Food Info Confidential Report No. 150

Effect of maturing squash on or off the vine on subsequent quality

Part B of a two-part report
NZ Buttercup Squash Council

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August 1995

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Food Info confidential Report No. 44
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1 EXECUTIVE SUMMARY

In some seasons and sites in New Zealand, squash fruit do not receive sufficient heat units on the vine to bring about the processes of abscision and skin hardening that indicate harvest maturity. These fruit may continue to accumulate photosynthate in cooler conditions but the accompanying indicators of maturity such as redness of flesh colour, sweetness, skin hardening and seed development do not reach acceptable levels as defined in the NZBSC Export Marketing Strategy. However, all of these indicators will develop after harvest.

In this experiment, we compared the quality of fruit harvested 15 days earlier than would normally be recommended, with fruit left on the vine to mature. The earlier harvested fruit were subjected to heat treatments chosen to simulate current harvest, export and shipping practices, so that they were ripened off the vine faster than would have occurred under natural environmental conditions. The number of heat units applied to the fruit was the same in each treatment whether the fruit were on or off the vine.

Fruit ripened off the vine by holding for a week at 25°C followed by two weeks at 12-14°C, were equivalent in sweetness to the fruit ripened on the vine. Fruit ripened at temperatures similar to fantainer conditions developed less sweetness and less redness in their flesh colour, although they experienced the same number of heat units. Because of the higher temperatures experienced by fruit in fantainers, this treatment required a shorter time to achieve the equivalent heat input. Therefore time appears to play a role as well as heat. The fruit in the fantainer condition may have increased in sweetness had they been held longer.

Fruit appeared to increase in sweetness during heat treatment and then to level off in the simulated reefer temperatures (12-14°C) in which they were held following the heat treatment.

These experiments showed that it is possible to accelerate the ripening of squash fruit according to indicators such as soluble solids levels and flesh colour. However, the final sweetness and flesh colour achieved did not appear to reach a higher level than the level that would have been achieved by leaving the fruit to ripen on the vine.

Fruit that are ripening slowly but have a high dry matter content (greater than 25%) could be harvested and subjected to accelerated ripening by heat treatment. In such cases, the maximum permissible holding time between harvest and export (21 days) should be calculated, not from the point of harvest, but from the point at the end of the heat treatment equivalent to the desired heat accumulation from fruit set to normal harvest date (around 350 growing degree days (GDD)).

It is recommended that fruit are harvested before reaching the flesh colour, seed development and sweetness levels normally associated with mature fruit, be given a post harvest heat treatment before export.

Fruit picked too early (penetrometer score less than 6.5-7.0 kg) will have low solids levels and a reduced sensory acceptability at market.

"Tired" looking fruit (faded green skin colour), which are sometimes seen when fruit are kept in warm conditions for too long after harvest, did not occur in these experiments.

2 INTRODUCTION

Early season squash exported from New Zealand often receive premium prices in the Japanese market by filling a niche in January, when competing countries can only supply low volumes. However, some early fruit may be too immature when harvested to ripen during shipment and may thus be of a lower quality when sold. Early season, low quality fruit may result in the suppression of prices for subsequent shipments. Cool seasons in some parts of New Zealand may also delay the maturity of squash at times when it is uneconomic to postpone harvesting.

Previous research (Harvey, Grant & Lammerink, 1995) indicates that once a certain level of maturity has been reached, squash will continue to ripen in storage. Furthermore, the quality of the squash is affected by the storage temperature both before and during shipment. Crop & Food Research conducted a two-part study (Part A; and Part B) to examine the possibility of providing a controlled temperature regime either before or during transit to ensure optimum quality of the fruit on arrival in Japan.

New Zealand squash have been compared unfavourably with Mexican squash but Mexican squash tested in New Zealand during another project (Harvey, unpublished) were no sweeter than New Zealand fruit tasted soon after harvest. It is believed that the post harvest transport and shipping of the Mexican fruit in a mixture of refrigerated and non-refrigerated transportation, improves their flavour (mainly sweetness) and texture by reducing total solids and sensory dryness character. New Zealand squash would have similar sensory qualities if they were harvested at the optimum maturity and if optimum post harvest storage and distribution times and temperatures were maintained.

In Part A (Bycroft 1995), we generated a range of time/temperature integrals by storing fruit harvested at two different maturities at a range of temperatures. This established the relationship between fruit maturity, the time/temperature integral and subsequent quality.

In Part B, we examined two alternative post harvest processes for accelerating the ripening of fruit harvested earlier than usual because of cool seasons or financially critical situations. We examined the quality of fruit matured off the vine with each process and compared it with field ripened fruit.

3 METHOD

Our research examined the possibility of maturing squash off the vine, and the effects of this process on the subsequent quality of the fruit.

A crop of buttercup squash (*Cucurbita maxima* var. Delica), planted on 23 November 1994 on the property of G. Lovett near Ashburton was used for these experiments. Temperature data from monitoring equipment in a nearby maize crop (courtesy of McCain Foods (NZ) Ltd) were used to provide temperature accumulation figures.

The first harvest of immature squash was taken on 7 March 1995. The crop was approximately 29-30 days from mid-flowering date, and fruit had accumulated approximately 219 Growing Degree Days (GDD). GDDs accumulated per day are calculated by recording the mean temperature over each 24 hour period and subtracting 8°C (the base temperature for growth). Heat accumulated each day is then summed to give the total GDD. One hundred individual fruit were identified in the range of penetrometer score 5-7 kg using KIWIFIRM, the non-destructive pressure tester being developed by Crop & Food Research and Industrial Research scientists under Vegfed funding (Harvey, Lush & Stuart, 1995).

Sixty-six of these fruit (mean penetrometer score 6.3 kg, s.e. 0.07) were harvested and thirty more tagged to be harvested at a date identified by the grower as the commercial maturity stage.

Six fruit were tested at harvest; thirty fruit from the first harvest were placed in Treatment 1 and thirty in Treatment 2.

3.1 Treatment 1 (1 week @ 25°C)

Treatment 1 fruit were stored for one week at 25°C followed by two weeks at 12-14°C. This temperature regime simulated a possible pre-shipment period of heat treatment followed by reefer shipment to Japan. A temperature of 25°C was intended but in fact it fluctuated between 27 and 24°C, giving an average of 25.7°C.

Temperatures	Heat Accumulation °C days
1 day @ 20°C	12
7 days @ 25.7°C	123.9
14 days @ 13°C	70
Total heat added	205.9°C days

Two fruit were tested after 7 days at 25.7°C and 14 fruit immediately following the full treatment (22 days). The other 14 fruit were left for an extra week at 13°C and then quality tested.

3.2 Treatment 2 (Fantainer simulation)

Treatment 2 fruit were stored under simulated fantainer temperatures over a 16 day period. This temperature regime was based on data obtained from John Smart of MG Marketing, from temperature recorders placed in commercial shipments during May 1994. Squash is on the ship approximately 14 days ex. Auckland and 18 days ex. Lyttleton. The average length of the journey - 16 days - was used.

Temperatures	Heat Accumulation °C days
1 day @ 20°C	12
7 days @ 15°C	49
2 days @ 25°C	34
2.5 days @ 29°C	52.5
1.5 days @ 30°C	33
1 day @ 25°C	17
1 day @ 20°C	12
Total heat added	209.5°C days

Six fruit were tested at harvest. The 30 fruit placed in this treatment were all quality tested together immediately after the treatment.

3.3 Treatment 3 (normal harvest date)

The thirty fruit tagged on 7 March were harvested on 22 March, 15 days after the first fruit were harvested. (A further 118 GDD of heat accumulated during the extra 15 days that the fruit were in the field.) These fruit had penetrometer scores at harvest averaging 8.6 kg (S.E. 0.12). The fruit were held at simulated reefer temperatures (12-14°C) for two weeks and then tested.

Temperatures	Heat Accumulation °C days
15 days in field (mean 15.9°C)	118
1 day @ 20°C	12
14 days @ 13°C	70
Total heat added	200°C days

(This gave a heat input approximately equivalent to the first two treatments. Equivalent heat treatments were given so that the effect of the other variables could be shown. This amount of heat input was chosen because of the practical implications of applying heat to fruit.)

The fruit were then held a further two weeks, and so were quality tested at harvest and after two, three and four weeks at reefer (13°C) temperatures.

Fruit in all three treatments received heat accumulation of approximately 420 GDD from flowering to testing. Some fruit from Treatments 1 and 3 were left in reefer temperatures for an extra one and two weeks to give an indication of what would happen after longer periods (Figures 1-3). In practice, all fruit would require longer than 16-22 days after harvesting to reach a satisfactory sensory standard.

3.4 Parameters measured

The following maturity characteristics were measured:

1. Heat accumulation (GDD).
2. Penetrometer score (using Effegi penetrometer and 4 mm diameter probe supplied by NZBSC) within 24 hours of harvest.
3. Total solids (dry matter %) by air oven method.
4. Soluble solids on the centrifuged juice squeezed from raw fruit, reported as °Brix and measured on an Atago™ digital refractometer.
5. Flesh colour measured on raw, freshly cut, crescent of fruit using a Hunterlab™ reflectance spectrophotometer and the CIE L*a*b* notation. This

colour notation shows green (-ve) to red (+ve) by the a* component; blue (-ve) to yellow (+ve) by the b*component; and pale (100) to dark (0) by the L* component.

6. Skin colour measured directly onto the skin surface using a Hunterlab™ reflectance spectrophotometer and the CIE L*a*b* notation.

4 RESULTS

Table 1 shows mean quality measurements made on fruit after they had been subject to the same number of heat units from fruit set (or approximately 200 GDD from the first harvest). Squash flesh colour varies little in the L* and b* components of colour during maturation and ripening but varies considerably in its a* component, so a* only is reported. Statistical t-tests for differences between means were performed and least significant differences (LSD) calculated.

Table 1: Comparing three treatments with equivalent heat accumulation.

Treatment no.	Days from first harvest	GDD from fruit set	Penetrometer score	Dry matter %	Soluble solids	a* of flesh colour
1	22	425	6.4	22	10	16.2
2	16	429	6.4	22.9	9.4	12.7
3	30	425	8.6	27.4	10.2	16
$LSD_{.05}$			0.4	2	0.5	0.9

Figures 1, 2 and 3 show how soluble and total solids, and flesh colour changed for fruit from the three treatments over the treatment time and afterwards at 12-14°C.

4.1 Soluble solids

The Brix score of expressed juices gives an indication of the sweetness of the fruit. Table 1 shows that fruit harvested when immature (mean penetrometer score of 6.3 kg) and subjected to a week at 25°C (Treatment 1) were not significantly less sweet than fruit from Treatment 3 which were left on the vine for a further two weeks to ripen (mean penetrometer score 8.5 kg). Fruit from Treatment 2 were tested only 16 days after harvesting and although they had received the same heat input as the other two treatments, the Brix levels were significantly lower than fruit from Treatments 1 and 3.

4.2 Dry matter or total solids

Figure 2 shows that dry matter was still accumulating in the fruit left on the vine for the extra two weeks. Dry matter dropped in all treatments during storage off the vine. Previous research has shown that the higher dry matter content of the fruit that stayed longer on the vine would improve its sensory texture and overall acceptability (Harvey & Grant, 1992).

4.3 Flesh colour

Flesh colour was the same for all fruit at harvest even though the second harvest fruit had received 118 GDD more heat on the vine. Fruit from Treatments 1 and 3 increased in the red component of flesh colour to a similar extent after the same amount of heat input (Table 1). The fruit in the fantainer treatment (Treatment 2) had not increased its flesh colour as much ($a^* = 11$ compared with $a^* = 16$ for the other fruit) after the same heat input (Fig. 3). The a^* value should be 20 or higher for good flesh colour. This was achieved after the fruit had been harvested for four weeks (Fig. 3). It is probable that the fruit from the fantainer simulation treatment would have continued to increase in the a^* component of flesh colour (less green and more red) had they been left for a longer period before testing.

4.4 Skin colour

Past research (Beever et al 1991) and some export shipping experience showed that the green colour of the skin faded, producing what were termed "tired" looking fruit, if fruit were stored for long periods at warm temperatures. Skin colour was measured for all treatments but no significant change in greenness was noted. Typical values for L*a*b* scores on the Hunterlab reflectance spectrophotometer were in the range:

L*	28 - 30
a*	-2 - -3
b*	+3 - +5

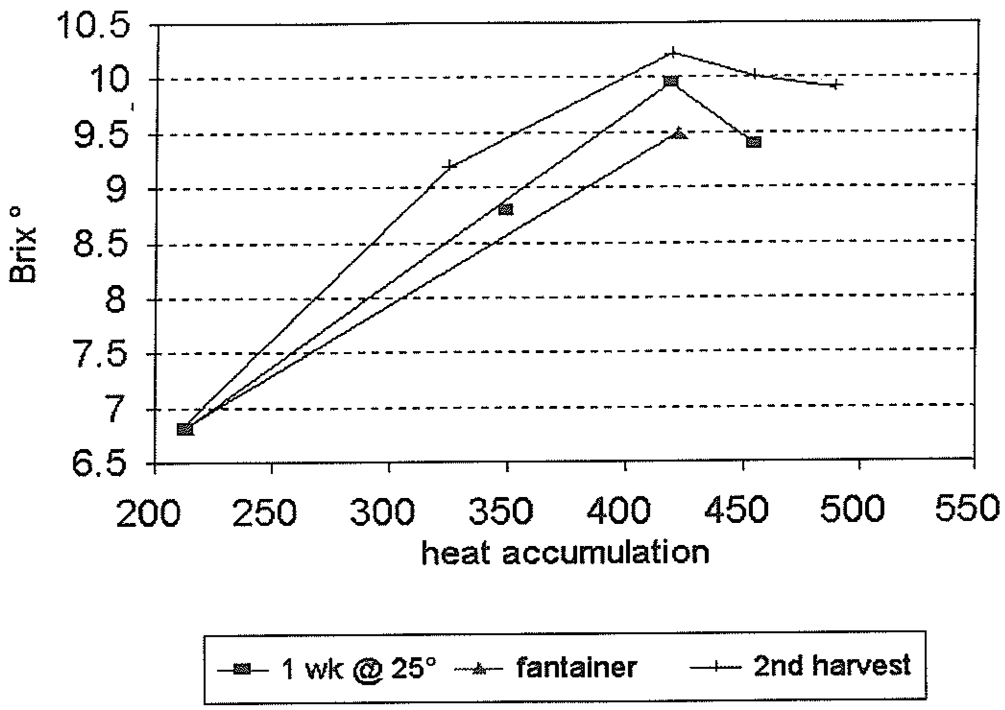

Figure 1: Relationship between soluble solids and heat input.

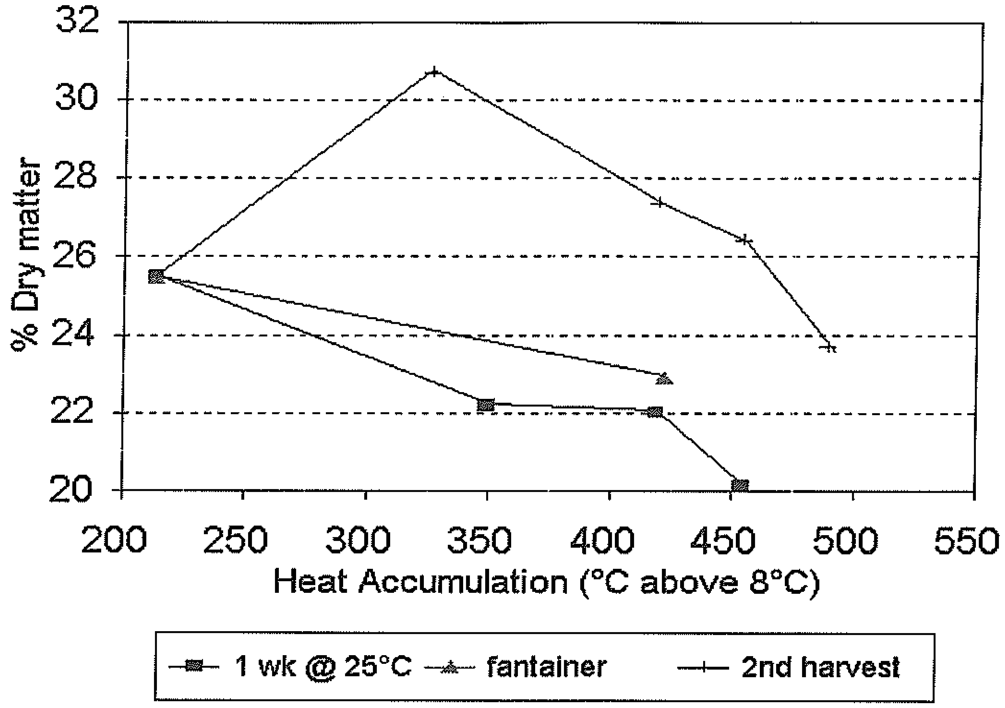

Figure 2: Relationship between dry matter and heat input.

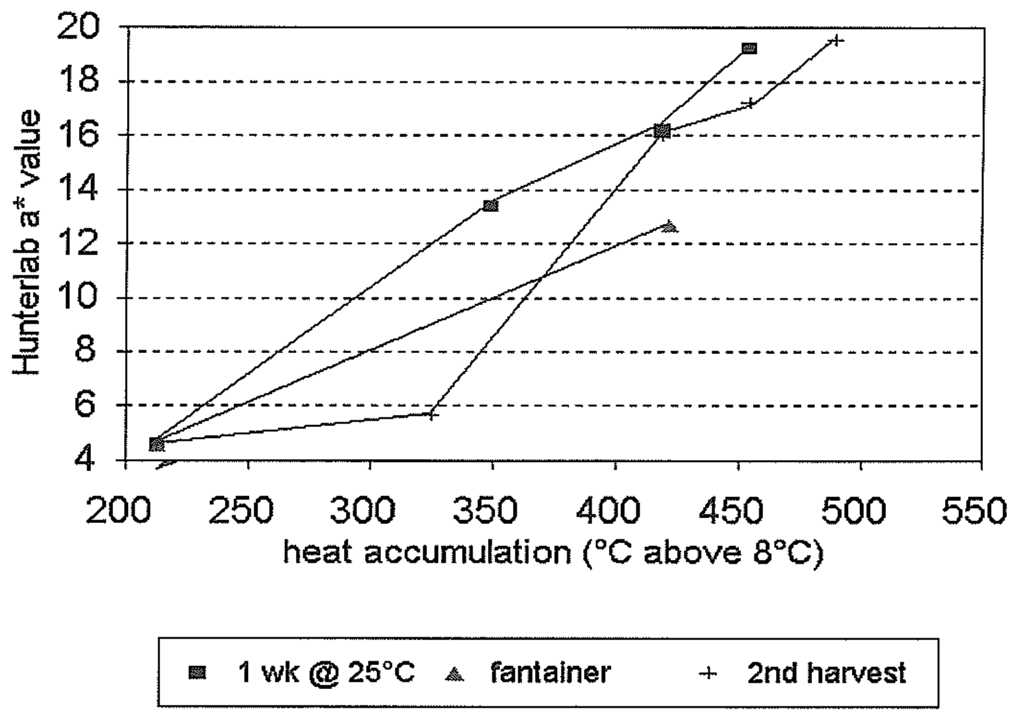

Figure 3: Relationship between development of flesh red colour and heat accumulation.

5 CONCLUSIONS

It appears that fruit can be harvested early and stored under controlled warm temperatures to improve colour and sweetness to levels equivalent to those in fruit allowed to mature at lower ambient temperatures on the vine. However, the extra time on the vine for those fruit increased the dry matter content of the fruit, which should result in improved sensory texture. The early harvested fruit were somewhat moist and fibrous in comparison with later harvested fruit. This reduced their sensory quality in spite of their sweetness and colour.

If fruit have high dry matter (above 25%) but are not reaching the correct penetrometer score for harvest because of cool weather, then harvest followed by heat treatment will improve sweetness and colour. Canterbury fruit appear to require at least four weeks post harvest before sale to allow development of acceptable colour and sweetness. Texture changes during storage, and in high dry matter fruit becomes more moist and acceptable. In low dry matter fruit, texture becomes even more moist and less acceptable. The fantainer treatment did not increase colour and sweetness as much as the other treatments. In this experiment, sweetness reached a maximum then plateaued (Figure 1).

It is important to determine the earliest time at which fruit can be picked and still benefit from a heat treatment. Fruit with penetrometer scores from 5 to 7 kgs were picked at the first harvest. The fruit with penetrometer scores of less than 6 kg had a high probability of being less than 20% in solids, and too low in sugars to reach adequate quality after storage. The previously recommended minimum penetrometer value of 7 kg at harvest is probably a safe level. Dry matter drops more rapidly in fruit picked at low dry matter levels (≤20%) than in fruit picked at high dry matter levels (≥25%).

This research confirms that sugars and the red component of flesh colour increase after harvest. The methods used to store fruit picked when less mature than the required point for commercial harvest can increase these two attributes to the levels found in later harvested fruit. However, lower dry matter in the earlier harvested fruit may make them less acceptable in their sensory quality than fruit allowed to reach a higher solids content before harvest. If the ripening of the fruit off the vine is accelerated by heat treatments, they should then be held for a further period at lower temperatures (12-14°C), including time before and during shipment, to improve the sensory quality.

Additional work is required to further refine storage and heat treatment programmes for squash to obtain adequate levels of all the major quality attributes that the market requires.

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