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Technical and Economical Evaluation of Traditional vs. Advanced Handling of Tomatoes in Jordan

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Abstract: Tomato (*Solanum lycopersicom* L.) fruit cv. "508" grown in plastic houses were obtained from two farms located in the Uplands and Jordan Valley. Fruits were harvested at the pink to light-red stages of development. Fruit samples were either kept as packed by the farmer (Group 1-traditional handling) or handled by the working team (Group 2-advanced handling). Harvesting was repeated three times with a week interval between harvests. Two main treatments were applied to the fruit samples: either held at 22°C continuously or at 12°C for 10 days and then removed to 22°C to the end of the experiment. Soluble Solid Content (SSC), firmness, water loss, decay and defects and shelf life were evaluated at 0, 10 and 20 days. Crop enterprise budgets are used in economic analysis to estimate the profitability of agricultural products High temperature inflicted serious deteriorative consequence evident by accelerating the rate of loss of firmness (softening), increasing weight loss and decay incidence, aggravating defects and reducing the shelf life of the fruits held at 22°C. Similarly, improper and rough handling (traditional handling) exerted detrimental effects clearly pronounced in fruits from group 2. Higher economic profits are obtained from tomatoes of the advanced handling comparable to those of the traditional handling.

Key words: *Solanum lycopersicom* L., firmness, weight loss, shelf life, handling

INTRODUCTION

Tomatoes, in open field and greenhouses, are produced for local and export markets year around in Jordan. Traditionally, tomatoes are harvested at the pink (for export) to red (for local market) stage of development.

The ripening of tomatoes is characterized by the softening of the fruit, the degradation of chlorophylls and an increase in the respiration rate, ethylene production, as well as the synthesis of acids, sugars and lycopene (Cano *et al*., 2003). The rate of fruit ripening is accelerated by high temperature, evident by increasing the rate of respiration which reflects the tissue metabolism. Firmness often dictates early harvest in order to avoid damage that might limit the postharvest life of the fruit.

Proper postharvest handling such as washing, sorting, packing and cooling, in addition to careful and gentle handling of the fruits will contribute considerably to quality maintenance and prolong the shelf life of the fruit.

Field heat removal within a short period of time after harvest reduces the respiration rate, degradation by enzymes, internal water loss and wilting, slows or inhibits the growth of decay-causing micro-organisms and reduces the sensitivity and production of the natural ripening agent ethylene (Boyette *et al*., 1998).

Jordan is in an urgent need for innovation and improvement of postharvest practices since washing, sorting, cooling, cold storage and careful handling is seldom practices by producers in Jordan. Hence, applied research in this area will greatly benefit farmers, not only in Jordan, but also in many other developing countries.

This study was undertaken to evaluate the effect of advance handling vs. traditional handling on tomatoes and estimate the consequential economic impact. Fruit quality parameters i.e., soluble solids content, firmness, weight loss, decay and defects and shelf life were evaluated.

MATERIALS AND METHODS

Plant materials: For two consecutive seasons, tomato (*Solanum lycopersicom* L.) fruit cv. "508" grown in plastic houses in two farms located in the Uplands (Jerash) and Jordan Valley were obtained in the year 2005 to conduct this study. Samples of tomato fruits at the pink to light-red stages of development (USDA, 1991) were obtained from each farm. For each harvest, fruits were either kept as

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packed by the farmers into shipping styrophoam containers (Group 1-Traditional handling), or washed with chlorinated water, air dried at ambient temperature and sorted to eliminate unwanted fruits (soft, decayed, defected, discolored etc.) or materials concurrently with place packing by the working team (Group 2-Advance handling). Tomato boxes, from each group, were divided into two main treatments: held continuously at 22±2°C for the duration of the experiment; or held at 12°C for 10 days, removed and then held at 22±2°C for shelf life evaluation. Sampling was repeated 3 times (harvests-designated as: 1st Harvest (1st H) to the 3rd Harvest (3rd H), with a week interval between harvests. The total number of boxes (10 kg each) was 96 boxes (16 boxes*2 farms*3 harvests). Collected fruit samples were transported on the same day to the storage rooms at the Fresh Fruit Company in Juwaideh, Amman, where testing of the studied parameters were performed.

Measurements: Color was evaluated according to USDA (1991): Pink 30 to 60% of the surface is not green (in the aggregate shows pink or red color) and Light red 60 to 90% of the surface is not green (in the aggregate shows pinkish-red or red).

Measurements were taken at 0 (first day), 10 days storage at 12 and 22°C and 20 days (10 days storage + holding the samples at 22°C for an additional 10 days). Fruit soluble solid contents were determined using a Refractometer (Abbe-Refractometer Nr. 301, Japan, BRMER LABORHANDEL GMBH), reading SSC in °Brix and converting to percent. Tomato fruit firmness was measured by using Fruit Pressure Tester (EFFEGI-480011 ALFONSINE, Italy). Fresh weight was taken directly using a balance (Model "NCI-30" Kemerlti Cad. 69. Karakoy. Istanbul). Decay was evaluated visually by identifying diseases according to Snowdon (1991) and the percentages of diseased and defected fruits were calculated from the total. Shelf life determination was based on the parameters tested above to the point where the tomatoes no longer could be marketable. Excessive softening, shriveling, microbial infection and defects determined the termination of shelf life.

Economical analysis: Crop enterprise budgets are used in economic analysis to estimate the profitability of agricultural products. In this research a crop enterprise budget for tomato produced in plastic houses was constructed using collected data from farmers specialized in this type of production. The budget shows the total revenue from selling the produce at the local market evaluated at the farm gate price. It shows also the different types of costs involved in the production process. The costs are classified into variable and fixed costs. The variable costs are those cost items that vary with the variation of the production level while the fixed costs do not change with the variation in production. The crop budget shows the costs of the different items involved in the production process for a unit of one hectare during the production season of 2005/2006.

Different economic indicators are used in this study including: (1) gross margins per hectare, (2) net returns and (3) benefit cost ratio. Gross margin per is estimated by deducting the total variable costs from the total revenues. The net returns represent the net profit per hectare that is estimated by deducting the total costs from total revenues. The benefit cost ratio is obtained by dividing the total revenues by the total costs per one dunum of tomato.

The three economic indicators were used in this study to evaluate in economic terms the impact of shifting from traditional handling to advanced handling. The analysis is based on the impact of treatment in terms of chlorination and sorting of produce on the farm-gate price of sold tomato under traditional postharvest handling (no treatment) and under the advanced postharvest handling (with the treatment).

Statistical analysis: Data obtained from each of the studied parameters were analyzed separately using Analyses of Variance (ANOVA) by the Statistical Analysis Systems computer package (SAS Institute, 2003) with main effects and interaction evaluated at p=0.05. Treatment means were separated by Least Significant Difference methods at the 0.05 level.

RESULTS

Technical results

Soluble Solids Content (SSC): An increase in the SSC percentages with time progression in storage in all treatments was observed, with significant differences among the values (Table 1). Temperature had no direct effect on SSC since no significant differences as a function of temperature among the SSC values were detected. However, a closer look at the initial values recorded at 0 day and comparing them with those obtained at 10 and 20 day, will reveal a sharp increase in SSC due to indirect effect of temperature, even though no significant differences were detected (Table 1). For example: an increase of 0.3% was noticed in tomatoes after 10 days of storage at 12°C in group 1 from the 1st harvest, while the increase for the same treatment at 22°C was 0.57%. Similar pattern was followed in almost all treatments as a function of temperature. No significant differences were observed among the SSC values of neither both group 1 and 2, nor harvests (Table 1).

Table 1: Soluble solid content tested at 0, 10 and 20 days of tomatoes of group 1 (traditional handling) and group 2 (advance handling) held at 22°C continuously; or at 12°C for 10 days and then removed to 22°C for an additional holding of 10 days

		SSC (%)			
		Treatments			
		Group 1		Group 2	
Harvest	Days	12°C	22°C	12°C	22°C
1st	0	4.13[1]ij[2]	3.96j	4.20ij	4.10ij
	10	4.43[1]hij	4.53hi	4.46hi	4.73gh
	20	5.57[3]bcd	5.63bcd	5.56b-e	5.63bcd
2nd	0	4.30hij	4.20ij	4.30hij	4.43hij
	10	5.10efg	5.50def	5.03fg	5.20d-g
	20	6.06ab	6.20a	6.16a	6.13a
3rd	0	4.46hi	4.40hij	4.45hi	4.06ij
	10	5.53de	5.36def	5.20d-g	5.36def
	20	6.06ab	6.23a	6.03abc	6.63a

[1]: Means are the average of 24 boxes of fruit, [2]: Values followed by the same letter(s) are not significantly different at the 0.05 level by the LSD method, [3]: Means are the average of 12 boxes of fruit

Table 2: Firmness tested at 0, 10 and 20 days of tomatoes of group 1 (traditional handling) and group 2 (advance handling) held at 22°C continuously; or at 12°C for 10 days and then removed to 22°C for an additional holding of 10 days

		Firmness (kg-force)			
		Treatments			
		Group 1		Group 2	
Harvest	Days	12°C	22°C	12°C	22°C
1st	0	3.80[1]bc[2]	3.80bc	3.76bcd	3.93ab
	10	3.26[1]ef	2.90fg	3.26ef	2.83gh
	20	2.60[3]g-j	2.33ijk	2.90fg	2.13k
2nd	0	4.23a	3.90ab	3.76bcd	3.86abc
	10	3.36e	2.83gh	3.33e	2.63g-j
	20	2.70ghi	2.26jk	2.83gh	2.10k
3rd	0	3.96ab	3.93ab	3.96ab	3.90ab
	10	2.93fg	2.70hij	3.50cde	3.40de
	20	2.63g-j	2.13k	2.80gh	2.46h-k

[1]: Means are the average of 24 boxes of fruit, [2]: Values followed by the same letter(s) are not significantly different at the 0.05 level by the LSD method, [3]: Means are the average of 12 boxes of fruit

Firmness: Temperature exerted a very well pronounce effect on firmness of tomato fruits, manifested by the acceleration of softening (loss of firmness) at the 22°C storage temperature. Even though, slight variation existed among the initial values of firmness, however, storage of fruits at 12°C for 10 days, to a greater extent preserved fruit firmness better than storage at 22°C (Table 2). Firmness declined sharply in tomatoes of group 1 as compared to those from group 2, with significant differences (Table 2). No significant difference among the firmness values of the three harvests.

Weight loss: Weight loss increased at 22°C as compared to that recorded at 12°C after 10 days storage in both groups, with significant differences (Table 3). However, weight loss was reduced in group 2 as compared to that in group 1. Weight loss in fruits removed from 12°C and placed at 22°C lost less weight as compared to those held continuously at 22°C when tested after 20 days storage. No significant difference among the weight loss values of the three harvests.

Table 3: Fresh weight loss tested at 0, 10 and 20 days of group 1 (traditional handling) and group 2 (advance handling) tomatoes held at 22°C continuously; or at 12°C for 10 days and then removed to 22°C for an additional holding of 10 days

		Weight loss (%)			
		Treatments			
		Group 1		Group 2	
Harvest	Days	12°C	22°C	12°C	22°C
1st	0	0.00[1]g[2]	0.00g	0.00g	0.00g
	10	1.06[1]f	4.60c	0.80f	3.70d
	20	3.10[3]e	5.86ab	2.96e	5.60b
2nd	0	0.00g	0.00g	0.00g	0.00g
	10	1.06f	4.43c	0.84f	3.93d
	20	3.00e	6.06a	2.93c	5.70ab
3rd	0	0.00g	0.00g	0.00g	0.00g
	10	1.16f	4.60c	1.16f	3.86d
	20	2.70e	6.13a	2.76e	5.93ab

[1]: Means are the average of 24 boxes of fruit, [2]: Values followed by the same letter(s) are not significantly different at the 0.05 level by the LSD method, [3]: Means are the average of 12 boxes of fruit

Table 4: Decay and defects tested at 0, 10 and 20 days of group 1 (traditional handling) and group 2 (advance handling) tomatoes held at 22°C continuously; or at 12°C for 10 days and then removed to 22°C for an additional holding of 10 days

		Decay (%)			
		Treatments			
		Group 1		Group 2	
Harvest	Days	12°C	22°C	12°C	22°C
1st	0	0.60[1]mn[2]	0.45no	0.00o	0.00o
	10	1.30[1]kl	3.66def	0.20no	1.86jk
	20	2.13[3]hij	8.50b	0.60mn	4.23cde
2nd	0	0.00o	0.55no	0.00o	0.00o
	10	1.60kjl	3.20g	0.40no	2.00ij
	20	2.56hi	8.10b	1.13lm	4.53cd
3rd	0	0.23no	0.48no	0.00o	0.00o
	10	1.73jk	3.96def	0.53no	2.63h
	20	3.40fg	9.83a	1.70jkl	4.76c

[1]: Means are the average of 24 boxes of fruit, [2]: Values followed by the same letter(s) are not significantly different at the 0.05 level by the LSD method, [3]: Means are the average of 12 boxes of fruit

Decay and defects: The initial values of decay incidence and defects revealed their presence in group 1 tested at day 0, with significant differences (Table 4). High temperature increased decay and defects in fruits held continuously at 22°C as compared to those at 12°C after removal from storage, with significant differences (Table 4). Decay and defects were less pronounced in fruits at 12°C from group 2 as compared to those from group 1 (Table 4).

Shelf life: An average of 7 and 10 days increase in shelf life of fruits held at 12°C and removed to 22°C and those held at 22°C continuously from group 1 and 2, respectively (Table 5). Furthermore, fruits stored at 12°C and removed to 22°C from group 2 had an average of 4.6 days longer than those from the same treatment in group 1 (Table 5). Likewise, fruits stored continuously at 22°C from group 2 had an average of 1.7 days longer than those from group 1 (Table 5). Significant differences were detected in all treatments and between group 1 and 2 (Table 5). Significant differences also exist among the shelf life values of the three harvests.

Table 5: Shelf life at the end of the experiment of group 1 (traditional handling) and group 2 (advance handling) tomatoes held at 22°C continuously; or at 12°C for 10 days and then removed to 22°C for an additional holding of 10 days

	Shelf life (days)		
Treatments	1st harvest	1st harvest	1st harvest
Group 1			
12°C	32.0[1]c[2]	30.0d	29.0d
22°C	25.0f	23.0g	22.0g
Group 2			
12°C	35.0b	37.0a	33.0c
22°C	27.0e	25.0f	23.0g

[1]: Means are the average of 12 boxes of fruit, [2]: Values followed by the same letter(s) are not significantly different at the 0.05 level by the LSD method

Economical results: As indicated above, the results show that there is a significant difference in the quality of marketed tomatoes under traditional and advanced postharvest handling. This difference quality was reflected in terms of average farm gate price of tomato sold. On average, the farm-gate price per one box of 10 kg of tomato treated in the traditional postharvest handling was sold at 1.5 Jordanian Dinar (i.e., 0.15 JOD kg^{-1}) while the farm gate price of the same box of tomato treated in the proposed advanced postharvest handling in this study was sold at 2.0 JOD (i.e., 0.20 JOD kg^{-1}). The two prices were used in the crop budget included in Table 6 to show the impacts of the different treatments in economic terms. Table 6 shows that the highest economic profits are obtained from tomatoes sorted and treated with

Table 6: Economic implications of shifting from traditional postharvest handling to advanced postharvest handling of tomatoes produced under plastic houses

	Traditional handling budget			Advanced handling budget		
Item	Unit	Price JD Unit	Total JD	Unit	Price JD Unit	Total JD
Crop produce (output) (kg)	15000.0	0.15	2250.00	15000.0	0.2	3000.00
By-products (if any) (kg)			0.00			0.00
Total gross output (JD)			2250.00			3000.00
Water requirements (m^3)	537.0	0.0	5.90	537.0	0.0	5.90
Seed/seedling (kg)	0.0	2850.0	14.30	0.0	2850.0	14.30
Seed transplanting (Du)	1.0	8.0	8.00	1.0	8.0	8.00
Manure-fertilizer (m^3)	6.0	8.0	48.00	6.0	8.0	48.00
Total chemical fertilizer (kg)			81.90			81.90
N (kg)	33.5	0.4	14.70	33.5	0.4	14.70
P_2O_5 (kg)	69.0	0.8	53.10	69.0	0.8	53.10
K_2O (kg)	20.0	0.7	14.00	20.0	0.7	14.00
Micro elements (kg)			0.00			0.00
Pesticides (Du)	1.0	250.0	250.00	1.0	250.0	250.00
Mulch (kg)	17.0	1.2	20.40	17.0	1.2	20.40
Costs of machinery (JD)			7.50			7.50
Land preparation (h)	1.0	3.5	3.50	1.0	3.5	3.50
Sowing/planting (h)			0.00			0.00
Husbandry (h)	1.0	4.0	4.00	1.0	4.0	4.00
Labor requirements (JD)	670.0		335.00	680.0		341.50
For land preparation (man h^{-1})	140.0	0.5	70.00	140.0	0.5	70.00
Sowing/planting (man h^{-1})	20.0	0.5	10.00	20.0	0.5	10.00
Husbandry (man h^{-1})	190.0	0.5	95.00	190.0	0.5	95.00
Harvesting and postharvest handling (man h^{-1})	320.0	0.5	160.00	330.0	0.5	165.00
Postharvest handling materials (Chlorine) (L)	1.0	0.0	0.00	1.0	1.5	1.50
Total variable costs (JD)			770.90			777.40
Gross margin (gross output-v.costs) (JD)			1479.00			2222.60
Fixed costs			609.00			609.00
Land rent (Du)	1.0	69.0	69.00	1.0	69.0	69.00
Depreciation (plastic, frame and drip) (Du)	1.0	540.0	540.00	1.0	540.0	540.00
Interest on working capital (JD)	0.1	1379.9	82.80	0.1	1386.4	83.20
Total fixed costs (JD)			691.80			692.20
Total cost (JD)			1462.70			1469.60
Net returns (JD)			787.30			1530.40
Benefit Cost Ratio (BCR) (ratio)			1.54			2.04

chlorination while profits are much lower from untreated tomatoes and handled by the traditional way of postharvest handling. The total net returns (profits) per dunum amounted to 787 Jordanian Dinar for each dunum cultivated with tomato under plastic housed and handled by the traditional way. While the net profits amounted to JOD 1,540 per dunum of tomatoes also produced under plastic housed but sorted and treated with chlorination. This implies that the proposed treatment has almost doubled the farmer's net profit.

The benefit-cost ratio has also increased from 1.54 to 2.04. This implies that shifting from traditional to advanced handling of tomato is economically effective and profitable.

It should be stated here that the actual economic benefits should be even higher than those estimated in this study. The researchers quantified only those benefits attributed to sorting and chlorination treatment, however if the other benefits from reducing decay and increasing the shelf life of the produce are added, the economic indicators would improve tremendously.

DISCUSSION

The increase in the Soluble Solids Content (SSC) percentages is a normal event in tomato fruit, which is a typical climacteric fruit that will continue the ripening process if harvested at the mature stage. The rate of ripening process depends mainly on the temperature, in addition to other factors, due to its profound affect on the rates of biological reactions (Saltveit, 2002). Hence, the steady increase in the SSC with time in storage in all treatments. Firmness, as an important quality attribute, determining the postharvest quality of fruits and vegetables (Gross *et al*., 2002), was declined by high temperature. Firmness is affected as such because it is an event associated with fruit ripening, which is the most important postharvest process responsible for softening (Wakabayashi, 2000). Proper sorting, selection and careful handling also played a role in the reduction of the rate of softening evident by the results from group 2. Proper and careful handling eliminate or reduce the number of fruits that most likely become softer at later stages.

Weight loss, which is mostly water loss (Wilkinson, 1965), increased substantially at high temperature. Water loss from the fruit is determined by the water gradient between the internal fruit space and the surrounding air (Maguire *et al*., 2001). Therefore, at higher temperature water loss will increase and consequently weight loss. It is of importance, in addition to temperature management, to carry out a careful handling, sorting and selection to eliminate defected and soft fruits that are more likely become subject to shriveling. Hence, the reduced weight loss in group 2. Tomatoes are susceptible to numerous fruit decays, from the field through postharvest handling. Postharvest decays normally develop in wounded, bruised and soft fruits (Sargent *et al*., 2002). Thus, proper handling (washing, sorting, selection etc.) resulted in less decayed and defected fruits in group 2. Whereas, improper and rough handling in group 1 was evident by the high percentages of decayed and defected fruits that were included in the boxes. This is in agreement with findings of El Assi (2004) at the farm level, who reported that grading, sorting and eliminating of the undesirable fruits were inadequate, in addition to the rough handling by the workers that inflicted most damage. The inflicted damage or bruises are not always immediately visible but they become noticeable during subsequent handling and shelf-life (Van Linden *et al*., 2006). Higher temperature will enhance the growth of most decay organisms and aggravating the existing defects and wounds, hence, the higher percentages of decay and defects noticed at high temperature. This is in agreement with Mohsenin (1986), suggesting that the bruise susceptibility of the commodity depends on a number of elements such as variety, texture, maturity, water status, firmness, temperature, size and shape. Moreover, It is known that vegetable quality is most often reduced by two factors: mechanical injury and poor temperature management (Florida Greenhouse Vegetable Production Handbook, 2001). Based on the above parameters, the shelf life was reduced considerably by holding at high temperature. In general, there is an inverse relationship between respiration rates and postharvest-life of fresh commodities (Saltveit, 2002). High temperature will increase the rate of respiration i.e., ripening, resulting in rapid deterioration of the tissues and reducing the shelf life of the fruit. In conclusion, optimum storage temperature, proper handling (advanced handling) proved to be highly beneficial in preserving and maintaining the quality and prolonging the shelf life of tomato fruit. Reduced rate of softening, weight loss and decay and defects occurrence were the advantages obtained by such practices.

In conclusion, lower temperature, sorting, chlorinatio and careful handling were more effective in preserving the quality, reduced postharvest losses and prolonging the shelf life of tomato fruits that might result from softening, shriveling, defects and decay. Additionally, more economic profits were gained by such practices comparable to traditional practices.

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