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Evaluation of aroma and pungent principles in raw ginger

Know-how for Horticulture™

VG310

Alan Wood
Queensland Department of Primary Industries

FINAL REPORT

VG310

This report is published by the Horticultural Research and Development Corporation to pass on information concerning horticultural research and development undertaken for the vegetable industry.

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FINAL REPORT

Project title

Evaluation of aroma and pungent principles in raw ginger (Project No. VG310)

Funding bodies

Horticultural Research and Development Corporation
Buderim Ginger Ltd

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2 years (commenced July 1993)

Organisation conducting research

Centre for Food Technology (formerly known as the International Food Institute of Queensland), Department of Primary Industries, 19 Hercules Street, Hamilton QLD 4007

Project team

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INDUSTRY SUMMARY

This project was jointly funded by the Horticultural Research and Development Corporation (HRDC) and Buderim Ginger Limited (BGL), Yandina to evaluate raw ginger grown on several farms supplying the ginger processing factory.

As the two most important criteria used by overseas buyers of Australian ginger are how strong is its ginger smell (aroma) and how hot is its taste (pungency), the aim of this project was to assess these parameters. This evaluation was in order to improve quality and to provide information to aid in the development of new products with improved attributes.

Volatile constituents (aroma) and pungent principles (hotness) were determined across the 1993 and 1994 harvest seasons. Moisture content, oil content, total volatiles and total pungency have been found to differ between seasons and appear to be related to the amount of rainfall and the amount of irrigation used for each year.

Farm location has also influenced moisture content, oil content, total volatiles and total pungency. Again it appears that the different rainfall/irrigation regimes are responsible. Even different paddocks sampled on the same farm have shown that soil type (clay retains water far more than sandy loam which allows water to seep away quickly) can determine these parameters.

Moisture content, oil content, total volatiles and total pungency were also determined for three different varieties of ginger grown in Queensland, namely Queensland, Hawaiian and Cantonese, all grown in the same paddock under the same conditions. Varietal differences indicated that the Queensland variety was higher in moisture, oil content and pungency, but lower in total volatiles making it more suitable for hotter tasting ginger products. Hawaiian and Cantonese varieties with higher solid content would be better suited for the manufacture of dried products.

Raw ginger was subjected to three different storage temperatures (4, 12 and 24°C) to see if any benefit could be derived in order to improve product quality. It was found that contrary to the literature which states that pungency generally increases with storage, results actually showed pungency to decrease. This decrease in pungency may allow a milder dried product to be produced.

TECHNICAL SUMMARY

This project was jointly funded by the Horticultural Research and Development Corporation (HRDC) and Buderim Ginger Limited (BGL), Yandina to evaluate raw ginger grown on several farms supplying the ginger processing factory.

As the two most important criteria used by overseas buyers of Australian ginger are how strong is its ginger smell (aroma) and how hot is its taste (pungency), the aim of this project was to assess these parameters. This evaluation was in order to improve quality and to provide information to aid in the development of new products with improved attributes.

To determine the aroma content of raw ginger, assessment of total volatile content was determined. Headspace gas chromatography, previously developed at these laboratories, was employed to collect the volatile compounds which were then analysed by gas chromatography/mass spectrometry (GC/MS).

A Masters Degree student from the Queensland University of Technology was employed on this research project and developed methodology using supercritical fluid technology for the successful extraction of oil from raw ginger. This was necessary as the pungents which reside in the oil, degrade readily as they are thermally labile. Determination of the concentration of these pungent principles was carried out using high performance liquid chromatography (HPLC) run at low temperature to avoid degradation.

The above mentioned methodologies were used to evaluate ginger grown to supply the processing factory from different localities as well as from different paddocks on the same farm. Raw ginger from the 1993 and 1994 harvest seasons were assessed as well as three different varieties of ginger.

Assessment of ginger subjected to storage at different temperatures (4, 12 and 24°C) was carried out to determine if any benefit in product quality or development could be obtained. It was found that contry to the literature which states that pungency increased with storage at 12^0C, results generally decreased. This may allow a milder dried product to be produced.

RECOMMENDATIONS

Extension/Adoption by industry

It is expected that Buderim Ginger Limited (BGL) will use this report to improve ginger quality as well as aid in the development of new ginger products.

- Ginger from farms with lower moisture and hence higher solid content could be used for more economical drying.
- Ginger oil would be more economically extracted during April and May instead of during June and July as is presently done in the ginger industry.
- Ginger containing higher oil content and hence having more pungency would be better harvested in April and May. The manufacture of hotter ginger than normal may take advantage of this asset.
- Conversely, milder pungency products may be manufactured from ginger containing less oil.

Directions for future research

This project has indicated that moisture content and hence oil content may be the most important factor in producing ginger of a consistent quality. Further research could be applied in establishing a soil moisture computer monitoring system to control the irrigation necessary in combination with received rainfall to gain maximum benefit.

Conversely such a monitoring system should be able to control the growth of ginger with less moisture to enable ginger to be dried more economically.

Financial/Commercial benefits

Production from Buderim Ginger Ltd (BGL) consists of 65% export products and 35% local markets. Results from this research will allow BGL to produce products of high quality as well as stimulate the development of new products eg highly aromatic and highly pungent ginger products. This would allow BGL to capture markets from competitors, particularly overseas, and to expand current existing local markets.

Benefits also to be realised from this project will be more economical use of land for better ginger growing by showing what ginger grown where is the most suitable for what product. Results will also allow more economical use of equipment during processing of the ginger.

It is estimated by BGL that the added value created by better products, new products and new markets originating from this research has the potential to increase their annual turnover by in excess of one million dollars.

INTRODUCTION

Ginger ("*Zingiber officinale*" Roscoe) is one of the most widely used spices in the world, and is a common additive in a number of compounded foods and beverages.

Ginger can be cultivated throughout the tropical and subtropical world where a heavy rainfall of sixty inches is experienced. Areas with lesser rainfall are supplemented by irrigation as is the case in Australia. Planting occurs from September to mid October with harvesting from early March to late October.

Ginger is harvested according to the specific requirements for different ginger products. In Australia, ginger harvested early during March and April is used as fresh, crystallised or syruped ginger. At this time, the ginger is still tender and relatively free from fibre. From April to June, a more mature ginger is used as fresh ginger and for making dried ginger. From July to October, a fully mature fibrous ginger is harvested for drying, grinding and extraction.

The two most important attributes used to classify ginger, particularly in overseas countries importing Australia ginger, are its aroma (volatile flavour constituents) and its pungency or hotness (Macleod and Pieris, 1984). There is a lack of data for these attributes in Australian ginger due to the incapabilities of previously existing methodologies and instrumentation.

If such data were available, particularly for raw ginger, showing variations due to season, variety and locality, then the most appropriate time to harvest to obtain the best results for the manufacture of a particular product would be apparent. Results would enable upgrading of existing products and also stimulate development of new products.

Australian ginger contains components such as geranial and neral (isomers of citral) which imparts a typical citrus or lemon-like flavour (Ekundayo, Laakso and Hiltunen, 1988). As this is a sought after attribute in some export products, the data collected from volatile constituent analyses will be useful in improving and tailor-making products for export markets.

Pungency has long been recognised as an important character related to ginger, particularly dried ginger (Chu-Chin Chen et al., 1986). The pungent principles of fresh ginger are primarily gingerol compounds, which are thermally labile due to the presence of a beta-hydroxy keto function in their structure. Chu-Chin Chen & Chi-Tang Ho (1987) have found that the heat from steam distillation extraction of the essential oil causes thermal degradation of the gingerol compounds (retro-Aldol and retro-Claisen Schmidt reactions) to produce aldehydes and ketones in the volatile flavour profile that are not initially present. Solvent distillation, depending on the solvent used, can cause similar degradation.

Analysis of these pungent principles therefore cannot be undertaken by GC determination due to thermal degradation in the hot injection port as found by early Australian researchers (Connell, 1970; Connell and Jordan, 1971; Connell and McLachlan, 1972). An alternative method of analysis of these pungents from ginger is HPLC (High Performance Liquid Chromatography) where no heat treatment is applied (Chu-Chin Chen et al., 1986; Baranoroski, 1985).

MATERIALS AND METHODS

Samples

The number of raw ginger samples collected for this project were 85 in 1993 and 112 in 1994. The total number of samples analysed in this project were 254 including stored and fresh ginger and each sample was analysed for volatile constituents and pungent components.

Fresh ginger

Ginger samples were collected across the harvest period of the 1993 and 1994 seasons. Samples were taken from the same field at the same location every two weeks. Replication was achieved by sampling at five separate locations on three farms.

The three farms used for sampling in this project were spread across a distance of approximately 90 kilometres north and south of the Yandina factory. This was done to be able to monitor any differences due to locality. The three farms selected were AGG (Australian Ginger Growers) which is located approximately 50 kilometres north of the factory, Waltons located approximately 40 kilometres south of the factory and Torvella at approximately 10 kilometres north of the factory. Details of the sampling regime are described in Table 1.

Table 1. Ginger sample description (1993 and 1994)

Year	Name	Location	Ginger variety	Time of harvest	Number of samples
1993	AGG 4	Middle of AGG (AGG is 30 km south of Gympie)	Queensland	from 18/3/93 to 28/10/93 every two weeks	85
	AGG 5	East of AGG	Queensland		
	AGG 7	West of AGG	Queensland		
	Torvella	10 km North of Yandina	Queensland		
	Waltons	8 km West of Beerwah	Queensland		
1994	AGG 4	Middle to AGG	Queensland	from 5/4/94 to 18/10/94 every two weeks	112
	AGG 6	East of AGG	Queensland		
	AGG 7	West of AGG	Queensland		
	Torvella	10 km North of Yandina	Queensland		
	Waltons	8 km West of Beerwah	Queensland, Canton, Hawaii		

Three different fields were sampled at the AGG farm to cover possible differences due to different soil type. Three varieties of ginger, Queensland, Canton and Hawaiian were sampled from the same field on Waltons farm and were used for varietal comparisons.

Stored ginger

Only the Queensland type ginger was chosen for storage at 4°C, 12°C and 24°C. Details of this storage regime are shown in Table 2. As this was a preliminary investigation into the storage of fresh ginger, replication was considered unnecessary.

Table 2. Description of stored ginger sample (1993 and 1994)

Year	Name	Temperature (°C)	Time	Sample period	Number of samples
1993	AGG 4	4, 12, 24	29/4/93 to 24/6/93	one month	4
	AGG 4	4, 12, 24	8/7/93 to 28/10/93	one month	12
1994	AGG 4	4, 12, 24	28/6/94 to 20/12/94	2 weeks	36

Sample treatment

Following their harvest, ginger rhizomes were washed free of dirt and drained overnight. Part of the sample was ground (blended) to make a pulp which was then stored in laminated cans under vacuum. This eliminated loss of volatiles and post harvest contamination. More of each sample was stored whole and as pulp in plastic storage bags for pungency analysis. Both cans and storage bags were frozen at -12°C until analysis. Previous work had shown this to be the best method for sample storage.

For the storage trials, washed ginger from the 1993 season was placed in cardboard fruit boxes with lids and stored at 4°C, 12°C and 24°C. This proved to be unsatisfactory due to the growth of mould. For this reason, 1994 season ginger was stored in open mesh onion bags and eliminated most mould growth. At a sampling time specified in table 2, a portion of the sample (50 g) was taken, blended to pulp and stored at -12°C to await analysis.

Moistures

Pulped whole ginger was weighed accurately (approximately 10 g) into an aluminium drying dish. Vacuum drying for 36-48 hours at 70°C to a constant weight was carried out. Each moisture determination was duplicated for every sample. The weight difference was obtained and % moisture and hence dry weight (% solids) was calculated. The final result was an average of the duplicate determinations.

Volatile flavour constituents (aroma) analyses

Analysis of volatiles from ginger is usually carried out by extraction of the essential oil using steam distillation followed by GC (gas chromatographic) or GC/MS (gas chromatographic/ mass spectrometry) for component identification (Miyazawa and Kamoeka, 1988; Ekundayo, Laasko and Hiltunun, 1988; Macleod and Pieris, 1984). However, this extraction procedure can cause artefacts to be produced.

A method of analysis which overcomes the production and detection of these artefact compounds during volatile flavour component analysis is headspace gas chromatography. This methodology has several worthwhile features:

- it gives a more realistic profile of the aroma
- it is easily performed and is repeatable
- it is non-destructive.

A system for headspace sampling and analyses has been developed by this laboratory and was found to be ideal for the determination of volatile components from ginger (Wood, Aston and Douglas, 1994). 10 g raw pulp ginger was used for each analysis with a 2 mL headspace injection volume employed.

Pungent analyses

To solve the problem of extraction of pungent principles from ginger without thermal degradation as with steam distillation, a method utilising supercritical fluid extraction (SFE) using liquid carbon dioxide was developed (Ngoc Bich Pham, 1996). Due to the large amount of water present in each sample, cellite as a drying medium was applied. 5 g ginger pulp was thoroughly mixed in the ratio of 2:1 of cellite:ginger as this was found to give the best extraction matrix for the supercritical fluid extraction process. The resultant extraction material consisted of a ginger oil and contained the pungent compounds. Since no waxes or fats were extracted from the ginger using SFE as is the case using solvent distillation to obtain oleoresins, the extraction material has been referred to as an oil throughout this report and not an oleoresin.

A further objective was to develop a technique to quantify the common pungent principles of ginger (6-, 8-, 10-gingerol; 6-, 8-, 10-shogaols and zingerone) by HPLC with respect to harvest time, growing location, ginger variety and storage conditions. The method used was that developed by Ngoc Bich Pham (1996) where better separation and resolution of peaks on the chromatogram has been achieved.

Pungency evaluation

Pungency, with respect to food flavours, is a desirable characteristic of a number of important spices eg capsicum, ginger and pepper. Because pungency is considered a very important contributor to mouthfeel and flavour, an estimation of a pungency value was considered necessary.

Early workers in the evaluation of pungency soon recognised that a dilution method needed to be used. In 1912, Scoville determined the pungency of capsicum by finding the greatest dilution at which the definite perception of "bite" (pungency) could be recognised (the recognition threshold), and expressed it as a reciprocal of the dilution. This figure has since been called the Scoville Heat Units (SHU) and is employed throughout this report.

Statistical analyses

All results on moisture, solids, oil content, total volatiles (aroma) and total pungency for raw ginger and corrected to a dry weight basis were subjected to statistical analyses to confirm conclusions drawn from the graphs.

The statistical analyses utilised was Analysis of Variance (ANOVA) using a factorial design consisting of 5 paddocks, 15 sample dates and 2 seasons. When a significant ratio was found ($P<0.05$), then pairwise comparisons were made using the least significant difference test.

RESULTS AND DISCUSSIONS

Locality comparisons

Profiles for the attributes of moisture content, oil content, total volatile contents and total pungency are considered for both the 1993 and 1994 harvest seasons. Each of the three individual fields for the AGG farm has been plotted along with Waltons and Torvella farms. An average of all Queensland variety ginger samples on all farms has been included for comparison purposes.

All results were statistically analysed and are recorded in Table 1, Appendix 1 for both the 1993 and 1994 harvest seasons. Results on a combined basis for both seasons are also shown in this table for overall assessment.

1993 Harvest season

Moisture/solids content

Each farm started with an initial content close to 95% in March dropping down to a minimum of approximately 85% in July and then rising slightly until the end of October (figure 1).

AGG block 4 had an overall higher moisture content than the average while blocks 5 and 7 are fairly consistent with the average. % Moisture for AGG block 4 statistically has been shown to be significantly higher to block 5 (and conversely % solids significantly lower). This is probably explained by the difference in soil type in these fields. Block 4 consists of a clay type soil which retains water to a greater extent than the sandy loam found in all other blocks on this farm.

The moisture content for Waltons farm overall throughout the season was below average. In fact, all AGG blocks were significantly higher than Waltons and Torvella farms with Waltons being significantly lower to Torvella. The supply of ginger from this farm could be put to better economical use in drying due to its higher solids content and hence require less power for this process.

The reverse of moisture content ie % solids is represented in figure 2 with a maximum generally occurring in July. Thus it is suggested that ginger harvested in July is the most economically suited for drying purposes.

Oil content

% Oil content as shown in figure 3 was fairly consistent for each farm with the average across the entire harvest period. Initial oil content of approximately 0.4% in the middle of March increased generally to a maximum range of 0.7 to 0.8% in April and May before gradually decreasing to about its original content

This variation trend was comparable to that found by Winterton and Richardson (1965) who used solvent distillation extraction compared to supercritical fluid extraction with liquid carbon dioxide. It is reasonable therefore to conclude that it would be advantageous to extract ginger oil during April and May instead of during June to August as is presently done in the ginger industry.

To be able to evaluate the differences in oil content between farms more realistically using a standard baseline, % oil content was calculated on a dry weight basis (figure 4). As a result of smaller solid content and higher oil yields at the start of the harvest season, % oil on a dry weight basis was highest (6-7%) for this time. Generally, oil yield then decreased to a minimum of 3-4% in June showing little change to the end of the season.

AGG block 4 had a tendency to be above the average in oil content in the latter half of the season while blocks 5 and 7 maintained the average. Statistically overall for all farms no significant difference existed. However when results are corrected to a dry weight basis, AGG block 4 is significantly higher to the other two AGG blocks. All AGG blocks resulted in being significantly higher in oil content to Waltons farm but only block 7 is significantly higher to Torvella farm.

Total volatiles

Figure 5 represents the total volatile content from 10 g fresh ginger reported as peak areas (arbitary units). Results for AGG block 4 have been found to be significantly higher to both other AGG blocks. No other significant differences were found to occur.

As previously, for more realistic evaluation of differences between farms for total volatile content, calculations on a dry weight basis were performed and appear in figure 6. Statistically AGG block 4 was found to be significantly higher to all other AGG blocks as well as Waltons and Torvella farms. AGG block 7 was found to be significantly higher to Waltons with Waltons and Torvella themselves showing a significant difference (Torvella is higher).

FIGURE 3. % Oil content of fresh ginger across the 1993 season

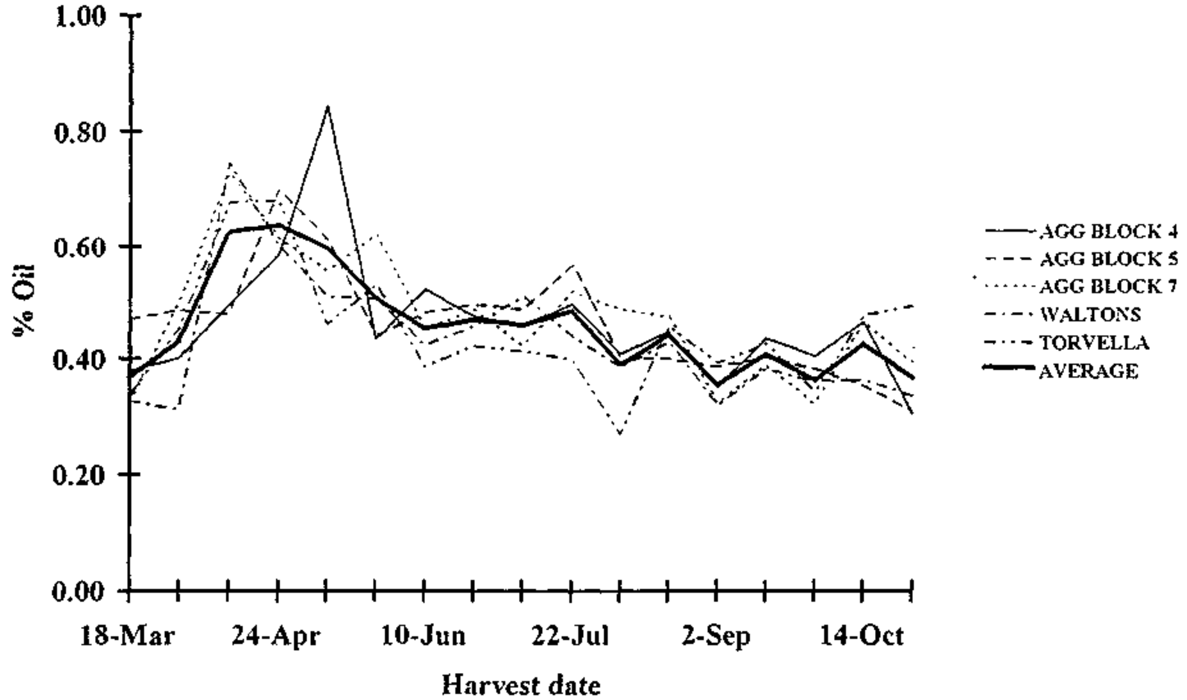


FIGURE 4. % Oil content expressed on a dry weight basis for ginger across the 1993 season

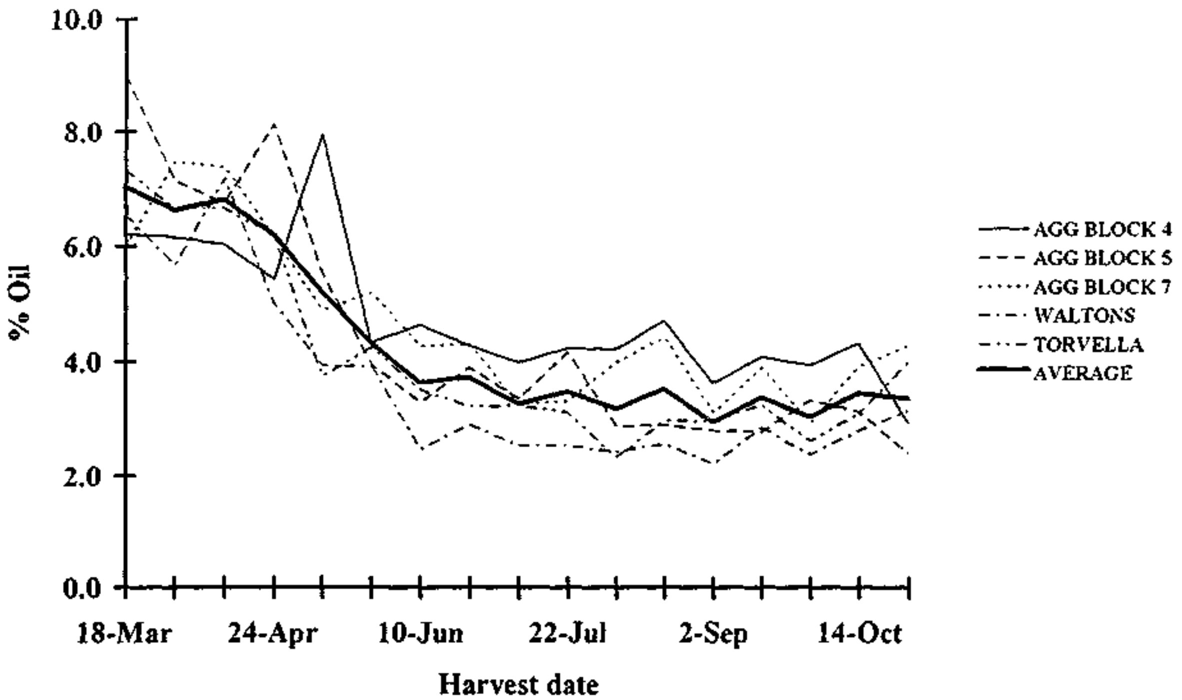


FIGURE 5. **Total volatile content of fresh ginger across the 1993 season**

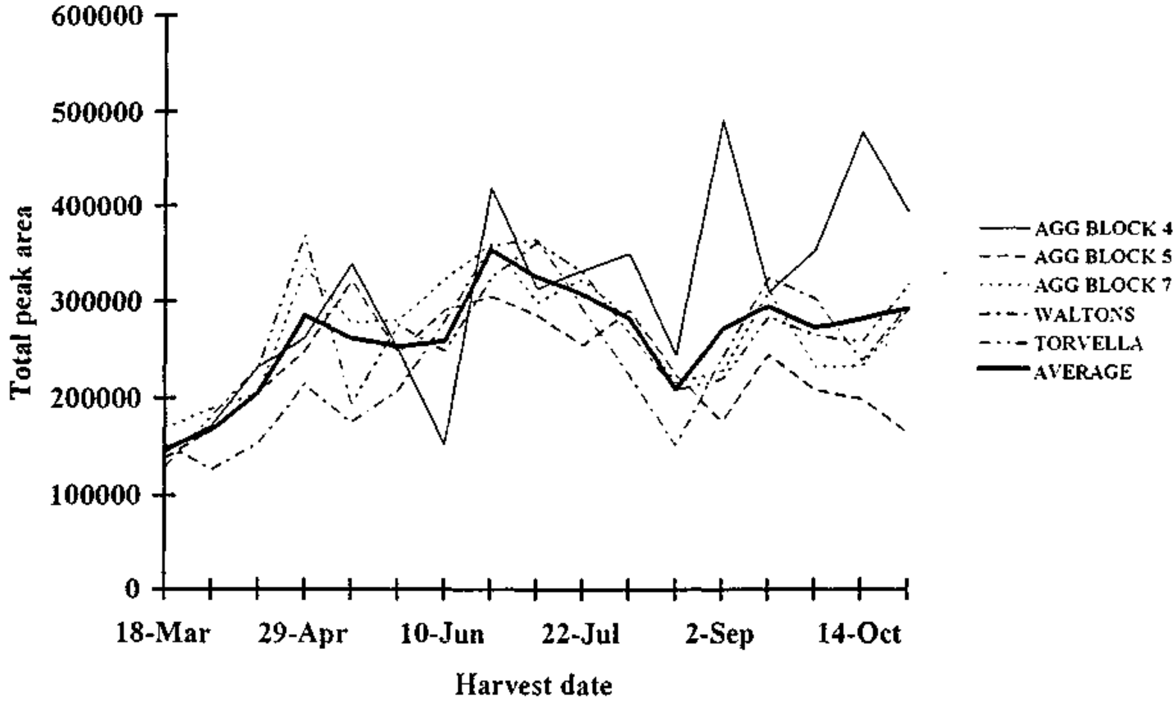
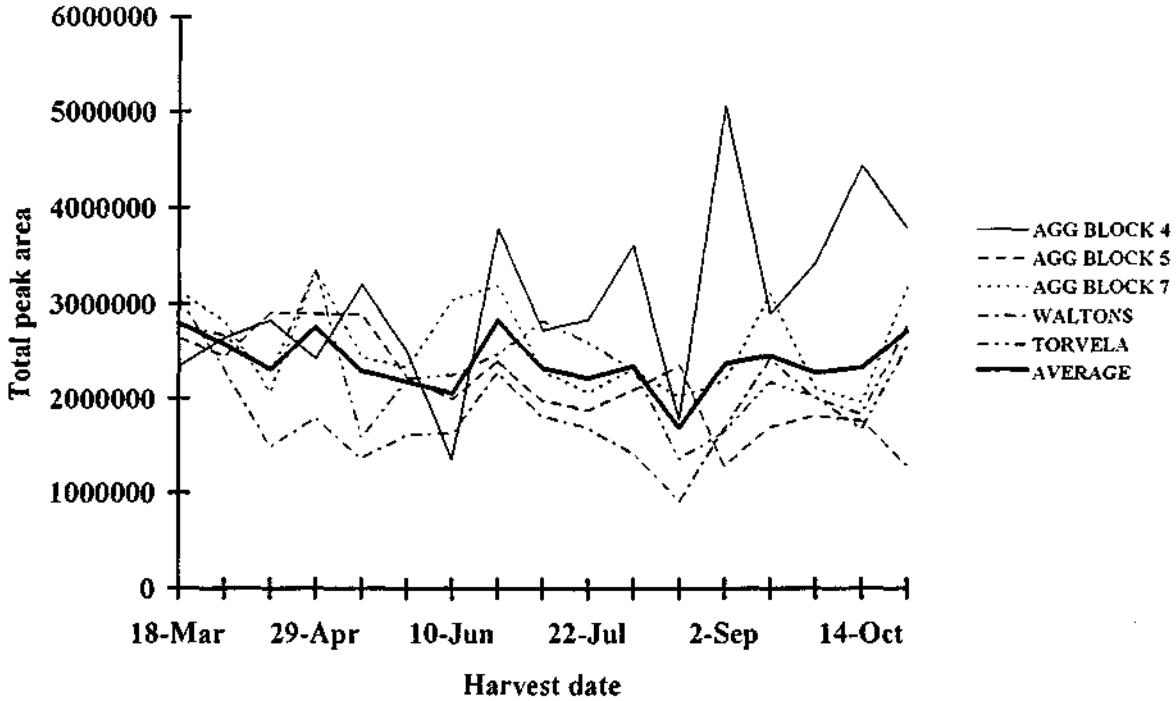


FIGURE 6. **Total volatile content expressed on a dry weight basis of ginger across the 1993 season**



It appears that some relationship exists between total volatile content and % oil content both on a dry weight basis as profiles for each show similar tendencies. This is feasible as volatile constituents (aroma) according to the literature reside in the ginger oil.

Total pungents

The total pungency concentration of 1 g of ginger oil was calculated from the amount of 6-, 8- and 10-gingerols; 6-, 8- and 10-shogaols and zingerone. 6-Gingerol occurs in the largest concentration and hence has the largest pungency factor. Therefore the variation of total pungency greatly depended on the 6-gingerol content. Total pungency expressed in SHU (Scoville Heat Units) have been plotted against harvest time for each farm (figure 7).

All profiles showed an initial increase in total pungency from a range of 80 to 120 SHU to a maximum value between 120 and 200 SHU in April tapering off to close to their original values by the end of the season.

Results of total pungency of fresh ginger from Torvella farm have been found to be significantly lower to AGG blocks 4 and 7. No other significant differences occurred.

As previously, differentiation between farms is better evaluated on a constant base line. Hence total pungency expressed on a dry weight basis is shown in figure 8. Results have shown AGG block 4 to be significantly higher to block 5. All AGG blocks were found to be significantly higher to Waltons and Torvella. Torvella was shown to be significantly lower than Waltons.

It may be feasible that ginger with lower pungency overall such as from Torvella farm may enable ginger products with less pungency (not so hot) to be manufactured.

As previously discussed, due to its direct relationship with oil content, ginger with highest total pungency would be best harvested in April/May. Manufacture of hotter ginger products for specialised markets could take advantage of this phenomenon.

FIGURE 7. Total pungency content of fresh ginger across the 1993 season

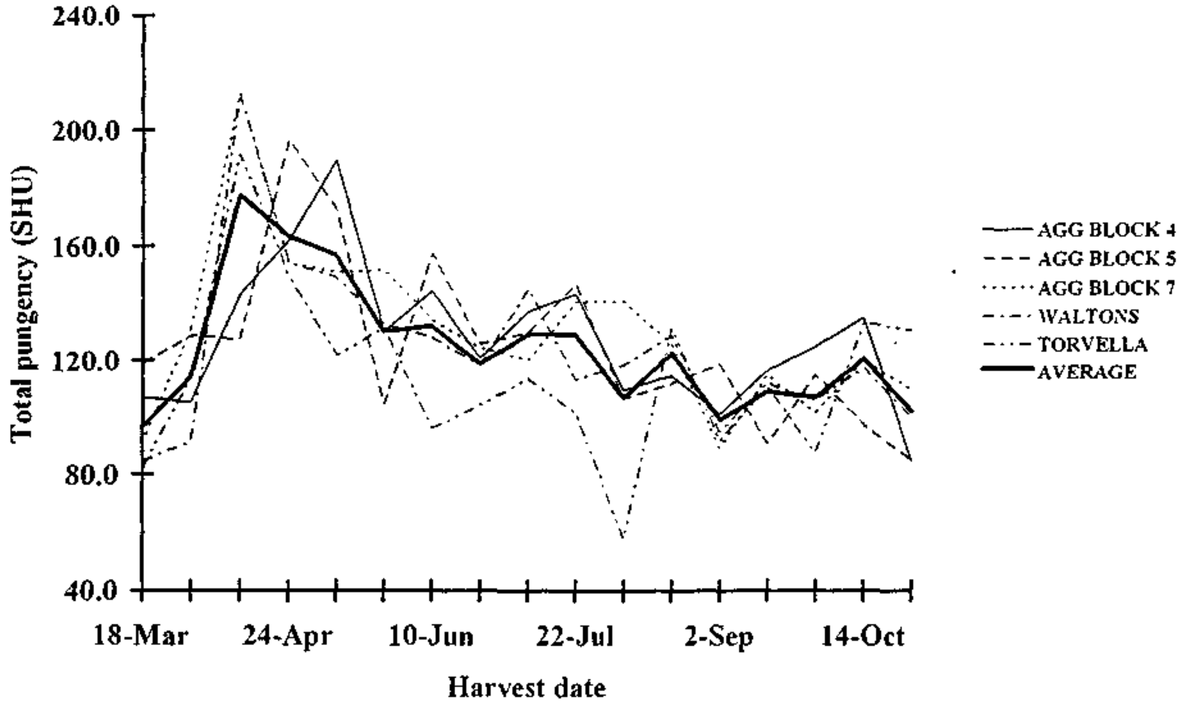
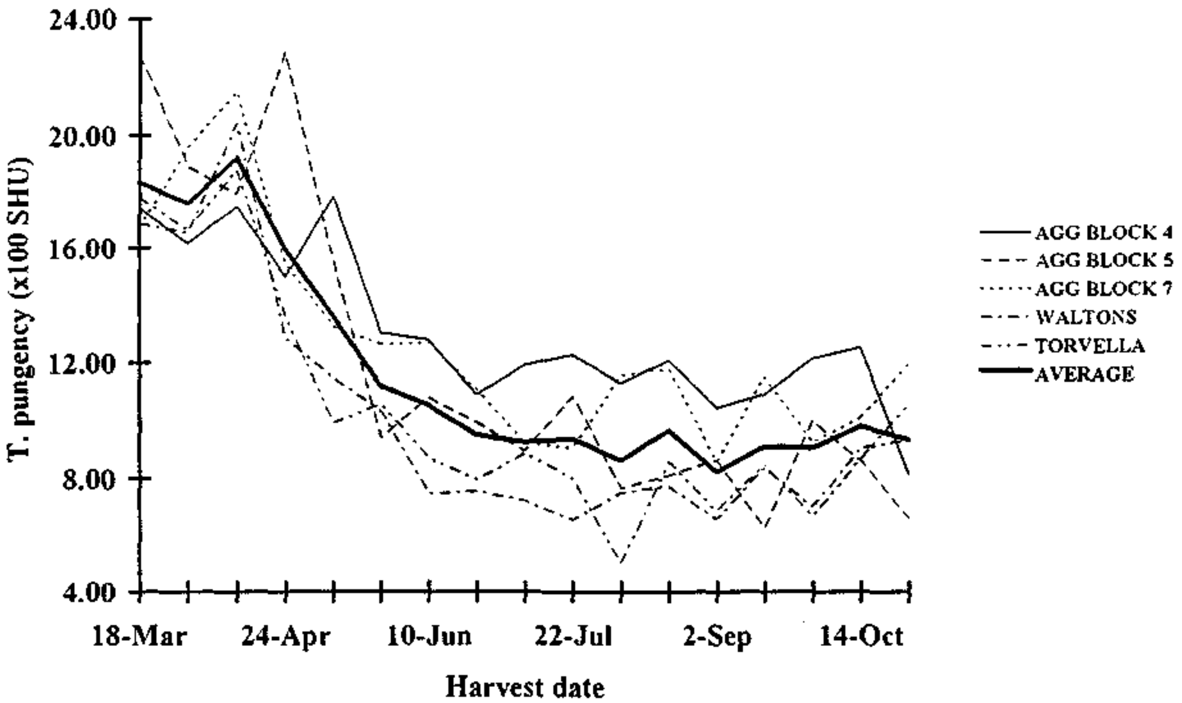


FIGURE 8. Total pungency content expressed on a dry weight basis of ginger across the 1993 season



1994 Harvest season

Moisture/solids content

The general trend showed the initial moisture content on each farm to range between 90 and 94% in early April dropping down to a minimum of approximately 85% in late June and then rising slightly to the end of the season (figure 9).

Results for % moisture content for AGG block 7 were found to be significantly higher than the other two AGG blocks. Waltons farm was significantly higher to AGG blocks 6 and 7 while Torvella was significantly higher to AGG blocks 4 and 6.

% Solids for each farm are plotted in figure 10. A maximum has generally occurred in June for each farm except Torvella where a steady increase occurred across the season.

Oil content

% Oil content for each farm is shown in figure 11. Initial content ranged between 0.4 and 0.6% in early April, peaked in late April, early May to a range of 0.6 to 0.7% before gradually decreasing to approximately original values by the end of the season.

% Oil content of fresh ginger for both Waltons and Torvella farms were shown to be significantly lower than all AGG blocks.

More realistic results are achieved when each farm oil content is plotted as expressed on a dry weight basis to give a common base line (figure 12).AGG block 6 was found to be significantly lower to block 7 as well as significantly higher than Waltons and Torvella farms. AGG block 4 is only significantly higher to Waltons farm.

FIGURE 9. % Moisture content of fresh ginger across the 1994 season

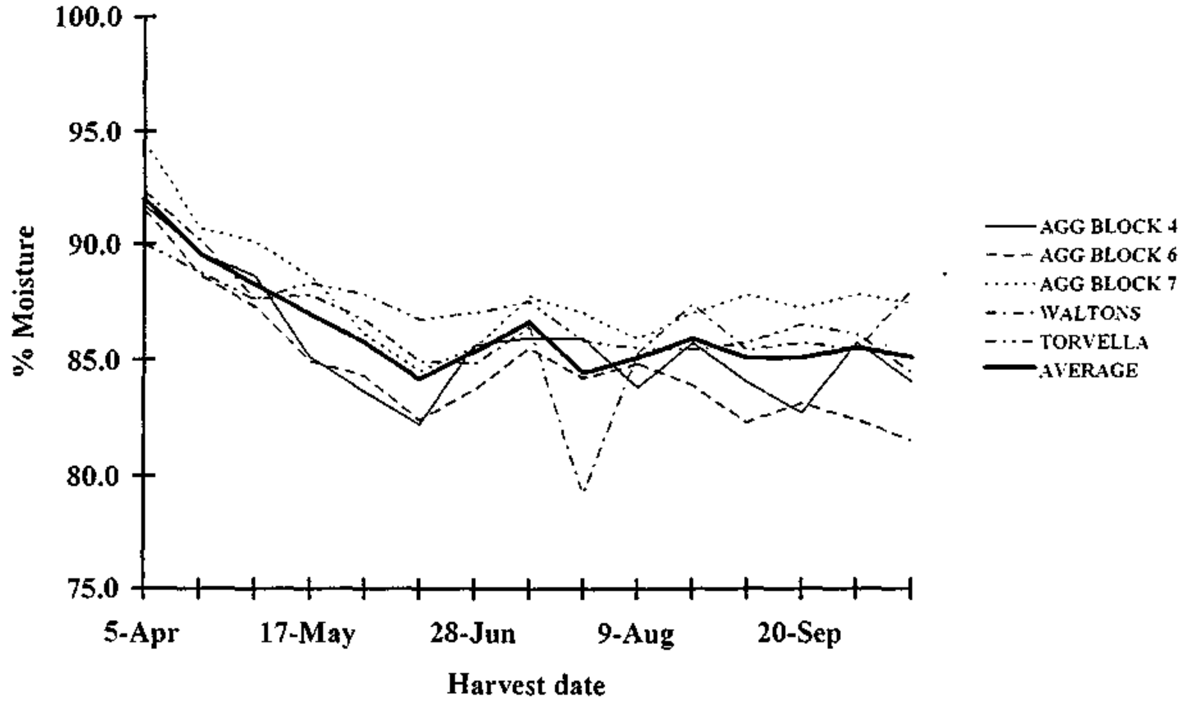


FIGURE 10. % Solid content of fresh ginger across the 1994 season

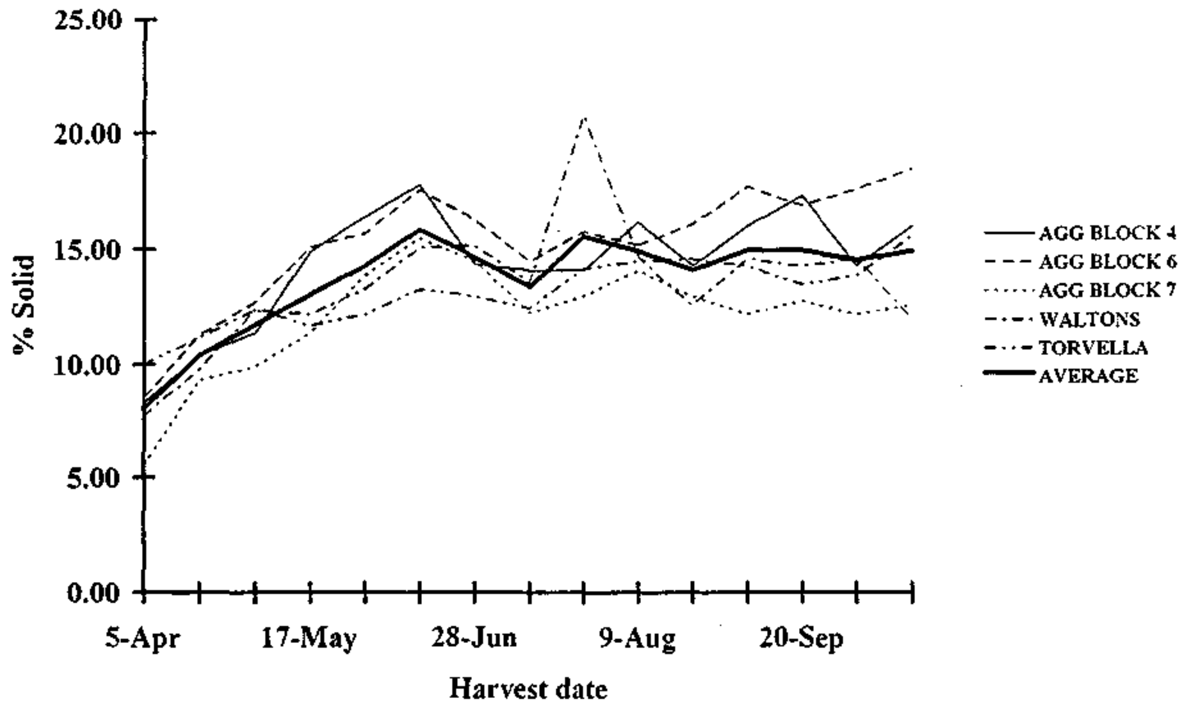


FIGURE 11. % Oil content of fresh ginger across the 1994 season

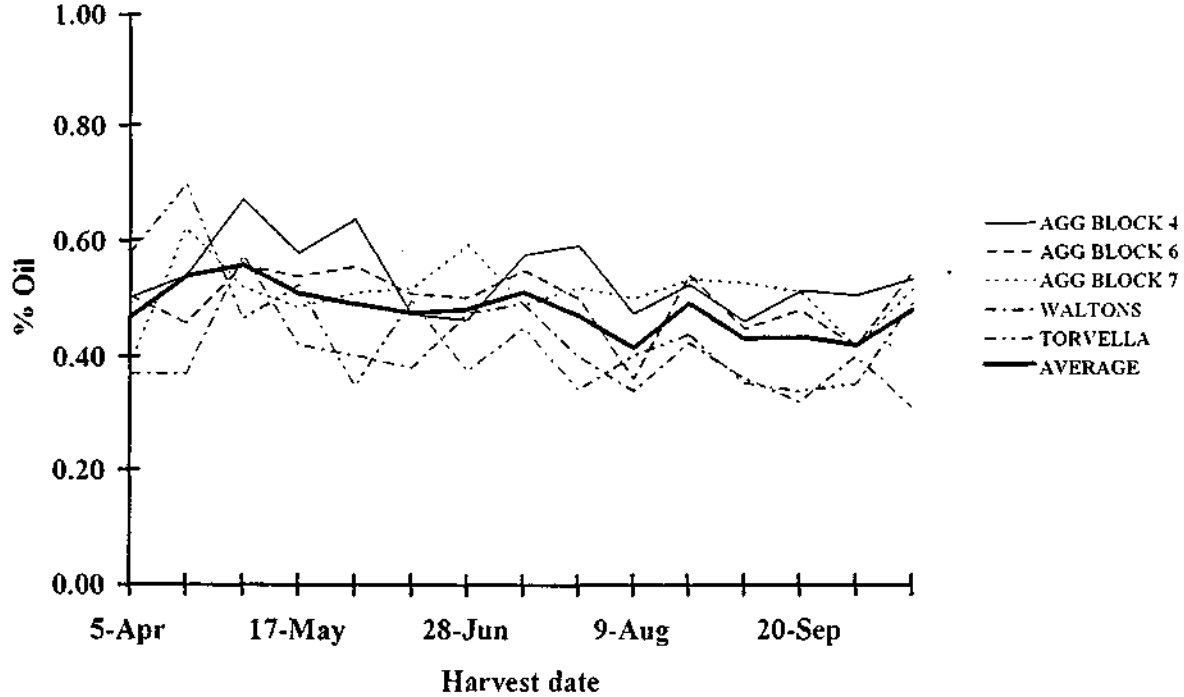
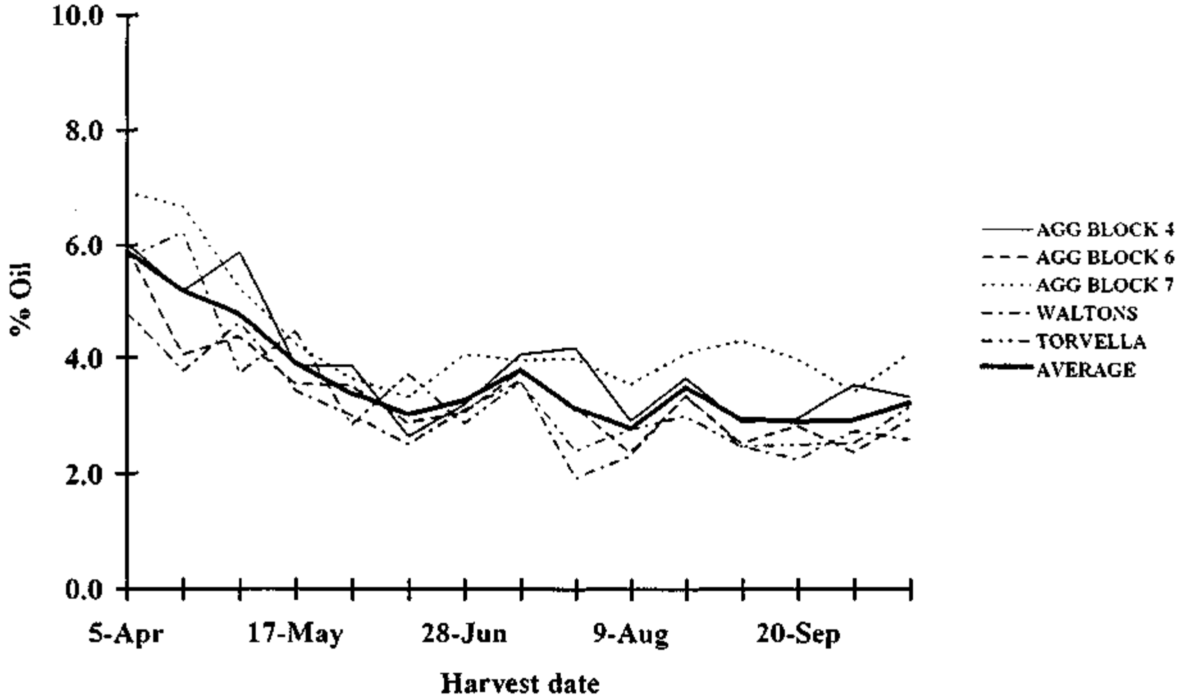


FIGURE 12. % Oil content expressed on a dry weight basis for ginger across the 1994 season



Total volatiles

Figure 13 represents the total volatile content from 10 g fresh ginger reported as peak areas (arbitary units). The results for AGG block 4 were found to be significantly higher to block 7 and Torvella while Waltons was shown to be significantly lower to all AGG blocks.

The more appropriate evaluation of total volatiles is to express these results on a dry weight basis as a common baseline (figure 14). AGG block 6 was found to be significantly lower to the other AGG blocks as was Waltons.

Total pungents

All profiles were plotted as SHU (Scoville Heat Units) against harvest time for each farm (figure 15). All profiles showed an initial increase in total pungency in the range of 80 to 140 SHU to a maximum of approximately 160 SHU in early May generally tapering off to initial value at the end of the season.

Results from AGG block 6 were significantly higher to the other AGG blocks. Waltons farm was found to be significantly lower to AGG block 4 and 7.

Differentiation between farms is better evaluated using a constant base line. Hence total pungency expressed on a dry weight basis is shown in figure 16. All AGG blocks were significantly higher to Waltons while only blocks 4 and 6 were significantly higher to Torvella.

Combined harvest seasons

Moisture/solids content

For a combined estimation of both seasons, % moisture and % solids from AGG block 4 were significantly higher and significantly lower respectively to both other AGG blocks as well as Waltons and Torvella.

FIGURE 13. Total volatile content of fresh ginger across the 1994 season

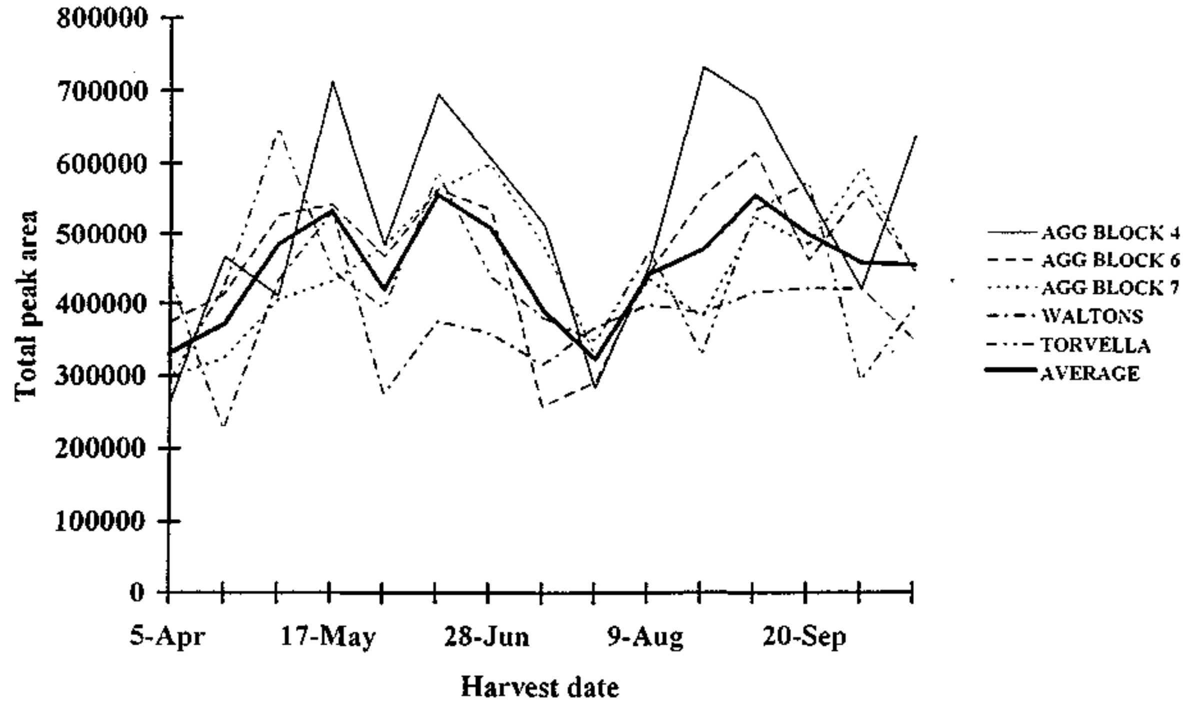


FIGURE 14. Total volatile content expressed on a dry weight basis of ginger across the 1994 season

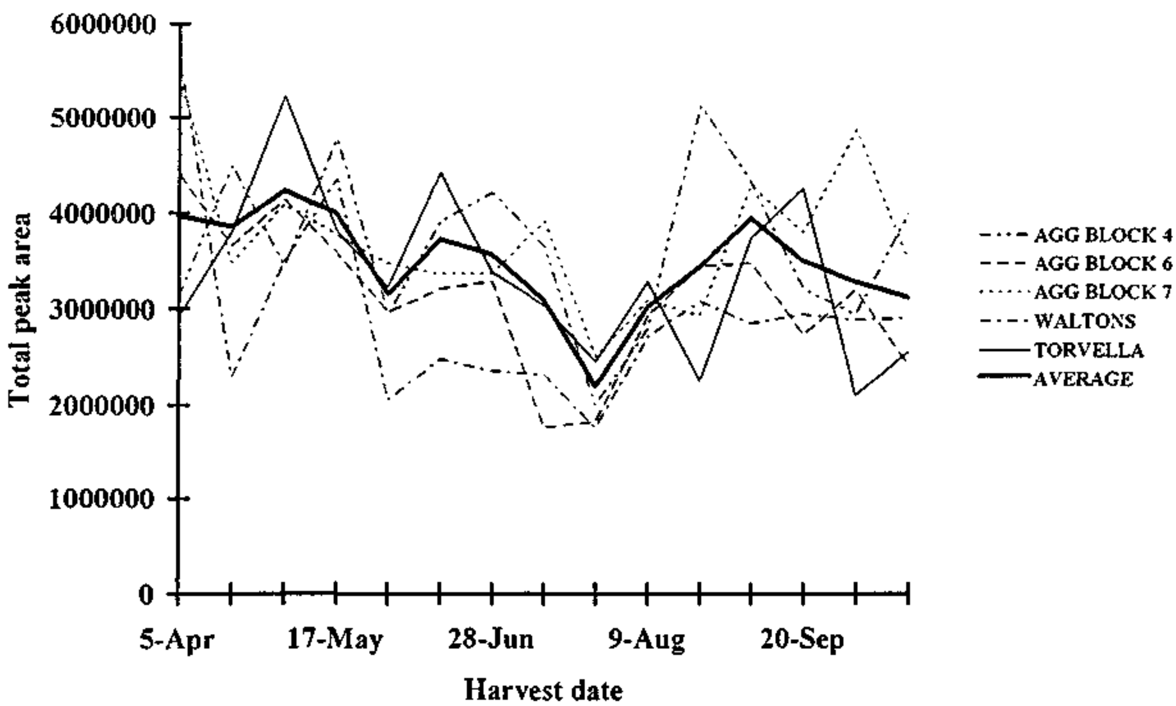


FIGURE 15. **Total pungency content of fresh ginger across the 1994 season**

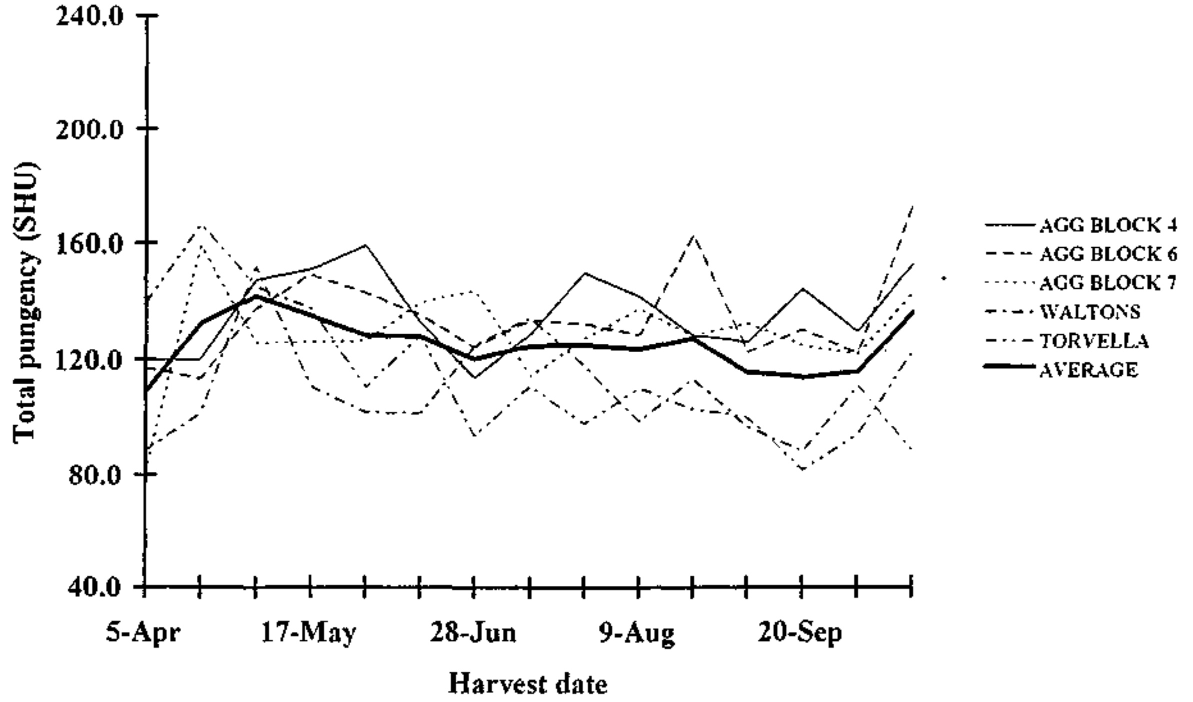
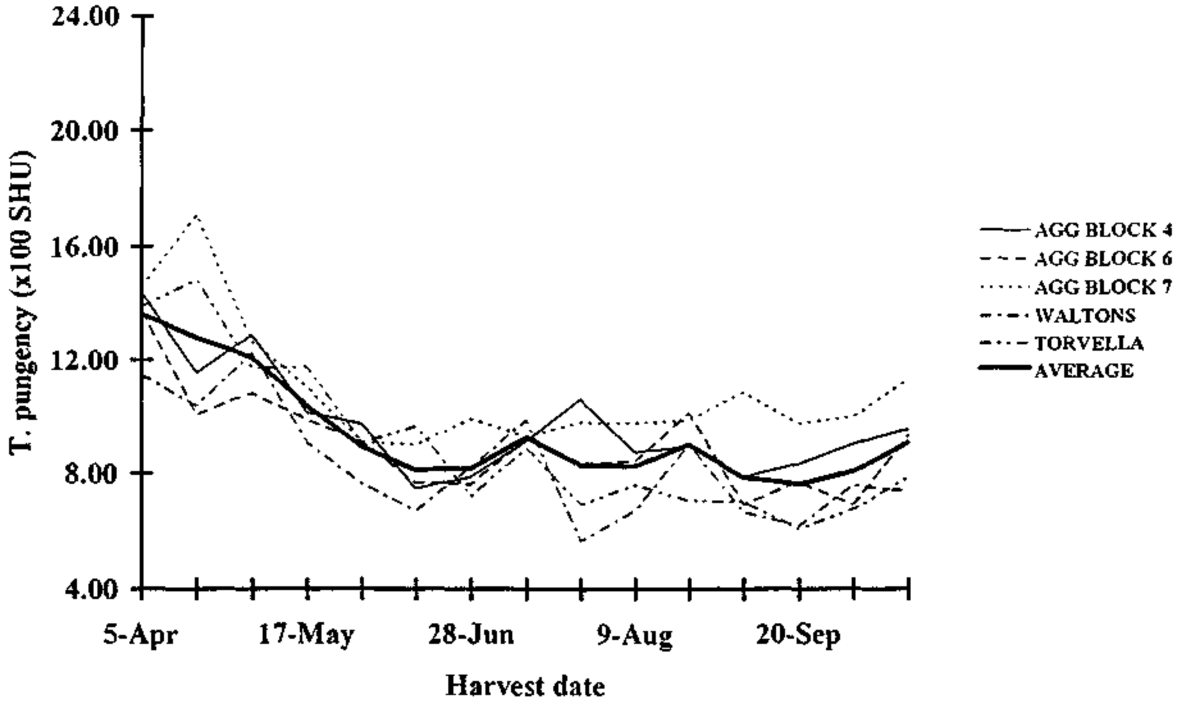


FIGURE 16. **Total pungency content expressed on a dry weight basis of ginger across the 1994 season**



For moisture content, AGG block 5/6 was found to be significantly lower to block 7 as well as Waltons and Torvella farms. Waltons was significantly lower to Torvella.

Oil content

On a combined seasonal basis, all AGG blocks are significantly higher to Waltons and Torvella farms. On a corrected dry weight basis, results show that AGG block 5/6 is significantly lower to both other AGG blocks. Block 7 is significantly higher to Torvella while Waltons and Torvella themselves are significantly different (Torvella is slightly higher).

Total volatiles

On a combined seasons basis, results for total volatiles from fresh ginger for AGG block 4 were significantly higher to both other AGG blocks as well as Torvella. Corrected to a dry weight basis, results showed AGG block 4 to be significantly higher to block 5/6, Waltons and Torvella. Block 7 is also significantly higher to block 5/6 and Waltons while Waltons and Torvella are significantly different to each other (Torvella).

Total pungency

For the combined seasons, total pungency for fresh ginger from Waltons and Torvella were both significantly lower to all AGG blocks. Corrected to a dry weight basis, results for total pungency show AGG block 5/6 to be significantly lower to the other AGG blocks. Both Waltons and Torvella were found to be significantly lower to all AGG blocks.

Seasonal comparisons

Profiles for the mean attributes of moisture content, oil content, total volatile content and total pungency have been compared on a seasonal basis. Results have been statistically analysed and are recorded in Table 3, Appendix 1.

Even though the mean results of most attributes mentioned above were significantly different, overall across the season profiles were similar as there were no significantly difference in the "F" ratios. Statistical analyses of the means have been recorded in Table 2, Appendix 1.

Moisture/solids content

Comparisons of the 1993 and 1994 harvests for average % moisture content for all samples have been plotted in figure 17. The 1994 season is consistently lower across the entire harvest period and ties in with a lower yearly rainfall. As can be seen in the appendix, 1993 seasonal rainfall was higher, particularly in the latter half of the season.

Mean results analyses found % moisture content to be higher for the 1993 season. Across the season, statistical analysis of the mean results showed a significant drop from the start of the season to the end of May where the % moisture content levelled off with no significant difference occurring to the end of the seasons.

As expected the converse was observed for average % solid content for the 1993 and 1994 ginger harvests as depicted in figure 18. Across the season, conversely the mean results for % solids showed a significant increase at the start of the season to the end of May and then no siginificant difference to the end of the season.

Oil content

Seasonal comparison of the average % oil content of fresh ginger is shown in figure 19. Both years, 1993 and 1994, have initially approximately 0.4%. However, 1993 season with better rainfall, increased further to 0.6% in May and then steadily decreased. Oil content in 1994 when rainfall was less, only peaked at 0.5% in May but did not decrease as rapidly across the season, actually being higher in content from mid June to the end of the season.

FIGURE 17. **Seasonal comparison of % moisture content of fresh ginger**

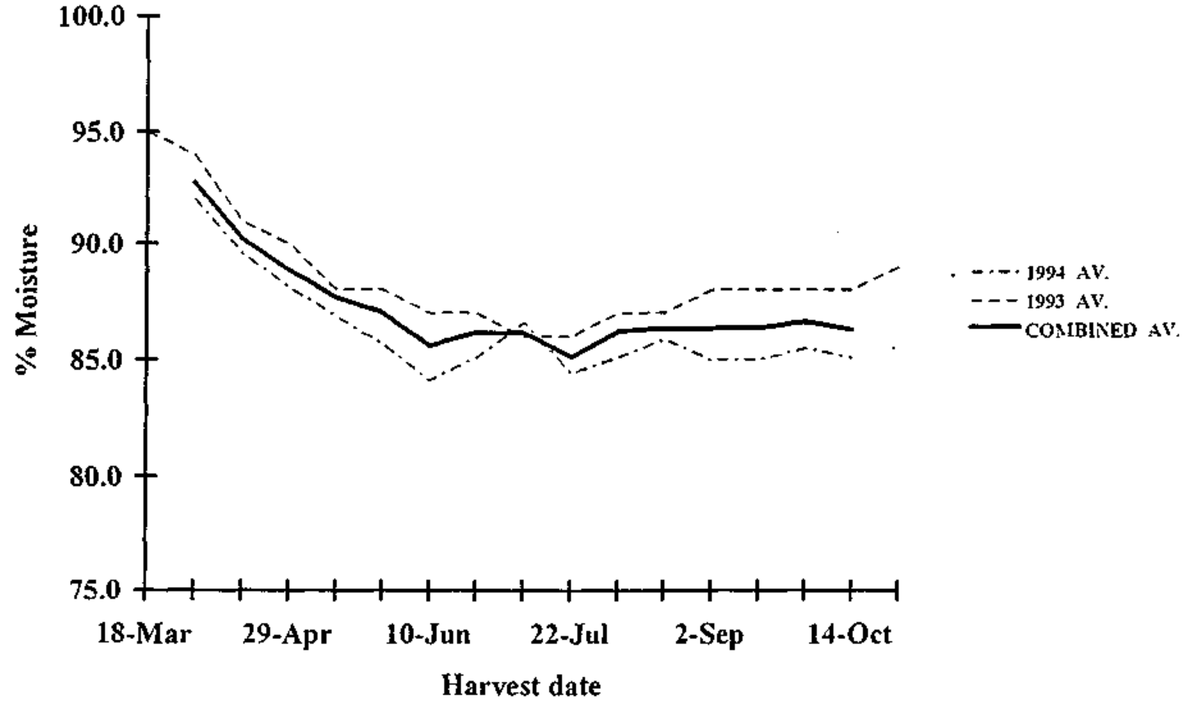


FIGURE 18. **Seasonal comparison of % solid content of fresh ginger**

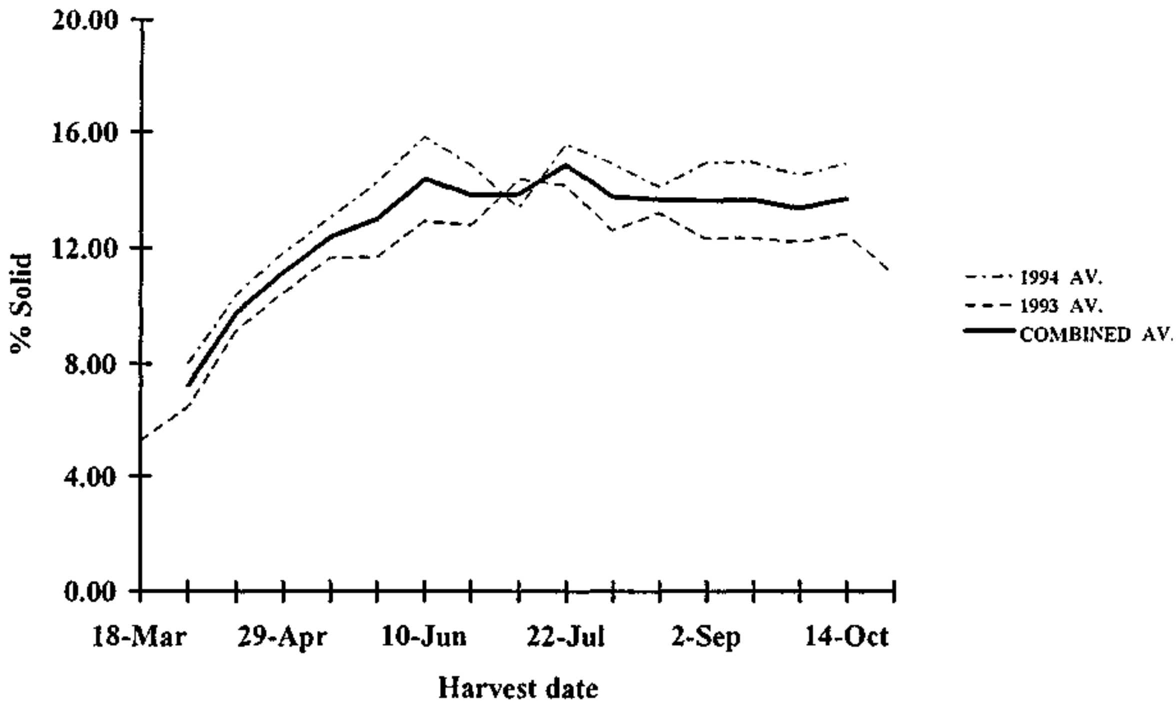


FIGURE 19. Seasonal comparison of % oil content of fresh ginger

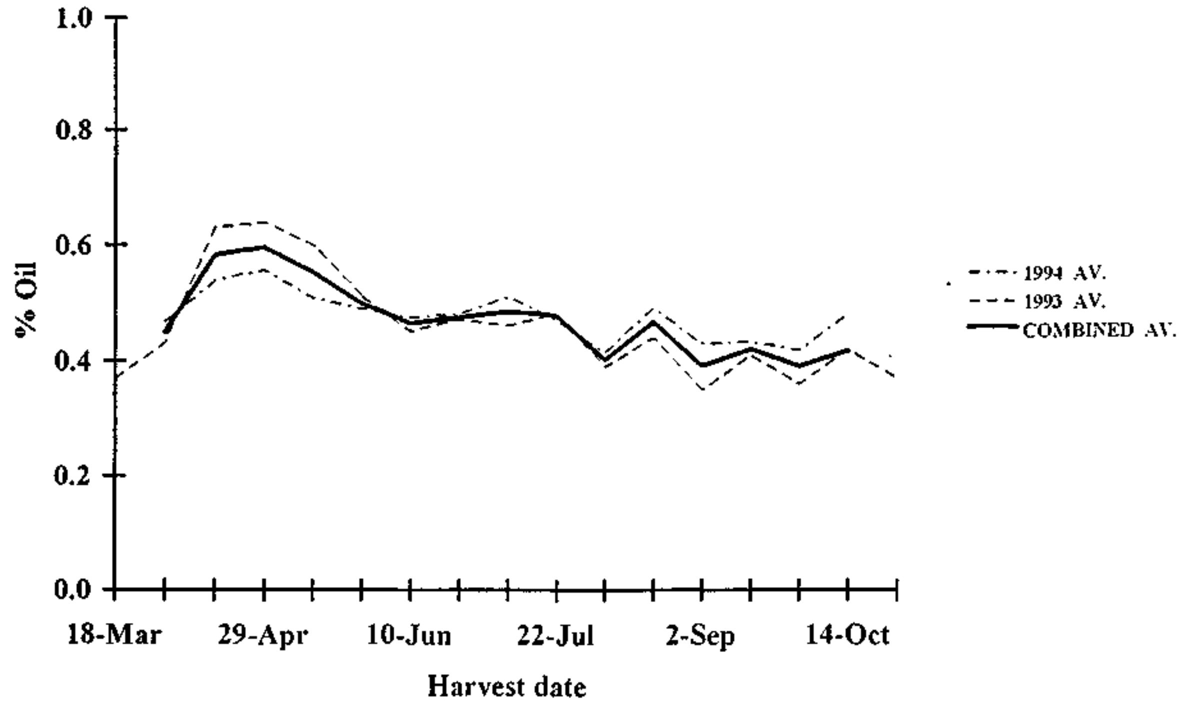
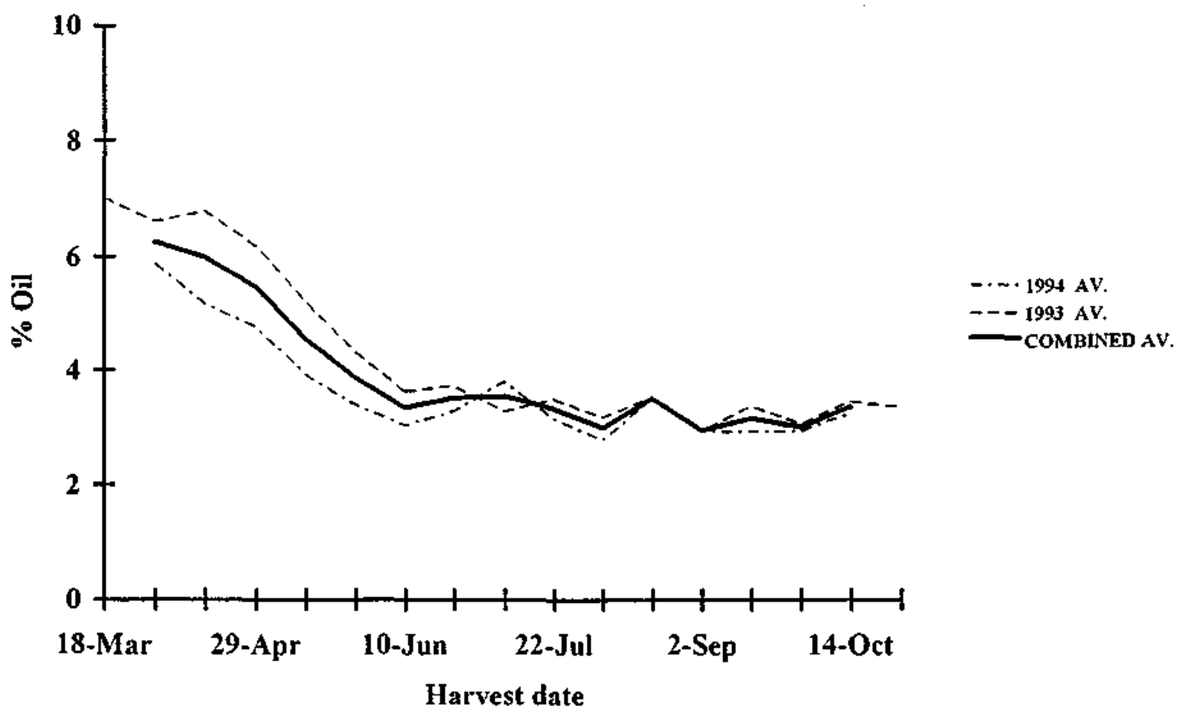


FIGURE 20. Seasonal comparison of % oil content expressed on a dry weight basis



Statistically, no significantly difference was found to have occurred for % oil content between seasons for fresh ginger.

Across the season, the mean results for % oil content of fresh ginger by statistical analysis showed a significant peak at the start of May decreasing to the start of June and remaining fairly level recording no significant difference to the end of the seasons.

Unless a common baseline for comparison is employed, results can be deceiving. Thus the average to % oil content expressed on a dry weight basis (figure 20) has shown the 1994 season to be statistically lower than 1993 for the full season. 1994 season had consistently lower rainfall.

Across the season,the mean results for % oil content expressed on a dry weight basis recorded a significant decrease from the start of the seasons to the start of June where it levelled out with no significant difference occurring to the end of the seasons.

Total volatiles

Seasonal comparisons of the average total volatile content from raw ginger depicted total peak area of the 1994 season to be statistically higher than the 1993 season totally across the harvest time. This is graphically represented in figure 21. Some relationship may be present between total volatile content and % solid content as both agree in their respective seasons.

Across the seasons, the mean result for total volatiles from fresh ginger showed three significantly different peaks at the end of April, mid June and the start of September.

Similar results were obtained when determinations were expressed on a dry weight basis (figure 22) again indicating a possible connection to solids content. Statistically, the results for the 1994 season were significantly higher to those of the 1993 season.

FIGURE 21. **Seasonal comparison of total volatile content of fresh ginger**

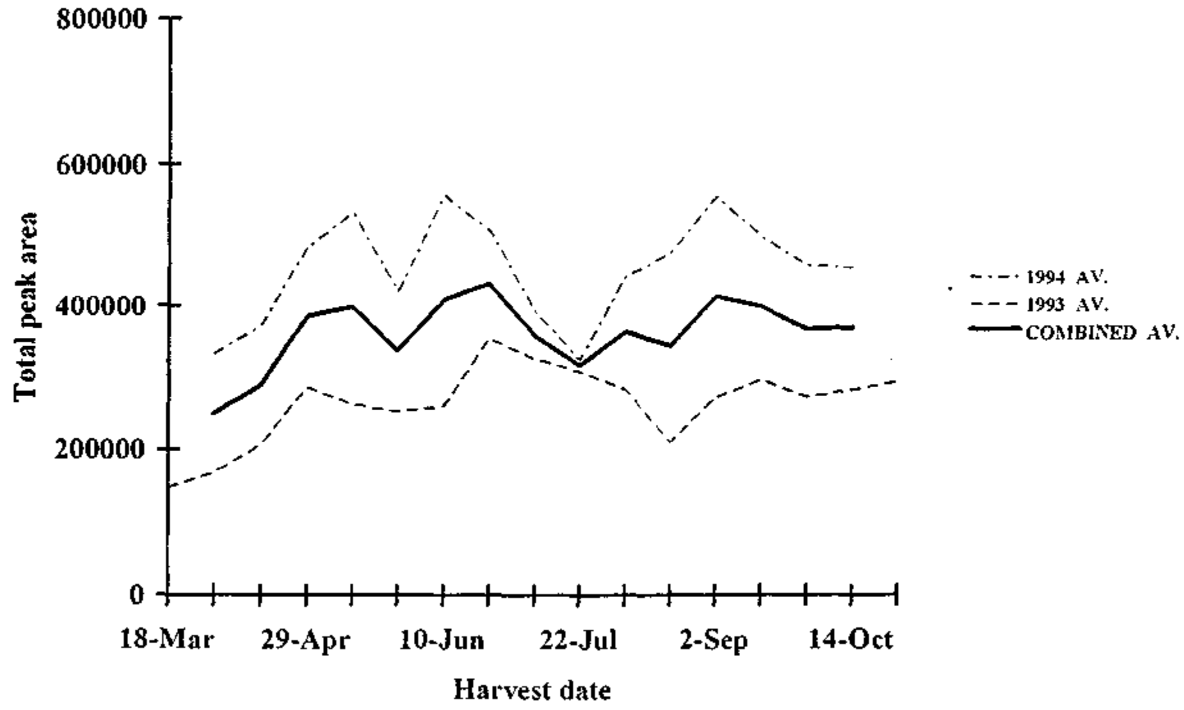
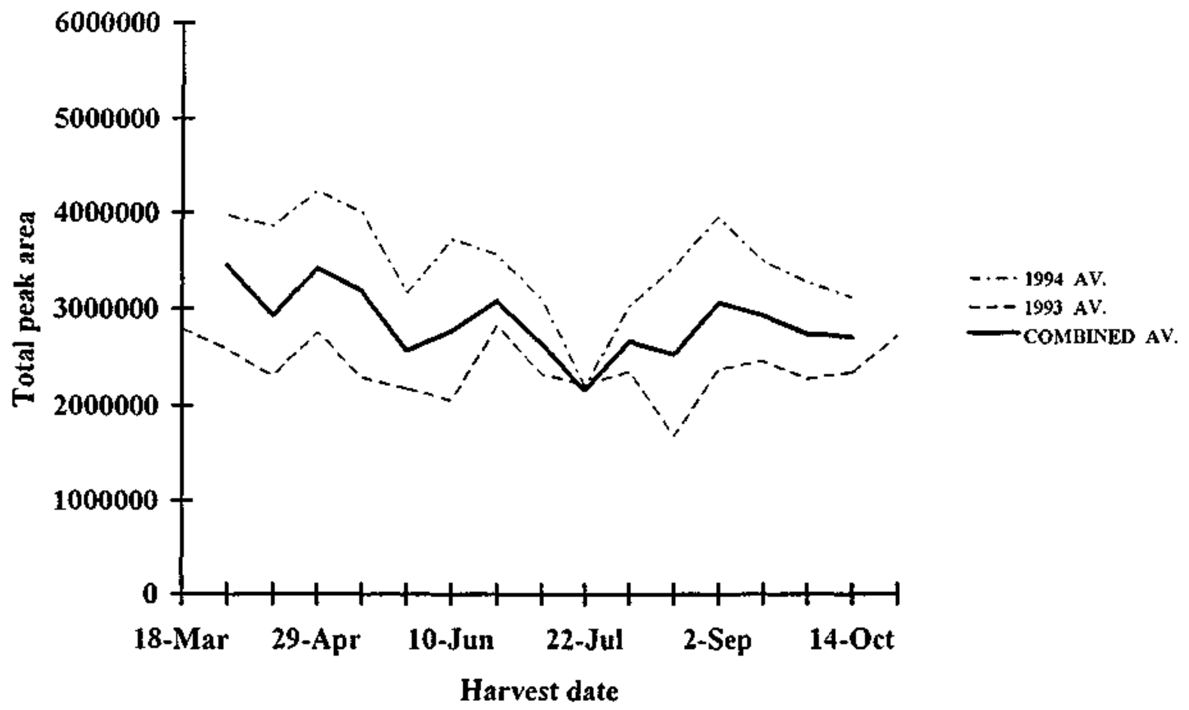


FIGURE 22. **Seasonal comparison of total volatile content expressed on a dry weight basis**



Across the season, mean results for total volatiles on ginger expressed on a dry weight basis showed three similar significant peaks at the same times for the fresh ginger.

Total pungency

Comparisons of average total pungency content of raw ginger and expressed on a dry weight basis for the 1994 and 1993 seasons have shown remarkably similar profiles (figures 23 & 24) to those obtained for oil content. This appears reasonable as the pungent components of ginger have been found to reside in the ginger oil.

Statistically, no significant difference occurred for results from fresh ginger.

Across the season, the mean result profile was very similar to that obtained for % oil content. By statistical analysis, a significant peak for total pungency for fresh ginger occurred at the start of May, decreased to the end to the start of June and levelled off with no significant difference to the end of the seasons.

However results corrected to a dry weight basis found total pungency for the 1993 season to be significantly higher than the 1994 season.

Across the season, the mean result profile was again very similar to % oil content expressed on a dry weight basis. Statistically, a significant decrease occurred from the start of the seasons to the start of June where it levelled out with no significant occurring until the end of the seasons.

Varietal comparisons

Profiles for the mean results of attributes of % moisture content, % oil content, total volatile content and total pungency have compared on a varietal basis. Results have been analysed statistically and are recorded in Table 2, Appendix 1

FIGURE 23. Seasonal comparison of total pungency content of fresh ginger

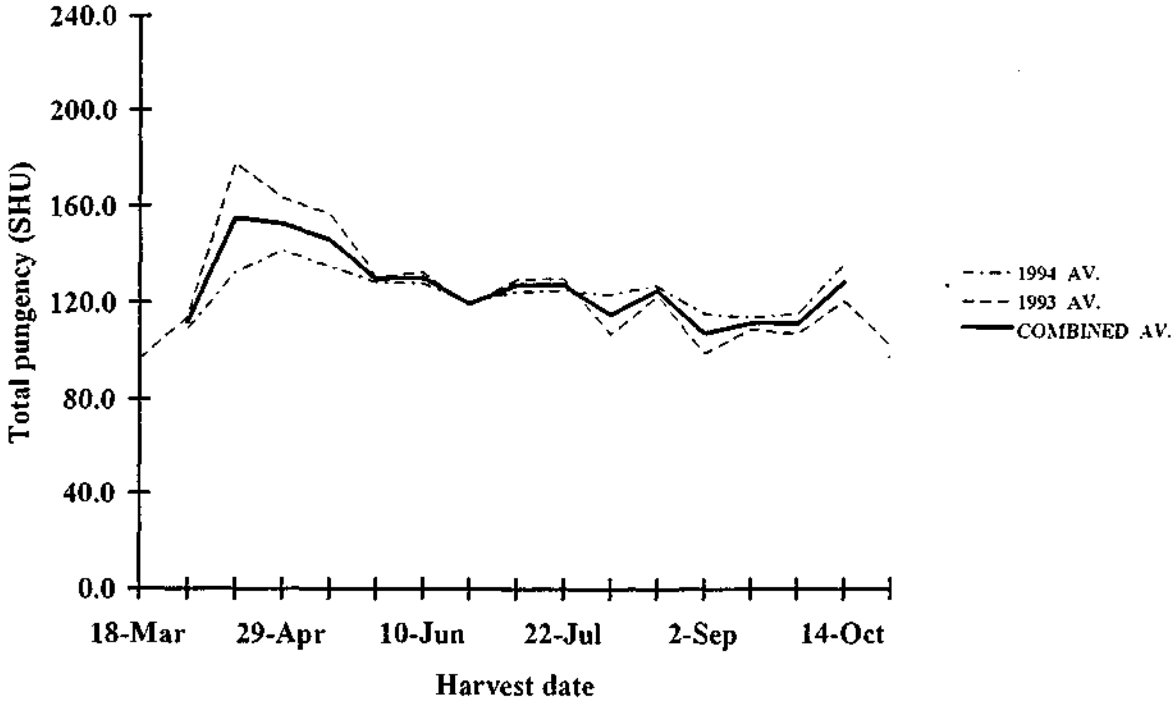
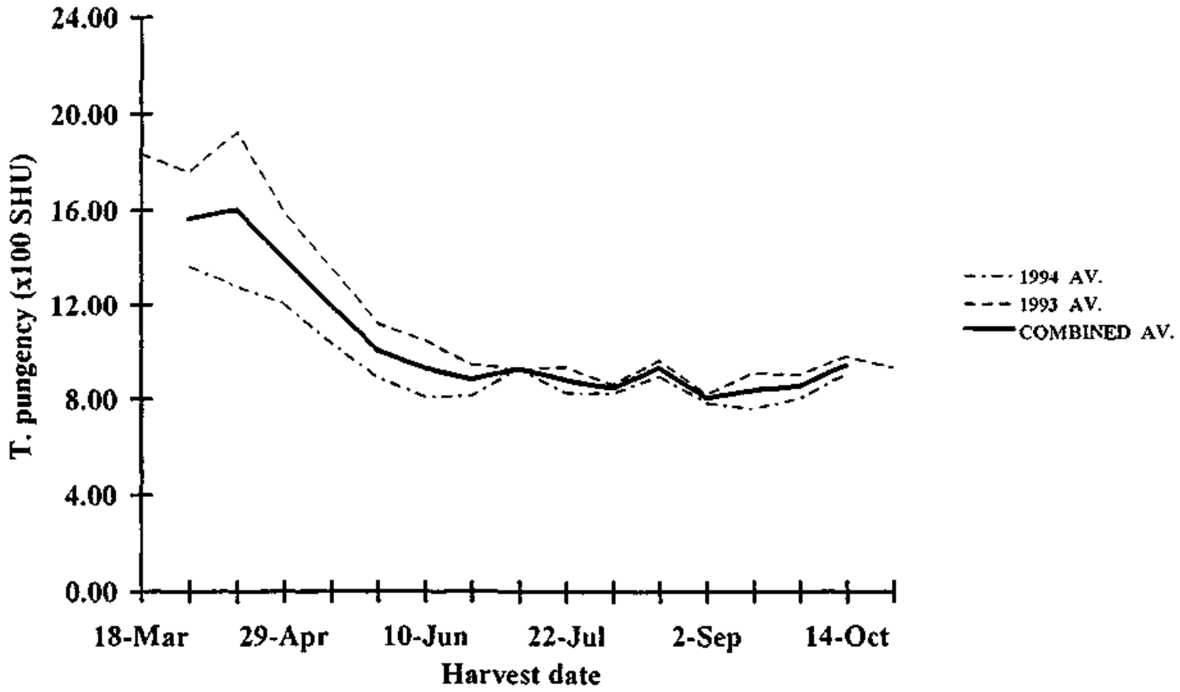


FIGURE 24. Seasonal comparison of total pungency content expressed on a dry weight basis



Moisture/solids content

Comparisons of the % moisture content of Queensland, Hawaiian and Cantonese varieties of raw ginger are depicted in figure 25. All varieties initially have approximately 92.5% moisture in early April, then gradually decrease to a range of 84-89% by the end of the harvest.

Statistical analysis of the mean results of fresh ginger for % moisture content found the Queensland variety of ginger to be significantly higher to both the Hawaiian and Cantonese varieties.

The conversion of % moisture content to % solid content has also been shown in figure 26 and depicts an increase for each variety across the season.

Statistical analysis of the mean results found the Queensland variety to be significantly lower in % solids when compared to the other two varieties.

Oil content

% Oil content of the three varieties is shown in figure 27. Statistically the mean results of % oil content have shown no significant difference between varieties.

When results have been corrected on a dry weight basis (figure 28), oil content ranges between 4.5% and 5.0% at the start of the season and gradually decreases to a range between 2% and 3% at the end of the season. Statistically, the mean results of % oil content for the Queensland variety now become significantly higher than the Hawaiian variety. Hawaiian and Cantonese varieties were not found to be significant.

FIGURE 25. Varietal comparison of moisture content of fresh ginger

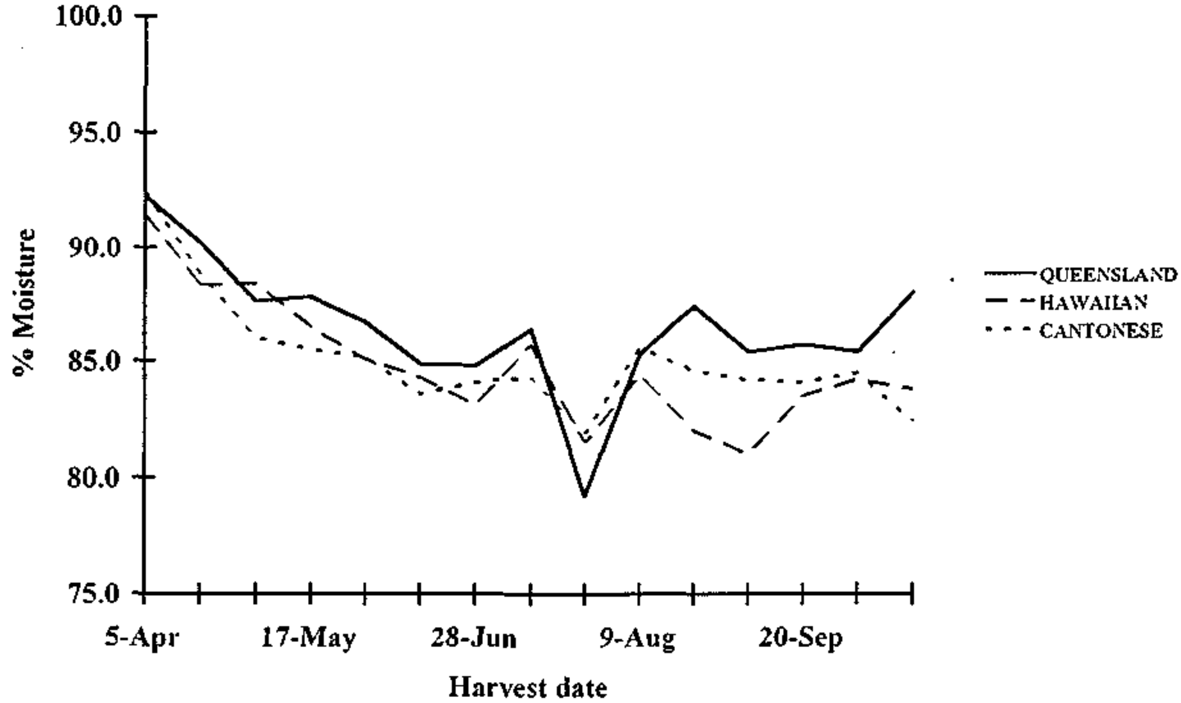


FIGURE 26. Varietal comparison of solid content of fresh ginger

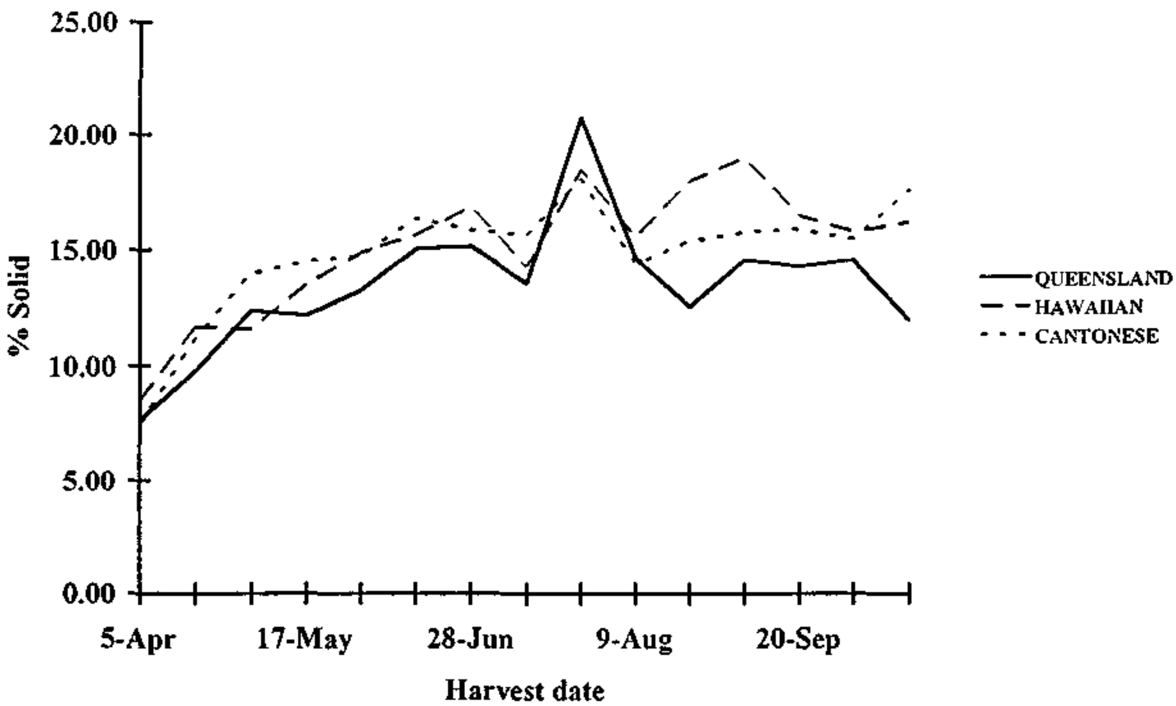


FIGURE 27. Varietal comparison of oil content of fresh ginger

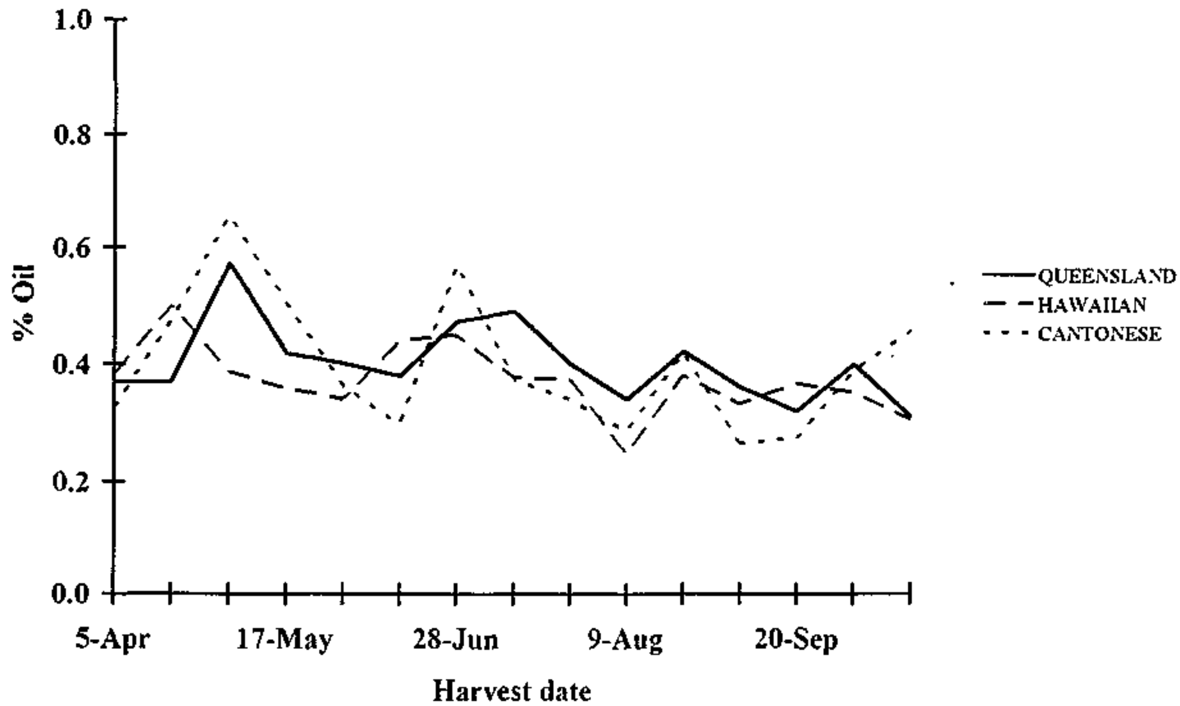


FIGURE 28. Seasonal comparison of oil content expressed on a dry weight basis

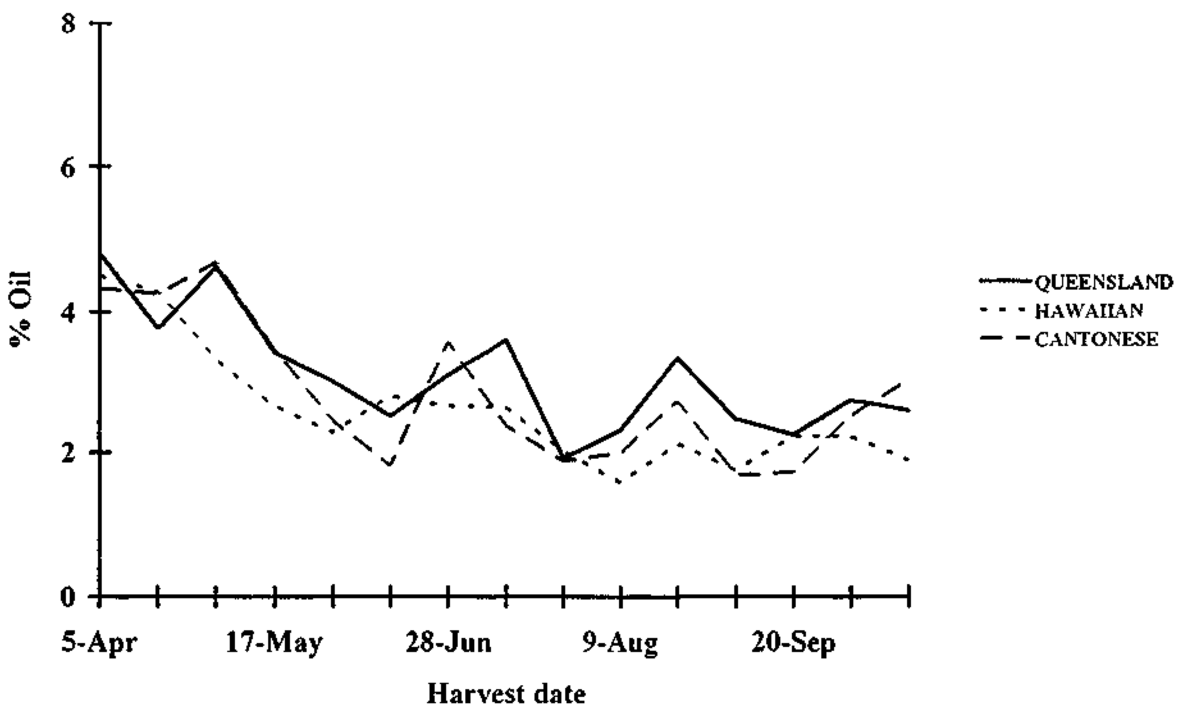


FIGURE 29. Varietal comparison of total volatile content of fresh ginger

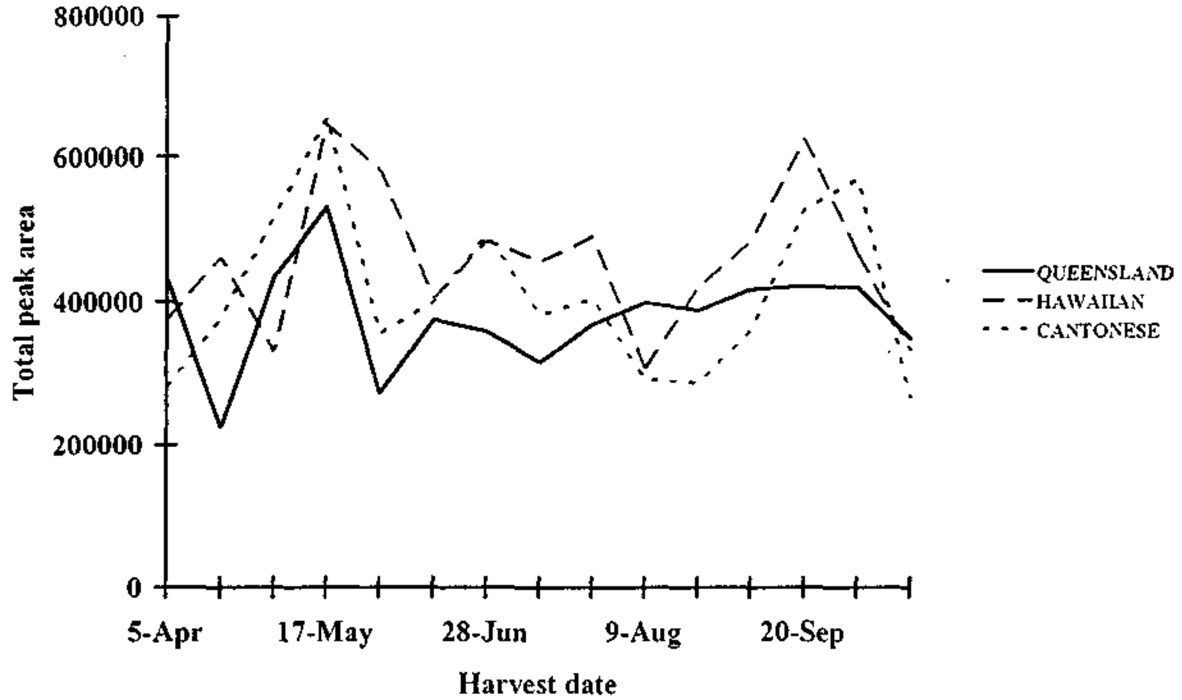
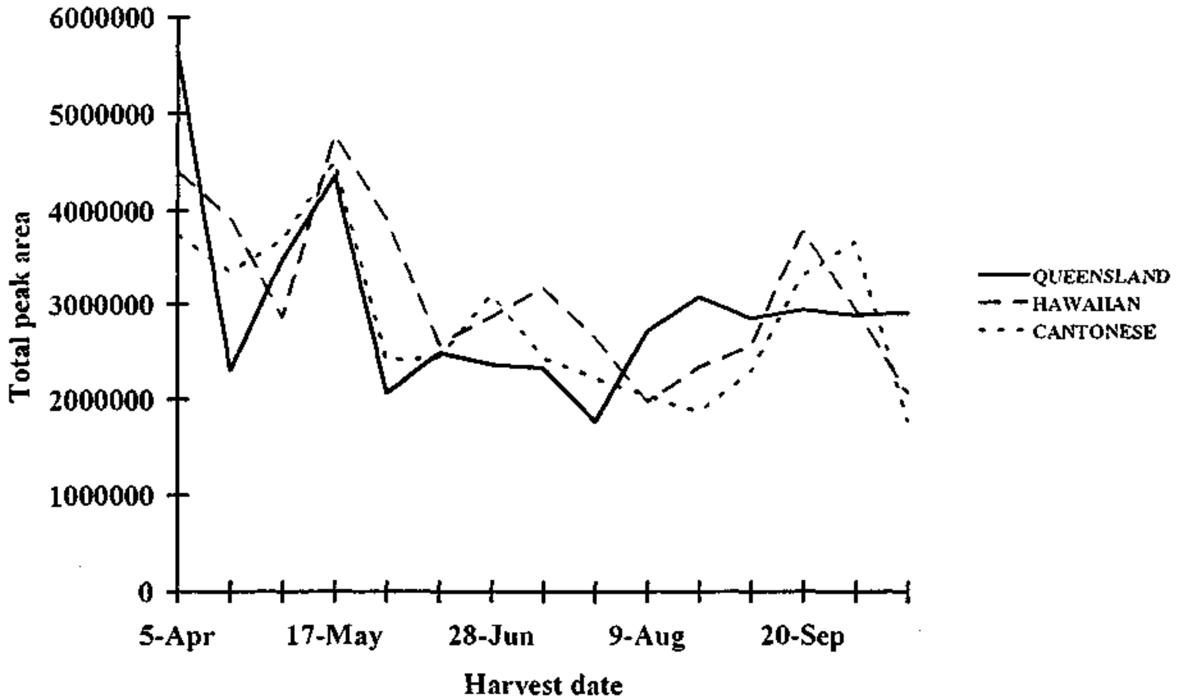


FIGURE 30. Varietal comparison of total volatile content expressed on a dry weight basis



Total volatiles

Queensland variety consistently has shown lower total volatile content across the harvest season when compared to Hawaiian and Cantonese ginger (figure 29). This attribute of higher volatiles (aroma) for Hawaiian and Cantonese, particularly Hawaiian ginger, may allow more aromatic (gingery) products to be produced.

Mean results for total volatiles from fresh ginger have shown the Queensland variety to be significantly lower to Hawaiian but not Cantonese.

When determinations have been applied to a dry weight baseline (figure 30), no significant differences were found between any of the varieties.

Total pungency

Similar profiles are obtained when comparing total pungency of the three varieties to that found for % oil content for raw ginger (figure 31). This again indicates the close relationship between oil content and pungency.

Mean results for total pungency from fresh ginger indicated that the Queensland variety was significantly higher to the Hawaiian variety.

Results expressed on a dry weight basis (figure 32) have shown total pungencyfor the Queensland variety to be significantly higher to both the Hawaiian and Cantonese varieties.

FIGURE 31. Varietal comparison of total pungency content of fresh ginger

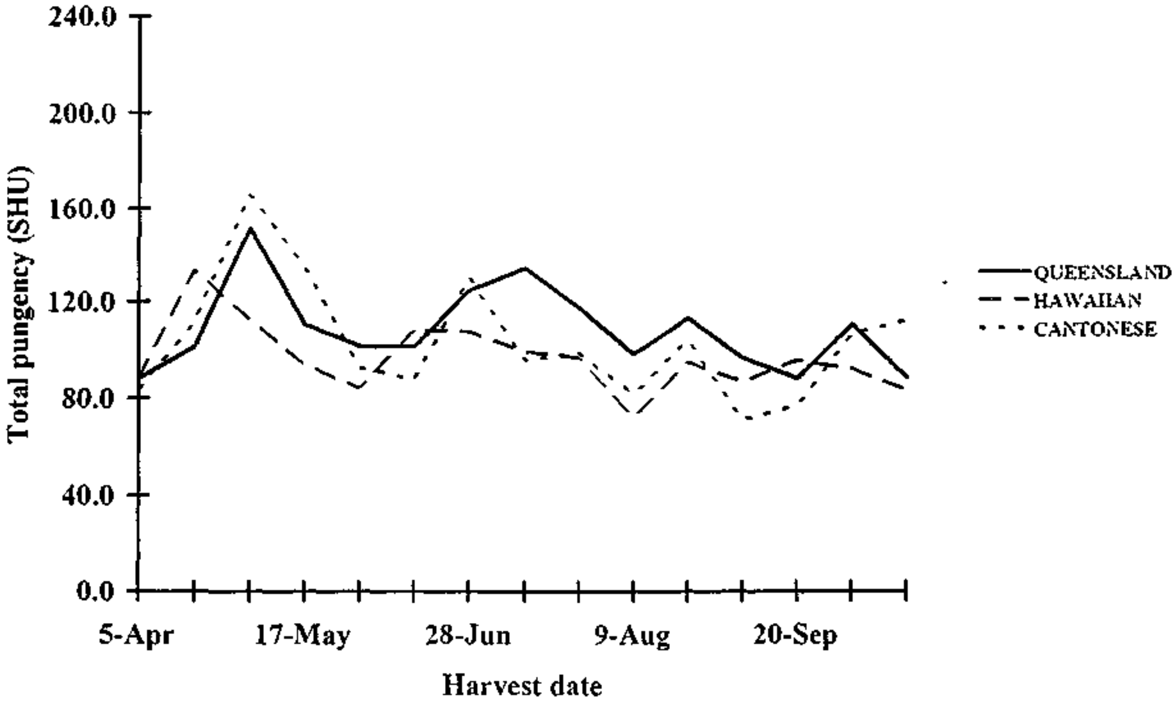


FIGURE 32. Varietal comparison of total volatile content expressed on a dry weight basis

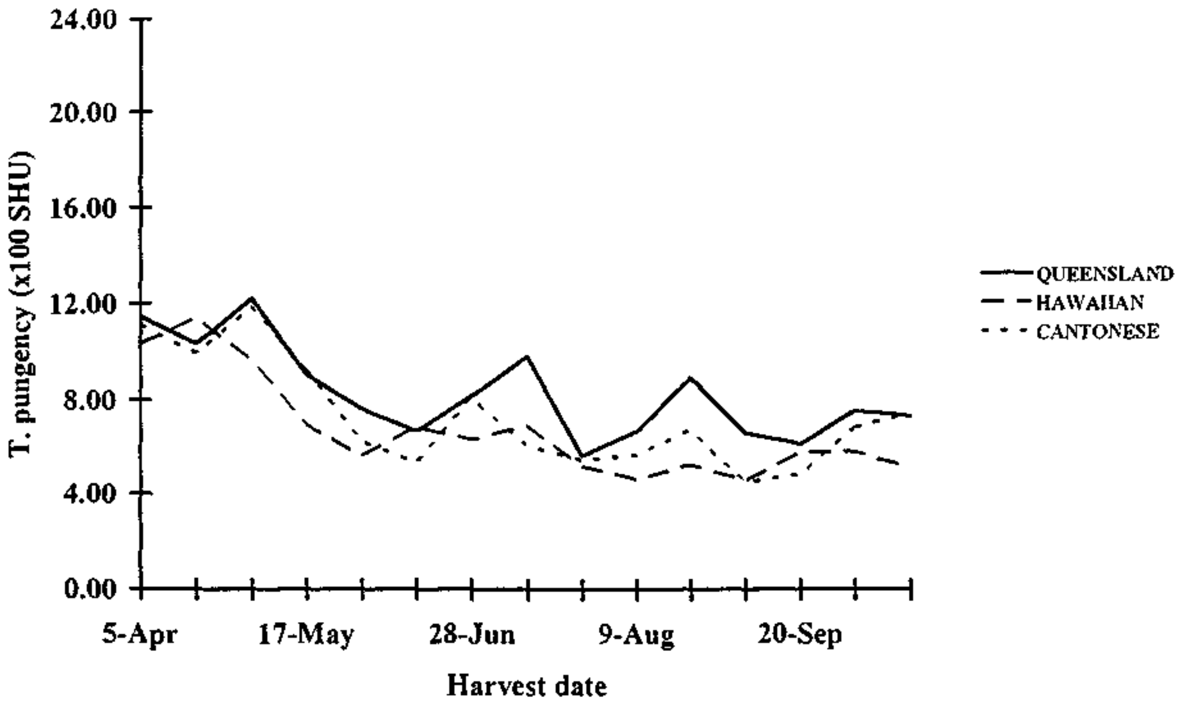


FIGURE 33. % Moisture content of 1993 fresh ginger stored at different temperatures

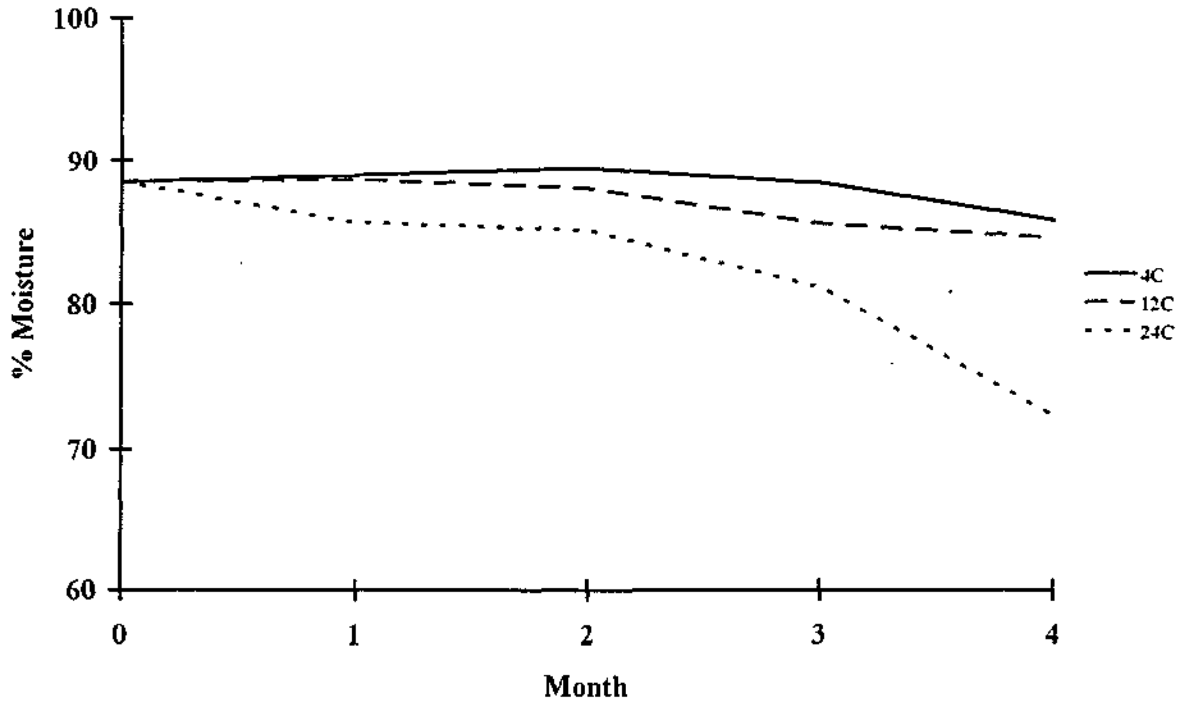
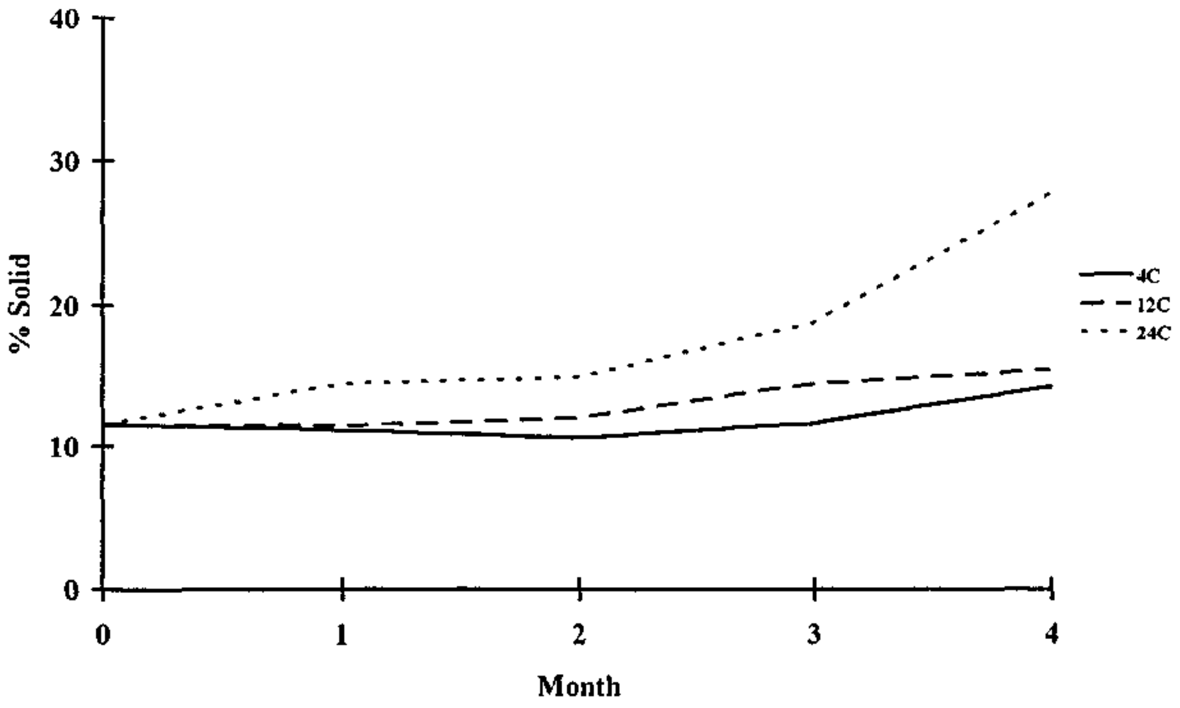


FIGURE 34. % Solid content of 1993 fresh ginger stored at different temperatures



Storage trials

Moisture/solids content

Figure 33 depicts the % moisture content of 1993 raw ginger that has been stored at 4°C, 12°C and 24°C for 4 months. Moisture content drops over time due to natural evaporation of water from the stored ginger and as expected, 4°C < 12°C and < 24°C in water loss.

Converse of % moisture content, ie % solid is also shown in figure 34 with similar results.

Figure 35 depicts to % moisture and % solid content of 1994 ginger. Inadvertently, the open mesh onion bag containing the 4°C storage ginger, was placed directly below the fan in the cold room. This resulted in the 4°C stored ginger drying under similar conditions to dehumidified drying giving reduced moisture content and conversely higher solid content (figure 36) similar to that found with the ginger stored at 24°C.

Oil content

% Oil content for 1993 raw ginger stored at 4°C, 12°C and 24°C has been plotted in figure 37. % Oil content remained constant across the storage time for 4°C and 12°C but increased slightly with time at 24°C with a larger increase between three and four months. This is due to the greater drying effect experienced by the ginger at the higher temperature of 24°C, ie more solid and hence oil content must exist as the sample becomes drier.

Correction of % oil content to a dry weight basis confirms that this drying effect is taking place (figure 38) by showing a more regular and slightly dropping oil content with time.

% Oil content for 1994 raw ginger stored at 4°C, 12°C and 24°C has been shown to increase slightly over the storage period with a greater increase over the last sampling period for 4°C and 24°C (figure 39). As previously explained, this is due to the greater

FIGURE 35. % Moisture content of 1994 fresh ginger stored at different temperatures

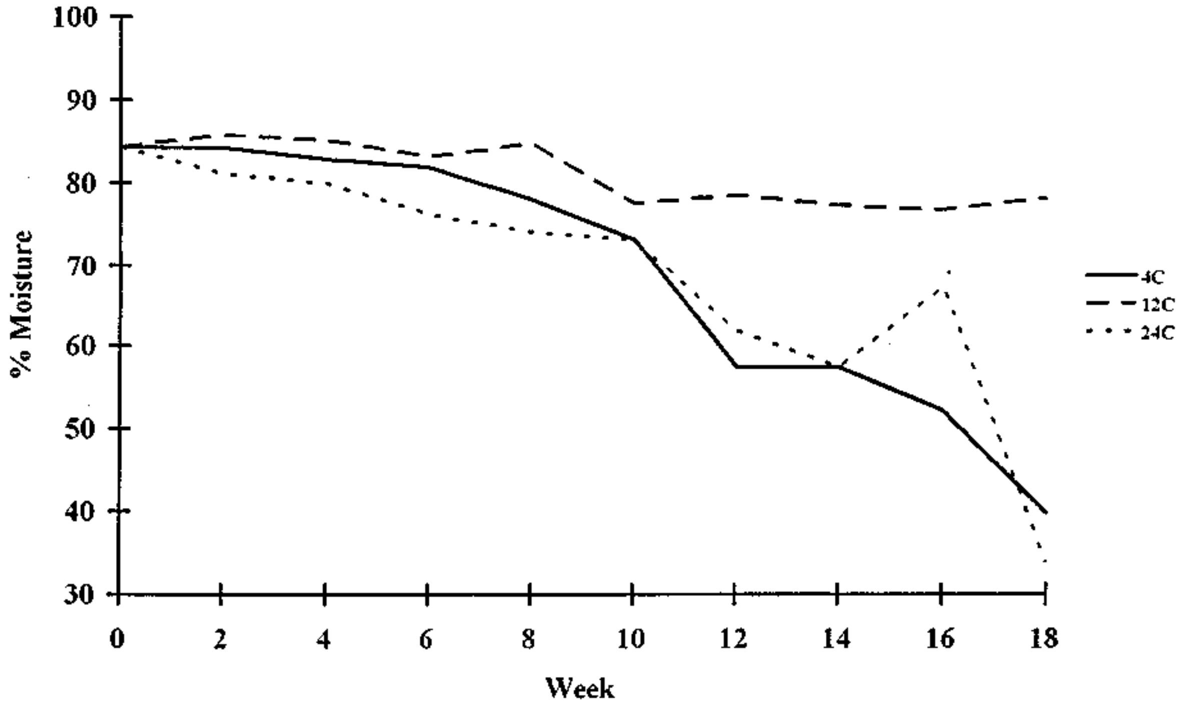


FIGURE 36. % solid content of 1994 fresh ginger stored at different temperatures

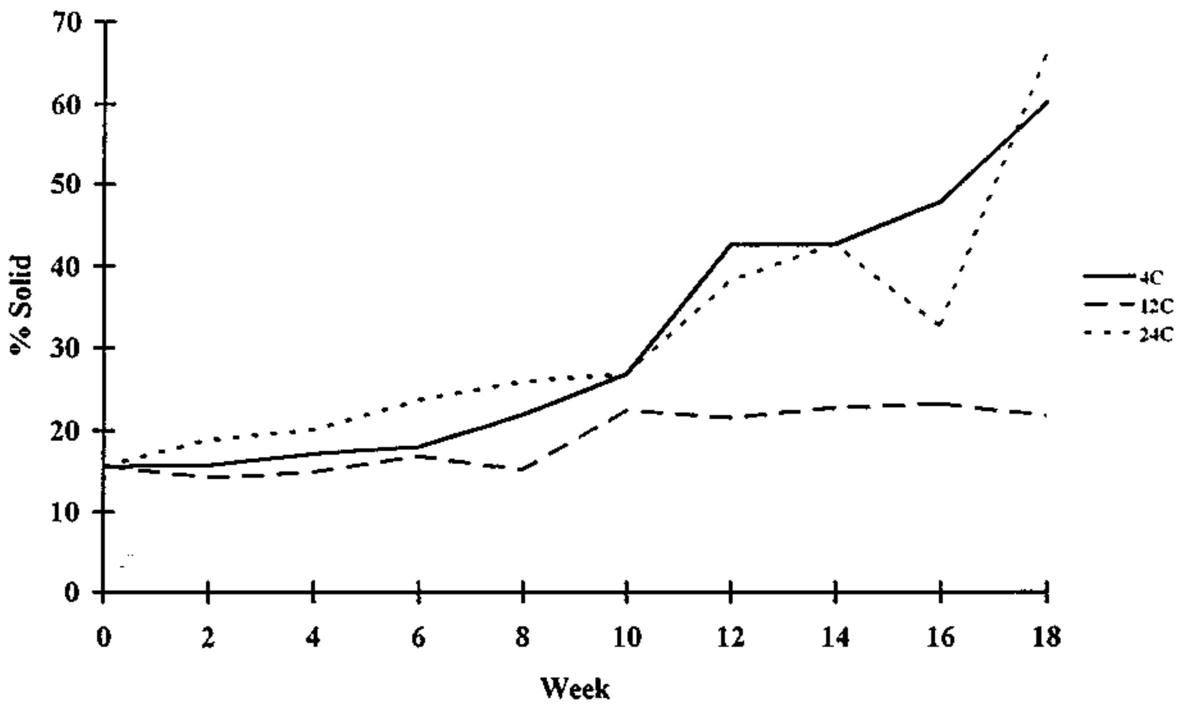


FIGURE 37. % Oil content of 1993 fresh ginger stored at different temperatures

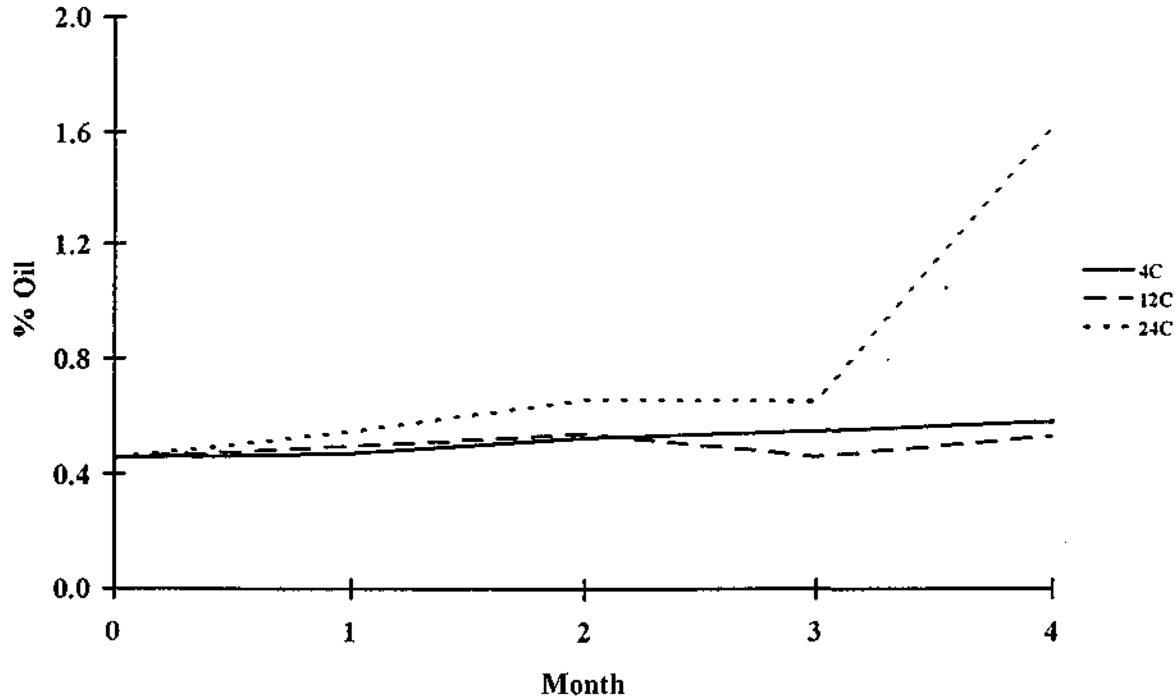


FIGURE 38. % Oil content of 1993 fresh ginger stored at different temperatures expressed on a dry weight basis

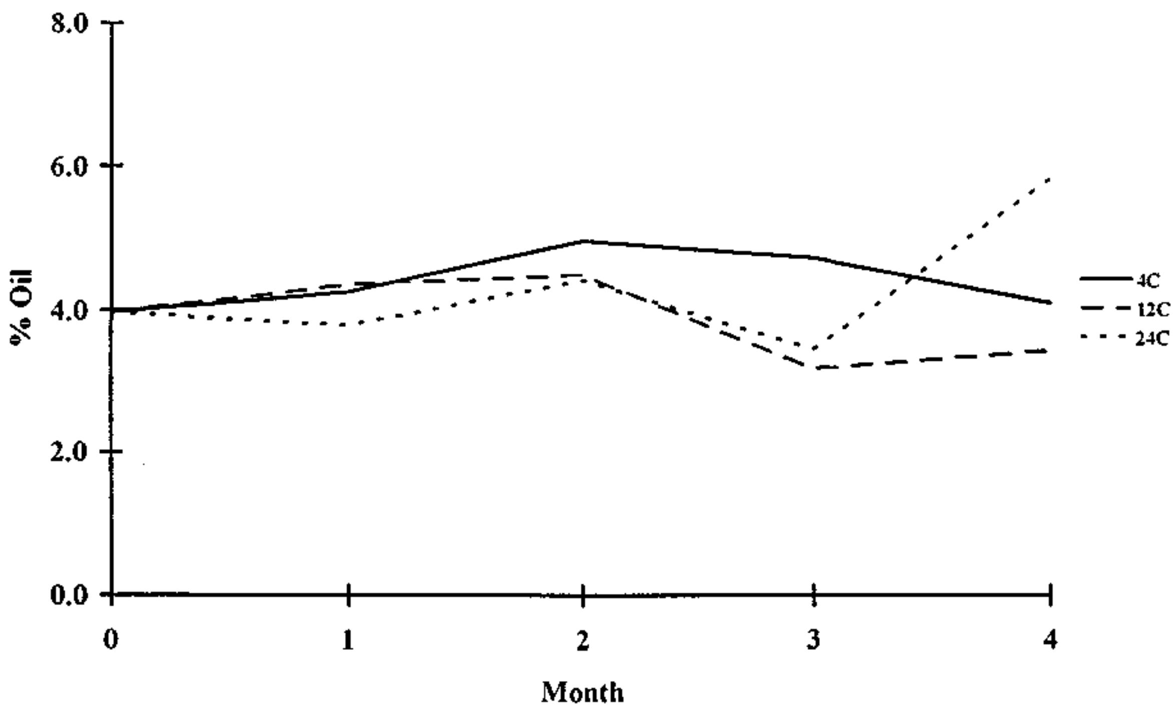


FIGURE 39. % Oil content of 1994 fresh ginger stored at different temperatures

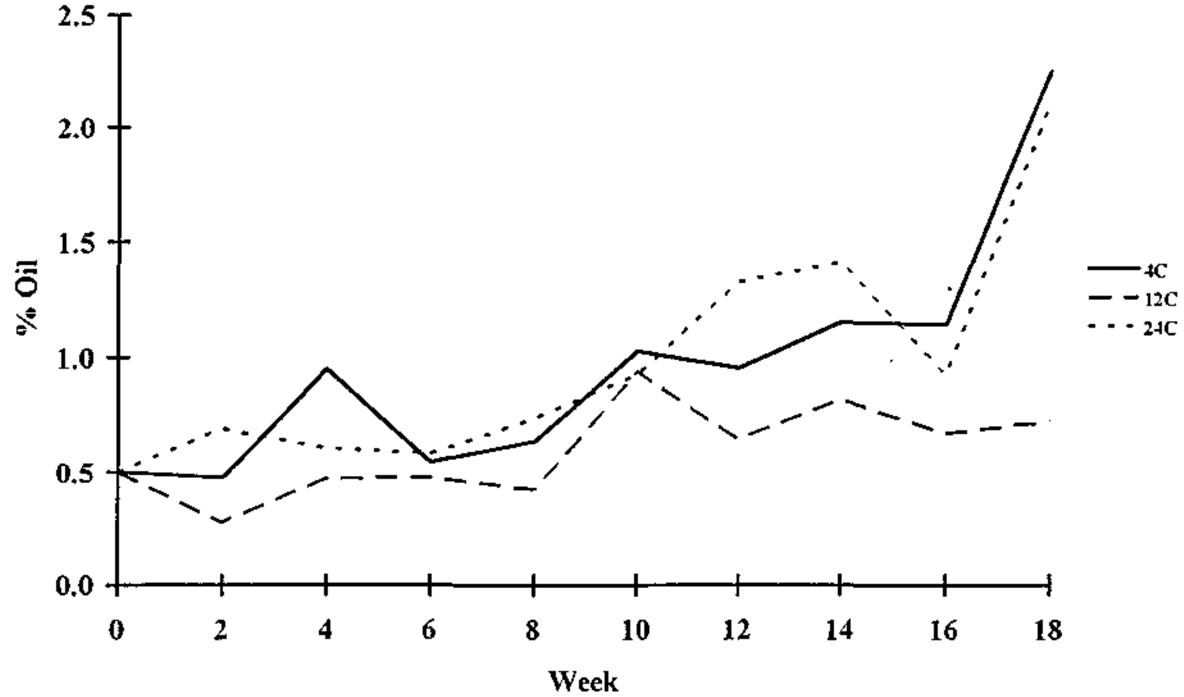
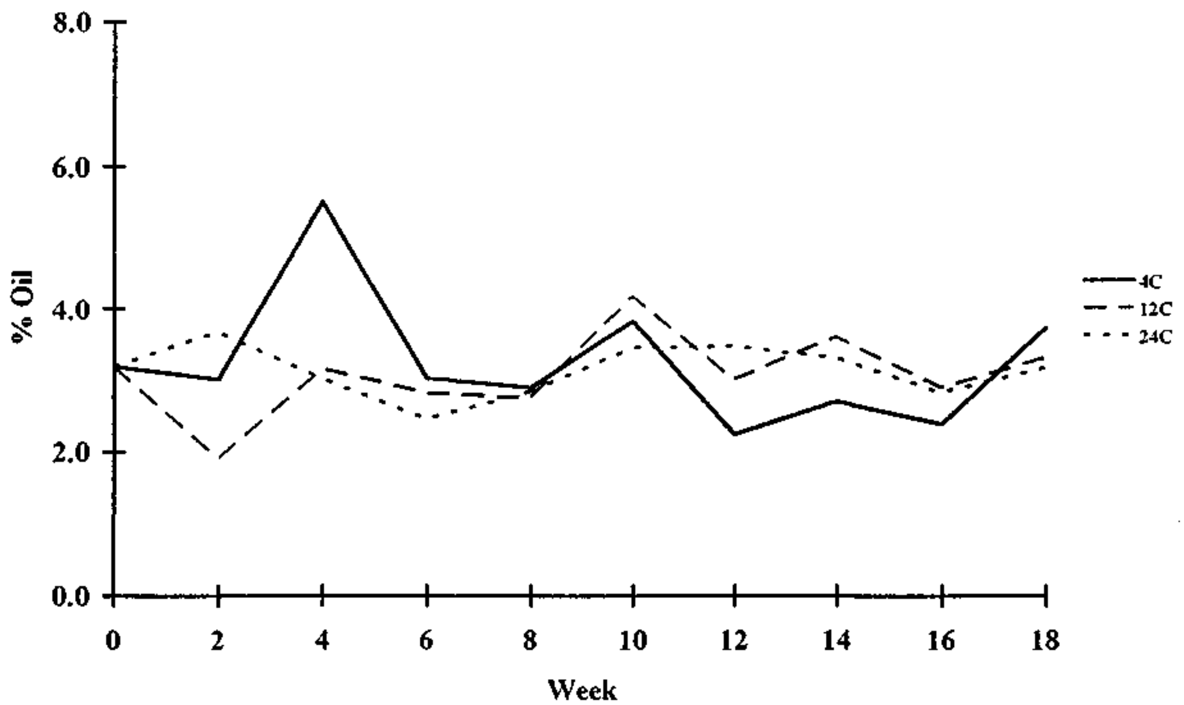


FIGURE 40. % Oil content of 1994 fresh ginger stored at different temperatures expressed on a dry weight basis



drying effect experienced at 4°C by dehumidified conditions and at 24°C by higher temperature.

Determinations on a dry weight basis has resulted in the % oil content for ginger stored at these temperatures to be relatively similar and consistent during the storage period (figure 40).

Total volatiles

Total volatile content for 1993 raw ginger stored at 4°C, 12°C and 24°C is shown in figure 41. A steady increase has resulted similar to solids content, as the stored ginger has dried out progressively over the storage time.

Figure 42 also shows the total volatile content corrected to the common baseline ie on a dry weight basis. Slight increases have occurred over the first month for 4°C and 12°C with a slight decrease occurring during the rest of the storage period. Total volatiles for ginger at 24°C have shown a steady decrease throughout storage.

Total volatile content for 1994 raw ginger stored at these temperatures of 4°C, 12°C and 24°C has been plotted in figure 43. The general trend for all three temperatures has shown a slight increase with time with 24°C storage results being consistently lower than 4°C and 12°C.

This is seen more easily when determinations are corrected to a dry weight basis (figure 44). Initially 4°C results are highest but decrease more sharply across storage time when compared to 12°C which remains fairly consistent.

Total pungency

In figure 45, total pungency has been plotted for 1993 raw ginger stored at 4°C, 12°C and 24°C. Generally, results have shown a slight decrease for 4°C and 12°C. 24°C has

FIGURE 41. Total volatile content of 1993 fresh ginger stored at different temperatures

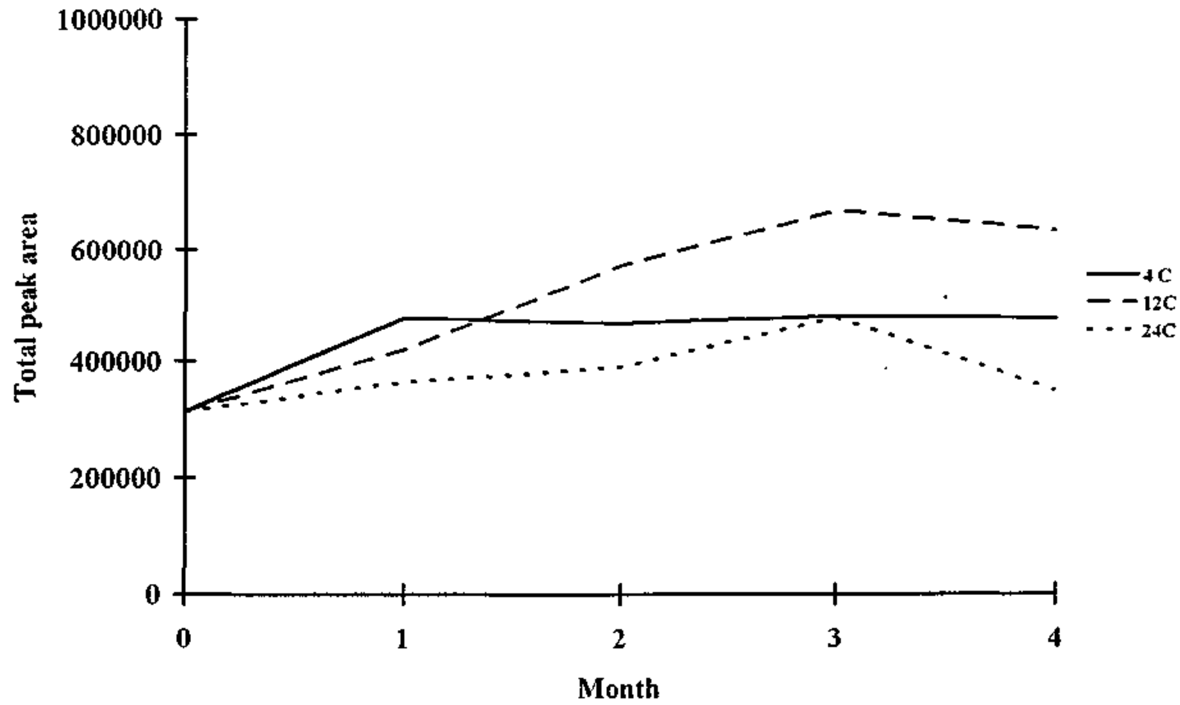


FIGURE 42. Total volatile content of 1993 fresh ginger stored at different temperatures expressed on a dry weight basis

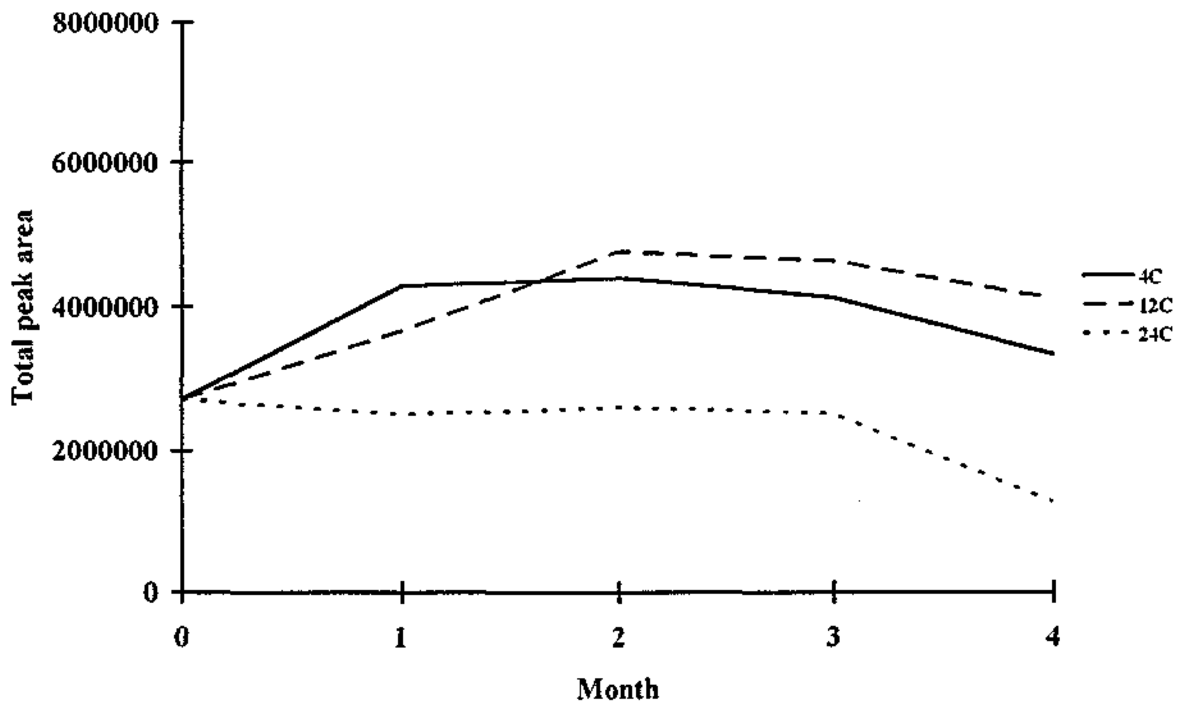


FIGURE 43. Total volatile content of 1994 fresh ginger stored at different temperatures

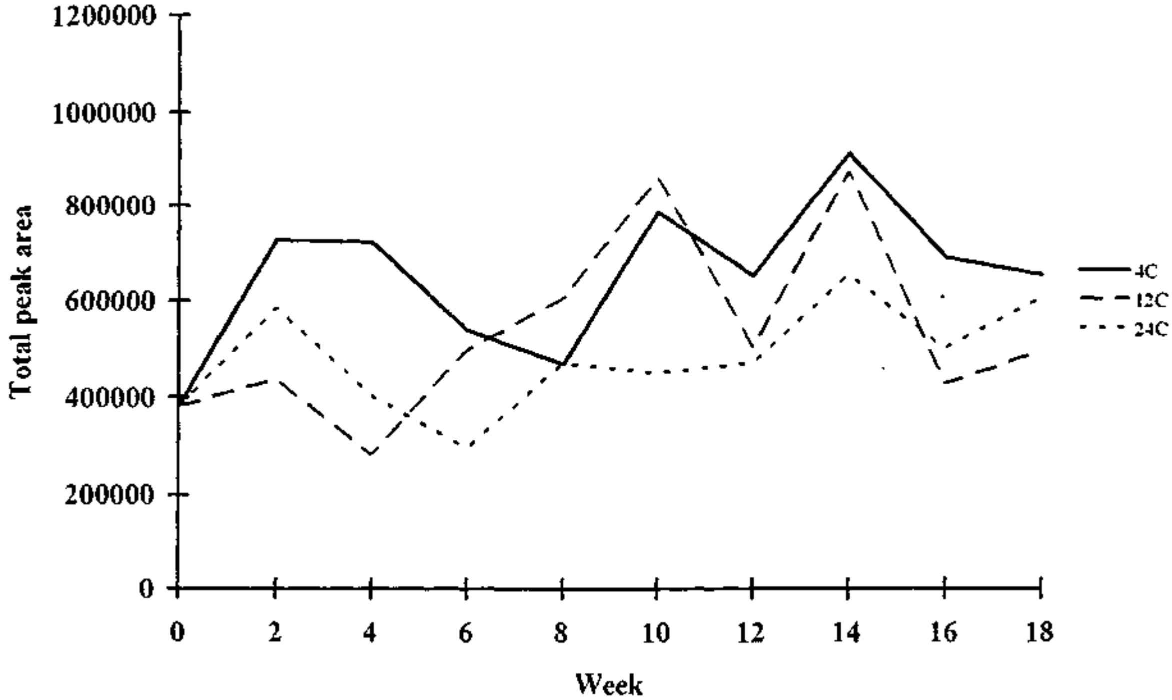


FIGURE 44. Total volatile content of 1994 fresh ginger stored at different temperatures expressed on a dry weight basis

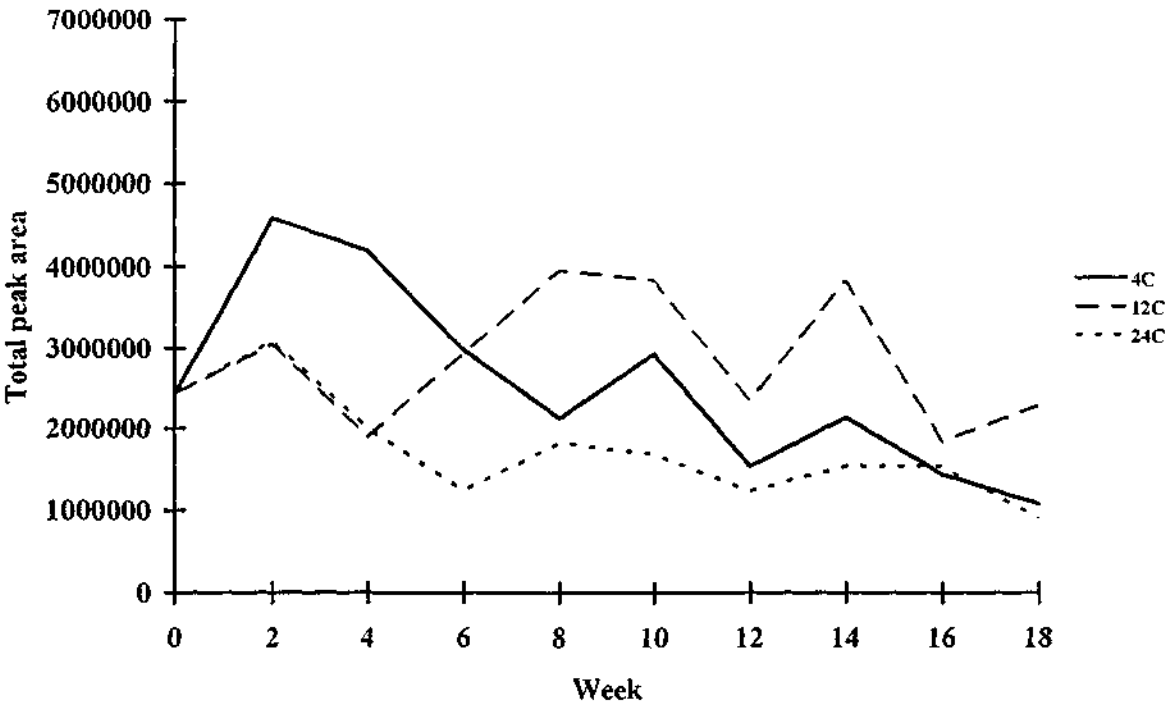


FIGURE 45. **Total pungency content of 1993 fresh ginger stored at different temperatures**

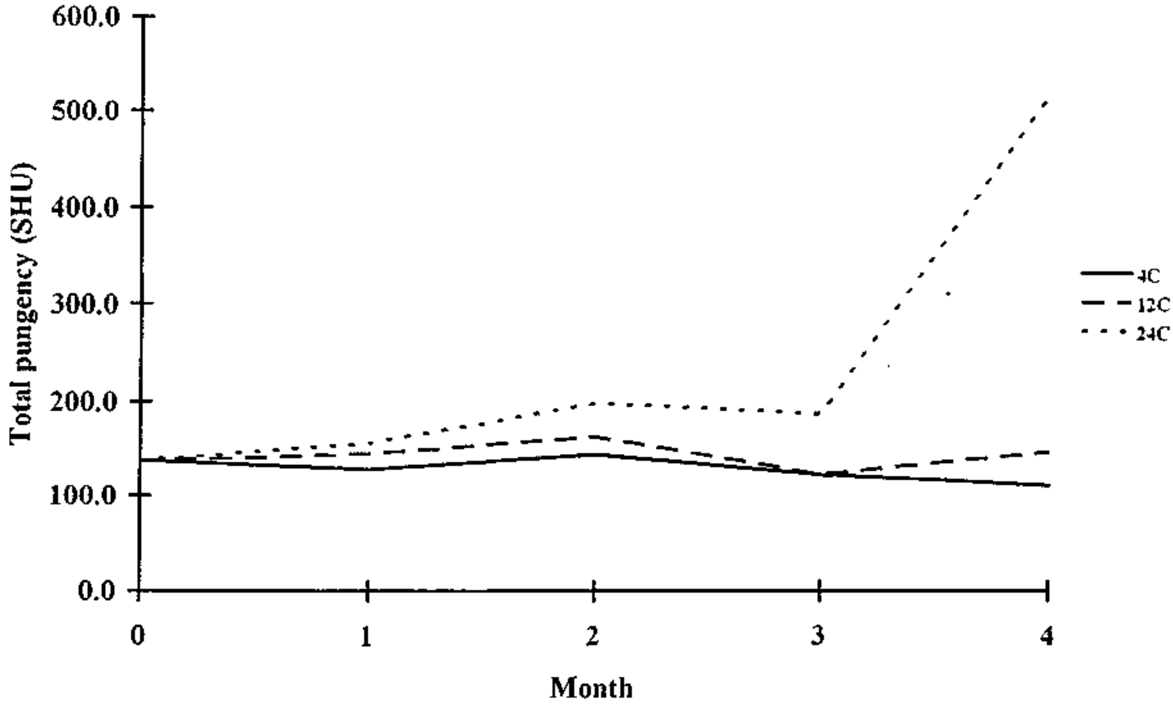
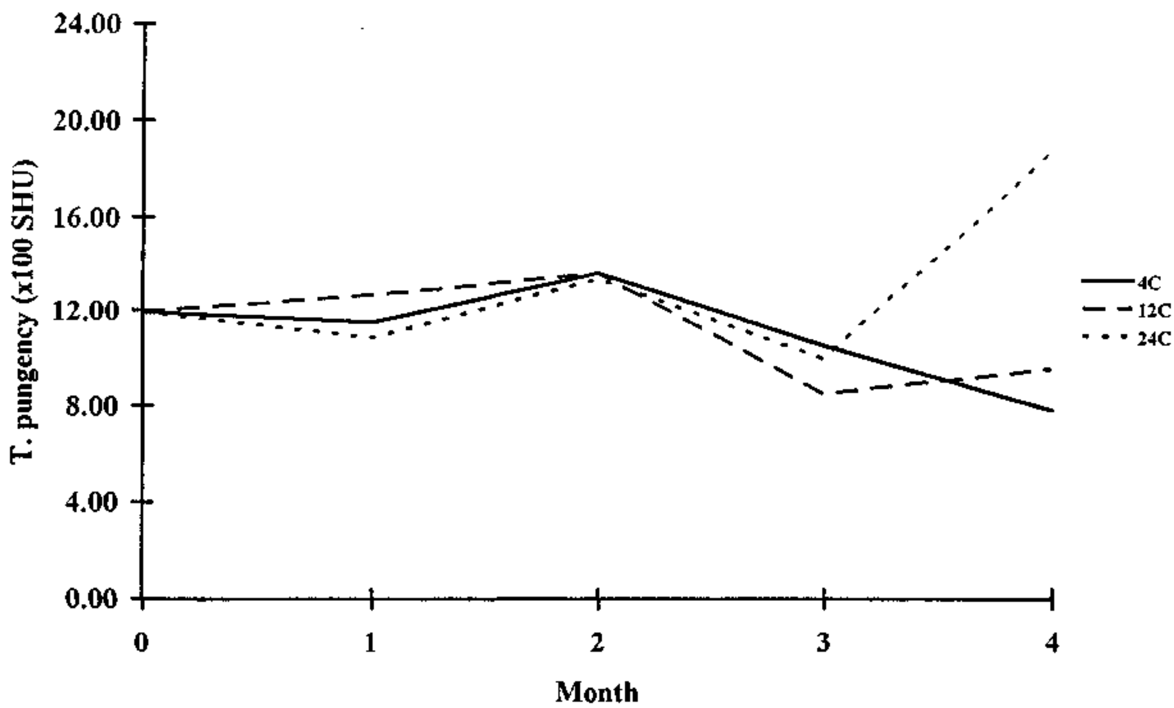


FIGURE 46. **Total pungency content of 1993 fresh ginger stored at different temperatures expressed on a dry weight basis**



resulted in a slight increase for the first three months followed by a larger increase in the fourth month. As previously stated, this larger increase is due to the drying out effect of the stored ginger where more oil and hence pungency per raw ginger is present.

Determinations to a dry weight basis (figure 46) corrects this misconception with the general trend for total pungency to decrease consistently across the storage range for all temperatures except for 4 months at 24^0C. At this temperature and time, the ginger sample has dried out to such an extent that the analysis of % moisture was subject to extreme error. Thus little credence was placed in this result.
Total pungency of 1994 raw ginger stored at 4°C, 12°C and 24°C is depicted in figure 47. An increase is shown in both 4°C and 24°C stored ginger as they have dried out to a greater extent as previously explained. Results for 12°C have shown only a slight increase over storage time.

When a common baseline of correcting to a dry weight basis is applied (figure 48), all ginger stored at all temperatures have shown a general decrease in total pungency across storage. This is the opposite as shown in the literature where a general increase in pungency at 12^0C has been claimed.

CONCLUSIONS

This project has indicated that several differences between farms and even differences between paddocks on the same farm do occur in respect to the quality of raw ginger. Not only does locality have a marked effect on the ginger grown, but soil type as well as season and variety.

AGG block 4 has been found to vary in moisture content, oil content, total volatiles and total pungency to the other AGG blocks during both seasons ie on farm variation of raw ginger quality does occur.

FIGURE 47. **Total pungency content of 1994 fresh ginger stored at different temperatures**

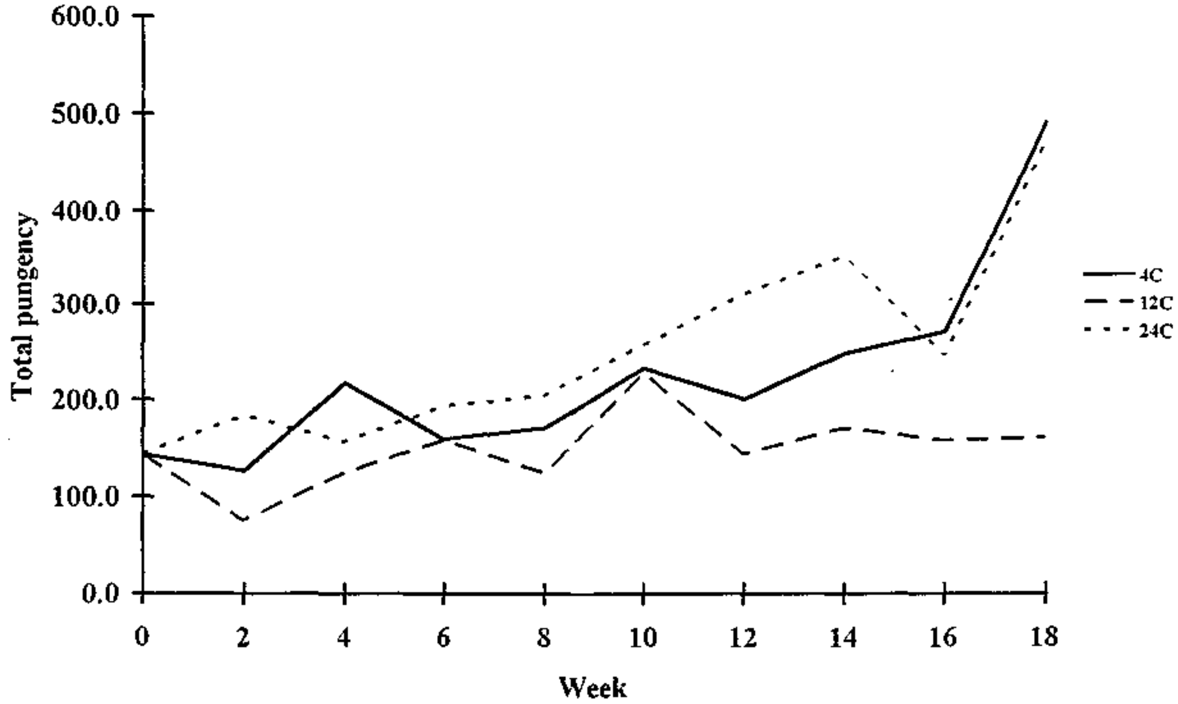
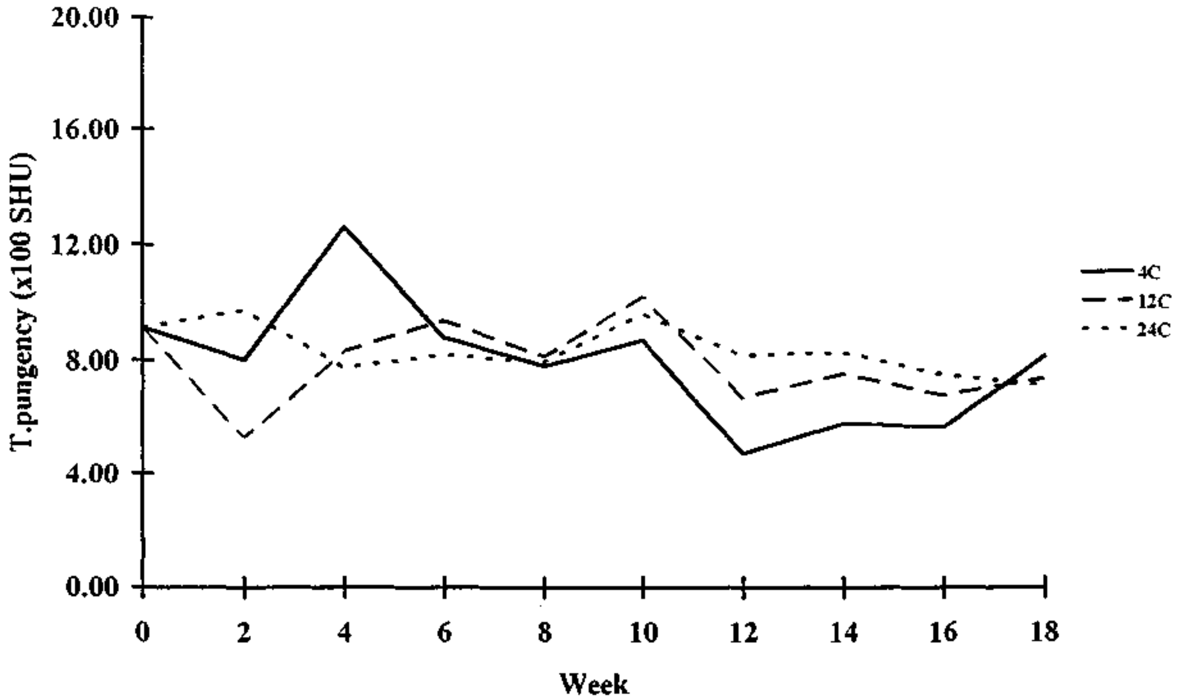


FIGURE 48. **Total pungency content of 1994 fresh ginger stored at different temperatures expressed on a dry weight basis**



All AGG blocks, Waltons and Torvella farms have been found to show variations in raw ginger indicating that locality does influence the quality.

Variations in all quality parameters assessed indicated differences due to seasons. This is most probably due to annual rainfall (1993 was much wetter than 1994).

Varietal differences indicated that the Queensland variety of ginger was higher in moisture, oil content and hence pungency but lower in total volatiles. Thus Queensland variety of ginger would be more suitable for hotter ginger products than the other two varieties. Hawaiian and Cantonese varieties are most suited for drying purposes due to their higher volatile content (aroma) and solids content.

Thus it can be seen that these different attributes if known during the harvesting period could be used to tailor-make ginger products of higher or lesser pungency and be used more economically for drying as well as developing more highly aromatic products.

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APPENDICES

APPENDIX 1 STATISTICAL TABLES

Table 1. Statistical analyses of mean results across time (harvest period) of moisture, solids, oil, total volatiles and total pungency for raw ginger and corrected to a dry weight basis for locality comparisons for the 1993 and 1994 seasons and a combination of seasons overall.

Location	% Moisture	% Solids	% Oil (Fresh ginger)	% Oil (Dry Wt. Basis)	Total Volatiles	Total Volatiles (Dry Wt. Basis)	Total Pungency	Total Pungency (Dry Wt. Basis)
1993								
AGG Block 4	89.55 a	10.15 e	0.481 a	4.786 a	313325 a	3032642 a	131.62 a	13.112 a
AGG Block 5/6	88.36 bc	11.64 bd	0.471 a	4.261 b	244946 b	2175149 bc	128.61 ab	11.620 bc
AGG Block 7	88.89 ab	11.11 cd	0.490 a	4.559 ab	272994 ab	2488073 b	134.20 a	12.469 ac
Waltons	85.83 d	14.17 a	0.449 a	3.424 d	243830 b	1747951 d	128.70 a	9.774 d
Torvella	87.82 c	12.28 b	0.452 a	3.849 c	268033 ab	2229806 bc	115.73 b	3.849 e
S.E.	0.37	0.36	0.018	0.178	21367	167390	5.02	0.476
1994								
AGG Block 4	85.58 c	14.42 ab	0.534 a	3.879 ab	527798 a	3661512 a	136.05 a	9.741 ab
AGG Block 5/6	84.69 d	15.31 a	0.497 a	3.383 bc	470291 ac	3136174 bc	134.69 a	9.049 b
AGG Block 7	87.79 a	12.21 d	0.508 a	4.370 a	451499 bc	3724958 a	128.42 c	10.921 a
Waltons	86.47 bc	13.53 bc	0.402 b	3.102 c	380633d	2943995 c	108.55 c	8.315 b
Torvella	86.87 ac	13.13 cd	0.443 b	3.471 bc	437671 cd	3364180 ac	115.99 bc	9.077 b
S.E.	0.37	0.36	0.018	0.178	21367	167390	5.02	0.476
Combined								
AGG Block 4	87.56 b	12.44 bc	0.508 a	4.332 a	420562 a	3347077 a	133.96 a	11.427 a
AGG Block 5/6	86.53 c	13.47 a	0.484 a	3.822 b	357618 b	2655662 c	131.65 a	10.334 b
AGG Block 7	88.34 a	11.66 c	0.499 a	4.465 a	362247 b	3106516 ab	131.31 a	11.695 a
Waltons	86.15 c	13.85 a	0.426 b	3.263 c	312231 c	2345972 d	118.38 b	9.044 c
Torvella	87.30 b	12.70 b	0.447 b	3.660 b	352852 b	2796993 bc	115.86	6.463 d
S.E.	0.26	0.25	0.013	0.126	15109	118360 .	3.55	0.337

<u>NOTE</u>: Within a set of variables, means followed by a different letter are significantly different ($P<0.05$).

S.E. Standard errors are listed to indicate variability of results.

Table 2 Statistical analyses of mean results of moisture, solids, oil, total volatiles and total pungency across the harvest period for both years combined for fresh ginger and expressed to a dry weight basis.

Date	% Moisture	% Solid	% Oil (fresh ginger)	% Oil (dry wt. basis)	Total Volatiles	Total Volatiles (dry wt. basis)	Total Pungency	Total Pungency (dry wt. basis)
5 April	92.77 a	7.23 g	0.448 cdef	6.252 a	249428 f	3440561 a	111.40 d	14.607 a
19 April	90.22 b	9.78 f	0.581 a	5.984 ab	288440 ef	2929030 abc	154.81 a	14.790 a
3 May	88.83 c	11.17 e	0.596 a	5.476 b	385126 abcd	3420513 a	154.29 a	13.261 a
17 May	87.63 cd	12.37 de	0.552 ab	4.554 c	396983 abc	3177310 ab	145.68 ab	11.364 b
31 May	87.00 de	13.00 cd	0.497 bc	3.882 d	336586 cde	2559382 cd	129.08 bc	9.418 c
14 June	85.60 fg	14.40 ab	0.463 cde	3.323 de	408162 abc	2765404 bc	129.72 bc	8.770 cd
28 June	86.17 efg	13.83 abc	0.473 cd	3.494 de	430637 a	3072724 abc	119.36 cd	8.341 cd
12 July	86.11 efg	13.89 abc	0.484 c	3.534 de	357673 abcde	2635942 cd	126.76 cd	8.693 cd
26 July	85.11 g	14.89 a	0.477 cd	3.305 de	315416 def	2167577 d	127.12 cd	8.311 cd
9 August	86.22 efg	13.78 abc	0.473 cd	2.977 e	362168 abcde	2655574 bcd	114.88 cd	8.153 cd
23 August	86.33 efg	13.67 bcd	0.466 cd	3.501 de	342733 bcde	2522611 cd	124.76 cd	8.753 cd
6 September	86.36 efg	13.64 bcd	0.393 f	2.934 e	423279 ab	3051972 abc	107.16 d	7.630 d
20 September	86.35 efg	13.65 bcd	0.419 def	3.134 e	397104 abc	2920877 abc	111.23 d	7.814 cd
4 October	86.64 def	13.36 bcd	0.390 f	2.974 e	364919 abcd	2735254 bcd	111.10 d	8.117 cd
18 October	86.29 efg	13.71 abc	0.452 cdef	3.334 de	367876 abcd	2701926 bcd	128.13 cd	8.868 cd
S.E.	0.45	0.44	0.022	0.217	26170	205010	6.15	0.583

NOTE: Within a set of variables, means followed by a different letter are significantly different ($P<0.05$).

S.E. Standard errors are listed to indicate variability of results.

Table 3. Statistical analyses of mean results across time (harvest period) of moisture, solids, oil, total volatiles and total pungency for raw ginger and corrected to a dry weight basis for comparisons for the 1993 and 1994 seasons and for three different varieties of ginger.

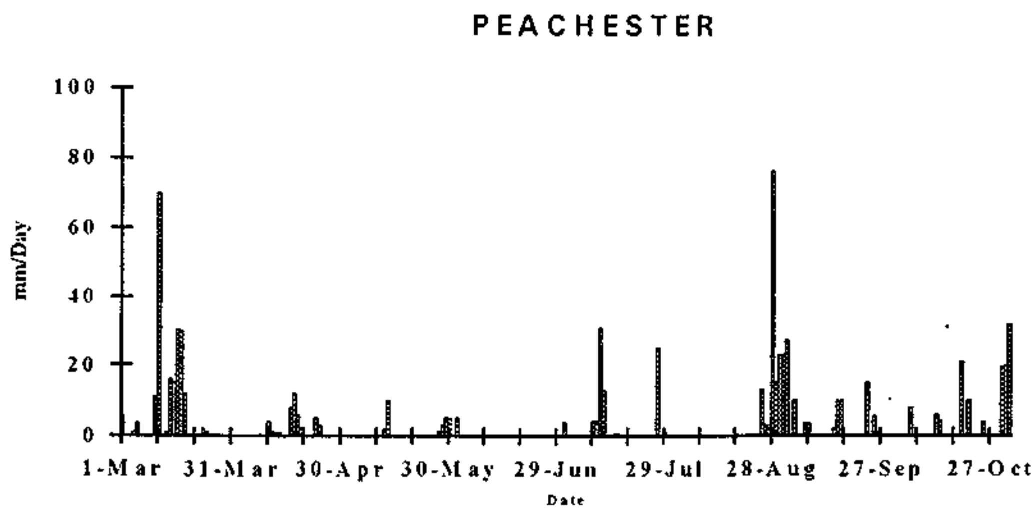
	% Moisture	% Solids	% Oil (Fresh ginger)	% Oil (Dry Wt. Basis)	Total Volatiles	Total Volatiles (Dry Wt. Basis)	Total Pungency	Total Pungency (Dry Wt. Basis)
Season								
1993	88.07 a	11.93 a	0.469 a	4.176 a	268626 a	2334724 a	127.72 a	10.165 a
1994	86.28 b	13.72 b	0.477 a	3.641 b	453578 b	3366164 b	124.74 a	9.421 b
S.E.	0.16	0.16	0.008	0.079	9556	74859	2.24	0.213
Variety								
Queensland	86.47 a	13.53 b	0.402 a	3.102 a	380633 b	2943995 a	108.55 a	8.315 a
Hawaiian	84.89 b	15.11 a	0.373 a	2.592 b	456915 a	3116209 a	96.65 b	6.719 b
Cantonese	85.15 b	14.85 a	0.400 a	2.833 ab	410728 ab	2854591 a	103.61 ab	7.314 b
S.E.	0.320	0.320	0.016	0.102	19622	14530	3.57	0.223

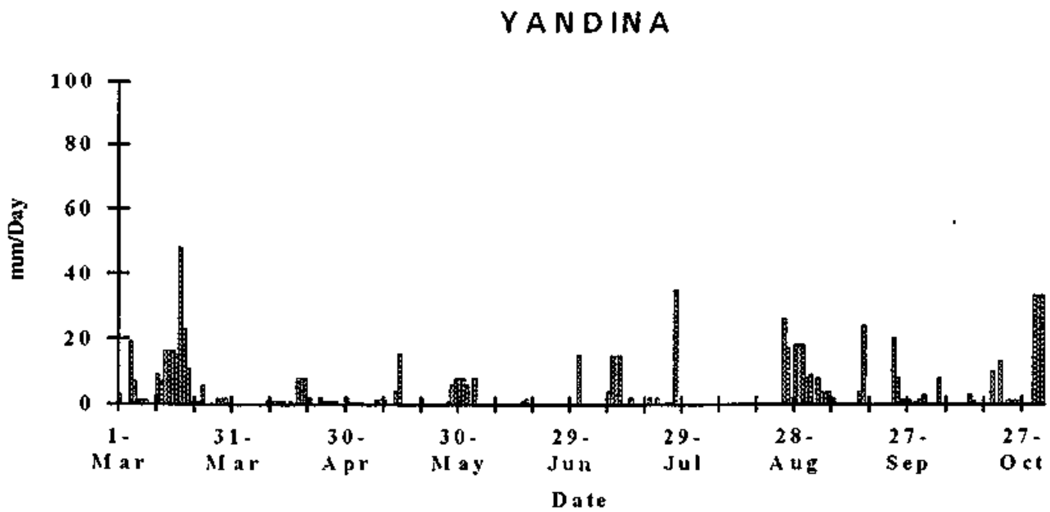
NOTE: Within a set of variables, means followed by a different letter are significantly different ($P < 0.05$).

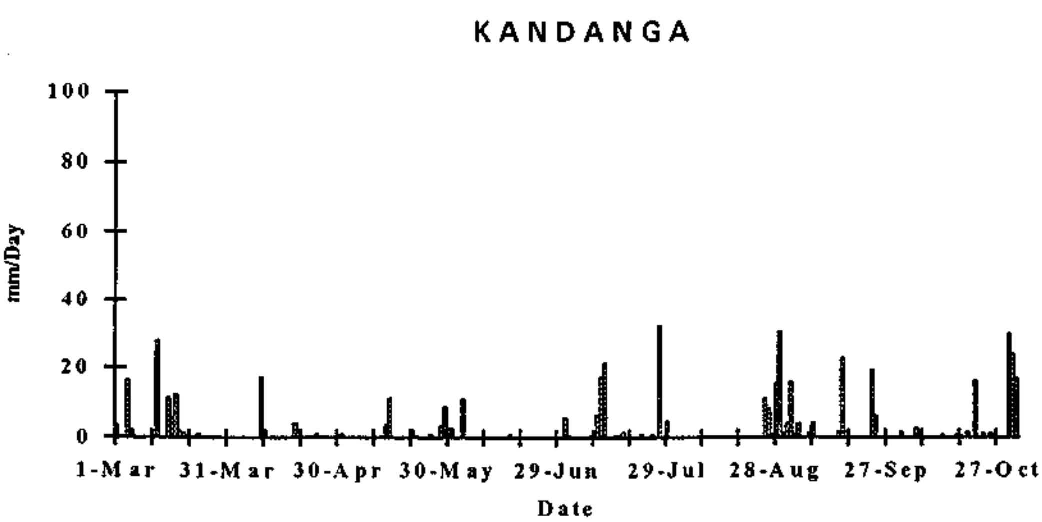
S.E. Standard errors are listed to indicate variability of results.

APPENDIX 2 1993 And 1994 SEASONAL RAINFALL

RAINFALL 1993

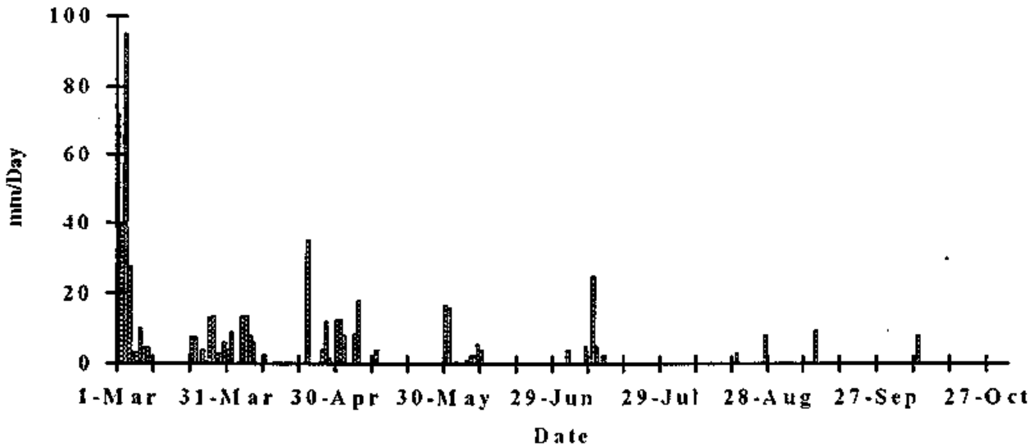






RAINFALL 1994

PEACHESTER



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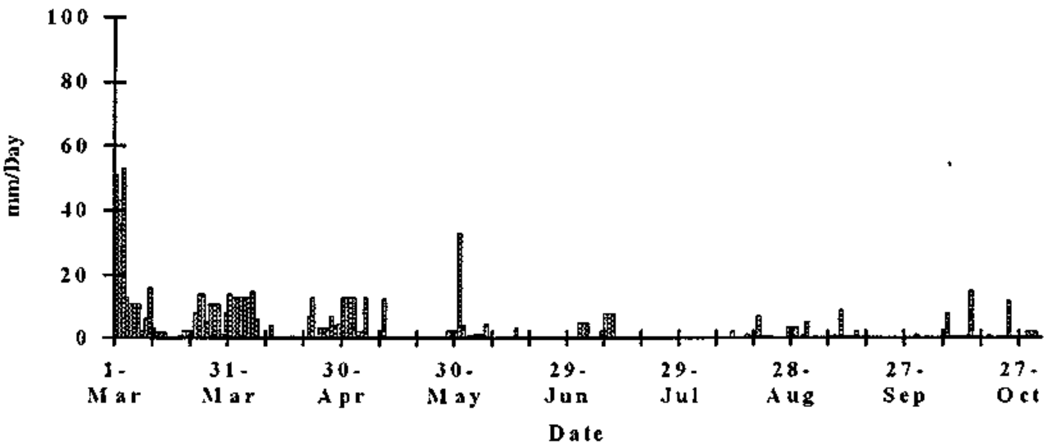

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