Ripening Promotion and Ethylene Evolution in Red Pepper (*Capsicum annuum*) as Influenced by Newly Developed Formulations of a Natural Lipid, Lysophosphatidylethanolamine

C.K. Kang
Bioregulator Lab, NIAST
RDA, Suwon, 441-707, Korea
E-mail: ckka@rda.go.kr

Y.L. Yang and G.H. Chung
Doosan Corporation, Yongin
449-840, Korea

J.P. Palta
Dept. of Horticulture
1575 Linden Drive
University of Wisconsin
Madison WI, 53706-1590, USA
E-mail: jppalta@wisc.edu

and

Nutra-Park Inc
3225 Deming Way Suite 140
Middleton, WI 53562, USA
E-mail: jpalta@nutrapark.com

Keywords: LPE, dry matter, fruit coloration, ethylene evolution, ethephon, natural lipids, fruit ripening, lysophospholipid, phospholipid, membrane lipid

Abstract

Application of the lysophosphatidylethanolamine (LPE) improved the yield of red pepper (*Capsicum annuum*) fruit, probably by enhancing the rate of color development. The effective concentration for this purpose was 100-200 µl/L, which resulted in a yield increase of ripened fruit over 30%. LPE application did not adversely affect fruit quality. No phytotoxicity was observed when LPE was applied on red peppers. Application of LPE at 100 ppm before first frost resulted in about 50% increase in the yield of red fruit. These results suggest that LPE can be used as a safe and effective agent to enhance the yield of ripened (marketable) red pepper fruit late in the season. In a second experiment, the influence of LPE on red color development was compared with ethephon. Both materials increased the yield of ripened red fruit. LPE caused neither defoliation nor leaf yellowing, while ethephon resulted in severe defoliation and leaf yellowing. A suspension concentrate (SC) formulation of LPE was more effective than wettable powder (WP) formulation for acceleration of red pepper color development. LPE application enhanced fruit ethylene evolution. In response to WP, SC, or ethephon, fruit ethylene evolution was increased 8-to-9 fold relative to control. These results suggest that LPE can stimulate the fruit ripening by enhancing ethylene evolution.

INTRODUCTION

Red (hot) pepper (*Capsicum annuum*) is a major crop in Korea. This crop requires extensive labor for harvest and suffers from yield losses due to bacterial soft rot and anthracnose if harvest is delayed. Furthermore the fruit does not ripen well in fall due to low temperatures. Ethephon, an ethylene-releasing compound was used to stimulate fruit ripening. However, this label was withdrawn in 1991 due to its phytotoxicity. Thus, a safe ripening aid is needed. Recent studies have provided evidence that lysophosphatidylethanolamine (LPE), a natural lipid, can accelerate ripening of tomato and cranberry fruits while prolonging their shelf life at the same time (Farag and Palta 1991, 1992, 1993a; Ozgen and Palta, 1999). LPE application enhances ethylene production in mature (ready to ripen) fruit whereas in ripened fruit this lipid suppresses ethylene and respiration thus enhancing their shelf life (Hong et al., 2001; Farag and Palta, 1993b). Our preliminary studies showed that a pre-harvest spray of LPE can stimulate color development in red peppers (Kang et al., 2001). We evaluated the efficacy and phytotoxicity of LPE when applied to red peppers in the presence and absence of ethephon.

Proc. XXVI IHC – Issues and Advances in Postharvest Hort.
Ed. R.K. Prange
Acta Hort. 628, ISHS 2003
Publication supported by Can. Int. Dev. Agency (CIDA)

MATERIALS AND METHODS

Experiments were conducted in 2000 and 2001 growing seasons in an upland grower field located in Chungju of Chungbuk province, Korea. 'Podocheong' red peppers were raised using standard cultural practices. The experiments were laid out with a randomized complete block design with 5 replications. Plot size included 15 plants in a linear row.

In the 2000 season, LPE applications were by hand sprayer at concentrations of 100, 200, and 400 ppm a.i. Siloxane (30% soluble liquid) was added as a wetting agent at the rate of 0.1 ppm to all the treatments. Spray application were made to the point of run-off. In 2000, applications were made on August 10, 17, and 28. The same treatments were repeated three times on the same plants. One week after each application ripened (red) fruit were harvested. Yield (number and weight) of marketable and disease-infested fruit was recorded for each plot. A sample of marketable fruit was used for measuring dry matter content and ethylene evolution. Ethylene evolution was measured by sealing the fruit in a glass container and quantifying the ethylene with a gas chromatograph (Farag and Palta, 1993b). To evaluate the potential of fruit coloring by LPE in late fall (prior to frost), spray applications of LPE with and without ethephon (250 ppm) were made on October 6. In this case ethephon was applied either mixed with LPE or 4 hours after the LPE application. All the yield parameters as described above were measured at harvest. In addition all the plots were rated for phytotoxicity on a scale of 0 to 10 (0 being no yellowing and no defoliation; 10 being 100% yellowing and defoliation).

In 2001, experiments were repeated in the same field, using the same plot size and layout as in the 2000 season. Two different formulations of LPE (10% suspension concentrate and 30% wettable powder) were evaluated for their efficacy. Treatments were applied on August 31 and fruit harvested on September 9. Both of these formulations were also evaluated along with ethephon to determine if LPE can reduce the foliage damage by ethephon. Details of the procedures used and data collection were the same as in the 2000 season.

RESULTS AND DISCUSSION

One week after the first application of LPE, the yield of red-colored fruit was not statistically enhanced (Table 1). However, second and third LPE applications (200 ppm) gave 49% and 39% increases in yield of ripened fruit, respectively. Total yield of red fruit harvested after three applications from the plants increased by 35% as a result of LPE application (Table 1). Similarly, total number of fruit harvested increased by about 30% (Table 2). These results demonstrate that LPE applied at 200 ppm can stimulate the development of color in red peppers. These results are also consistent with the stimulation of color production by LPE in tomato, grapes, and apples (Farag and Palta 1993a; Hong et al., 2001; Farag and Palta, 1991; Farag and Palta, 1992; Ozgen and Palta, 1999a).

No leaf yellowing was observed when LPE was used as a ripening enhancer (Table 3). Furthermore, the proportion of fruit infested with pathogens was reduced by LPE application. These results are consistent with the observed improvement in membrane stability by LPE (Farag and Palta, 1993b; Ryu et al., 1997). Reduced ion leakage from leaf and fruit tissue occurs in the presence of LPE (Farag and Palta, 1993). Furthermore LPE inhibits the activity of phospholipase D, an enzyme known to cause membrane degradation during senescence. It is possible that LPE was preventing pathogen attack by keeping cell membranes intact. There were no differences in the dry matter content (Table 3).

We also investigated the efficacy of LPE on fruit ripening with and without ethephon late in the season, before fall frost (Fig. 1 and 2). Application of LPE at 100 ppm resulted in about 50% increase in the yield of red pepper compared with control (Fig. 2). Furthermore, application of LPE (100 ppm) and ethephon (250 ppm) resulted in almost a 100% increase in the yield of red fruit. These results suggest that LPE with or without ethephon can be used to enhance the yield of marketable fruit in late fall.

Two newly-developed formulations of LPE were tested for their effect on ethylene synthesis and percent ripened fruit as measures of fruit ripening. Both of these formulations stimulated these two ripening parameters without foliage injury (Table 4). SC formulation performed better than WP. In support of the ripening stimulation effect of LPE, we found that LPE stimulated ethylene production in the fruit (Table 4). These results are consistent with the observed effect of LPE on the stimulation of ethylene production and color development in tomato fruit (Hong et al., 2001).

The efficacy of the two formulations of LPE was also evaluated in the presence of ethephon. Ethephon applied alone or in combination with LPE stimulated fruit ripening (Table 5). However, these applications caused defoliation and leaf yellowing. The leaf yellowing by ethephon was reduced when LPE was included in the spray solution. Ethephon mixed with LPE (SC) gave the highest yield of ripened fruit. In this case, the yield of ripened fruit was increased by over 100% (Table 5). As expected, these treatments resulted in a dramatic increase in ethylene production by the fruit (Table 5). These results are consistent with the ripening stimulation by LPE in the presence of ethephon on tomatoes and with the observation that LPE can mitigate foliage injury caused by ethephon (Farag and Palta, 1993; Ozgen and Palta, 1999b; Ozgen et al., 2000).

CONCLUSIONS

The results of the present study support the use of LPE as a non-phytotoxic and natural agent to enhance the yield of marketable (red) friut. A pre-harvest application of LPE was effective for this purpose either alone or in the presence of ethephon. Our results show that LPE can be used to mitigate the foliage injury by ethephon. Currently, there is no product available for stimulating ripening (increasing the yield of marketable fruit) in red peppers in Korea. Our results suggest that LPE has the potential to be used as a ripening enhancer for red peppers. Furthermore these results suggest LPE may stimulate ripening in a ready-to-ripen (mature) fruit by enhancing ethylene production.

Literature Cited

Farag, K.M. and Palta, J.P. 1991. Enhancing ripening and keeping quality of apple and cranberry fruits using lysophosphatidylethanolamine, a natural lipid. HortScience 26:683 (Abstr.).

Farag, K.M. and Palta, J.P. 1992. Evidence for reduction of abscission in 'McIntosh' apple fruits and for enhancing the ripening and color uniformily by lysophosphatidyl-ethanolamine. HortScience 27:592 (Abstr.).

Farag, K.M. and Palta, J.P. 1993a. Use of natural lipids to accelerate ripening and enhance storage life of tomato fruit with and without ethephon. HortTechnology 3:62-65.

Farag, K.J. and Palta, J.P. 1993b. Use of lysophosphatidylethanolamine, a natural lipid, to retard tomato leaf and fruit senescence. Physiol. Plant. 87:5155-521.

Hong, J.H., Araya, L., Altwies, J.R. and Palta, J.P. 2001. Stimulation of ripening of fresh market tomato fruit by a postharvest dip in lysophosphatidylethanolamine (LPE), a natural lipid. HortScience 36:598 (Abstr.).

Kang, C., Kim, S., Chung, G. and Palta, J.P. 2001. Effect of lysophosphatidylethanol-amine (LPE) on the ripening stimulation and ethylene evolution in red pepper. HortScience 36:509 (Abstr.).

Ozgen, M., and Palta, J.P.1999a. Use of lysophosphatidylethanolamine (LPE), a natural lipid, to accelerate ripening and enhance shelf life of cranberry fruit. HortScience 34:538 (Abstr.).

Ozgen, M. and Palta, J.P. 1999b. Use of lysophosphatidylethanolamine (LPE), a natural lipid, to prevent damaging effects of ethephon on tomato plants. HortScience 34:538 (Abstr.).

Ozgen, M., Palta, J.P. and Ryu, S.B. 2000. Mitigation of ethephon injury to tomato plants by a natural lipid lysophosphatidylethanolamine (LPE): influence on the activity of phospholipase D (PLD). HortScience 35:503 (Abstr.).

Ryu, S.B., Karlsson, B.H., Ozgen, M. and Palta, J.P. 1997. Inhibition of phospholipase D by lysophosphatidylethanolamine, a lipid-derived senescence retardant. Proc. Natl. Acad. Sci. 94:12717-12721.

Tables

Table 1. Yield of ripened red pepper fruit per 15 plants as influenced by LPE application in 2000. LPE was applied to the same plots on August 10, 17, and 28 and harvests were August 17, 18, and September 4, respectively.

Treatment	Weight of ripened fruit (g/15 plants)			
	1st Harvest (Aug. 17)	2nd Harvest (Aug. 28)	3rd Harvest (Sept. 4)	Total
Control	2014.0 a[1]	2559.1c	732.2b	5305.3b
LPE 100 ppm	2412.2a	3502.1ab	835.5b	6749.8a
LPE 200 ppm	2360.7a	3814.2a	1004.4a	7179.3a
LPE 400 ppm	2348.9a	3066.7bc	879.1ab	6294.4a

[1]Means with the same letter are not significantly different at 5% level using Duncan's multiple range test.

Table 2. Number of fruit harvested per 15 plants as influenced by LPE application in 2000.

Treatment	Ripened fruit (No/15 plants)			
	1st Harvest	2nd Harvest	3rd Harvest	Total
Control	134.2a[1]	180.8b	58.3c	373.3b
LPE 100 ppm	161.0a	233.6a	62.6bc	457.2a
LPE 200 ppm	157.2a	247.0a	79.0a	483.2a
LPE 400 ppm	167.5a	218.0ab	71.4ab	457.0a

[1]Means with the same letter are not significantly different at 5% level using Duncan's multiple range test.

Table 3. Fruit quality parameters as influenced by LPE applications in 2000. For details see Materials and Methods section.

Treatment	Disease-infested fruit (% of total)	Dry matter (%)	Phytotoxicity to foliage	Fruit color development
Control	2.6a[1]	18.9a	None	Red
LPE 100 ppm	1.5b	18.8a	None	Red
LPE 200 ppm	1.7ab	19.3a	None	Red
LPE 400 ppm	1.6ab	18.8a	None	Red

[1]Means with same letter are not significantly different at 5% level using Duncan's multiple range test.

Table 4. Yield of red pepper marketable fruit and relative rates of ethylene evolution as influenced by a pre-harvest application of two formulations of LPE in 2001. Fruit were harvested one week after spray application.

Treatment	Concentration ppm	Ripened Fruit (% of total)	Ethylene evolution from red fruit (% of control) after treatment (days)		
			2	4	6
Control	—	17.9b[1]	100	100	100
LPE 10% SC[2]	50	23.8 ab	137	154	116
	100	24.0 ab	229	170	128
	200	24.8 a	202	270	189
LPE 30% WP	50	23.6 ab	106	96	76
	100	22.5 ab	156	176	115
	200	22.4 ab	190	248	142

[1]Means with same letter are not significantly different at 5% level using Duncan's multiple range test.
[2] SC = suspension concentrate, WP = Wettable powder

Table 5. Influence of Ethephon and LPE combinations on the yield of ripened (red) fruit, fruit ethylene evolution and foliage injury in 2001.

Treatment	Defoliation (0-10)[1]	Leaf yellowing (0-10)[1]	Ripened fruit (%)	Ethylene evolution from red fruit (% of control) after treatment (days)		
				2	4	6
Control	0	0	20.1	100	100	100
Ethephon	5.7	5.7	39.1	760	689	552
LPE (SC)[2] + Ethephon	5.7	4.3	45.2	918	785	675
LPE (WP) + Ethephon	4.0	3.7	36.5	893	666	546

[1]Visual rating of foliage from scale 0-10 with 0 being 100% healthy (no defoliation, no yellowing) and 10 being 100% unhealthy (total defoliation and total yellowing of leaves).
[2]SC= Suspension Concentrate; WP= Wettable Powder.

Figures

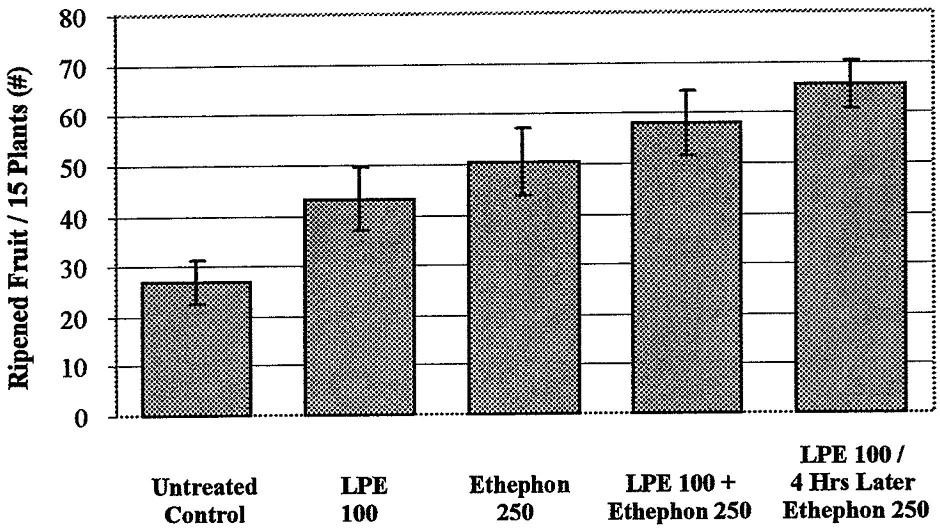

Fig. 1. Influence of a pre-harvest spray of LPE on the mass of ripened red pepper fruit per 15 plants in the presence and absence of ethephon. Applications were made a week before fall frost and fruit were harvested one week after application. Data represents means of five replications.

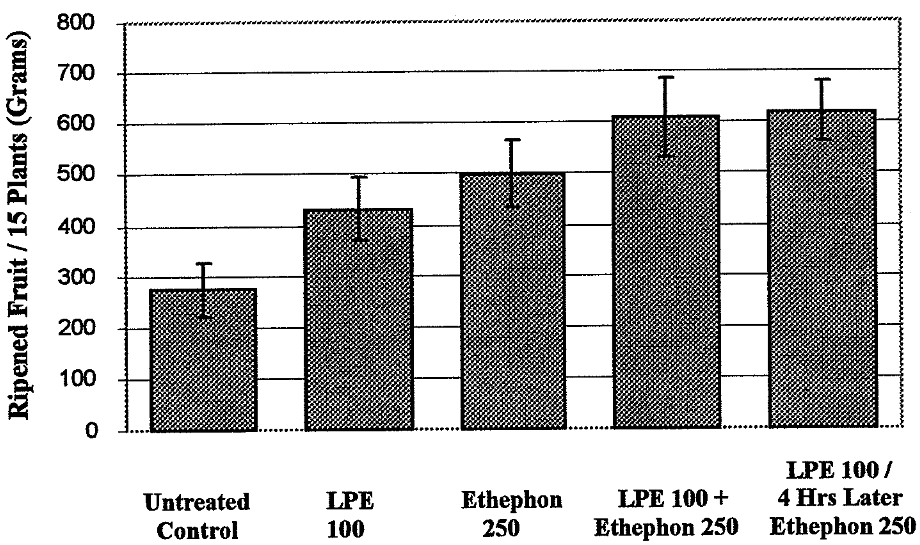

Fig. 2. Influence of a pre-harvest spray of LPE on the weight of ripened red pepper fruit in the presence and absence of ethephon. Applications were made a week before fall frost and fruit were harvested one week after application. Data represents means of five replications.