FINAL PROJECT REPORT
WTFRC Project Number: CH-05-501

Project Title: Coatings and other treatments to improve cherry quality

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Budget History:

Item	**Year 1:**	**Year 2:**	**Year 3:**
Salaries		10,200	2,516
Benefits		4,998	1,484
Wages			
Benefits			
Equipment			
Supplies	3,500	3,500	4,000
Travel		500	1,000
Miscellaneous			
Total	3,500	19,198	9,000

Significant findings:

- A new clamshell prototype with smaller openings than the commercial clamshell was developed. The new clamshell decreased moisture loss and doubled the shelf-life of ‘Regina’, ‘Lapins’, and ‘Bing’ fruit.
- An ethanol release pad placed in the clamshell maintained better stem and fruit quality of ‘Lapins’.
- The efficiency of coatings to reduce postharvest moisture loss of cherries is coating formulation and fruit variety dependent.
- Sucrose fatty acid ester was the only coating that significantly improved shininess of cherry fruit.
- Chitosan coatings maintained fruit firmness and stem retention better than control and other coatings.
- Ca propionate dips helped maintain fruit firmness but $CaCl_2$ did not.
- Peroxyacetic acid, a sanitizer, maintained better fruit quality than control and other dipping treatments.
- For stem coatings, paraffin + polyethylene decreased water loss and browning, decreased stem detaching, and water loss. However, other film forming formulations did not affect stem quality. GA_3 dips slowed down stem browning of ‘Bing’ cherries.

Results and Discussion

Clamshell (Fig. 1-4): Currently commercial clamshells are very inefficient because 2-5% of the total surface area is exposed to air (Fig. 1). This opening allows fruit weight to decrease more than 5% when stored at 33°F for 14 – 21 days. The critical point at which fruits and vegetables deteriorate due to water loss is at about 5%. Thus, as a result of this exposure to air, cherry stems dry or turn brown, and fruit shrink and deteriorate.

We developed a better product – our new clamshell significantly decreased fruit weight loss and nearly doubled cherry shelf life. This new clamshell includes smaller openings with the opening ratio to total surface area is from 0.05-0.50% (Fig. 1). Because of the small opening, the relative humidity (RH) inside the clamshell with fruit was 5-6% higher than the commercial clamshell (Fig. 2). The water loss rate of fruit in the new clamshell was only half in comparison with which in the commercial clamshell (Fig. 3). Fruit in the new clamshell had high flesh firmness, less stem discoloration (data not shown), and less incidence of pitting at 33°, 50° and 68°F (1°, 10°, and 20°C), respectively (Fig. 4).

The result with our clamshell is that fruit will store longer, have better quality, and ultimately have happier consumers.

Commercial clamshell — Experimental clamshell

Fig. 1. Commercial (left, with large openings) and experimental (right, with small opening) clamshells (2006).

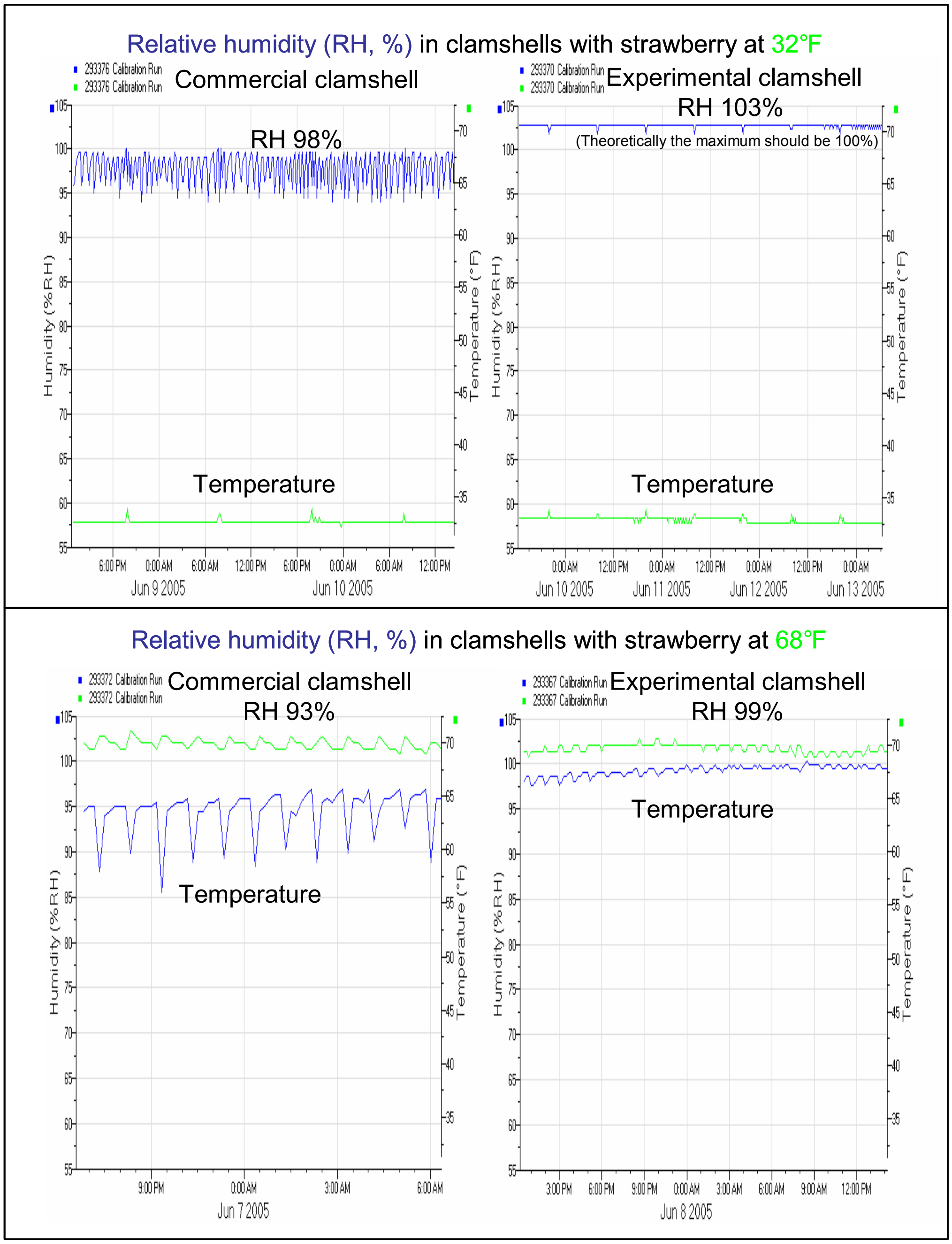

Fig. 2. Effect of clamshell opening on relative humidity (%) in clamshell with one pound of cherries at 32°F (upper) or 68°F (bottom). Opening ratio: Commercial clamshell-3.38%; Experimental clamshell-0.18%. (Average RH and the stability, 2005).

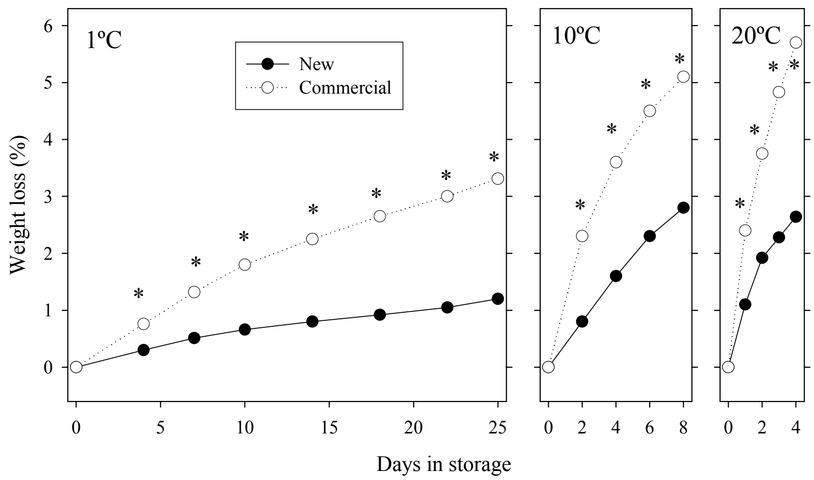

Fig. 3. Effect of clamshell on weight loss of sweet cherries stored at 33°, 50°, and 68°F, respectively (2006).

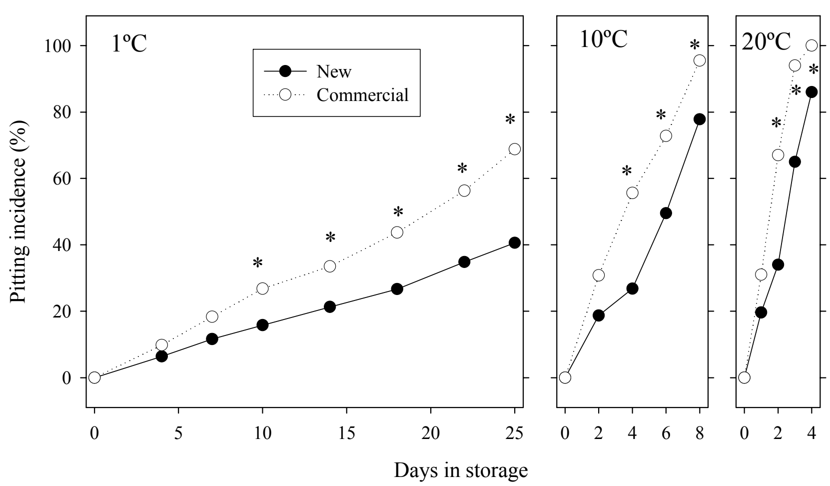

Fig. 4. Effect of clamshell on pitting of 'Lapins' cherries stored at 33°, 50°, and 68°F, respectively (2006).

Ethanol release powder (Fig. 5-6 and **Table 3):** The presence of an ethanol-release pad (Antimold Mild®, Freund Industrial, Japan) in the clamshell allows ethanol vapor to diffuse gradually (Fig. 5). It is made from ethanol absorbed onto silica gel that is packed in a special film, laminated with ethylene-vinylacetate and a proprietary Japanese paper, which regulates ethanol diffusion. The ethanol pad was glued on the top lid of clamshell.

Softening of fruit and browning of stems were retarded by ethanol pads (Fig. 6). Ethanol treatment affects ripening and senescence in some fruit and vegetables (Bai et al., 2004; Plotto et al., 2006; Suzuki et al., 2004). Ethanol vapor treatment of tomato fruit suppressed the climacteric respiratory rise, lycopene synthesis, and chlorophyll breakdown (Saltveit and Mencarelli, 1988). Ethanol injected into the seed cavity of muskmelon and honeydew inhibited softening (Ritenour et al., 1997). Furthermore, ethanol solution prolonged the vase life of cut carnations by suppressing respiration and transpiration (Pun et al., 2001).

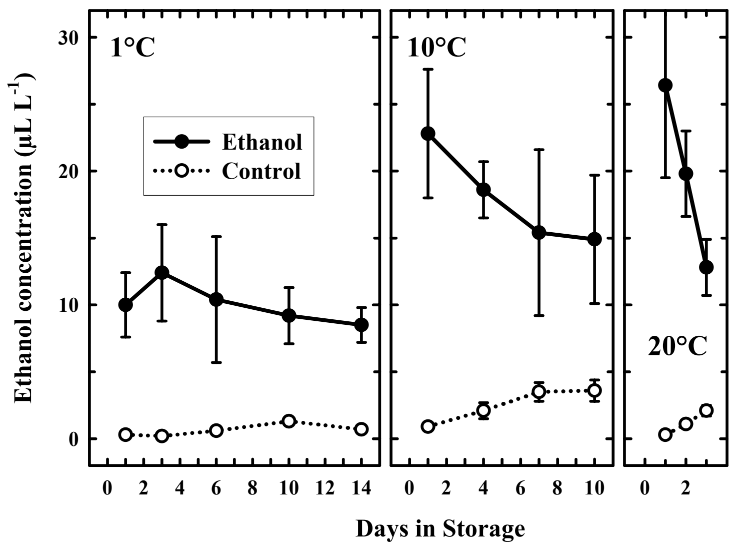

Fig. 5. Ethanol concentration in the headspace of clamshell with or without ethanol pad. 'Lapins' cherries were packed in the clamshell and stored at 33, 50 and 68°F, respectively (2005).

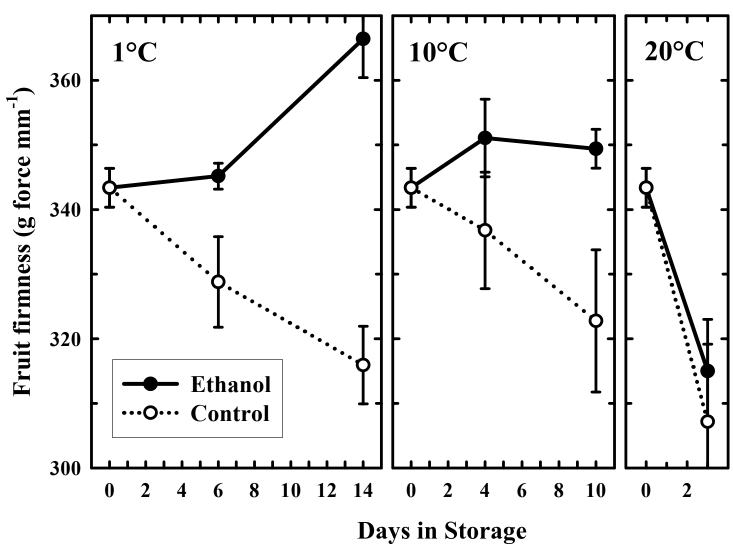

Fig. 6. Effect of ethanol pad on fruit firmness of 'Lapins' cherries. Fruit were packed in the clamshell and stored at 33, 50 and 68°F, respectively (2005).

Fruit coating and other dipping treatments (Table 1-3): The following experimental or commercial coatings and other chemical agents were used, alone or in combination. 1) Natural or artificial film-formers, such as carnauba, resin, chitosan or sucrose fatty acid esters which provide a barrier for protecting against moisture loss while moderately modifying fruit internal atmosphere; 2) Antioxidant agents, such as acetyl cysteine, ascorbic acid or 4-hexyl resorcinol to protect fruit and stems from discoloration; 3) Calcium salts which maintain membrane system of plant cells and increase fruit firmness; 4) Gibberellic acid, a plant regulator which may delay the senescence process of fruit; and 5) A sanitizer, such as peroxyacetic acid. Dipped fruit were stored at 33°, 50°, or 68°C to simulate the commercial storage and marketing in cold room or container car, cold shelf, or ambient shelf. We conducted the coating experiments for two years (2004 and 2005). Treatments that showed good results in 2004 were evaluated again in 2005.

Sucrose fatty acid esters, resins and vegetable oil emulsions are major commercial coatings for cherries. Most of these coatings, more or less, prevented moisture loss of fruit (Table 1). Fruit coated with sucrose fatty acid ester had the highest gloss (data not shown). However, these coatings did not significantly improved appearance of cherries (Table 2). Chitosan is a relatively new coating material. Chitosan forms a film when applied on fruit surface, which resulted in reducing moisture loss, modifying internal atmosphere of fruit, and reducing decay (Bai and Baldwin, 2002). Chitosan also decreased loss of fruit firmness and prolonged stem retention (Table 2). El Gaouth (1991, 1992, and 1997) reported that chitosan coating reduce decay for tomato, pepper and strawberries, therefore it could be a promising coating for cherries, too.

Table 1. Water loss (%) of cherry fruits coated with different formulations and then stored for 28 days at 33 °F (2004)

Treatment	Bing	Lambert	Lapins
Carnauba	-	2.77 b [z]	3.32 ab
Chitosan I	2.14 a	-	-
Chitosan II	2.54 a	3.25 a	2.14 c
Sucrose fatty acid ester	2.32 a	2.20 c	-
Resin I	-	-	2.58 b
Resin II	-	-	2.58 b
Resin III	-	-	1.91 c
Control	2.32 a	3.28 a	3.75 a

[z] Mean value (n = 3) not followed by the same letter are significantly different (P<0.05) by Duncan's multiple range test.

A firming agent, Ca propionate also extended stem retention (Table 2). Ca^{++} has been applied in horticultural crops preharvest and postharvest to improve the postharvest stability of produce (Patterson et al., 1983).

Table 2-1. Bing: effect of coating, gibberellic acid, and calcium salt dipping on fruit and stem quality of sweet cherries after storage at 33 °F for 14 days (2004)

Treatment	Fruit		Stem	
	Firmness (g force mm^{-1})	Appearance index [z]	Detachment force (g force)	Appearance index
Film forming agents				
Carnauba	293 b [y]	0.39 b	511 bc	0.80 a
Chitosan I	332 a	0.46 ab	546 b	0.73 ab
Chitosan II	331 a	0.47 ab	643 a	0.71 ab
Sucrose fatty acid ester	290 b	0.41 b	463 c	0.87 a
GA3				
10 ppm	282 b	0.40 b	401 d	0.73 ab
50 ppm	269 c	0.47 ab	466 c	0.70 ab
100 ppm	264 c	0.49 a	467 c	0.71 ab
Firming agents				
CaCI2	292 b	0.39 b	452 cd	0.61 b
Ca Propionate	317 ab	0.50 a	642 a	0.68 ab
Control	289 b	0.42 b	423 d	0.60 b

[z] Index for stem appearence: 0 = clear; 1 = more than 75% of whole stem length browned; index for fruit appearance: 0 = clear; 1 = inedible.

[y] Mean value (n = 3) not followed by the same letter are significantly different ($P<0.05$) by Duncan's multiple range test.

Table 2-2. Lambert: effect of coating, gibberellic acid, and calcium salt dipping on fruit and stem quality of sweet cherries after storage at 33 °F for 14 days (2004)

Treatment	Fruit		Stem	
	Firmness (g force mm^{-1})	Appearance index [z]	Detatchment force (g force)	Appearance index
Film forming agents				
Carnauba	283 ab	0.71	608 b	0.17 b
Chitosan II	287 ab	0.75	747 a	0.16 b
Sucrose fatty acid ester	288 ab	0.76	492 cd	0.18 b
GA3				
10 ppm	310 a	0.75	588 bc	0.15 b
50 ppm	292 ab	0.69	489 cd	0.15 b
100 ppm	270 b	0.65	528 c	0.17 b
Firming agents				
CaCI2	295 ab	0.71	509 cd	0.22 b
Ca Propionate	296 a	0.72	612 b	0.35 a
Control	261 c	0.71	449 d	0.17 b

[z] Index for stem appearence: 0 = clear; 1 = more than 75% of whole stem length browned; index for fruit appearance: 0 = clear; 1 = inedible.

[y] Mean value (n = 3) not followed by the same letter are significantly different ($P<0.05$) by Duncan's multiple range test.

Table 3. Effect of coating and other dipping treatments and ethanol-release pad on fruit and stem quality of 'Lapins' cherries. Fruit were stored at 32°F for 14 days (2005)

Treatment	Weight loss (%) [z]		Stem quality index [y]		Fruit quality index	
	Regular	Ethanol	Regular	Ethanol	Regular	Ethanol
Chitosan	12.5 a [x]	13.1 a	1.4 f	1.7 f	2.7 d	3.6 cd
Sucrose fatty acid esters	8.8 b	10.6 ab	6.3 c	7.7 ab	5.1 a-d	5.0 a-d
Ca^{++} + antioxidants	6.6 b	5.6 b	3.6 e	5.7 cd	6.0 a-c	6.8 a-c
Peroxyacetic acid	7.5 b	10.3 ab	4.9 d	7.9 ab	8.1 a	7.3 ab
Control	13.1 a	13.6 a	7.3 b	8.6 a	6.4 a-c	4.0 b-d

[z] + 1 day at 68°F
[y] Stem and fruit index: 1 = best; 10 = worst.
[x] Mean value (n = 3) not followed by the same letter are significantly different ($P<0.05$) under same attribute.

Stem coating and other dipping treatments (Table 4): In 2004, cherry stems were dipped in different coatings, Ca salts and GA3, respectively, using a screen system which holds the fruit when stems are in the solution. GA3 and chitosan coating decreased stem browning of 'Bing' and 'Lapins' cherries, respectively (Table 4). In 2005, 'Lapins' cherry stems were dipped in chitosan, GA3, paraffin + polyethylene, carnauba or shellac coating/solution. Paraffin + polyethylene coating decreased water loss and browning, and prevented stem detaching (data not shown). We observed surface wax and stomata structure of cherry stem under scanning electricity microscopy (SEM). The results shows that there were clear stomata on the stem and the coating did not cover the stomata well. Surface natural wax was destroyed rapidly at ambient temperature. Shellac and paraffin coating on the surface cracked easily, but chitosan coating showed a good cover on the stem surface (data not shown).

Table 4. Effect of stem coating with different formulations on stem quality of cherries. Fruit were stored for 14 days at 33 °F after coating (2004)

Treatment	Browning index [z]		
	Bing	Lambert	Lapins
Film forming agents			
Carnauba			0.51 b [y]
Chitosan I	0.45 b		
Chitosan II		0.49 ab	0.12 d
Sucrose fatty acid ester	0.4 b	0.53 a	
Resin I			0.67 a
Resin II			0.63 ab
Resin III			0.65 ab
GA3			
10 ppm	0.38 bc	0.46 ab	0.70 a
50 ppm	0.30 c	0.53 a	0.67 a
100 ppm	0.35 bc	0.46 ab	0.4 bc
Firming agents			
CaCI2	0.45 b	0.52 a	0.74 a
Ca Propionate	0.58 a	0.52 a	
Control	0.43 b	0.37 b	0.32 c

[z] Index: 0 = clear; 1 = more than 75% of whole stem length browned.

[y] Mean value (n = 3) not followed by the same letter are significantly different ($P<0.05$) by Duncan's multiple range test.

Literature cited:

Bai, J., Abe, K., Kurooka, H. 1990. Effect of harvest maturity, perforation ratio of polyethylene package and storage temperature on quality of Hassaku (Citrus hassaku hort. Ex Tanaka) fruit. J. Japan. Soc. Cold Preserv. Food. 16:97—104.

Bai, J., Baldwin, EA. 2002. Postprocessing dip maintains quality and extends the shelf life of fresh-cut apple. Proc. Fla. State Hort. Soc. 115:297-300.

Bai, J., E.A. Baldwin, R. Soliva-Fortuny, J.P. Mattheis and J.K.Brecht. 2004. Effect of pretreatment of intact 'Gala' apple with ethanol vapor, heat or 1-methylcyclopropene on quality and shelf life of fresh-cut slices. J. Amer. Soc. Hort. Sci. 129:583-593.

El Gaouth, A., Arul, J., Wilson, C., Benhamou, N. 1997. Biochemical and cytochemical aspects of the interactions of chitsan and Botrytis cinerea in bell pepper fruit. Postharvest Biol. Technol. 12:183-194.

El Gaouth, A., Ponnoampalam, R., Castaigne, F., Arul, J. 1992. Chitosan coating to extend the storage life of tomatoes. HortSci. 27:1016-1018

El Gaouth, A., Arul, J., Ponnoampalam, R., Boulet, M. 1991. Chitosan coating effect on storability and quality of fresh strawberries. J. Food Sci. 56.: 1618-1620.

Patten, K., Patterson, ME., Kupferman, E. 1983. Reduction of surface pitting in sweet cherries. Post Harvest Pomology Newsletter, 1 (2): pp6.

Plotto, A., J. Bai, J.A. Narciso, J.K. Brecht, and E.A. Baldwin. 2006. Ethanol vapor prior to processing extends fresh-cut mango shelf-life by decreasing spoilage, but does not always delay ripening. Postharvest Biol. Technol. 39: 134-145.

Pun, U.K., Rowarth, J.S., Barnes, M.F., and Heyes, J.A. 2001. The role of ethanol or acetaldehyde in thebiosynthesis of ethylene in carnation (Dianthus caryophyllus L.) cv. Yellow Candy. Postharvest Biol. Technol. 21:235-239.

Ritenour, M.A., Mangrich, M.E., Beaulieu, J.C., Rab, A., and Saltviet, M.E. 1997. Ethanol effect on the ripening of climacteric fruit. Postharvest Biol. Technol. 12:35-42.

Saltveit, M.E., and Mencarelli, F. 1988. Inhibition of ethylene synthesis and action in ripening tomato fruit by ethanol vapors. J. Amer. Soc. Hort. Sci. 113:572-576.

Suzuki, Y., Uji, T., Terai, H. 2004. Inhibition of senescence in broccoli florets with ethanol vapor from alcohol powder. Postharvest Biol. Technol. 31: 177-182.