Effect of tomato post-harvest fungicide treatment and storage conditions on the quality of fruits, and biological value of tomato pulp and concentrated pulp*

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Abstract

The influence of storage conditions on the quality of tomato fruits was tested. The rate of ripening was established in normal air, where tomatoes ripen quickly, under controlled atmosphere, where they ripen more slowly and under low pressure, where they ripen slowest. The influence of post-harvest benomyl or methylthiophanate treatment on tomato rot, ripening, and biological value were examined. Post-harvest tomato treatment did not reduce fruit rot. The color of fruits and the processed products depended on the fungicide treatment. Concentrated tomato pulp made of fruits treated with methylthiophanate was redder than the others. The fungicide treatment increased or decreased the level of some chemical substances in the fruits in dependence on the applied fungicide, storage conditions and the length of storage, e.g. tomatoes treated with benomyl and stored for 14 days contained the highest level of vitamin C under 0% CO₂:3% O₂, and tomatoes treated with methylthiophanate contained the highest level of vitamin C under 38 mm Hg. Degradation of vitamin C in pulp was faster than in the concentrated pulp. Tomato pulp made of tomatoes treated with methylthiophanate contained the lowest level of vitamin C.

INTRODUCTION

The biological value is a very important factor for establishing the quality of fruits and processed products.

Prolongation of storage life of tomatoes is in many cases necessary, particularly before processing. Tomatoes mature green when picked, must be stored, and during the storage period the chemical contents and colour of fruits change (Gould, 1974; Freeman and Woodbridge 1960; Hall, 1961).

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The storage conditions influence the speed of colour change and physiological changes in fruits. The temperature recommended for tomato storage is between 13-15°C; at lower temperature tomatoes do not ripen (Agr. Handbook, 1973); carbon dioxide concentration in the air ought not to be higher than 5% (Hall, 1961; Kader and Morris, 1974; Parsons et al., 1970; Pantastico, 1975). In search for a method of minimizing post-harvest disorders, chemical treatments, and various storage conditions were used. A new concept for preservation of fruits, vegetables and cut flowers is to store them under low pressure (hypobaric) conditions. This method is widely considered for prolongation of life of horticulture crops (Bubb, 1975; Kader and Morris, 1974; Loughheed et al., 1978; Sharpless and Langridge, 1973; Wu et al., 1972). Post-harvest treatment with chemicals is the easiest method used for controlling fungal diseases. The presence of fungicide residues in the treated tomatoes and other fruits is well known (Ben Arie, 1975; Channon and Thompson, 1973; Lockhart and Forsyth, 1964), but none of them has examined the influence of the biological activity of these residues on the biological value of the treated tomatoes stored under various conditions; therefore this is the aim of our work.

MATERIALS AND METHODS

Two cultivars of tomatoes were tested viz. 'Pangham Cross', a glasshouse growing cultivar, and 'Szkarłatna Kula', outdoors cultivar mostly used for processing. Experiments were conducted during two years, 1976 and 1977. Both cultivars before storage and processing were treated with benomyl 0.1% a.i. and methylthiophanate 0.1% a.i. Untreated fruits were also examined.

'Pangham Cross' tomatoes picked in the green stage of maturity, were kept under low pressure storage (LPS) 38 mm Hg, 76 mm Hg, 190 mm Hg and under controlled atmosphere (CA) 5% CO₂:3% O₂, 0% CO₂:3% O₂ and in normal air. Tomatoes were stored for 4, 7, 14, 20 and 34 days. Sample of stored tomatoes consisted of 10 fruits was one replication, three replications were used. After storage the colour of tomatoes was established as green, yellow-orange and red. The number of fruits of each colour was counted after 20 and 34 days of storage. Similarly the healthy fruits were counted. After treatment 'Szkarłatna Kula' was processed, pulp and concentrated pulp were prepared. The products were placed in glass "twist off" jars and stored for 30 and 90 days at 18°C.

The biological value of fruits and their processed products was analysed on 100-g sample. Three replications of analyses were done.

Dry weight was determined with a refractometer, vitamin C — by means of Tilliams method, and the results are presented in mg%; acidity was analysed with a potentiometer and the results were calculated as mg% of citric acid; the level of

total sugars was established by the Luffa Schoorla method. The ratio of sugars to acids was calculated. The method of column chromatography was used to determine the contents of carotene and lycopene presented in mg%. Total, chlorophyll *a* and chlorophyll *b* were analysed by the Vernon method. The colour of processed products and fruits before processing were established by the Hunter apparatus. The biological value of tomato pulp and concentrated pulp was similarly analysed.

All results were statistically analysed and mean values by Student's *t*-test were compared.

RESULTS AND DISCUSSION

Tomatoes in green stage of maturity are commercially stored. The speed of tomato ripening is a very important factor of storage, because slow ripening fruits can be stored longer. Controlled atmosphere and low pressure storage delayed the speed of tomato ripening in comparison with normal air. It is known that the level of carotene increases during ripening of tomatoes. The fruits change their colour from green to yellow because of the appearance of carotenoid pigments (Pantastico, 1975). The colour and colour changes of fruits mark both the stage and rate of maturation. It was observed that the colour of tomatoes stored under low pressure conditions changes very slowly. After 34 days of storage most fruits were yellow-orange and those stored under 5%CO₂:3%O₂ were yellow-orange after 20 days of storage. Tomatoes stored in normal air were fully red after 20 days of storage (Fig. 1).

Storage conditions influenced not only the physiological life of stored fruits, but also the development of pathogenic fungi. The number of healthy fruits proves the effect of fungicide treatment and storage conditions. Untreated fruits stored under low pressure 38 or 76 mm Hg were healthy after 14 days of storage. Fungicide treatment decreased the number of healthy fruits (Table 1). Tomatoes stored under these conditions for 20 days were healthy too, similarly as those stored in normal air, but tomatoes stored in normal air were fully ripened (Fig. 1), whereas those stored under low pressure conditions behaved in an opposite way. Tomatoes cv. 'Pangham Cross' stored for 34 days rotted in a high percent, in the best case 50 or 60 percent of fruits were healthy (Table 2).

The biological value of fruits is the next very important factor for establishing the quality of fruits; particularly the level of vitamin C or carotene and lycopene. The biological value of fruits depended on such factors as the size of fruits, cultivar, fertilization applied during the growth of plants, method of growing and many others (Gould, 1974). The influence of fungicide treatment has not been tested yet under various conditions. The biological value of stored tomatoes cv. 'Pangham Cross' was examined after 4, 7 and 14 days of storage in normal air at 15°C. We established that fungicide treatment either decreased or increased the

Fig. 1. Stage of tomato maturity under various conditions at 15°C depending on the treatment
1 — benomyl; 2 — untreated; 3 — methylthiophanate 0.1% a.i.

Table 1

Percent of healthy tomatoes cv. 'Pangham Cross' depending on fungicide treatment and storage conditions in 1976

Storage conditions	Treatments and days of storage					
	untreated		benomyl 0.1% a.i.		methylthiophanate 0.1% a.i.	
	7	14	7	14	7	14
Pressure 38 mm Hg	100 f	100 f	97.5 ef	82.5 cd	100 f	67.5 b
Pressure 76 mm Hg	100 f	100 f	100 f	95.0 ef	95.0 ef	95.0 ef
0% CO ₂ : 3% O ₂	85.0 d	80.0 cd	92.5 e	82.5 cd	100 f	55.0 a
5% CO ₂ : 3% O ₂	95.0 ef	72.5 bc	90.0 de	92.5 e	85.0 d	77.5 c
Normal	100 f	92.5 e	92.5 e	95.0 ef	87.5 de	95.0 ef

L = 0.05

Table 2

Percent of healthy tomatoes cv. 'Pangham Cross' depending on the fungicide treatment and storage conditions in 1977

Storage conditions	Treatments and days of storage					
	untreated		benomyl 0.1% a.i.		methylthiophanate 0.1% a.i.	
	20	34	20	34	20	34
Pressure 38 mm Hg	100 g	20.0 b	93.3 f	60.0 cd	93.3 f	43.3 c
Pressure 76 mm Hg	100 g	56.7 cd	93.3 f	63.3 d	96.7 fg	46.7 cd
Pressure 190 mm Hg	63.3 d	0 a	93.3 f	0 a	83.3 e	0 a
5% CO ₂ : 3% O ₂	90.0 ef	50.0 cd	83.3 e	33.3 bc	73.3 de	50.0 cd
Normal	100 g	60.0 cd	100 g	53.3 cd	100 g	43.3 c

L = 0.05

contents of some chemical substances, but this depended on the storage length. Untreated fruits showed both higher acidity and percent of dry weight until the 14 th days of storage; less total sugars, carotene and lycopene were found after 14 days of storage (Table 3). The biological value of 'Pangham Cross' tomatoes was also examined after 14 days of storage under various conditions. The level of vitamin C and lycopene was the lowest under 5%CO₂:3%O₂; acidity under 76 mm Hg, pH — under 0%CO₂:3%O₂, carotene under 38 mm Hg (Table 4). The level of vitamin C increased during storage of tomatoes.

Table 3

Biological value of tomato cv. 'Pangham Cross' treated with fungicides stored in normal air at 15°C in 1976

Treatment	% of dry weight	Vit. C mg %	Acidity % of citric acid	pH	Sugar total %	Ratio sugar: acids	Carotene mg %	Lycopene mg %
Mature-green								
Untreated	5.3 b	3.92 b	0.57 c	4.60 a	3.63 c	6.4 a	0.095 a	0.04 a
Benomyl 0.1% a.i.	5.2 a	4.90 c	0.49 a	4.65 b	3.36 a	7.4 b	0.110 b	0.05 ab
Methylthiophanate 0.1% a.i.	5.2 a	2.52 a	0.55 b	4.65 b	3.48 b	6.3 a	0.108 b	0.07 b
Mature-yellow-pink after 4 days of storage								
Untreated	6.0 c	1.96 b	0.60 b	4.52 a	3.01 b	5.05 a	0.19 b	0.04 b
Benomyl 0.1% a.i.	5.8 b	1.96 b	0.52 a	4.61 b	3.04 b	5.75 b	0.04 a	0.04 b
Methylthiophanate 0.1% a.i.	5.6 a	2.94 a	0.52 a	4.60 b	2.79 a	5.30 a	0.02 a	0 a
Mature-pink after 7 days of storage								
Untreated	6.0 c	2.45 a	0.59 a	4.61 a	2.80 c	4.75 b	0.09 a	1.02 a
Benomyl 0.1% a.i.	5.8 b	2.49 b	0.59 a	4.65 b	2.59 a	4.43 a	0.09 a	1.38 b
Methylthiophanate 0.1% a.i.	5.6 a	2.45 a	0.59 a	4.65 b	2.60 b	4.43 a	0.13 b	1.93 c
Mature-red after 14 days of storage								
Untreated	5.4 b	4.41 b	0.53 a	4.56 a	2.75 a	5.17 a	0.25 a	12.75 a
Benomyl 0.1% a.i.	5.6 c	4.41 b	0.52 a	4.60 b	3.01 b	5.95 b	0.28 b	12.80 a
Methylthiophanate 0.1% a.i.	5.2 a	4.19 a	0.53 a	4.60 b	2.78 a	5.22 a	0.25 a	14.27 b

L = 0.05

Table 4

Biological value of tomato cv. 'Pangham Cross' stored for 14 days under various conditions at 15°C

Treatment	Storage conditions	% of dry weight	Vit. C mg %	Acidity % of citric acid	pH	Sugar total %	Carotene mg %	Lycopene mg %
Untreated	76 mm Hg	4.0 a	7.19 b	0.36 a	4.78 b	2.22 b	0.31 c	4.17 c
	38 mm Hg	4.0 a	7.15 b	0.38 b	4.75 b	2.07 b	0.08 a	2.07 c
	0% CO ₂ :3% O ₂	4.8 b	7.24 b	0.47 c	4.60 a	2.54 c	0.19 b	4.02 c
	5% CO ₂ :3% O ₂	4.0 a	6.65 a	0.38 b	4.70 b	1.75 a	0.08 a	1.25 a
Benomyl 0.1% a.i.	76 mm Hg	4.2 a	7.27 b	0.36 a	4.71 c	2.25 c	0.26 ab	4.8 b
	38 mm Hg	4.4 b	7.15 b	0.38 a	4.71 c	2.10 a	0.07 a	1.8 a
	0% CO ₂ :3% O ₂	4.2 a	7.61 c	0.41 b	4.51 a	2.18 b	0.37 c	6.1 c
	5% CO ₂ :3% O ₂	4.4 b	6.47 a	0.42 b	4.60 b	2.13 ab	0.36 c	6.0 c
Methylthiophanate 0.1% a.i.	76 mm Hg	4.4 b	7.24 c	0.38 a	4.70 c	2.34 c	0.34 b	6.9 c
	38 mm Hg	4.6 c	7.52 d	0.42 c	4.74 d	2.11 b	0.26 a	3.7 b
	0% CO ₂ :3% O ₂	4.0 a	7.07 b	0.40 b	4.55 a	1.97 a	0.26 a	4.7 b
	5% CO ₂ :3% O ₂	4.0 a	6.39 a	0.39 b	4.63 b	2.06 ab	0.25 a	2.5 a
Before storage								
Untreated		4.6 a	4.04 a	0.47 c	4.60 a	1.84 a	0.26 a	4.4 c
Benomyl 0.1% a.i.		4.6 a	5.32 c	0.46 b	4.69 c	2.26 c	0.33 b	3.5 a
Methylthiophanate 0.1% a.i.		4.8 b	4.54 b	0.44 a	4.65 b	1.94 b	0.32 b	3.6 b

L = 0.05

Table 5
Biological value of tomatoes cv. 'Szkarłatna Kula' just before processing depending on fungicide treatment

Treatment	Dry weight %	Vit. C mg %	Acidity % of citric acid	pH	Sugar Total %	Ratio sugar: acids	Carotene mg %	Lycopene mg %
1976								
Untreated	5.2 b	12.2 b	0.44 a	4.56 a	2.72 b	6.18 b	0.31 a	14.3 b
Benomyl 0.1% a.i.	5.0 a	10.5 a	0.43 a	4.60 b	2.60 a	6.08 a	0.33 a	12.4 a
Methylthiophanate 0.1% a.i.	5.0 a	12.4 b	0.43 a	4.60 b	2.72 b	6.30 c	0.31 a	17.0 c
1977								
Untreated	4.8 a	18.2 b	0.35 a	4.00 b	2.66 b	7.62 ab	0.07 a	15.8 ab
Benomyl 0.1% a.i.	5.2 c	22.8 c	0.36 a	3.95 a	2.83 c	7.88 b	0.15 b	15.3 a
Methylthiophanate 0.1% a.i.	5.0 b	17.1 a	6.35 a	4.00 b	2.52 a	7.20 a	0.14 b	17.6 b

L = 0.05

The biological value of the fruits for processing was also examined. 'Szkarlätna Kula' is a very common outdoor cultivar mostly used for processing. The biological value of these tomatoes varied with years. This probably depended on the weather conditions during plant growth (Table 5). Processed products were stored mostly at 18°C, so their biological value was established after storage in these conditions. The pulp and concentrated pulp were examined. The pulp made of treated fruits contained a higher level of vitamin C, than that made of untreated tomatoes, but the rate of decrease of vitamin C was faster in them than in untreated fruits. The level of vitamin C in concentrated pulp decreased slower than in the pulp. The highest level of vitamin C was found in the pulp made of tomatoes treated with benomyl after 90 days of storage (Table 6).

Table 6

Degradation of vitamin C, in mg %, during storage period of pulp and concentrated pulp made of tomatoes cv. 'Szkarlätna Kula' in 1976, depending on fungicide treatment

Treatment	Directly after processing	After 30 days of storage	After 90 days of storage
Pulp			
Untreated	6.79 e	6.58 e	5.28 d
Benomyl 0.1% a.i.	7.62 g	7.25 f	3.88 c
Methylthiophanate 0.1% a.i.	7.46 g	3.26 b	1.96 a
Concentrated pulp			
Untreated	13.67 b	13.98 b	10.78 a
Benomyl 0.1% a.i.	15.81 d	15.84 d	14.21 c
Methylthiophanate 0.1% a.i.	17.71 e	15.60 d	13.03 b

L = 0.05

The colour of processed products is one of the important factors describing the quality. The colour of pulp made of tomatoes treated with benomyl contained more lightness and was more yellow than the others. The concentrated pulp made of tomatoes treated with methylthiophanate was redder than the others (Table 7).

The method for prolongation the storage life of tomatoes should not be expensive and it should minimize storage losses. It is very difficult to find such a method; everything depends on the cultivar and destination of fruit. Tomatoes for fresh fruit can be stored under more expensive conditions because of the better price for them, and during the storage period they must change colour slowly. It seems to be best to store them under 0%CO₂:3%O₂ without fungicide treatment, but the problem of the best conditions for tomato storage must be studied in the future. The situation is quite different with fruits for processing. It is necessary to store them for a short period in the cheapest conditions, that is in normal air. Post-harvest fungicide treatment is not recommended because it is ineffective.

Table 7

Colour of tomatoes cv. 'Szkarłatna Kula' and their processed products depending on the fungicide treatment and length of storage

L = lightness of colour, a = reddish, b = yellowish, a/b = hue, $a^2 + b^2$ = saturation of colour

Treatment	L	a	b	a/b	$a^2 + b^2$	L	a	b	a/b	$a^2 + b^2$
Fresh fruit before processing										
Untreated	43.0 c	24.4 b	9.5 b	2.57	26.18					
Benomyl 0.1% a.i.	41.5 b	24.2 a	9.3 a	2.60	25.90					
Methylthiophanate 0.1% a.i.	40.7 a	24.5 b	9.8 c	2.50	26.38					
pulp						concentrate pulp				
Just after processing										
Untreated	38.0 a	24.1 c	8.4 b	2.87	25.52	37.8 a	19.3 a	6.5 a	2.99	20.34
Benomyl 0.1% a.i.	39.8 b	22.8 a	8.6 b	2.67	24.35	39.2 b	20.8 b	7.8 b	2.66	22.16
Methylthiophanate 0.1% a.i.	37.8 a	23.4 b	8.1 a	2.89	24.76	39.4 c	21.6 c	8.1 c	2.67	22.65
After 30 days of storage										
Untreated	37.4 b	25.4 b	7.1 a	3.57	26.32	37.7 a	21.4 a	5.9 a	3.65	22.13
Benomyl 0.1% a.i.	38.0 c	24.2 a	7.4 b	3.27	25.28	38.0 b	21.6 b	6.3 b	3.42	22.45
Methylthiophanate 0.1% a.i.	37.1 a	25.6 c	7.1 a	3.62	26.55	38.7 c	23.1 c	7.1 c	3.25	24.16
After 90 days of storage										
Untreated	36.5 a	18.7 c	7.4 a	2.53	23.08	36.3 a	13.3 a	5.6 a	2.37	14.47
Benomyl 0.1% a.i.	37.0 a	17.3 a	7.4 a	2.34	17.76	37.7 b	15.1 b	6.8 b	2.23	16.55
Methylthiophanate 0.1% a.i.	36.4 a	17.7 b	7.2 a	2.47	19.10	37.9 c	16.3 c	7.2 c	2.26	27.77

L = 0.05

REFERENCES

- Agriculture Handbook, 1973. The commercial storage of fruits, vegetables, and florist and nursery stocks. USDA 66: 52.
- Ben Arie R., 1975. Benzimidazole penetration, distribution and persistence in post-harvest treated pears. *Phytopath.* 65: 1187-1189.
- Bubb M., 1975. Hypobaric storage. *Rep. E. Malling Res. Stat.* 1974: 81.
- Channon A. G., Thompson M. C., 1973. The effect of benomyl on the infection of tomatoes by *Fusarium oxysporum* sp. *lycopersici* and *Botrytis cinerea*. *Ann. Appl. Biol.* 75: 31-39.
- Freeman J. A., Woodbridge G. G., 1960. Effect of maturation ripening and truss position on the free amino acid content in tomato fruits. *PASHS* 78: 515.
- Gould W. A., 1974. Tomato production, processing and quality evaluation. The AVI Publishing Comp. Inc. Westport, Connecticut: 228-276.
- Hall C. B., 1961. The effect of low storage temperatures on the colour carotenoid pigments, shelf-life and firmness of ripened tomatoes. *PASHS* 78: 480-487.
- Kader A. A., Morris L. L., 1974. The effect of reduced oxygen tension attained by hypobaric conditions vs modified atmospheres on ripening behaviour of tomato fruits. *Hort. Sci.* 9: 274.
- Lockhart C. L., Forsyth F. R., 1964. Influence of fungicides on the tomato and growth of *Botrytis cinerea* Pers. *Nature*, 204: 1107-1108.
- Lougheed E. C., Murr D. P., Berard L., 1978. Low pressure storage for horticulture crops. *Hort. Sci.* 13: 21-27.
- Parsons C. S., Anderson R. E., Penney R. W., 1970. Storage of mature green tomatoes in controlled atmospheres. *J. Am. Soc. Sci.* 95: 791-794.
- Pantastico Er. B., 1975. Post-harvest physiology, handling and utilization of tropical and subtropical fruits and vegetables. Westport, Connecticut AVI: 213.
- Sharpless R. D., Langridge J. W., 1973. Reduced pressure storage. *Rep. E. Malling Res. Sta.* 1972: 108.
- Wu M. T., Jadhav S. J., Salunkhe D. K., 1972. Effects of subatmospheric pressure storage on ripening of tomato fruits. *J. Food Sci.* 37: 952-956.

Wpływ posprzętowego stosowania fungicydów i warunków przechowywania pomidorów na jakość owoców i wartość biologiczną przecierów i koncentratów

Streszczenie

Zbadano wpływ stosowania fungicydów, benomylu i metylotiofanatu, na jakość i wartość biologiczną pomidorów w zależności od warunków w jakich je przechowywano. Stwierdzono, że dojrzewanie pomidorów przebiegało najwolniej w warunkach obniżonego ciśnienia, nieco szybciej w kontrolowanej atmosferze, a najszybciej w normalnych warunkach. Posprzętne stosowanie fungicydów nie zmniejszało gnicia pomidorów w czasie krótkiego, 7 lub 14 dni trwającego, przechowywania, natomiast miało wpływ na owoce przechowywane przez dłuższy okres czasu, zwłaszcza ponad miesiąc. Stosowanie fungicydów miało wpływ na wartość biologiczną pomidorów. W wielu przypadkach stosowanie fungicydów zwiększało ilość witaminy C i karotenu. Posprzętne traktowanie pomidorów fungicydami miało wpływ na barwę przecieru i koncentratu pomidorowego. Przecier zawierał mniej witaminy C od koncentratu pomidorowego. Najmniej witaminy C było w przecierze z pomidorów opryskiwanych metylotiofanatem, po przechowywaniu przez 30 i 90 dni, a najwięcej w koncentracie pomidorowym z owoców opryskiwanych benomylem.