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VARIATION IN FATTY ACID COMPOSITION OF APPLES IN RELATION TO SOFT SCALD

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Abstract—The distribution of fatty acids within individual fruits was uneven early in storage. When soft scald developed in the fruit, the affected tissue contained less linoleic acid than sound tissue. Differences in fatty acid composition were also found between freshly harvested fruit from different trees within an orchard. Apples that were stored at 0° had a low linoleic acid content during the early weeks of storage when the fruit are susceptible to the disorder but the content then increased substantially during subsequent storage. It seems that a low linoleic acid content renders the fruit more susceptible to soft scald.

INTRODUCTION

Soft scald is a physiological disorder of apples that occurs during storage at temperatures below 2° and appears as discrete but irregularly shaped areas of browning of the skin and the underlying tissue with a sharp line of demarcation between the affected tissue and sound tissue. The disorder is normally manifested after 6–12 weeks storage and if the fruit show no symptoms after *ca* 12 weeks cool storage they are highly unlikely to develop symptoms on further storage. The susceptibility of fruit to develop the disorder varies, not only between cultivars but also within a cultivar, and different trees in an orchard invariably have differing susceptibility. The susceptibility also varies greatly between seasons; an orchard may be severely affected with soft scald in one season and be free of the disorder in the subsequent season [1–4].

The metabolic reactions leading to the development of the disorder are not known, but Wills *et al.* [5, 6] found that the application of a range of fatty acid Me esters and glyceride-type fats and oils to apples inhibited the development of soft scald. Various workers [7–11] have reported that the amount of the unsaturated fatty acids, linoleic and linolenic acids in the surface lipids of apples increased during cool storage. In this paper we have examined the fatty acid composition of Jonathan apples over three seasons for differences within fruit, between fruit from different trees, in sound and scald-affected tissues and changes during cool storage. We have attempted to relate these variations in lipid composition to differences in susceptibility of fruit to soft scald.

RESULTS

The distribution of fatty acids within a fruit was examined by determining the fatty acid composition of the lipids extracted from ten Jonathan apples of uniform size and maturity that had been each cut longitudinally into quarters (excluding the core). Table 1 shows that fatty acid composition was not always uniform between the four quarters from each fruit. It was considered that a difference of 4% in the amount of a fatty acid would represent a real difference between samples as the experimental method was able to reproduce the data to ±1% for each fatty acid for successive analyses using aliquots of the same apple sample. Seven of the ten fruits showed differences in the composition, for some fatty acids, of 4% or greater; thus more than half the fruit were considered to have an uneven distribution of fatty acids around the fruit.

Table 1. Composition of fatty acids within individual Jonathan apples stored at 0° for two weeks

	Fatty acid composition (% of total FA)				
Apple	16:0	18:0	18:1	18:2	18:3
1	17–22	3	4–13	43–48	23–27
2	17	2–5	4–5	48–52	23–28
3	20	3–4	4	43–44	28–29
4	15–16	2–3	3–7	48–50	25–30
5	14–15	1–2	3–4	43–45	34–40
6	16–19	3–4	4–5	46–50	24–28
7	15–17	3–4	3–4	47–49	27–31
8	15–17	3–4	4–9	47–49	22–31
9	12–13	2–3	3–4	50–52	29–31
10	13–14	3	3	57–59	22–23

A considerable range in fatty acid composition of surface lipids between fruit from different trees was also found (Table 2), with all acids showing substantial variation. No values are presented for linolenic acid since an unknown compound in the lipid fraction co-chromatographed with linolenate. The surface lipids were examined as they are associated with the area of the fruit that develops soft scald.

Table 2. Composition of fatty acids of surface lipids of Jonathan apples from ten trees in each of two orchards

	Fatty acid composition (% of total FA)				
Orchard	14:0	16:0	18:0	18:1	18:2
1	5–10	24–33	6–10	19–26	28–40
2	5–9	19–36	4–7	19–23	34–48

The surface lipids were extracted from two units of five freshly harvested apples from each tree and a mean value was derived for each tree. The values presented are the range of values for the ten trees in each orchard.

The fatty acid composition of apple tissue that was affected with soft scald was compared with that of an equal area of sound tissue obtained from the same fruit; the sound tissue being taken from the opposite side of the fruit to the scald-affected tissue. The most consistent difference was with linoleic acid; in all 21 comparisons of sound and affected tissue the percentage of linoleic acid in the sound tissue was greater than that in the scald tissue with the difference between individual pairs ranging from 1% to 35% in magnitude. In most cases there was a corresponding increase in the percentage of the saturated lipids in the scalded tissue but the effect was not consistent for any one saturated acid. The average data are shown in Table 3.

Changes in fatty acids of surface lipids of Jonathan apples during storage at 0° are shown in Table 4. In Experiment I, the amount of total fatty acids decreased for the first 11 days of storage and then increased rapidly. Changes in all the individual fatty acids followed a similar pattern with the changes in linoleic acid being the most substantial. After seven weeks the content of linoleic acid was *ca* five times greater than that at harvest. Similar changes in linoleic acid were shown in Experiment II where the amount of linoleic acid was low during the first few weeks storage at 0° and then increased in subsequent weeks. The amounts of other fatty acids tended either to increase during storage (stearic and oleic acids) or have a maximum value early in storage (palmitic acid).

DISCUSSION

Soft scald develops relatively early in cool storage and by 6–12 weeks the maximum level of disorder is usually present. The cause of the disorder has been attributed to an accumulation of some organic volatile compound during storage [12], possibly hexanol [13, 14]. The factors which lead to production of the toxic compound are presumably initiated well before the manifestation of disorder symptoms. The most prominent change in the fatty acid composition during storage was that the linoleic acid content of the surface lipids was lowest during the first few weeks of storage and markedly increased in later weeks. Workers investigating chilling injury in various plant species have found that membrane lipids from chilling-sensitive plant species have a higher ratio of saturated to unsaturated fatty acids than do lipids from resistant species [15–17]: the inference is that cell membranes which are low in linoleate are more susceptible to collapse and hence browning. It is possible that, in apples, a low concentration of linoleic acid early in storage initiates the metabolic changes which lead to the development of soft scald. The increase in linoleic acid later in storage could be sufficient to prevent any further development of the disorder.

The lower content of linoleic acid present in tissue affected with soft scald compared to that in sound tissue suggests that the disorder develops preferentially on those areas of the fruit with a lower concentration of linoleic acid. It is possible that the difference between sound and affected tissue could be a post-mortem result of the injury rather than an involvement with the initial cause of the disorder. However, the distribution of fatty acids was found to be uneven throughout an apple, well before the manifestation of soft scald, and areas of the fruit with the lowest amounts of linoleic acid were presumably those which were the most suceptible to the disorder. The substantial differences in overall fatty acid composition encountered between fruit, between trees and between orchards could be responsible for differences in susceptibility of apples to soft scald with a low content of unsaturated fatty acids predisposing the fruit to develop the disorder. The reactions that lead to the development

Table 3. Average fatty acid composition of lipids extracted from scalded and unaffected areas of Jonathan apples stored at 0°

			Fatty acid composition (% of total FA)				
Season	*n**	Tissue	16:0	18:0	18:1	18:2	18:3
I	5	scald affected	59	2	11	26	2
		sound	53	3	5	36	3
II	8	scald affected	23	10	9	46	12
		sound	21	9	9	51	10
III	10	scald affected	34	14	6	31	15
		sound	23	9	9	45	14

*n is the number of paired samples analysed.

Table 4. Fatty acid composition of external lipids from Jonathan apples during storage at 0°

Storage time (days)	Amount of fatty acid (μg/100 cm^2 surface)					
	14:0	16:0	18:0	18:1	18:2	Total FA
Experiment I						
0	20	220	68	118	119	545
4	22	165	67	120	171	545
7	11	133	46	83	94	367
11	5	66	34	53	66	223
16	14	101	41	61	83	300
21	17	106	59	80	108	365
36	23	142	146	144	418	872
49	20	149	163	214	552	1097
Experiment II						
0	6	45	18	14	12	95
14	12	86	20	16	7	141
28	12	87	50	17	14	180
42	9	65	46	26	39	185
56	9	67	50	32	51	209

Each value is the mean of extractions from four lots of five fruits in Experiment I and six lots of 10 fruits in Experiment II.

of browning still need to be determined, but since chilling injury and soft scald are both associated with reduced amounts of unsaturated fatty acids, there may be some aspects of metabolism which are common to both disorders.

EXPERIMENTAL

Large mature Jonathan apples were harvested from a commercial orchard. Total lipids were extracted from 50 g blended tissue in a Sorvall Omnimix with 150 ml $CHCl_3$–MeOH (1:2). An additional 50 ml $CHCl_3$ was added, the mixture blended for 30 sec then filtered in a Buchner funnel. H_2O (47 ml) was added to the filtrate, the liquid centrifuged and the upper aq. layer removed. The $CHCl_3$ layer containing total lipids were evapd on a rotary evaporator. Surface lipids were removed by sequential immersion of whole fruits in 200 ml petrol (bp 60–80°) for 2 min and rinsing with fresh petrol. The solvent was removed on a rotary evaporator. Lipids were methylated by the method of ref. [18] and analysed by FID GC using a 1.6 m × 2 mm column packed with 10% DEGS-PS (Supelco) run isothermally at 185°; N_2 20 ml/min; injector and detector temp. 200°.

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