



Use of maturity sorting and reducing ethylene with potassium permanganate to enhance marketing of tomatoes in Laos at ambient tropical temperatures

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ABSTRACT

Purpose: Demand for tomato is increasing in Laos but marketing options are limited due to ripening during transit. This study quantified changes in fruit ripening during commercial transit to the major urban market in Laos, and investigated extension in market life achieved by inclusion of an ethylene absorbent into packages of green fruit. **Research method:** Ripening during the transport tomatoes of mixed maturity in the same package from to Vientiane was assessed by scoring fruit colour at harvest and arrival at the market. An intervention trial was then conducted where green tomatoes were packed with an ethylene absorbent and ripeness assessed over seven days at ambient temperature. **Findings:** During the 24-hour journey of 750 km from farm to urban market, the mean colour score increased from 2.4 to 3.5 with the proportion of green fruit (score 1) decreasing from 35 % at harvest to 5 % at Vientiane. In the trial where tomatoes were sorted so only green (score 1) and breaker (score 2) fruit were packed in containers, the inclusion of sachets of a low-cost potassium permanganate ethylene absorbent significantly delayed ripening - 75% of fruit remained green after 7 days storage which was double that in control boxes. **Research limitations:** Findings need to be confirmed on larger shipments to a range of markets. **Originality/Value:** On-farm sorting for maturity coupled with the marketing of ripening fruit on local markets and green fruit held in reduced ethylene to more lucrative markets can increase the economic situation for Lao farmers.

INTRODUCTION

Tomato (*Solanum lycopersicum*) is an internationally popular climacteric fruit with increasing production in many countries (Arah et al., 2016). The demand for tomato is increasing in Lao PDR and the Lao government has prioritised research into issues related to tomato production (DoA, 2017). However, postharvest handling issues have been neglected even though substantial postharvest losses of tomatoes are known to occur in the supply chain (Genova et al., 2006). The postharvest life of ripe tomatoes is relatively short (Babatola et al., 2008) and extending the market life commonly depends on maintaining fruit at the green pre-climacteric stage of maturity where they are also less susceptible to handling damage and microbial wastage (Wills & Golding, 2016). Holding unripe fruit at an optimum low temperature is used in many countries to inhibit fruit ripening but refrigerated facilities are not generally available or affordable in many developing countries including in Lao PDR. In addition, rough handling, packing without sorting and improper packaging in the supply chain have been identified as causing substantial postharvest losses of horticultural crops in developing countries (Arah et al., 2016; Hailu & Derbew, 2015; Porat et al., 2018).

Technologies that can delay ripening of tomatoes held at ambient temperature would be of considerable value for Lao PDR. Ethylene at a concentration as low as $0.005 \mu\text{L L}^{-1}$ in the storage atmosphere has been shown to initiate ripening of a range of climacteric fruit including tomatoes (Wills et al., 2001). A number of technologies related to ethylene action such as fumigation with 1-methylcyclopropene (1-MCP) (Ku & Wills 1999; Wills & Ku, 2002) and modified atmosphere storage (Mathooko, 2003; Nakhasi et al., 1991) have been found to inhibit ripening of tomatoes. However, these approaches present some difficulties in countries such as Lao PDR as they require the use of fumigation facilities or specific plastic films, respectively. Reducing the level of ethylene around tomatoes during marketing could extend the market life in the absence of temperature control. Applying a solid material that has been impregnated with potassium permanganate (KMnO_4) to oxidise atmospheric ethylene was first shown to inhibit ripening of bananas (Scott et al., 1970) but is now well recognised as an effective low-cost technology with easy application. The use of potassium permanganate absorbents has been shown to extend the postharvest life of various climacteric fruit at ambient temperatures (Azad et al., 2008; Sardabi et al., 2013) but no study has been reported for tomatoes at tropical ambient temperatures. The most widely used commercial method of application of a KMnO_4 -based ethylene scavenger is in a small sachet can be easily inserted into individual packaging (Janjarasskul & Suppakul, 2018).

The marketing of tomatoes in Lao PDR commonly involves harvesting fruit at a range of ripeness, packing the fruit into Styrofoam boxes without sorting for maturity, then transporting packages for about 24 hr from the production area in the south of country to the capital city of Vientiane, or short distance supply between neighbouring cities or provinces which take about 12 hr from harvest to destination. Anecdotal market information is that there is substantial ripening of fruit during the journey which limits marketing options to withhold fruit from the market if the price is depressed or in over supply. The initial study mapped an existing common supply chain network to quantify the change in fruit ripening during transit and then conducted an intervention study where only green and breaker tomatoes were packed together with KMnO_4 -based ethylene absorbent sachets to inhibit ripening.

MATERIALS AND METHODS

Mapping the ripening of tomatoes in the current supply chain from farm to urban market

Commercial consignments of tomatoes (*Solanum lycopersicum* cv. Tomat) grown on three planting sites in the Lao-China Cooperation in the Paksong district, Champasak province were tracked during transport to Vientiane Capital during September - October 2016. Fruit from each planting site was packed into three Styrofoam boxes that held approximately 25 kg of tomatoes. The temperature in each box was monitored by inclusion of a temperature and humidity logger (HOBO U12, Onset Computer Corporation, Cape Cod, Massachusetts, USA) in the middle of the box. From each box, 30 tomatoes from the bottom, middle and top layer respectively were labelled and the fruit skin colour was recorded based on the USDA (1975) tomato colour chart which defines the fruit ripening stages as 1=green, 2=breaker, 3= turning, 4=pink, 5=light red and 6=red. When the boxes arrived at Vientiane Capital, they were immediately taken to the Clean Agriculture Standard Center (CASC) laboratory where data on the temperature logger was downloaded and the labelled tomatoes were scored for colour. A two-way ANOVA was performed on the colour scores to determine the significance of any change during transit.

Delaying tomato ripening with an ethylene absorbent

Tomatoes (cvs Perfect and Detta) at mature green and breaker stages were harvested from three farms located in Ban Ang Gnay, Vientiane Capital. Fruit from each farm without any defect was selected at the packing hut on the farm and were distributed into a pair of Styrofoam boxes each holding about 10 kg (about 110 tomatoes). In total, three pairs of boxes from each farm were packed. Four sachets of a commercial potassium permanganate based ethylene absorbent (Bion, 5 g of absorbent per sachet, Bioconservacion, Barcelona, Spain) were inserted into one of each pair boxes with two sachets in the middle and on the top layer. All boxes were transported 55 km to CASC by open tray truck, a journey that took about 3.5 hr. Upon arrival at CASC, the boxes were stored at room temperature (26-37 °C). After 5, 7 and 9 days at the laboratory, one pair of boxes were opened and the colour of each tomato was scored using the USDA (1975) colour chart. Linear regression was calculated to determine the rate of change in fruit colour score for each treatment from each farm. An applied linear statistical model was used to compare the significance of the slope of the regression lines; $y = 100 + bx$, where y = % of unripe fruit and x = storage time (days) with the y intercept fixed at 100 % for $x = 0$ days. The data from the three farms were aggregated for each treatment and the mean regression equation calculated

RESULTS AND DISCUSSION

Ripening in the current tomato supply chain

The tomato supply chain studied involved a distance of 750 km between farms and the market and a normal public bus was used to transport the tomatoes to Vientiane Capital. The journey took 22-24 hours from the harvest time of about 8 am and arrival in the market the following morning. The temperature around tomatoes in the boxes was about 25 °C when packed and had risen about 7 °C to about 32 °C during the journey.

The current marketing practice for tomatoes in Lao PDR was followed with the three consignments where fruit was packed into the Styrofoam boxes without any sorting for

maturity. The mean skin colour of tomatoes just prior to packing was scored as 2.4 but had increased ($P=0.06$) to 3.5 on arrival in the market. The change in fruit colour between harvest and market is illustrated in Figure 1 which shows that there was a wide range of fruit maturity on packing with one-third of the fruit being green (score 1) and one-third at the breaker (score 2) stage. In the 24 hours between harvest and assessment for colour in Vientiane Capital, only about 5 % of fruit remained green with about 60 % of fruit either at the turning (score 3) or pink (score 4) stages.

The rate of ripening of tomatoes at ambient tropical temperatures has been poorly documented in the literature with most studies being at lower temperatures. In this study it was surprising to find a relatively rapid increase in ripening over the 24 hours between harvest and market which is attributed to the both high temperatures tomatoes encountered during the supply chain and the mixed maturities of tomatoes in a box where the ethylene generated by the ripening fruit would trigger ripening in green fruit. While all fruit were of marketable quality on arrival in Vientiane Capital, there was limited flexibility to obtain a better price by deferring marketing if the market was over-supplied or to transport to more distant markets. This situation could be improved if the fruit were sorted for the stage of ripeness on the farm and green and ripening fruit packed in separate boxes with different marketing strategies for each group. Ripening fruit would need to be marketed within a short period but greener fruit could have an extended marketing period either on a local market destination or after transport to other provinces or regional markets such as Thailand. The advantage of the latter scenario would be enhanced by having a simple technology to further delay the onset of ripening of tomatoes.

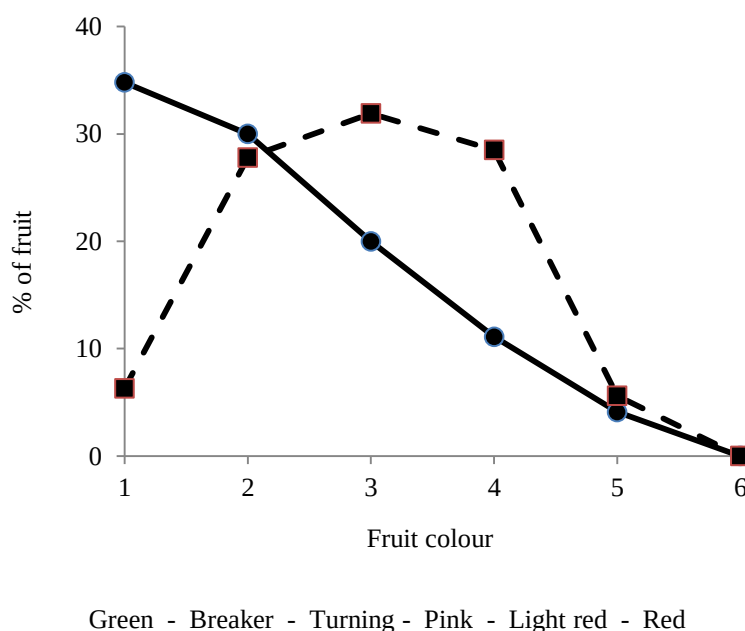


Fig. 1. Proportion of tomatoes at each ripeness colour score at the farm (●) and on arrival at the market (■). Values were derived from assessments of 810 tomatoes (3 consignments x 3 boxes x 90 fruit).

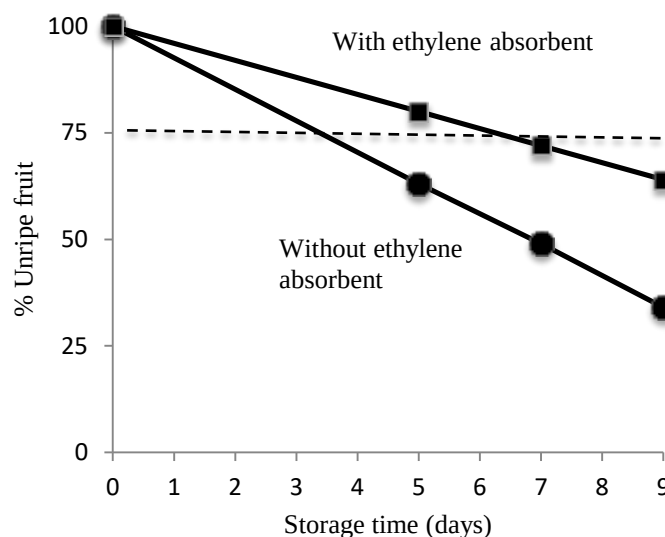


Fig. 2. Proportion of unripe tomatoes in boxes with and without an ethylene absorbent during nine days storage. Each value is the mean of 3 replicates (3 farms x 110 tomatoes).

Delaying ripening with an ethylene absorbent

A trial was therefore conducted on tomatoes sourced from three farms to investigate the delay in ripening that could be achieved by the absorption of ethylene generated at tropical temperatures as most published studies have been conducted at lower temperatures. Sachets of a commercial KMnO_4 based ethylene absorbent were placed into boxes containing fruit that had been pre-sorted to contain only green (colour score 1) or breaker (colour score 2) tomatoes. The rate of ripening was significantly inhibited over the nine day storage period at 26-37°C in boxes containing the ethylene absorbent. Table 1 shows the significant linear relationship for fruit from each farm with a higher slope for the control fruit than for fruit with the ethylene absorbent. Figure 2 shows the overall trend across the three farms for the percentage of unripe fruit remaining in a box over the storage period. On an assumption that an acceptable market outcome is achieved if 75% of tomatoes are green when the container is marketed, containers with ethylene absorbent sachets can survive a 7 day supply chain which is double the 3.5 days for fruit in control containers. All fruit in both treatments ripened normally after removal from the container.

Ethylene absorbent sachets are of relatively low cost (600 kip (US\$0.07)/sachet, B. Rogers, Bioconservacion, pers. comm.) and the economic benefit from use of the ethylene absorbent sachet can be assessed. In this study, an investment of four sachets (5g/sachet) at 2400 kip (US\$0.28) maintained 75% of unripe tomato for 7 days. Since the control container had 50 % unripe fruit at seven days, the sachet resulted in an extra 2.5 kg from the original 10 kg of tomatoes per container to be marketable after 7 days. An average price for tomatoes in the Vientiane wholesale market is 10,000 kip (US\$1.25)/kg which values the 2.5 kg of additional marketable tomatoes per container at 25,000 kip (US\$3.10) revenue – a return of over 1000 % from the investment in the sachets.

Table 1. Linear regression equations for decrease of % unripe fruit (y) in the container with increasing storage time (x days) for tomatoes from three farms

Farm	Linear regression of % unripe fruit v. storage time		
	Control	Ethylene absorbent	P value
A	$Y=100-5.9x$	$Y=100-3.8x$	0.04
B	$Y=100-10.8x$	$Y=100-5.9x$	0.004
C	$Y=100-5.3x$	$Y=100-2.4x$	0.03

Unripe fruit were designated as having colour score 1 or 2. Each box contained about 110 tomatoes.

CONCLUSION

Tomatoes marketed in the current 24 hour Paksong –Vientiane Capital tomato supply chain was found to be unsatisfactory. The increase of 6-8°C in fruit temperature during the journey together with the mixed maturity of tomatoes packed into the same container resulted in 95% of tomatoes having entered the ripening stages on arrival at the market destination. The fruit need then to be marketed immediately and limits any alternative marketing strategy that could provide a better economic return to farmers.

The marketing options of tomatoes in the Lao PDR could be improved by sorting fruit after harvest and consigning to the local market only those fruits that had commenced ripening (score 2+). Alternate higher value markets can then be targeted for tomatoes that have not ripened particularly if an ethylene absorbent was included in a container. For such fruit the market life was found to be extended by 100% after 7 days over fruit in containers without the ethylene absorbent. The sachets are of relatively low cost and required no technical skill for application. The simple attempt at economic modelling showed that the return to the farmer through the increased volume of fruit that can be marketed and the ability to access more lucrative markets is much greater than the cost of the sachets.

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CONFLICT OF INTEREST

The authors have no conflict of interest to report.

REFERENCES

- Arah, I. K., Ahorbo, G. K., Anku, E. K., Kumah, E. K. & Amaglo, H. (2016). Postharvest handling practices and treatment methods for tomato handlers in developing countries: A mini review. *Advances in Agriculture*, 2016, 1-8.
- Azad, M. I., Mortuza, M. G., Nahar, N. A., Huq, S. & Alam, M. A. (2008). Effect of potassium permanganate on physico-chemical changes and shelf life of mango (*Mangifera indica* L.). *The Agriculturists*, 6, 54-59.
- Babatola, L. A., Ojo, D. O. & Lawal, O. I. (2008). Effect of storage conditions on tomato (*Lycopersicon esculentum* Mill) Quality and shelf life. *Journal of Biological Sciences*, 8, 490-493.

- DoA. (2017). *Yearly Report of 2017 and Action Plan of 2018 for CASC*, Document No. 0316/CASC. Department of Agriculture, Lao PDR.
- Genova, C., Weinberger, K., Chanthasombath, T., Inthabungsee, B., Sanatem, K. & Somak, K. (2006). Postharvest loss in the supply chain for vegetables –The case of tomato, yardlong bean, cucumber and chili in Lao PDR. AVRDC - The World Vegetable Center. Shanhua, Taiwan ROC. AVRDC Publication No. 06-684, Working Paper No. 17.
- Hailu, G. & Derbew, B. (2015). Extent, causes and reduction strategies of postharvest losses of fresh fruits and vegetables – A review. *Journal of Biology, Agriculture and Healthcare*, 5, 49-64.
- Janjarasskul, T. & Suppakul, P. (2018). Active and intelligent packaging: the indication of quality and safety. *Critical Reviews in Food Science and Nutrition*, 58, 808-831.
- Ku, V. V. V. & Wills, R. B. H. (1999). Effect of 1-methylcyclopropene on the storage life of broccoli. *Postharvest Biology and Technology*, 17, 127-132.
- Mathooko, F. M. (2003). A comparison of modified atmosphere packaging under ambient conditions and low temperatures storage on quality of tomato fruit. *African Journal of Food Agriculture Nutrition and Development*, 3(2), 2-9.
- Nakhasi, S., Schlimme, D. & Solomos, T. (1991). Storage potential of tomatoes harvested at the breaker stage using modified atmosphere packaging. *Journal of Food Science*, 56, 55-59.
- Porat, R., Lichter, A., Terry, L. A., Harker, R. & Buzby, J. (2018). Postharvest losses of fruit and vegetables during retail and in consumers' homes: Quantifications, causes, and means of prevention. *Postharvest Biology and Technology*, 139, 135-149.
- Sardabi, F., Mohtadinia, J., Shavakhi, F. & Jafari, A. A. (2013). Effect of 1-methylcyclopropene and potassium permanganate-coated zeolite nanoparticles on extending the shelf life and quality of Golden and Red Delicious apples. *Iranian Journal of Nutrition Sciences and Food Technology*, 8, 135-144.
- Scott, K. J., McGlasson, W. B. & Roberts, E. A. (1970). Potassium permanganate as an ethylene absorbent in polyethylene bags to delay ripening of bananas during storage. *Australian Journal of Experimental Agriculture and Animal Husbandry*, 10, 237-240.
- USDA, (1975). Visual Aid TM-L-1. The John Henry Co, Lansing, MI.
- Wills, R. B. H. & Golding, J. B. (2016). *Postharvest: An Introduction to the Physiology and Handling of Fruit and Vegetables*. 6th ed.: Sydney: University of New South Wales Press.
- Wills, R. B. H. & Ku, V. V. V. (2002). Use of 1-MCP to extend the time to ripen of green tomatoes and postharvest life of ripe tomatoes. *Postharvest Biology and Technology*, 26, 85-90.
- Wills, R. B. H., Warton, M. A., Mussa, D. M. D. N. & Chew, L. P. (2001). Ripening of climacteric fruits initiated at low ethylene levels. *Australian Journal of Experimental Agriculture*, 41, 89-92.

استفاده از مرتب سازی بر اساس بلوغ و کاهش اتیلن با پرمنگنات پتاسیم برای

افزایش بازاریابی گوجه فرنگی در لائوس در دمای هوای گرمسیری

ویویان کو، بوتساکن اینتالنجی و رون ویلز

چکیده:

تقاضا برای گوجه فرنگی در لائوس در حال افزایش است اما گزینه‌های بازاریابی به علت رسیدگی محصول در طول حمل و نقل محدود می‌باشد. در این مطالعه تغییرات در رسیدگی میوه در هنگام ترانزیت تجاری را به بازار اصلی شهرها در لائوس و تحول در زندگی بازار که با افزودن جاذب اتیلن به بسته‌های میوه سبز حاصل شده است، مورد بررسی قرار گرفت. رسیدگی در طی حمل و نقل گوجه فرنگی از ویتنایان که با بلوغ متفاوت در همان بسته بندی قرار داشتند با ارزیابی رنگ میوه در هنگام برداشت و هنگام عرضه به بازار انجام شد. سپس یک آزمایش مداخله‌ای انجام گرفت که گوجه فرنگی‌های سبز با جاذب اتیلن بسته بندی شده و رسیدگی در طی هفت روز در دمای محیط بررسی شد. در طی سفر ۲۴ ساعتی ۷۵۰ کیلومتری از مزرعه به بازار شهری، نمره متوسط رنگ از ۲/۴ به ۳/۵ افزایش یافت و نسبت میوه سبز (نمره ۱) از ۳۵ درصد در برداشت تا ۵ درصد در ویتنایان کاهش یافت. در آزمایشی که فقط گوجه فرنگی‌ها در رنگ سبز (نمره ۱) و بریکر (نمره ۲) در ظروف بسته بندی شدند، افزودن بسته بندی کم هزینه پرمنگنات پتاسیم و جاذب اتیلن به طور معنی‌داری رسیدگی میوه را به تاخیر انداخت. ۷۵٪ میوه پس از ۷ روز انبار داری سبز باقی ماند. که در جعبه های کنترل دو برابر بود. مرتب سازی در مزرعه برای بلوغ همراه با بازاریابی رسیدگی میوه در بازارهای محلی و نگهداری میوه سبز و با اتیلن کاهش یافته، موجب بازارهای با سودآوری بیشتر شده که می‌تواند وضعیت اقتصادی برای کشاورزان لائوس را افزایش دهد.

کلمات کلیدی: اتیلن، پرمنگنات پتاسیم، رسیدگی، زنجیره تامین، گوجه فرنگی