The effect of Temperature on the Quality of Tomato and Eggplant Fruits during Distribution

Nei, Daisuke
Laboratory of Poshtharvest Science, Division of Bioproduction System Science, Department of Bioproduction Environmental Sciences, Graduate School of Bioresoruce and Bioenvironmental Sciences, Kyushu University

Uchino, Toshitaka

Sakai, Natsumi
Laboratory of Poshtharvest Science, Division of Bioproduction System Science, Department of Bioproduction Environmental Sciences, Graduate School of Bioresoruce and Bioenvironmental Sciences, Kyushu University

Tanaka, Shun-ichiro

https://doi.org/10.5109/4638

出版情報：九州大学大学院農学研究院紀要. 50 (1), pp.213-221, 2005-02-01. Faculty of Agriculture, Kyushu University

J. Fac. Agr., Kyushu Univ., **50** (1), 213–221 (2005)

The Effect of Temperature on the Quality of Tomato and Eggplant Fruits during Distribution

Daisuke NEI[1], Toshitaka UCHINO*, Natsumi SAKAI[1] and Shun–ichiro TANAKA

Laboratory of Postharvest Science, Division of Bioproduction System Science,
Department of Bioproduction Environmental Sciences, Faculty of Agriculture,
Kyushu University, Fukuoka, 812–8581, Japan
(Received November 5, 2004 and accepted November 11, 2004)

The temperature of tomato and eggplant fruit was measured during distribution from harvest in Fukuoka to arrival at a wholesale market in Tokyo. There were three critical points to be improved where the fresh produces were possibly exposed to high temperature. First, the produce temperature remarkably rised before pre–cooling, and at this point, the temperature reached the maximum. Second, after pre–cooling, the fresh produces were again warmed during sorting and packaging in the packing house in which the temperature was not controlled. Third, the temperature increased in the packing house was remained in the truck.

Using the experimental data simulated the temperature during distribution, the effect of temperature changes on the internal quality of fresh produces was examined. The results showed that the temperature changes remarkably decreased the organic acid and sugar contents of the fresh produces while the firmness was little affected. Therefore, it is considered that the fresh produces should be consistently kept at low temperature by improving the critical points during distribution in order to preserve the internal quality of fresh produces.

INTRODUCTION

Fresh produces have the feature in which the quality decreases after harvest. Accordingly, the quality of the fresh produces is kept by the methods of low temperature storage, CA storage and MAP in order to satisfy the consumer requirement for high quality produces. In these methods, low temperature storage is the most basic, and the fresh produces except for those which are susceptible to chilling injury are desirable to be consistently kept at low temperature from harvest to consumption. Therefore, cold chain from pre–cooling at the producing district via, the cold auction room at the wholesale market and the refrigerated truck to refrigerated showcase at retailing has been developed in Japan. However, the temperature of fresh produces is difficult to be consistently kept low. For example, the time lag from harvest to pre–cooling causes a temperature rise of fresh produces, especially under the direct solar radiation, the temperature rises drastically as Inaba and Crandall (1988) reported on it to reach 50–55 °C. Moreover, the temperature rise is not able to be avoided when the truck is loaded up/down with the fresh produces, and a remarkable change in temperature was actually reported by Nakano

[1] Laboratory of Postharvest Science, Division of Bioproduction System Science, Department of Bioproduction Environmental Sciences, Graduate School of Bioresource and Bioenvironmental Sciences, Kyushu University
* Corresponding author (E–mail: toshiu@bpes.kyushu–u.ac.jp)

and Maezawa (2002). During current distribution of the fresh produces, the cool–ability of refrigerated truck may not unexpectedly lower the produces temperature because too many fresh produces, especially for the long distance transportation, are loaded onto the truck. However, there are not sufficient reports that actually measured the temperature of fresh produces during distribution nevertheless the fresh produces suffer from high temperature and temperature change (Nakano and Maezawa, 2002).

There is possibility that the temperature rises often cause a remarkable deterioration of the fresh produces. Not only temperature rises, but also temperature change itself may reduce the quality of fresh produces. Akimoto *et al.* (1997) measured the respiration rate of spinach under the constant temperature and the temperature periodically changing, and indicated the respiration rate at the latter condition was higher than that at former one. However, they measured only respiration rate, and the effect of actual temperature change during distribution, which was considered to be more irregular, on internal quality of fresh produces was not clear.

In this paper, the temperature of fresh produces was measured with elapsed time from harvest to wholesale market in order to study the practical temperature control of fresh produces during the current distribution, and the effect of the temperature change during distribution on the quality of fresh produces was examined.

MATERIALS AND METHODS

Measuring the temperature during distribution

Tomato fruits (*Lycopersicon esculentum* Mill. cv. AS73) and eggplant fruits (*Solanum melongena* L. cv. Chikuyo) were harvested in the morning on 23 June at the farm in Fukuoka Prefecture. These produces were practically handled as shown in Table 1. The temperature of tomato fruits were not controlled until pre–cooling at 7 °C by the room cooling. After pre–cooling, the tomato fruits were sorted, packaged, and loaded onto a refrigerated truck of which setting temperature was 7 °C. These handlings were

Table 1. Time schedule of handling and temperature during distribution of fresh produces.

	Date	Time	Handling	Setting temperature
Tomato	23 June	9:00	Harvest	none
		18:00	Aggregate fruits	none
		18:00–8:00	Pre–cooling	7 °C
	24 June	16:30	Sorting and packaging	none
		17:00	Loading	none
		17:30–	Transportation	7 °C
	25 June	15:00	Arrival at a wholesale market	none
Eggplant	23 June	9:00	Harvest	none
		11:00	Aggregate fruits	none
		14:00	Sorting and packaging	none
		16:30	Loading	none
		17:30 –	Transportation	7 °C
	24 June	12:50	Arrival at a wholesale market	none

done in packing house in which the temperature was not controlled. The eggplant fruits were almost similarly handled to the tomato fruits except for pre–cooling, because eggplant fruits were susceptible to chilling injury (Kozukue *et al.*, 1979; Fallik *et al.*, 1995).

The temperature of fresh produces was measured by inserting sheathed temperature sensor into the center of tomato fruit, or embedding the button type temperature loggers in the center of eggplant fruit from farm in Fukuoka to wholesale market in Tokyo. Ambient temperature near the fresh produces was also measured by the button type temperature logger which was fixed on the side of container before packaging, and on the inner wall of the corrugated cardboard box after packaging. After loading the fresh produces onto the truck, the temperature in the body of truck was also measured by the button type temperature loggers fixed on the side wall of the body.

Measuring the quality of fresh produces

Tomato fruits (*Lycopersicon esculentum* Mill. cv. Momotaro) and eggplant fruits (*Solanum melongena* L. cv. Hakata–naganasu) were stored at a constant temperature of 7 °C, and 10 °C, respectively. In addition, these produces were set in a programmable incubator (Yamato Scientific Co, Ltd., IL700) which simulated the temperature during distribution from harvest to the wholesale market described above. The storage periods of all experiments including the constant temperature tests were equal to the period from harvest to the wholesale market arriving.

Firmness, sugar content, and organic acid content of the fresh produces were measured before and after storage. After measuring firmness, 5 g of juices were made by homogenizing individually these five fruits, and each were diluted with 75% acetonitrile to make samples for analyzing sugar content by HPLC (Shimadzu Co., LC10–AD, detector: RID–10A, column: Shodex Asahipak NH2P). For analyzing organic acid content by HPLC (Shimadzu Co. LC10–AD, detector, CDD–6A, column: SCR–102H), further 5 g of juices were squeezed, and were diluted with distilled water.

RESULTS AND DISCUSSION

Temperature during distribution

The temperature of the fresh produces is shown in Fig. 1. The temperature of tomato fruit in the greenhouse after harvest was 29.5 °C, then increased with elapsed time until pre–cooling. The maximum temperatures of tomato fruit and ambient reached 35.2 °C and 39 °C, respectively. Such high temperatures resulted from placing tomato fruits in greenhouse for a long time. Woolf *et al.* (1999) showed that the temperature of avocado fruit on the side exposed by direct solar radiation regularly exceeded 35 °C, while the ambient temperature never exceeded 25 °C, and they reported the temperature of exposed fruit reached 10–15 °C above ambient temperature. Woolf *et al.* (2000) similarly reported on the difference of temperature between exposed and unexposed fruits by solar radiation. In this measurement, tomato fruits were not exposed by direct solar radiation. If the fruits were exposed, the temperature might reach to 50–55 °C as reported by Inaba and Crandall (1998). At the end of pre–cooling, the tomato fruit temperature reached to the minimum temperature of 8.7 °C which was closed to the setting temperature of 7 °C in the pre–cooling room. After pre–cooling, the tomato fruit and

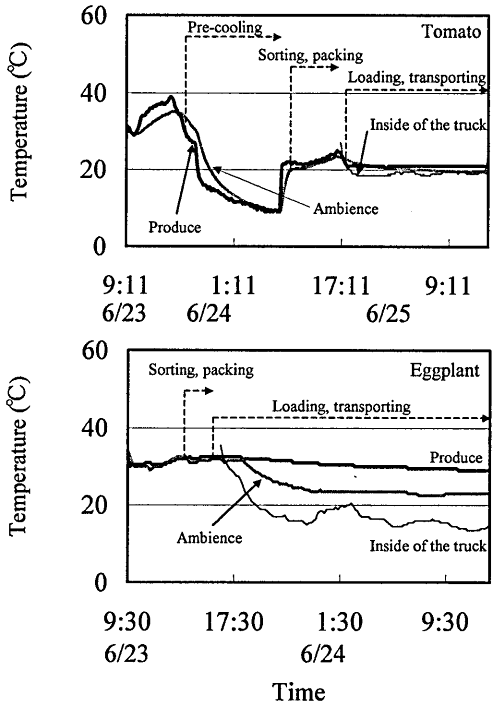

Fig. 1. Changes in temperature of tomato and eggplant fruits during distribution from farm in Fukuoka to wholesale market in Tokyo.

ambient temperatures remarkably increased until the tomato fruits were loaded onto the truck. These temperature rises were caused by natural temperature condition of packing house. After loading, the tomato fruit temperature gradually decreased in the truck, finally reached to 19.5 °C at the arrival of a wholesale market in Tokyo. During transportation, there was a large difference between the temperature actually measured and the setting temperature of 7 °C in the truck. It is suggested that the cool–ability of the refrigerator in the truck was insufficient. The cooling load of fresh produces was too large because of a large amount of loadage, and the respiratory heat of produces. Moreover, the thermal insulation effect of corrugated cardboard box was considered to inhibit the tomato fruits from being cooled.

The initial temperature of eggplant fruit was 33.5 °C. Until loading onto the truck, the temperature of eggplant fruit fluctuated between 30 °C and 33.5 °C. After loading the eggplant fruits onto the truck, both of the eggplant fruit and ambient temperatures gradually decreased until the truck arrived at the wholesale market. At the wholesale market, the temperature of eggplant fruit reached to the minimum temperature of 29 °C which was remarkably higher the setting temperature of 7 °C in the truck. The reason was similar to the case in tomato: a large cooling load and the thermal insulation effect of corrugated cardboard were considered to inhibit the eggplant fruits from being cooled.

In this experiment, three critical points to be improved where the fresh produces could be exposed to high temperature were observed. First, the produce temperature remarkably rised before pre–cooling, and at this point, the temperature reached the maximum. Second, after pre–cooling, the produces were again warmed when the produces were sorted and packaged in the packing house under the natural temperature condition. Third, the heat stored at sorting and packaging after pre–cooling might be remained in the truck. In order to achieve the severe temperature control, and to supply the high quality produces, it was required to make improvement upon these critical points during distribution.

The effect of temperature during distribution on the produces quality

The temperature which were simulated the distribution temperature history by the programmable incubator was demonstrated in Fig. 2. The simulated temperatures relatively agreed with those actually measured. Accordingly, it was reliable to carry out the experiments under the simulated temperatures in order to examine the effect of temperature during distribution on the internal quality of fresh produces.

Fig. 3 shows the changes in firmness of the tomato and eggplant fruits before and

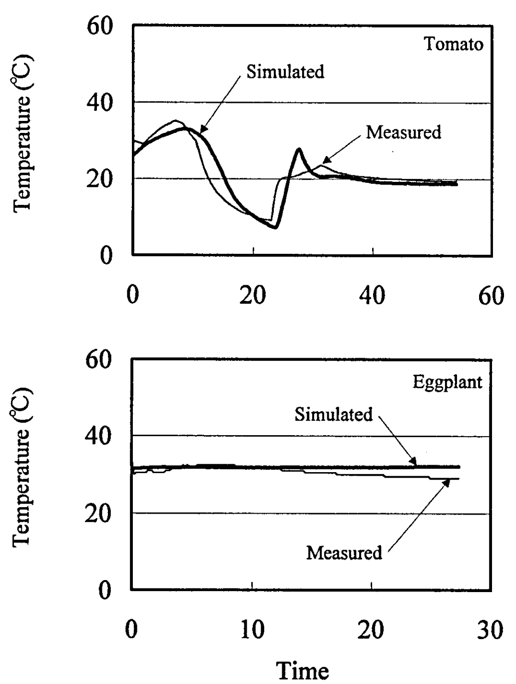

Fig. 2. Temperature history which was simulated and actually measured during distribution of tomato and eggplant fruit.

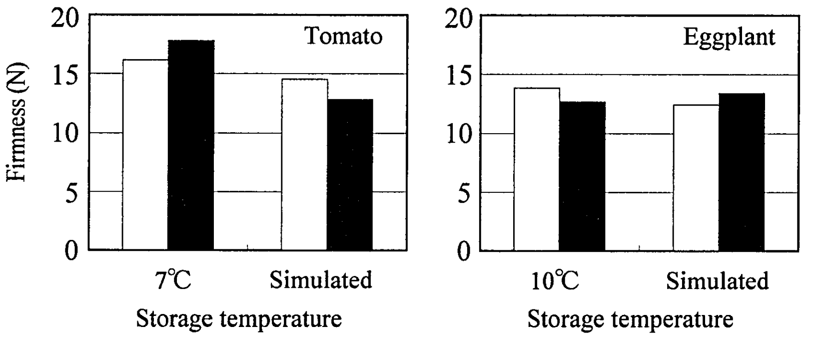

Fig. 3. Firmness of tomato and eggplant fruits before (□) and after (■) storage. Data are the mean of 5 fruits.

after storage at 7 °C for tomato fruits, at 10 °C for eggplant fruits, and at the simulated temperature during distribution for both fruits. The initial firmness of tomato fruits was about 15N. After storage, the firmness was a little increased at 7 °C, in contrast, that was slightly decreased at the simulated temperature. Before storage, firmness of eggplant fruits was about 13N, and then firmness was increased at the simulated temperature, on the other hand, it was decreased at the constant temperature of 10 °C. The difference in the firmness between before and after storage was a little, so that the effect of temperature during distribution on the firmness of the tomato and eggplant fruits was considered to be negligible for such a short term storage.

Fig. 4 shows citric and malic acid contents of tomato fruits before and after storage. The initial citric and malic acid contents of tomato fruits ranged from c.a. 4.0 to 4.5 (mg gFW^{-1}), and c.a. from 0.3 to 0.4 (mg gFW^{-1}), respectively. Citric acid was mainly contained in tomato fruits, and malic acid which was about 10% of citric acid followed, as also

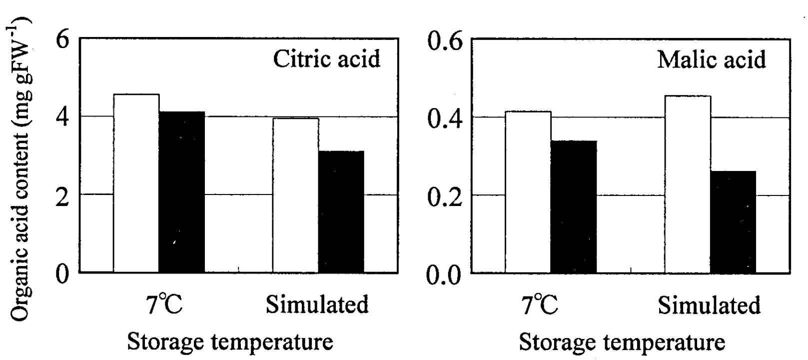

Fig. 4. Organic acid contained in tomato fruits before (□) and after (■) storage. Data are the mean of 5 fruits.

reported by Maezawa *et al.* (1993). Citric acid content after storage at 7 °C and at the simulated temperature were 90%, and 79% of initial values, respectively. Similarly, malic acid decreased during storage, and malic acid contents after storage at 10 °C, and at the simulated temperature were 82%, 58% of initial values, respectively. Auerswald *et al.* (1999) reported the decrease of titratable acid in the 4–day storage at 20 °C. In this study, the decrease of organic acid content, though it could not simply compare with titratable acid, was also obtained in the storage. The decrease of citric and malic acid contents at the simulated temperature was remarkable in comparison with those at the constant temperature of 7 °C for tomato fruits. It is considered that the respiratory metabolism of tomato fruits by which citric and malic acids were consumed was promoted by high temperature of tomato fruits. However, considering the decrease of malic acid of tomato fruits at simulated temperature was very high, the decomposition of malic acid into other acids might be also promoted in addition to consumption in respiratory reaction. Anyway, it appears that high temperature or temperature change itself during distribution considerably decreases citric and malic acid contents of tomato fruits. However, for eggplant fruits in which malic acid was mainly contained as reported by Kodukue *et al.* (1978), there was no significant difference in the rate of decrease of

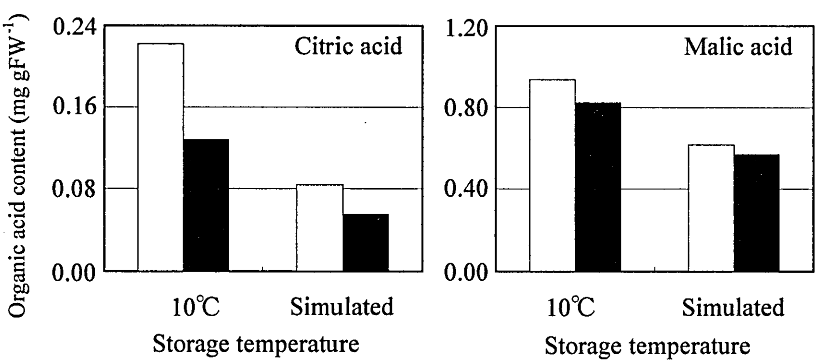

Fig. 5. Organic acid contained in eggplant fruits before (□) and after (■) storage. Data are the mean of 5 fruits.

organic acid content regardless of temperature conditions (Fig. 5).

Fig. 6 indicates the sugar content of tomato and eggplant fruits. The initial sugar content of tomato fruits ranged from c.a. 40 to 48 (mg gFW^{-1}), and decreased during storage regardless of temperature conditions. The decrease of sugar content of tomato fruits at the simulated temperature was greater than that at the constant temperature of 7 °C. After storage, sugar contents of tomato fruits at the constant temperature of 7 °C, and at the simulated temperature were 98%, 79% of initial values, respectively. For eggplant fruits, the sugar decrease was also promoted at the simulated temperature: the sugar contents of eggplant fruits after storage were about 91% at 10 °C, and 54% at the simulated temperature of initial values. The decrease of sugar content of eggplant fruits at the

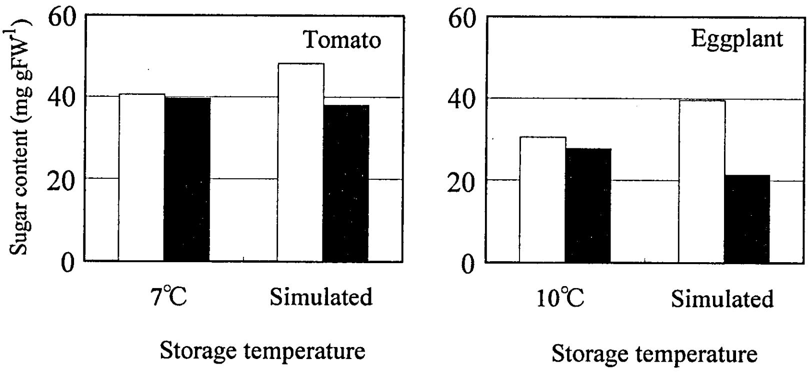

Fig. 6. Sugar content of tomato and eggplant fruits before (□) and after (■) storage. Data are the mean of 5 fruits.

simulated temperature was remarkable. The consistently high temperature during eggplant distribution from harvest to a wholesale market was considered to promote the respiratory reaction in which sugar was consumed as major respiratory substrate.

The high temperature or temperature change during distribution little influenced the firmness of tomato fruits and eggplant fruits. However, the fresh produces were exposed to a danger which caused the deterioration of internal quality such as sugar and organic acid contents. If keeping quality of the fresh produces is preferential, it is ideal that the fresh produces are pre–cooled as soon as possible after harvest, and was sorted and packaged in a packing house air–conditioned. In Japan, the truck transportation tends to be loaded a lot of fresh produces to cut down a transportation cost. However, considering that the fresh produces are required not only to be reasonable, but also to be high quality for consumers, the load quantity is needed to be reduced as the fresh produces are sufficiently cooled for the quality preservation.

CONCLUSION

In the current distribution, fresh produces are possibly exposed to a danger of being placed under high temperature, especially, before pre–cooling, during sorting, packaging, and in the refrigerated truck loading with a large amount of produce packages. Such high temperature or temperature change during distribution could induce the decreases of sugar and organic acid contents of the fresh produces in a short period such as from harvest to wholesale market. Therefore, in order to supply the high quality of fresh produces, the temperature control must be improved before pre–cooling, during sorting, packaging, and in the refrigerated truck.

ACKNOWLEDGEMENTS

The authors would like to acknowledge National Federation of Agricultural Co–operative Assosiation, Fukuoka Prefectural Headquarters for their considerable supports for measuring temperature of fresh produces.

REFERENCES

Akimoto, K. and S. Maezawa 1997 Effects of Fluctuating Temperature on the Relation and the Quality of Spinach. *Journal of The Society of Agricultural Structures, Japan*, **27**(4): 195–198 (in Japanese with English abstract)

Auerswald, H., P. Peters, B. Bruckner, A. Krumbein and R. Kuchenbuch 1999 Sensory analysis and instrumental measurements of short–term stored tomatoes (*Lycopersicon esculentum* Mill.). *Postharvest Biology and Technology*, **15**: 323–334

Fallik, E., N. Temkin–Gorodeiski, S. Grinberg and G. Davidson 1995 Prolonged low–temperature storage of eggplants in polyethylene bags. *Postharvest Biology and Technology*, **5**: 83–89

Inaba, M. and P. G. Crandall 1988 Electrolyte Leakage as an Indicator of High–Temperature Injury to Harvested Mature Green Tomatoes. *J. Amer. Hort. Sci.* **113**(1): 96–99

Kodukue, N., E. Kodukue, M. Kishiguchi and S. Lee 1978 Studies on keeping–quality of vegetables and fruits. Ⅲ. Changes in sugar and organic acid contents accompanying the chilling injury of eggplant fruits. *Scientia Horticulturae*, **8**: 19–26

Kodukue, N., E. Kodukue and M. Kishiguchi 1979 Changes in the contents of phenolic substances, phenylanine ammonia–lyase (PAL) and tyrosine ammonia–lyase (TAL) accompanying chilling–injury of eggplant fruit. *Scientia Horticulturae*, **11**: 51–59

Maezawa, S., H. Yamada and K. Akimoto 1993 Postharvest Yellowing of Tomato "Momotaro" as a Function of Maturity and Ripening Temperature. *Journal of the Japanese Society for Horticultural Science*, **62**(3): 647–653 (in Japanese with English abstract)

Nakano, K. and S. Maezawa 2002 Effect of the time course from harvest to starting pre–cooling on quality changes of spinach during distribution process. Proc. 2002 JSRAE Ann. Conf., Okayama, pp. 467–469 (in Japanese with English abstract)

Woolf, A., B., J. H. Bowen and I. B. Ferguson 1999 Preharvest exposure to the sun influences postharvest responses of "Hass" avocado fruit. *Postharvest Biology and Technology*, **15**: 143–153

Woolf, A., B., A. Wexler, D. Prusky, E. Kobiler and S. Lurie 2000 Direct Sunlight Influences Postharvest Temperature Responses and Ripening of Avocado Cultivars. *J. Amer. Hort. Sci.* **125**(3): 370–376