Effect of Seasol® fertigation on post-harvest quality of strawberry

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Summary

A previous study in the 2016 season demonstrated the beneficial effects of Seasol® fertigation on fungal disease inhibition and postharvest quality in strawberry fruit (Lopresti et al., 2016). The results from a trial repeated in the 2018 season confirms that Seasol® fertigation significantly and consistently reduces fungal rot incidence and severity under various storage and marketing scenarios, whilst also marginally improving fruit flavour via higher SSC to acid ratio, and visual quality as a result of more uniform red surface colour. Reducing the potential for development of fungal rots during storage and marketing is commercially important and can result in less wastage, higher financial returns, and in greater retailer and consumer confidence that they are receiving and consuming a high quality product with reasonable shelf-life.

Although Seasol® treatment did not significantly increase soluble solids concentration (SSC), titratable acidity or SSC to acid ratio in the current trial, in both seasons it was found that SSC to acid ratio was up to 0.5 to 1 units higher in treated fruit compared to control fruit mainly due to a lower citric acid concentration in treated fruit. Higher SSC to acid ratio is usually associated with better flavour in temperate fruit and thus the potential benefits of Seasol® fertigation in improving berry eating quality requires further investigation. In the 2018 experiment red colour uniformity was up to 4% higher in treated fruit and significantly greater than in control fruit, confirming results from 2016 where no significant difference in colour uniformity was found but treated fruit were again 3 to 4% more uniformly red than control fruit. Although the difference in red uniform colour was marginal in both seasons any improvement in visual quality can potentially result in more consumer purchases and higher returns for growers.

Among two seasons of trials Seasol® fertigation treatment significantly reduced the development of fungal disease incidence and severity in strawberry during postharvest storage for up to 10 days at 4°C. In 2018 a relative reduction of 50% in both disease incidence and severity were observed in treated fruit stored at 4°C for 5 and 10 days.

Scientific recommendations

Based on two seasons of experiments showing that Seasol® fertigation reduces postharvest disease development, and improves quality, in strawberry, it is recommended that future studies focus on:

- One more season of experiments to further confirm the beneficial effects of Seasol® fertigation on strawberry visual quality and flavour;

- Determining the biochemical mechanism by which postharvest fungal disease development is inhibited in strawberry fruit treated with Seasol®

Experimental objectives

The objectives of this preliminary experiment were to:

- Investigate the effect of Seasol® fertigation treatment on visual quality, flesh firmness and composition of marketable berries at harvest;
- Determine whether Seasol® fertigation treatment reduces fungal disease incidence and severity compared to the untreated control after postharvest storage of fruit.

Postharvest experimental methods

Fruit harvest, delivery and preparation

At each of three harvests strawberry fruit were picked from each field plot. Fruit were supplied for quality assessments on the 6th January, 27th February and 18th May 2018. Both treated and control fruit supplied at the third harvest showed poor colour development and were not of marketable quality and thus were assessed or placed in cool storage. At each harvest 15 to 25 fruit per field plot were carefully picked and placed in a ventilated strawberry punnet. Strawberries were then placed in an esky containing Refreeze™ ice packs and transported to a postharvest laboratory where they were refrigerated overnight at 3 - 4 °C. Within 24 hours of harvest ten fruit per punnet were selected and removed for quality assessments whilst the remaining fruit were placed back in cool storage to be assessed for fungal disease after storage.

Experimental design

The experimental unit in the trial was a field plot which was represented by a single punnet once fruit were harvested. The experiment was a randomised complete block design with two factors, harvest and treatment, and eight replicates (field plots) per treatment. At harvest ten fruit per punnet were assessed for quality whilst remaining fruit were placed in cool storage at 4°C and 75% relative humidity prior to disease assessments. First harvest fruit were assessed for disease incidence and severity after storage at 4°C for 3 and 7 days, whilst second harvest fruit were assessed after storage at 4°C for 5 and 10 days,

Fruit quality assessments

At each harvest fruit in each punnet were weighed and ten fruit per punnet (field plot) were randomly selected for quality assessments avoiding very small fruit. The ten fruit were then weighed and after warming to 18°C each fruit was assessed for visual quality, colour uniformity, flesh firmness, flavour (1st harvest only) and soluble solids concentration. An unfiltered composite juice sample from the ten fruit per punnet was also collected for measurement of titratable acidity and placed at -20°C storage.

Visual quality

Each fruit was scored for overall visual quality using a 5-point rating scale where 5 = excellent, 4 = very good; 3 = good; 2 = poor; and 1 = very poor. Fruit with a score of 3 or less would be considered unmarketable. The main parameters considered when assessing loss of visual quality in each fruit were bruising or soft spots, poor colour uniformity, misshapen fruit and very dark fruit.

Figure 1. Examples of strawberry fruit with reduced visual quality due to soft spots, dark colour, poor colour uniformity and poor shape.

Colour uniformity

Each fruit was scored for uniformity of red surface colour as a percentage of fruit surface (modified from Cheng et al., 2016) with 100% representing fully-uniform red colour (i.e., no green or light red colour on a fruit) (Fig. 2).

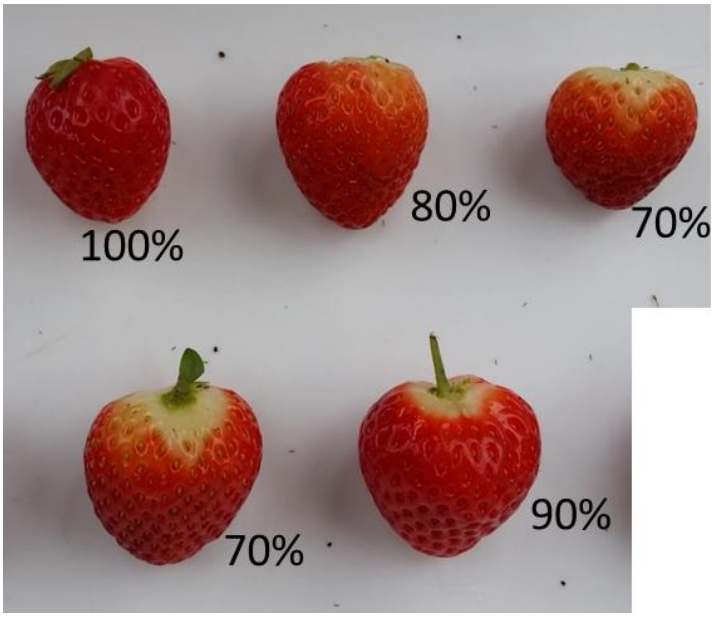

Figure 2. Example of uniform red colour range encountered in strawberry fruit.

Flesh firmness

Flesh firmness was measured on both cheeks of each fruit at its widest point with a hand-held Agrosta® Durofel DFT 100 digital firmness tester using the Shore A hardness 0 to 100 scale where 0 = extra soft, 20 = soft, 40 = medium soft, 70 = medium hard and 90 = hard. During firmness measurements soft spots on fruit were avoided. The firmness tester was calibrated to zero prior to measurements at each harvest.

Fruit flavour score

Each fruit at the first harvest was scored for overall flavour after tasting by a single assessor trained in fruit sensory assessment using a 5-point hedonic rating scale (modified from Jouquand and Chandler, 2008; and Azodanlou et al., 2003), where 5 = excellent (very sweet), 4 = very good (sweet); 3 = good (sweet/ sour); 2 = poor (not sweet/ sour); and 1 = very poor (not sweet/ not sour). The bottom half of each berry was tasted and spat out with distilled water used to clear the palate between tastings. Fruit with a score of 1 or 2 would be considered too sour or too tasteless for a majority of consumers. The main parameters considered when assessing flavour in each fruit were overall flavour and aroma, balance between sweetness and acid, juiciness and blandness.

Soluble solids concentration (SSC)

SSC in °Brix was measured by slicing the tip of each fruit with a knife and squeezing fruit to release approximately 0.5 ml of juice onto the lens of a temperature-compensated digital refractometer (ATAGO PAL-1) with a measurement accuracy of ± 0.2 °Brix (Tonutare et al., 2009; Gil et al., 1997). The refractometer was calibrated with distilled water prior to SSC measurements at each harvest.

Titratable acidity

After SSC measurements the ten fruit per punnet were crushed in a plastic bag by hand, 8 ml of juice collected in an eppendorf tube, and juice frozen at -20°C until completion of all harvests. All juice samples were thawed at 20°C and 3 ml of juice from each sample diluted in 5 ml of distilled water once juice temperature in all samples was above 15 °C. Titratable acidity of each sample was then measured via endpoint titration to pH 8.2 with 0.1 M NaOH (Tonutare et al., 2009; Gil et al., 1997) using an automatic titrator (Steroglass Titre X), AS23 Micro autosampler and Hamilton® Slimtrode pH electrode. Mean titratable acidity for fruit in each punnet was calculated as grams of citric acid equivalent per litre of juice using the NaOH titre volume. Sugar to acid ratio for each punnet (field plot) was calculated from mean SSC and titratable acidity measurements using the formula; SSC to acid ratio = SSC ÷ titratable acidity × 10.

Fungal disease assessments

Ten to twenty fruit per punnet (field plot) were assessed after cool storage at 4°C for fungal disease symptoms and their severity. Disease severity was scored on each infected fruit using a five-point

rating scale (modified from Nunes et al., 2012) for percent of fruit surface infected where: 1 = 1 to 5%; 2 = 6 to 15%; 3 = 16 to 25%; 4 = 26 to 50%; and 5 = > 50%. Mean disease incidence per punnet was calculated as; % Incidence = number of fruit with disease ÷ total fruit in the punnet × 100.

For each punnet mean disease severity (DS) was calculated using the Townsend-Heuberger formula (Townsend & Heuberger, 1943):

$DS\ (\%) = \sum(dn) \div DN \times 100$; where

d = degree of infection according to severity scoring scale (i.e., 1, 2, 3 or 4)

n = number of fruit per disease severity category

D = highest degree of infection possible

N = total fruit within a punnet assessed for disease symptoms

Statistical analyses

To determine the harvest and treatment main effects, and interaction effects, on fruit quality and disease development, data were analysed as a factorial experiment with eight replicates per treatment using two-way ANOVA in GenStat 17 (VSN International Ltd., Oxford, UK).

Violations of the ANOVA assumption of normality in the data, such as non-normality (Skewness, Kurtosis) or heterogeneity of treatment variance, were assessed using residual error plots, skewness and kurtosis tests of normality, and Bartlett's test of homogeneity of variance. Where necessary the appropriate data correction transformation was applied to data prior to ANOVA based on optimal values of lambda calculated from Box-Cox analysis in Genstat.

Multiple comparisons of treatment means were conducted at each assessment using Fisher's Least Significant Difference (LSD) test with statistical differences between means determined at a 5% significance level ($\alpha = 0.05$). Note that in the report the term 'significant' refers to statistical significance rather than to effects that may be commercially significant. Treatment means that were back-transformed from transformed data used for ANOVA are indicated in results tables.

Results & Discussion

Presentation of results

For each quality factor measured during fruit assessments Analysis of Variance (ANOVA) results are presented in a consistent format where mean values for treated and control fruit are shown at each assessment i.e., 1st harvest, after cool storage for 5 days etc. Three *P*-values from ANOVA are provided in each table where a value of $P < 0.05$ indicates a statistically significant effect. In each table 'Treatment *P*-value' indicates whether Seasol® fertigation treatment is significantly better than no treatment. 'Harvest or Assessment *P*-value' indicates whether the time of assessment has an effect on quality or disease development when the average of the two treatments are combined. Finally 'Treatment x Harvest or Assessment *P*-value' indicates whether there is an interaction between treatment and assessment, that is whether any differences between treatments are consistent across assessments or not, with $P < 0.05$ indicating that the time of fruit harvest or removal from storage influences the size of the observed difference, if any, between treated and control fruit.

Strawberry fruit quality

Berry weight and visual quality

No significant difference in mean berry weight was found among treated and control fruit at either first or second harvest with less than 1 g difference in overall mean berry weight (Table 1). At first harvest treated fruit were approximately 2 g larger than control fruit but no such difference was observed at the second harvest.

Table 1. Harvest and treatment effect on mean berry weight among fruit; within a harvest different letters indicate a statistically significant difference at $P < 0.05$.

	Berry weight (g)		
Treatment	**1st harvest**	**2nd harvest**	**Overall**
Seasol	23.4 a	21.0 a	22.2 a
Control	21.4 a	21.2 a	21.3 a
Treatment *P*-value	0.262		
Harvest *P*-value	0.116		
Treatment x Harvest *P*-value	0.176		

Both treated and control fruit had very uniform red colour at both harvests but at the second harvest and overall, treated fruit were significantly more uniform in mean red surface colour, by 4% and 3%, respectively (Table 2). Although no significant difference in fruit colour uniformity was

found in the 2016 strawberry trial, treated fruit tended on average to also be 2 to 6% higher in colour uniformity than control fruit.

Table 2. Harvest and treatment effect on mean berry colour uniformity; within a harvest different letters indicate a statistically significant difference at $P < 0.05$.

	Berry colour uniformity (%)		
Treatment	**1st harvest**	**2nd harvest**	**Overall**
Seasol	98.3 a	88.9 a	93.6 a
Control	97.0 a	85.0 b	91.0 b
Treatment *P*-value	0.003		
Harvest *P*-value	<0.001		
Treatment x Harvest *P*-value	0.094		

No significant difference in mean visual quality (VQ) score was found among treated and control fruit at either first or second harvest, or overall (Table 3). Due to wet season mean VQ score was less than 4 in both treated and control fruit at both harvests (Fig. 3 and 4) whereas in 2016 mean VQ among all fruit and harvests was consistently above 4. Both treated and control fruit were of poor quality at the third harvest (Fig. 5).

Table 3. Harvest and treatment effect on mean berry visual quality score; within a harvest different letters indicate a statistically significant difference at $P < 0.05$.

	Berry visual quality score		
Treatment	**1st harvest**	**2nd harvest**	**Overall**
Seasol	3.8 a	3.2 a	3.5 a
Control	3.8 a	3.1 a	3.5 a
Treatment *P*-value	0.202		
Harvest *P*-value	<0.001		
Treatment x Harvest *P*-value	0.555		

Figure 3. Comparison of visual quality among Seasol-treated (top) and control (bottom) fruit picked at the 1st harvest.

Figure 4. Visual quality among fruit picked at the 2nd harvest.

Figure 5. Example of poor quality fruit picked at 3rd harvest.

Berry firmness and composition

As in the 2016 trial no significant difference in mean berry flesh firmness among treated and control fruit was found as measured using the Shore A hardness scale (Table 4), with fruit from the second harvest being significantly less firm than fruit from the first harvest.

Table 4. Harvest and treatment effect on mean berry flesh firmness; within a harvest different letters indicate a statistically significant difference at $P < 0.05$.

	Berry flesh firmness (Shore A)		
Treatment	**1st harvest**	**2nd harvest**	**Overall**
Seasol	54.2 a	44.6 a	49.4 a
Control	55.4 a	44.9 a	50.2 a
Treatment *P*-value	0.775		
Harvest *P*-value	<0.001		
Treatment x Harvest *P*-value	0.867		

Mean fruit SSC among treated and control fruit at three assessments was very similar with no significant difference among treatments at each assessment (Table 5). Fruit were more than 1 °Brix lower in SSC compared to the 2016 experiment but in both trials little difference in SSC was found among treated and control fruit.

Table 5. Harvest and treatment effect on mean berry soluble solids concentration (SSC); within an assessment different letters indicate a statistically significant difference at $P < 0.05$.

	Berry SSC (°Brix)			
Treatment	**1st harvest**	**1st harvest + 7 days**	**2nd harvest**	**Overall**
Seasol	8.4 a	9.2 a	9.2 a	8.4 a
Control	8.3 a	9.2 a	9.1 a	8.3 a
Treatment *P*-value	0.513			
Harvest/ Assessment *P*-value	<0.001			
Treatment x Harvest *P*-value	0.918			

At each assessment the effect of treatment on mean berry titratable acidity (TA) was not significant but on average fruit from control plots were 0.2 to 0.4 g/L lower in citric acid than fruit from among treated plots (Table 6), whilst a consistent difference in TA was found across assessments. Mean berry SSC to acid ratio was approximately two units lower among fruit harvest in 2018 as compared to that in 2016 but in both cases no significant difference in SSC to acid ratio was found between treated and control fruit (Table 7). In 2018 treated fruit were found to be consistently higher in SSC to acid ratio across assessments by 0.4 to 0.7 units and this result could be correlated with the significant difference in fruit flavour score found among treated and control fruit from the first harvest (Table 8), as a higher SSC to acid is strongly associated with improved flavour in strawberry fruit (Jouquand and Chandler, 2008; Pelayo-Zaldivaer et al., 2005; Wozniak et al., 1997; Shamaila et al., 1992).

Table 6. Harvest and treatment effect on mean berry titratable acidity; within an assessment different letters indicate a statistically significant difference at $P < 0.05$.

	Berry titratable acidity (g citric acid/L juice)			
Treatment	**1st harvest**	**1st harvest + 7 days**	**2nd harvest**	**Overall**
Seasol	7.4 a	8.9 a	8.3 a	8.2 a
Control	7.8 a	9.2 a	8.5 a	8.5 a
Treatment *P*-value	0.229			
Harvest/ Assessment *P*-value	<0.001			
Treatment x Harvest *P*-value	0.939			

Table 7. Harvest and treatment effect on mean berry SSC to acid ratio; within an assessment different letters indicate a statistically significant difference at $P < 0.05$.

	SSC to acid ratio			
Treatment	**1st harvest**	**1st harvest + 7 days**	**2nd harvest**	**Overall**
Seasol	11.4 a	10.5 a	11.1 a	11.0 a
Control	10.8 a	10.0 a	10.8 a	10.5 a
Treatment *P*-value	0.187			
Harvest/ Assessment *P*-value	0.136			
Treatment x Harvest *P*-value	0.935			

Table 8. Treatment effect on mean berry flavour at a single harvest; different letters indicate a statistically significant difference at $P < 0.05$.

	Berry flavour score
Treatment	**1st harvest**
Seasol	2.7 a
Control	2.1 b
Treatment *P*-value	0.001

Fungal disease incidence and severity

Berry fungal disease infection was observed at all assessments in both treated and control fruit with disease incidence marginally, but not significantly, higher in first harvest control fruit compared to treated fruit after cool storage at 4°C for 3 and 7 days (Table 9). Seasol® fertigation treatment significantly reduced mean fungal disease incidence compared to control fruit at both assessments on berries from the second harvest stored at 4°C for 5 and 10 days. Grey Mould (*Botrytis cinerea*) and Rhizopus rot (*Rhizopus* spp.) were the main pathogens observed with *B. cinerea* the pathogen observed in higher levels during the four assessments (Fig. 6 and 7).

As for disease incidence, a significant reduction in disease severity was found in treated fruit relative to control fruit among both harvests, with high disease severity observed in second harvest control fruit after storage at 4°C for 10 days (Table 10). In the 2016 trial high disease severity was observed among all treatments and assessments, and although differences in severity between treated and control fruit were not significant, disease severity was consistently higher in untreated berries.

In 2016 no disease symptoms were observed on either treated or control fruit after postharvest storage at 4°C and thus fruit were incubated at 20°C to induce disease expression. Although disease incidence was much higher in fruit during the 2016 experiment as fruit were incubated at 20°C prior to assessment, a significant reduction in disease incidence due to treatment was also found, and among two seasons of trials Seasol® fertigation treatment appears to reduce the development of fungal disease incidence and severity in strawberry during postharvest storage and marketing.

Table 9. Harvest and treatment effect on mean berry fungal rot incidence; within an assessment different letters indicate a statistically significant difference at $P < 0.05$.

	Disease incidence (%)				
Treatment	**1st harvest + 3 days**	**1st harvest + 7 days**	**2nd harvest + 5 days**	**2nd harvest + 10 days**	**Overall**
Seasol	1.0 a	2.2 a	2.8 a	24.5 a	7.6 a
Control	2.9 a	5.1 a	15.4 b	51.7 b	18.8 b
Treatment *P*-value	<0.001				
Assessment *P*-value	<0.001				
Treatment x Assessment *P*-value	<0.001				

Table 10. Harvest and treatment effect on mean berry fungal rot severity; within an assessment different letters indicate a statistically significant difference at $P < 0.05$.

	Disease severity (%)				
Treatment	**1st harvest + 3 days**	**1st harvest + 7 days**	**2nd harvest + 5 days**	**2nd harvest + 10 days**	**Overall**
Seasol	0.6 a	2.1 a	0.6 a	15.2 a	4.6 a
Control	1.8 a	4.3 b	4.5 b	33.7 b	11.1 b
Treatment *P*-value	<0.001				
Assessment *P*-value	<0.001				
Treatment x Assessment *P*-value	<0.001				

Figure 6. Examples of fungal disease incidence and severity among Seasol-treated fruit from the second harvest after storage at 4°C for 10 days.

Figure 7. Examples of fungal disease incidence and severity among control fruit from the second harvest after storage at 4°C for 10 days.

Conclusions

Two seasons of postharvest trials to determine the effect of Seasol® fertigation on strawberry quality have demonstrated that treatment significantly and consistently reduces fungal rot incidence and severity under various storage and marketing scenarios, whilst also marginally improving fruit flavour via higher SSC to acid ratio, and red colour uniformity. Seasol® fertigation treatment does not appear to significantly increase SSC in strawberries but a slight reduction in acidity compared to control fruit has been observed in both seasons.

Reducing rot incidence and severity in strawberries is critical in reducing wastage during commercial storage and marketing whilst also resulting in greater retailer and consumer confidence that they are receiving and consuming a high quality product with reasonable shelf-life.

Literature cited

Cheng JH, Sun DW, Nagata M, and JG Tallada (2016). Quality Evaluation of Strawberry, Chapter 13 *in Computer Vision Technology for Food Quality Evaluation*, Elsevier Inc., p. 327-349.

Gil MI, Holcroft DM, and AA Kader (1997). Changes in strawberry anthocyanins and other polyphenols in response to carbon dioxide treatments, J. Agric. Food Chem., 45:1662-1667.

Jouquand C and C Chandler (2008). A sensory and chemical analysis of fresh strawberries over harvest dates and seasons reveals factors that affect eating quality, J. Amer. Soc. Hort. Sci., 133(6):859-867.

Lopresti J, Villalta O and S Mattner (2016). Effect of Seasol® treatment on post-harvest quality of strawberry. Confidential report for Seasol® International, 26 pp.

Nunes MCN, Morais AMMB, Brecht JK, Sargent SA, Bartz JA, Allen RA, Lee JH, Pires DM amd J Pittet-Moore (2012). Occurrence of gray mold in stored strawberries as affected by ripeness, temperature and atmosphere. Proc. Fla. State Hort. Soc., 125:287-294.

Pelayo-Zaldivar C, Ebeler SE and AA Kader (2005). Cultivar and harvest date effects on flavour and other quality attributes of California strawberries, J. Food Quality, 28:78-97.

Shamaila M, Baumann TE, Eaton GW, Powrie WD, BJ Skura (1992). Quality attributes of strawberry cultivars grown in British Columbia, J. Food Sci., 57:696-699.

Tonutare T, Moor U, Molder K and P Poldma (2009). Fruit composition of organically and conventionally cultivated strawberry 'Polka', Agronomy Research (Special issue II), 755-760.

Townsend GR and JV Heuberger (1943). Methods for estimating losses caused by disease in fungicide experiments. Plant Disease Report 24: 340-343.

Wozniak W, Radajewska B, Reszelska-Sieciechowicz A and I Dejwor (1997). Sugars and acid content influence organoleptic evaluation of fruits of six strawberry cultivars from controlled cultivation, Acta. Hort, 439:333-336.