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Effects of Different Levels of Preharvest Shading on the Storage Quality of Strawberry (*Fragaria* x *ananassa* Duchesne) cv. Ostara II. Chemical Characteristics

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ABSTRAK

*Untuk mengkaji kesan penaungan sebelum tuai yang berlainan (74, 58, 48, 38 dan 5% penembusan cahaya yang dilambangkan sebagai S_0, S_1, S_2, S_3 dan S_4 masing-masing) ke atas buah strawberi (*Fragaria x ananassa *Duchesne) cv. Ostara yang sedang membesar, beberapa ciri ujikaji kimia (pH, jumlah pepejal larut dan keasidan tertitrat) yang berkaitan dengan mutu telah dijalankan. Hasil kajian menunjukkan walaupun darjah penaungan yang berlainan ini memberi kesan yang bererti ke atas ciri-ciri kimia yang dikaji, perbezaan ini hanya boleh dikesan pada buah yang dinaungi oleh S_4 dan S_3. Walau bagaimanapun, bagi jumlah pepejal larut, keputusan menunjukkan wujudnya interaksi yang bererti di antara lokasi dan jenis buah dan juga di antara hari penyimpanan dan jenis buah.*

ABSTRACT

*To study the effects of different levels of preharvest shading (74, 58, 48, 38 and 5% of light penetration which were denoted by S_0, S_1, S_2, S_3 and S_4 respectively) on developing strawberry (*Fragaria x ananassa *Duchesne) cv. Ostara fruits, some chemical tests (pH, total soluble solids and titratable acidity) associated with fruit quality were carried out. Results showed that although the different levels of preharvest shading were found to demonstrate a significant effect on the chemical parameters studied, this could only be detected in fruits shaded by S_4 and S_3. However, for total soluble solids, significant interactions were observed between location of fruit and fruit type and also between storage day and fruit type.*

INTRODUCTION

Part I (Osman and Dodd 1994) reported on a study of the effect of different levels of preharvest shading on the physical attributes of postharvest quality of strawberry cv. Ostara. Part II now describes changes in the chemical characteristics associated with postharvest quality.

The taste of sweetness and sourness is due primarily to the balance between sugar and water-soluble acid content (Huelin 1961; Moore and Sistrunk 1980). In the strawberry, a proper balance of these quality components not only produces the desired level of sweetness, but also enhances other flavour components (Moore and Sistrunk 1980). The latter are responsible for the typical strawberry taste (Went 1957). Sugar forms a high proportion of soluble solids (Huelin 1961).

Soluble solids content and acidity appear to be fairly consistent among cultivars (Scott and Lawrence 1975). Variations are mainly due to maturity, date of harvest and other field factors. Went (1957) pointed out that the sugar content is entirely a function of the light intensity to which the plants are subjected during the day and is independent of the photo- or nyctotemperature. However, he reported that the development of the aromatic substances or flavour components requires only a short period (not more than two hours daily) of high intensity light at low temperature and that the lower the phototem- perature, the stronger the taste. Many res- earchers have pointed out that citric acid is the dominant organic acid in strawberry fruit (Whiting 1958; Markakis and Embs 1964; Sistrunk and Cash 1973). They expressed percentage of titratable acidity as percent- age of citric acid. However, in this study, since no attempt was made to determine the dominant acid found in this strawberry variety, titratable acidity was expressed as ml of 0.1 M NaOH used per 6 ml fruit juice (Shaw *et al.* 1987). This experiment was carried out to study the effects of different levels of preharvest shading from flowering to harvest on the changes in the chemical (pH, total soluble solids and titratable acidity) characteristics associated with postharvest quality of strawberry fruits.

MATERIALS AND METHODS

Planting Materials and Fruit Source

The experiment was conducted at Wye College, University of London, England. The experimental details pertaining to the preharvest shading treatments and experimental design were reported earlier (Osman and Dodd 1994). Five levels of preharvest shading of 74, 58, 48, 38 and 5% light penetration (denoted as S_0, S_1, S_2, S_3 and S_4 respectively) were employed by covering the strawberry plants with netting of different levels of light penetration. The three fruit types (primary, secondary and tertiary) under these different levels of preharvest shading were further sub-divided into above (completely exposed) and below (hidden by leaves) indicating their location. The ripe fruits were harvested 32 ± 2 days after anthesis.

The same fruits, ten of each type (primary, secondary and tertiary) from each treatment and replicate used for the determination of fruit firmness (Osman and Dodd 1994) were used for the determination of total soluble solids, pH and titratable acidity of the fruits. The punctured fruits were immediately placed in labelled plastic bags and stored in a freezer (-80°C) for the determination of the above chemical characteristics.

Total Soluble Solids

The frozen strawberry fruits were thawed at ambient condition before crushing with a pestle in a mortar. The juice was squeezed through four thicknesses of cheesecloth (Duewer and Zych 1967; Shaw *et al.* 1987). Total soluble solids (TSS) of the expressed juice (15°C) were determined using a hand refractometer (Bellingham and Stanley model). Readings are presented in °Brix.

pH of Fruit Juice

The pH of the strained strawberry fruit juice was determined with a pH meter (Beckman Model 3500 Digital). Before each observation the accuracy and sensitivity of the pH meter were checked using standard solutions of pH 4 and 7.

Titratable Acidity

Juice from the fruit sample was passed through four layers of cheesecloth. Six ml of the expressed juice was diluted to 50 ml with distilled water and titrated with 0.1 M NaOH to pH 8.2, with a pH meter (Beckman Model 3500 Digital). The analysis was done in duplicate. Titratable acidity was expressed as ml of 0.1 M NaOH used per 6 ml of fruit juice (Shaw *et al.* 1987).

RESULTS

The ANOVA table in Table 1 shows the effect of different levels of preharvest shading, location of fruit, fruit types, storage time (days) and their interactions on total soluble solids, pH and titratable acidity of strawberry.

Total Soluble Solids

There was a significant response of total soluble solids content of the fruit to the different levels of preharvest shading (Table 1). The total soluble solids content was found to decrease with a decline in the percentage light penetration reaching the plants and fruits (Table 2). Fruits under S_4 which showed the lowest value were significantly different from fruits of the other levels. However, fruits under S_0, S_1 and S_2 did not show any significant difference.

Total soluble solids content also showed a significant increase with storage time (Table 2). Location of fruit alone did not affect total soluble solids content. Total soluble solids content was also found to be unaffected by the different fruit types (Table 2). Nevertheless, there was signifi-

TABLE 1
Mean squares of the analyses of variance of three parameters of strawberry fruits as influenced by different levels of preharvest shading.

Source of Variation	df	Total Soluble Solids (°Brix)	pH	Titratable Acidity (ml of 0.1 M NaOH per 6 ml fruit juice)
Shading (S)	4	99.9979**	1.2562**	76.122**
Error a	8	2.1170	0.0351	5.396
Location (L)	1	0.0271	0.0055	0.738
S x L	4	0.8192	0.0077	1.437
Error b	10	0.7743	0.0078	1.331
Day (D)	2	15.8082	0.0952*	41.853**
S x D	8	0.3569	0.0310	0.170
L x D	2	0.0040	0.0109	2.052
S x L x D	8	0.4399	0.0076	0.212
Error c	40	0.5590	0.0232	1.438
Fruit (F)	2	1.2760	0.1140*	2.052
S x F	8	1.2332	0.0234	1.882
L x F	2	3.8028**	0.0064	0.145
D x F	4	2.2438**	0.0474	0.497
S x L x F	8	0.7537	0.0277	2.308
S x D x F	16	0.4670	0.0209	1.638
L x D x F	4	0.5480	0.0221	0.672
Error d	124	0.4288	0.0234	1.397
Total	252			

*, ** are significant at 5% and 1% levels respectively

cant interactions between shading and fruit type, location of fruit and fruit type and storage time and fruit type (*Figs. 1a-1c*). Primary fruits that were hidden (below) by the leaves had a lower total soluble solids content than the exposed (above) fruits (*Fig. 1b*). However, the reverse was true for the tertiary fruits. At day 0, total soluble solids content of tertiary fruit was lower than that of primary fruits (*Fig. 1c*) but the reverse was true at day 4.

pH of Strawberry Fruit Juice

It was found that pH of fruit juice increased significantly with decreasing percentage of light

TABLE 2
Mean values for pH, total soluble solids and titratable acidity of strawberry fruits.

Major Effect	Total Soluble Solids (°Brix)	pH	Titratable Acidity (ml of 0.1 M NaOH/ per 6 ml fruit juice)
Shading (S)			
S_0 (Control)	8.48	3.40	9.36
S_1	8.08	3.46	8.82
S_2	7.93	3.47	8.76
S_3	7.45	3.52	8.34
S_4	5.04	3.82	6.25
$LSD_{0.05}$	0.65	0.08	1.03
Location (L)			
A	7.39	3.53	8.34
B	7.49	3.53	8.32
$LSD_{0.05}$	NS	NS	NS
Day (D)			
0	7.02	3.54	7.73
2	7.34	3.56	8.12
4	7.96	3.50	9.15
$LSD_{0.05}$	0.23	0.05	0.36
Fruit (F)			
F_1	7.53	3.56	8.45
F_2	7.30	3.49	8.28
F_3	7.27	3.55	8.27
$LSD_{0.05}$	NS	0.05	NS
Grand Mean	7.42	3.53	8.32

F_1, F_2, F_3 are primary, secondary and tertiary fruits respectively.
A and B are above and below (location of fruit) respectively.
S_0, S_1, S_2, S_3 and S_4 are 74, 58, 48, 38 and 5% light penetration respectively.
Day 0, Day 2 and Day 4 are 0, 2 and 4 days after harvest.
NS - Not Significant.

penetration from S_0 to S_4 (Table 2). However, no significant differences were detected between preharvest shading levels S_0 to S_2. This suggests that pH of fruit juice is only affected when subjected to a very low level of light intensity such as S_3 and S_4.

Location of fruits under the preharvest shading did not affect pH. The pH was found to be affected by storage time, whereby a significant decrease could only be observed between day 2 and day 4 (Table 2). A significant difference was found between secondary and the other fruit types but not between primary and tertiary fruits. None of the interactions were found to be significant (Table 1).

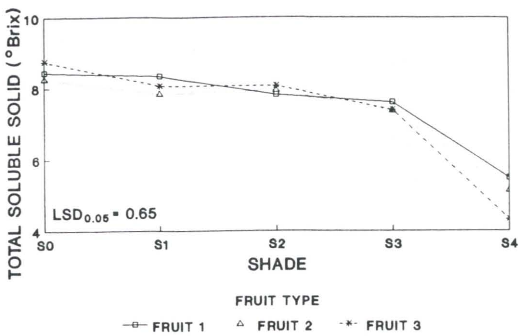

Fig. 1a

Fig. 1a: Interaction between levels of shading (S_0 to S_4) and fruit types (primary (F_1), secondary (F_2) and tertiary (F_3)) on total soluble solids content of the fruit juice. Values are means of fruits from all types under each shading level. Trend analysis is provided in Table 1

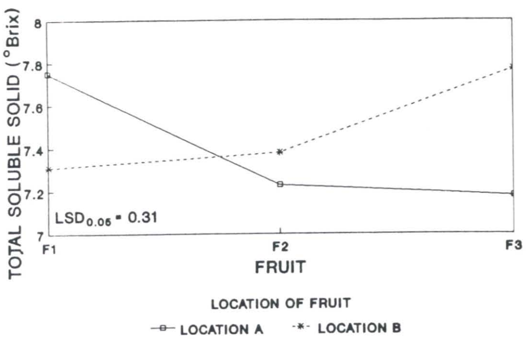

Fig. 1b

Fig. 1b: Interaction between location of fruit (above[A] and below[B]) and fruit types (primary (F_1), secondary (F_2) and tertiary (F_3)) on total soluble solids content of the fruit juice. Values are means of fruit from all types in each location. Trend anaylisis is provided in Table 1

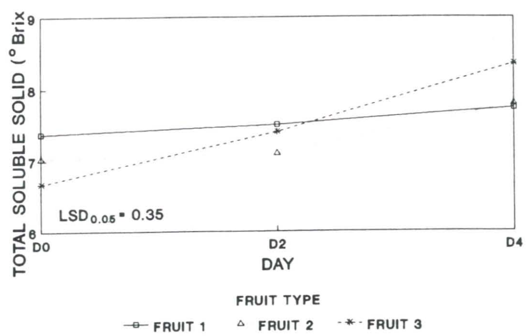

Fig. 1c

Fig. 1c: Interaction between storage time (day 0 to day 4) and fruit types (primary (F_1), secondary (F_2) and tertiary (F_3) on total soluble solids content of the fruit juice. Values are means of fruits from each day of storage. Trend analysis is provided in Table 1

Titratable Acidity

Fruit titratable acidity was found to decrease significantly with decreasing percentage light penetration reaching the plants and developing fruits (Tables 1 and 2). However, no significant difference was detected in the fruits shaded within the range of S_1 to S_3.

Fruit titratable acidity was also found to increase significantly during the storage time. By day 4, mean titratable acidity increased significantly (18.36%). The results in Table 1 indicated that titratable acidity of fruit juice was only significantly affected by very low levels of preharvest shading and storage time. All the other factors and interactions were not significant.

DISCUSSION

The chemical characteristics (pH, total soluble solids and titratable acidity) measured in this study were influenced significantly by the different levels of light penetration reaching the plants and developing fruits. There was a significant decrease in total soluble solids and titratable acidity with declining percentage light penetration from S_0 to S_4. Nevertheless, there was a significant increase in pH as the light intensity decreased. These findings confirm the observations that shading reduces soluble solids in apples (Heinicke 1966; Seeley *et al.* 1980; Robinson *et al.* 1983; Morgan *et al.* 1984) and in sweet cherries (Ryugo and Intrieri 1972; Patten and Proebsting 1986). The findings of these researchers and those of the present study are, however, in contrast to what has been stated by Sistrunk and Moore (1983). They mentioned that soluble solids are related to fruit size, being higher in smaller fruit within a cultivar. This is due to smaller cell size and compactness of fruit as well as greater density.

Nevertheless, results of fruit titratable acidity obtained in the present study were in contrast to those reported by Robinson *et al.* (1983) who found that fruit total acidity correlated negatively with percentage light penetration. As fruit ripens, starch levels decrease and soluble solids increase with the conversion of starch to sugar (Olsen and Martin 1980). Robinson *et al.* (1983), however, found that fruits from unshaded branches contained both greater solids and starch reserves than shaded fruits, in addition to a greater percentage of dry matter. They suggested that the effects of light environment do not seem to be due only to advanced maturity of unshaded fruits. The adverse effect of shading on fruit size, carbohydrate content and dry matter content suggests that with crop density held at a constant, the competition for resources among fruits and between fruits and shoots results in a linear reduction of fruit size, internal carbohydrate supply and dry matter content as light exposure is reduced (Heinicke 1966; Jackson and Palmer 1977; Jackson *et al.* 1977). However, in the present study fruit carbohydrate content was not determined.

All the quality attributes measured in the present study changed significantly with storage time (days). This was expected since the fruits under study were stored at ambient condition (20 ± 1°C, 70 ± 5% relative humidity). Our observation showed that fruits from all treatments (different levels of preharvest shading) were found to be unacceptable due to excessive surface dehydration and loss of glossiness after day 4 (Osman and Dodd 1994). These attributes were also observed in fruits which were not subjected to any preharvest shading treatment. Therefore, shading does not extend the storage life of strawberry fruit if it is just stored at ambient condition after harvest.

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