganisms. Low performance of all storage structures lined with polyethylene sheet may be due to fluids resulted from rotting of some fruits not out flow. This fluid may contain decaying pathogens that supply initial inoculums for undamaged fruits in the storage structure.

Cost benefit analysis for integrated tomato fruit rot management through washing and store in different storage structures was done using partial budget analysis. Calculated value for partial cost benefit shows that the maximum (1409.5 ETB/box) total gross marketable fruit benefit was obtained from fruits washed with bleach, rinsed in water, dried and stored in plastic box without plastic lining (Table 3). The least gross benefit of 210.5 ETB/basket was obtained from unwashed fruits and fruits washed with water alone and stored with traditional basket lined with polyethylene sheet.

The highest net profit of 1298.5 ETB/box with marginal rate of return (MRR) 11.6% was obtained from fruits washed with bleach, rinsed in water, dried and stored in plastic box without plastic lining, but all fruits stored with different storage structures lined with polyethylene sheet had lower net profit than control (478.0 THB/box). The least net benefit of 118.5 ETB/basket with MRR of -6.9% was obtained from fruits washed with water alone and stored in traditional basket lined with polyethylene sheet. From these results, it is possible to conclude that the use of polyethylene sheet for lining storage structure is not justifiable due to their low marginal benefit and marginal rate of return.

The highest (820.5 ETB/box) marginal benefit was obtained when fruits washed with bleach, rinsed in water, dried and stored in plastic box without plastic lining, while the least (359.5 ETB/basket) was obtained in fruits washed with water alone and stored in traditional basket lined with polyethylene sheet. In general, it is possible to conclude from this result that the highest net profit and marginal benefit was obtained from fruits washed with bleach, rinsed in water, dried and stored in plastic box without plastic lining. The highest cost benefit ratio of 1: 12.5 and 1: 11.6 was obtained from fruits washed with bleach, rinsed in water, dried and stored in traditional basket and plastic box without plastic lining followed by fruits washed with bleach, rinsed in water, dried and stored in bamboo basket without plastic lining (1: 11.6), while the least (1: 1.2) was obtained by fruits washed by water alone and stored in wooden box lined with polyethylene sheet. Since plastic box has the highest life span treatments in plastic box will have the highest profit in long run.

Table 3. *Partial budget analysis of storage structure treatments on washing systems.*

		BBA	BBLPS	WBA	WBLPS	PBA	PBLPS	TBA	TBLPS
	WBRWD								
1	Marketable fruit (Kg)	255.9	97.2	262.4	110.2	281.9	112.3	246.2	100.4
2	Tomato sale (Birr/Kg)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
3	Sale revenue (1x2)	1279.5	486.0	1312.0	551.0	1409.5	561.6	1231.0	502.0
4	Total input cost (Birr/SS)	101.0	137.0	171.0	207.0	111.0	147.0	91.0	127.0
5	Marginal cost (Birr/SS)	61.0	97.0	131.0	167.0	71.0	107.0	51.0	87.0
6	Net profit (3-4) (Birr/SS)	1178.5	339.0	1141.0	344.0	1298.5	414.6	1140.0	375.6
7	Marginal benefit (Birr/SS)	700.7	-139.0	663.0	-134.0	820.5	-63.4	662.0	-102.4
8	MRR (7/5) (%)	11.4	-1.4	7.4	-0.8	11.6	-0.6	12.9	-1.2
9	Cost benefit ratio (CBR)	11.6	2.5	6.7	1.7	11.7	2.8	12.5	3.0
	WWAD								
1	Marketable fruit (Kg)	113.4	45.4	152.3	84.2	136.1	74.5	103.6	42.1
2	Tomato sale (Birr/Kg)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
3	Sale revenue (1x2)	567.0	227.0	761.5	422.5	655.5	372.5	518.0	210.5
4	Total input cost (Birr/SS)	66.0	102.0	136.0	172.0	76.0	112.0	56.0	92.0
5	Marginal cost (Birr/SS)	26.0	62.0	96.0	132.0	36.0	72.0	16.0	52.0
6	Net profit (3-4) (Birr/SS)	501.0	125.0	625.5	250.5	579.5	260.5	462.0	118.5
7	Marginal benefit (Birr/SS)	23.0	-353.0	147.5	-227.5	101.5	-217.5	-16.0	-359.5
8	MRR (7/5) (%)	0.9	-5.7	1.5	-1.7	2.8	-3.0	-1.0	-6.9
9	Cost benefit ratio (CBR)	7.7	1.2	4.6	1.5	7.6	2.3	8.3	1.3
	WOW								
1	Marketable fruit (Kg)	113.4	45.4	152.3	77.8	136.0	74.5	103.6	42.1
2	Tomato sale (Birr/Kg)	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
3	Sale revenue (1x2)	567.0	227.0	761.5	389.0	680.0	372.5	518.0	210.5
4	Total input cost (Birr/SS)	50.0	86.0	120.0	156.0	60.0	96.0	40.0	76.0
5	Marginal cost (Birr/SS)	10.0	46.0	80.0	116.0	20.0	56.0	0.0	36.0
6	Net profit (3-4) (Birr/SS)	517.0	141.0	641.5	233.0	620.0	276.5	478.0	134.5
7	Marginal benefit (Birr/SS)	39.0	-337.0	163.5	-245.0	142.0	-201.5	0.0	-343.5
8	MRR (7/5) (%)	3.9	-7.3	2.0	-2.1	7.1	-3.6	0.0	-9.5
9	Cost benefit ratio (CBR)	10.3	1.6	5.3	1.5	10.3	2.9	0.0	1.8

WBRWD= washing with bleach, rinsing in water and drying; WWAD= washing by water alone and drying; WOW=without washing; BBA= bamboo basket alone; BBLPS= bamboo basket lined with polyethylene sheet; WBA= wooden box alone; WBLPS= wooden box lined with polyethylene sheet; PBA= plastic box alone; PBLPS= plastic box lined with polyethylene sheet; TBA= traditional basket alone; TBLPS= traditional basket lined with polyethylene sheet; and MRR= marginal rate of return.

4. Conclusion

This study revealed that washing of tomato fruits by bleach, rinsing in water, drying and storing in plastic box without polyethylene sheet lining appeared to be promising and can be applied conveneintly for the management of fruit rotting during storage and transportation. However, further research is needed evaluate the efficacy of promising washing treatments in different areas and develop approperiate manegment technology. In addition, further research is needed to evaluate promising treatments for use in integreted pest management strategy to manage these diseases.

Abrivations

LSD	Least Segnificant Defference
RCBD	Randomized Complete Block Design
SAS	Statistical Analysis System
USDA	United States Department of Agriculture

Author Contributions

Reshid Abdirshikur is the sole author. The author read and approved the final manuscript.

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Conflicts of Interest

The author declares no conflicts of interest.

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