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ENHANCING SHELF LIFE OF TOMATO (*Solanum lycopersicon* L.) USING RICE STRAW AS STORAGE MEDIUM

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ABSTRACT

Storing tomatoes is already a practice of farmers in the province of Ilocos Norte, Philippines. It has become an added source of income, aside from farming. However, using their own practice, farmers encountered high rotting percentage. This study was conducted to evaluate and improve existing farmers' methods, identify appropriate container to use, and determine the optimum length of storing tomatoes.

Biological wastes, like rice straw, has been found effective as storage medium to enhance the shelf life of tomatoes. The incorporation of rice straw with tomatoes inside the storage container resulted in lower percentage rotting and maintained the quality of fruits. The container could be a paper box or a plastic sack, which is placed in an elevated area with good ventilation.

The length of time storing tomato is critical in determining the profitability. The longer the fruits are stored, the more fruits are rotten. It is profitable to store tomatoes for two months but not beyond 67 days.

Keywords: *Tomato shelf life, post-harvest storage of tomato, storage media for tomato, post harvest handling practices for tomato*

INTRODUCTION

Tomato (*Solanum lycopersicon* L.) is one of the most important and most cultivated vegetables worldwide. With the many uses and nutritional value of tomato, it is an indispensable ingredient in a man's diet. It is very important for most of the people in the Ilocos region because it is one of the main ingredients of the most famous Iluko vegetable dish 'pinakbet' or vegetable stew.

Production of tomato in the Philippines covers an area of 17,700 ha producing about 199,000 MT with an average of 10.10 MT ha^{-1} (BAS, 2010). The province of Ilocos Norte is one of the major producers of tomato in the country. In 2009, it ranked third in terms of its contribution (11.7%) to the total volume of production (BAS, 2010).

Ilocos Norte farmers usually plant tomato during the months of December to January, and the peak of harvest is observed in March. There is usually a market glut during the month of March and the price of tomato ranges from ₱3.00 to ₱5.00kg^{-1} only. However, during the rainy season from May to October, the price escalates to as much as ₱60 to ₱80kg^{-1}. It is during this time that some farmers store their produce to wait for a better price. Storage of commodities can be profitable when the quality of the product can be maintained for a longer period.

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Refrigerated storage is so far the best method, but this is very costly. Refrigeration can keep tomato for 7 to 14 days (https://homecookbasics.com/how-long-do-tomatoes-last/#fresh-tomatoes). This will vary slightly depending on the kind of tomato. Several studies have been done to improve the storage practices of the farmers which will decrease rotting, maintain the quality of fruits and eventually increase profit. Other practices used to prolong the postharvest life of tomatoes at ambient temperatures are hanging (Tome and Bautista, 2018; Gabriel *et al.*, 2001); modified atmosphere storage (Torres M, 2005); using ash (Garcia and Bautista, 2016; Garcia ES, 2014); rice hull (Felipe CM, 2004); coco coir dust (Mariottt *et al.*, 2015), and modified atmosphere storage with coco coir dust (Masilungan, *et al.*, 2009 in http://mb.com.ph/articles/225764/scientists-develop-a-practical-way-storing-fresh-tomato). This storage technique, using Modified Atmosphere Packaging (MAP), prolongs the storage life of fresh tomatoes under ordinary condition using locally available materials.

Masilungan said that this MAP technology can be easily adopted by vegetable farmers at the village level production especially during periods when the price of tomato is low due to abundant supply, giving them up to three more weeks to store their produce while waiting for higher selling price.

Rice straw is a biological waste after separating the grains from the plant. It is abundant and available in the locality. Rice straw (RS) is high in silica and cellulose (http://animalfeedscience.com/article/SO377-8401(06)00050-2/abstract). These components are desiccants which maintain the relative humidity inside the container, and thus preserves the fruits. Thus, this study aimed to: 1) identify appropriate media and container for storing tomato fruits, 2) determine the optimum length of storing tomatoes and 3) evaluate the profitability of storing tomatoes using rice straw as a storage medium.

METHODOLOGY

Three independent experiments were conducted to develop a technology for storing tomato: a) Comparison of sawdust and RS as storage media using paper box, b) Evaluation of different containers with and without RS, and c) Optimum length of storing tomato using paper box with RS as storage medium. About 10kg of tomato fruits were used per experimental unit using harvested green mature fruits (var. Ilocos Red). The plants from which the test fruits were harvested were not irrigated one to two weeks before harvesting. Harvesting was done early in the morning.

All the three experiments were laid out in Completely Randomized Design (CRD) in three replicates with the following treatments:

The saw dust used was collected from nearby saw mill while the rice straw was taken from newly harvested rice plants. Both the rice straw (RS) and sawdust were sun-dried prior to use. The following treatments were used:

a. Comparison of sawdust and RS as storage media using paper box

T1- Paper box (measuring with approximately 35cm x 60cm x 0.4cm)

T2- Paper box + sawdust (sawdust were taken from a furniture shop then fully dried to kill the harbored microorganisms). The tomato fruits were embedded in sawdust inside the paper box. A layer of tomato fruits was placed, then covered with 2cm thick sawdust followed by another layer of fruits alternately with sawdust until the 10kg fruits were accommodated in the container, then sealed with packaging tape.

T3- Paper box + RS (freshly threshed RS was sun-dried for three days prior to use. Tomato fruits were placed inside the paper box lined with 2cm RS. A layer of tomato fruits was placed followed by a layer of RS until all the 10kg fruits were accommodated in the container, then similarly sealed with packaging tape.

b. Evaluation of different containers with and without RS

The treatments were: T1 - Paper box alone, T2 - Paper box + RS, T3 - Bamboo basket alone, T4 - Bamboo basket + RS, T5 - Plastic sack alone, and T6 - Plastic sack + RS.

c. Optimum length of storing tomato using paper box + RS as storage medium and stored for the following number of days: **T1** - 15 days, **T2** - 30 days, **T3** - 45 days, **T4** - 60 days, **T5** - 67 days, **T6** - 75 days, **T7** - 82 days, and **T8** - 90 days.

After packing the fruits, the containers were sealed. For the first two experiments, all the experimental units were placed under ambient temperature which ranged from 26.0°C to 34.0°C and a daily reading of relative humidity ranging from 64.0% to 88.3%. After two months of storage, the containers were opened and the stored tomatoes were evaluated. For the optimum storage length experiment, the packed tomatoes were placed under ambient temperature which ranged from 29.1 to 32.5°C and relative humidity which ranged from 57 to 73%.

Treatment effects were evaluated based on percent weight loss, rotting, and shriveling. Fruit quality after storage for the second and third experiments was also rated based on the following visual quality rating (VQR): 9, 8 - excellent, field fresh; 7, 6 - defects minor; 5, 4 - fair, defects moderate; 3 - poor, defects serious, limit of salability; 2 - limit of edibility; and 1 - non-edible. The price of tomato in the public market was also regularly monitored from the month of May to August to serve as input in the costs and returns analysis.

RESULTS AND DISCUSSION

Comparison of saw dust and RS as storage media

The incorporation of RS as storage medium resulted in significantly lower percentage rotting and consequently, higher marketable fruits than paper box with and without sawdust (Table 1). The high percentage of rotting in sawdust could be due to high moisture content of this storage medium. In contrast, RS as a storage medium served as cushion which does not allow the fruits to touch each other. As the fruits respire, heat is generated and water is also a product. The high porosity of RS absorbs the moisture produced and also prevented the building up of heat. This condition is contributory to the slower deterioration, lower rotting percentage and better quality of fruits. Temperature, moisture, gases and the presence of microorganisms

Table 1. Rotten and marketable fruits of tomato fruits as affected by rice straw and sawdust as storage media after two months of storage

STORAGE METHOD	ROTTEN FRUITS (%)	MARKETABLE FRUITS (%)
	**	**
Paper box + sawdust	39.59a	21.63c
Paper box + RS	3.75c	69.96a
Paper box	31.88ab	42.51ab
CV (%)	43.70	22.70

** - significant at 1% level
In a column, means marked with the same letter are not significantly different using LSD test at 1% level.

are the factors that affect the shelf life of a perishable commodity (Bautista and Esguerra, 2007). A low temperature slows down the metabolic activity slowing down the deterioration process. On the other hand, the paper box where the tomato was stored could have modified the atmosphere in the immediate environment of tomatoes by lowering the amount of oxygen and increasing the amount of carbon dioxide. This condition slows down also the metabolism of the commodity (Artes and Bautista, 2007). Lower moisture also inhibits the multiplication of microorganisms.

Evaluation of different containers for storage with or without RS

The treatments showed significant effect on the percentage of rotten fruits, marketable fruits, and weight loss. However, the percentage of shriveled fruits was not significantly affected.

In general, percent rotten fruits were significantly higher if without RS regardless of the container used in the following order paper box > bamboo basket > plastic sack (Table 2). With RS, the percentage of rotten fruits was more than six times less in paper box, three times in plastic sack and twice in bamboo basket.

Significantly higher percent weight loss and lower percent marketable fruits were observed in storage containers without RS. After two months of storage, percent marketable fruits were reduced to 64.44% in plastic sack and to 50.03 and 55.57% in paper box and wooden basket, respectively. With RS, the percentage of marketable fruits was only reduced by less than 25% regardless of the type of storage container. The incorporation of RS in the storage container provided aeration which probably controlled the building up of temperature inside the container.

In terms of VQR (general appearance, fruit color and juiciness), fruits stored in paper box + RS had the best quality with VQR value of 8 (excellent, field fresh). Except for bamboo basket storage container with a VQR of 6 (defects minor), all other treatments garners a rating of 7 which is also described as with minor defects.

Table 2. Percent rotten, shriveled and marketable fruits, percent weight loss and the visual quality rating of tomato fruits stored for two months using different containers with the incorporation of rice straw

CONTAINER	ROTTEN FRUITS (%)	SHRIVELED FRUITS (%)	MARKETABLE FRUITS (%)	WEIGHT LOSS (%)	VISUAL QUALITY RATING
	*	ns	*	*	-
Paper box	38.24a	2.57	50.03c	49.97a	7
Paper box + RS	6.39c	1.04	74.34ab	25.66bc	8
Bamboo basket	34.71ab	2.77	55.57bc	44.43ab	6
Bamboo basket + RS	16.25bc	6.04	77.92a	22.08c	7
Plastic sack	14.78bc	7.78	64.44abc	35.56abc	7
Plastic sack + RS	5.10c	6.14	77.11a	22.89c	7
CV (%)	56.60	68.80	33.10	33.10	-

* - significant at 5% level
ns - not significant
In a column, means marked with the same letter are not significantly different using LSD test at 5% level

Visual Quality Rating:
9,8 - excellent, field fresh
7,6 - defects minor
5,4 - fair, defects moderate
3 - poor, defects serious, limit of salability
2 - limit of edibility
1 - non-edible

Optimum length of storage using paper box with RS as storage medium

Stored tomato up to 15 and 30 days still showed good quality, VQR of 9 (excellent, field fresh), no rotten and shriveled fruits yet, and with minimal percent weight loss (Table 3). At 45 days, although rotting, overall quality and weight loss did not differ from 15 and 30 days of storage, a significant increase in the percentage of shriveled fruits was observed and the VQR already went down to 7 (minor defects). At 60 days, percent weight loss was significantly higher than the preceding storage periods but percent shriveled fruits did not increase significantly and hence, VQR was still 7.

At 67 days, 25.73% of the fruits were rotten. This increased abruptly to about 75% at 75 days and then to 91.03% at 82 days. A week later, almost all the fruits were rotten. In terms of weight loss, this registered 31.01% at 60 days increasing significantly to 78.67% at 75 days and then to more than 94% two weeks later. VQR also went down to 5 (fair, defects moderate) at 67 days, then 3 (poor, defects serious, limit of salability) at 72 days and ultimately 1 (non-edible) at 82 days.

Cost and return analysis

The price of tomatoes during the peak season was PhP5 kg^{-1}, on the average. The farmers stored 1000kg of their harvest from 15-90 days following the recommended RS storage technology (Table 4). As expected, the percentage recovery at different periods was decreasing. Assuming that the average market price per kilogram of tomato was constant for the first three weeks the fruits were stored, the highest return above variable cost (RAVC) was attained at 15 days of storage. This period also had the highest percent recovery. As the market price increased, the tomatoes stored for 60 days and sold gave the highest RAVC. Despite the decreasing recovery rate, the fruits were still of better quality hence, sold at a higher price compared to the previous periods.

Table 3. Rotten fruits, marketable fruits, weight loss, fruit recovery and visual quality rating of tomato fruits stored in paper box with rice straw at different length of storage

STORAGE LENGTH (day)	ROTTEN FRUITS (%)	MARKETABLE FRUITS (%)		WEIGHT LOSS (%)	RECOVERY (%)	VISUAL QUALITY RATING
		Good Quality	Shriveled			
	**	**	**	**	-	-
15	0.00d	100.00a	0c	2.33d	97.67	9
30	0.00d	100.00a	0c	5.83d	94.17	8,9
45	1.67d	92.34a	5.99b	13.00d	87.00	7
60	6.80d	85.50a	7.71b	31.33c	68.67	7
67	25.73c	58.98b	15.29a	40.33c	59.67	5
75	74.34b	17.34cd	8.32b	78.67b	21.33	3
82	91.03a	0.00d	8.97b	94.17a	5.83	1
90	98.77a	0.00d	1.23c	98.90a	1.10	1
CV (%)	12.10	7.70	57.10	12.20	-	-

** - significant at 1% level
ns - not significant
In a column, means marked with the same letter are not significantly different using LSD test at 1% level

Visual Quality Rating:
9,8 - excellent, field fresh
7,6 - defects minor
5,4 - fair, defects moderate
3 - poor, defects serious, limit of salability
2 - limit of edibility
1 - non-edible

Table 4. Cost and return analysis of tomato (1 ton) stored in paper box with RS at different number of days

ITEM	LENGTH OF STORAGE (days)							
	15	30	45	60	67	75	82	90
Cost of 1.0 ton tomato fruits @PhP5 kg^{-1}	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Packaging material, paper box	300	300	300	300	300	300	300	300
Rice straw (cost of hauling)	200	200	200	200	200	200	200	200
Labor	400	400	400	400	400	400	400	400
Sub-total	5,900	5,900	5,900	5,900	5,900	5,900	5,900	5,900
% Recovery	97.7	94.2	86.8	80.3	59.7	21.3	5.8	1.1
Weight of tomato fruits left (kg)	977	942	868	803	597	213	58	11
Actual market price	12	12	12	15	20	25	25	25
Gross Income (PhP)	11,724	11,304	10,416	12,045	11,940	5,325	1,450	275
RAVC (PhP)	5,824	5,404	4,516	6,145	6,040	-575	-4,450	-5,625
Increase of price by 50%	18	18	18	22.5	30	37.5	37.5	37.5
RAVC (PhP)	11,686	16,956	9,724	12,167	12,010	2,087	-3,725	-5488
Decrease of price by 50%	6	6	6	7.5	10	12.5	12.5	12.5
RAVC (PhP)	-38	-248	-692	122	70	-3238	-5175	-5762

Note: Average market price from 15-45 days is PhP12 kg^{-1} with the assumption that harvest is still at its peak.

Storing the product up to 60 days allowed the farmer to wait for a higher price and earned more income. In fact, a positive RAVC was still attained up to 67 days. This scenario was observed assuming a 50% increase in the price per kilogram due to the decreasing supply of tomatoes in the market over time.

Storing the product up to 60 days allowed the farmer to wait for a higher price and earned more income. In fact, a positive RAVC was still attained up to 67 days. This scenario was observed assuming a 50% increase in the price per kilogram due to the decreasing supply of tomatoes in the market over time.

CONCLUSIONS

Rice straw was the best medium identified in storing tomato using a paper box with a capacity of 10 kg. With better aeration, cushion, and absorption of moisture, rotting of the tomatoes was limited.

Sack can also be used as long as it is hanged or laid horizontally with good ventilation.

Tomatoes stored in a paper box with RS until 67 days was profitable. Longer storage resulted to negative returns.

Overall, tomatoes stored using the technology kept better quality of the fruits, sold timely at a higher price and gave higher returns for the farmers.

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