Beetroot Variety Isolation In Relation to Colour Pigmentation

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Golden Circle Limited

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BEETROOT VARIETY ISOLATION IN RELATION TO COLOUR PIGMENTATION

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VGO6140

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Geoff Houldsworth

Research to isolate a beetroot variety with high colour pigment, in correlation with soil conditions and planting windows.

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1. MEDIA SUMMARY

Natural colourants have been utilised by the food industry for many years. The growing consumer demand to deviate from synthetic dyes has prompted researchers to source alternative colour pigments from fruits and vegetables. The root vegetable beetroot has an array of colour pigments within, commonly known as betalains. Pigments extracted from red beetroot juice can provide various shades of reds, pinks, purples, oranges and yellows. Commonly these extracted pigments are utilised in dairy products, confectionary, fruit preparations and beverage applications.

Isolation of a specific variety which will return higher colour pigmentation, will allow the development of a beetroot concentrate which can compete with current commercial concentrates. Currently Australian supply is sourced from Europe and China. To produce an Australian beetroot concentrate with high colour pigment could replace these imports, with the potential to also export. With an expected increase in demand, this will in turn benefit the Australian beetroot grower to specifically grow additional beetroot for colour, an extension to current demand for canning grade beetroot.

The scope of this project was to isolate a beetroot variety in relation to levels of colour pigmentation, and to additionally establish optimum growing practices. Methodically three beetroot varieties were grown within the Lockyer Valley – Queensland, within two varied planting windows and two varied soil types.

The beetroot variety '*Pablo*' was identified to return a highest colour pigment within the raw extracted beetroot juice. Furthermore the effect of the planting window did determine how this variety preformed.

The recommendations of this project, is to explore further work into the area of beetroot variety and operational processing.

2. TECHNICAL SUMMARY

The increasing demand and consumer focus to replace synthetic food colouring with natural derivatives within the food industry has driven industry to source colour pigments from fruits and vegetables. "Beetroot contains a complex mixture of betalain pigments" (*Nottingham, 2004)*. Colour pigments within beetroot, known as betalains have been well researched. Betalaines are divided into two colour shades, betacyanin and betaxyanthin. Betacyanin are the pigments which appear violet to red, where as the betaxyanthin pigments appear orange to yellow. "However, the characteristic purple-red-violet colour of beetroot is mainly derived from a betacyanin pigment called betanin" *(Nottingham, 2004).* Within this study predominant analysis focused on the betanin content of extracted beetroot juice.

On a laboratory scale, preliminary investigations during the 2006 beetroot season at Golden Circle Limited (GCL) concluded that beetroot variety does impact end colour recovery in beetroot juice. During this research growing practices were not investigated, however significant colour variation throughout the season was observed.

Colour pigmentation versus beetroot variety was achieved by selecting three high pigment beetroot varieties from the preliminary 2006 investigations. Beetroot varieties identified as '*BT5004*', '*Deep Detroit Red*' *(DDR)* and '*Pablo*' were then:

1. Planted in two soil types. Heavy Black Cracking Clay and Light Clay Loam
2. Planted during two planting windows. Early and Mid Beetroot Season.

Research of beetroot variety isolation in relation to colour pigmentation was aimed to identify:

1. Which cultivated beetroot variety yielded higher colour pigmentation
2. The impact of planting and harvesting windows on colour pigmentation
3. The impact of soil conditions on colour pigmentation

The scope of these plantings was to identify a beetroot variety on a commercial representative scale which would yield higher colour pigmentation and to further investigate the effect of soil types and planting windows in relation to colour recovery.

Existing processing equipment at the GCL – Northgate site was utilised as a pilot line to extract juice and further concentrated to an average nominated brix of 65º. Extracted beetroot juice and concentrate samples were analysed using a UV-spectrophotometer at 538 nanometers in a 1 percent, buffered solution, a method to determine betanin content *(Nilson, 1970).*

Due to the instability characteristics of betalaines, the end concentrate betanin recovery resulted in low values, when compared against the assumed betanin value calculated from the raw juice prior to concentration. Therefore recommendations are associated with raw juice betanin values.

Conclusively:

1. *'Pablo'* yielded highest betanin content
2. Soil type marginally affected betanin recovery
3. Seasonality impact is inconclusive

3. INTRODUCTION

“Betanin was first discovered in around 1920, while a crystalline form of betanin dye was produced in the 1960s” *(Nottingham, 2004)*. With greater consumer focus on wellbeing within the food industry, there is an increasing trend towards the use of natural colours across a wide variety of applications. “There are four main classes of plant pigment: chlorophylls, carotenoids, flavonoids and betalains” (*Nottingham, 2004).*

Beetroot has long been identified as a raw material source for the extraction of naturally occurring colour pigments, providing vibrant red to violet tones that can be further refined into yellow/orange and blue/purple pigments. “Up to 200mg of betanin is typically found in one beetroot” *(Nottingham, 2004).* The dominant class of colour pigments in beetroot are identified as Betalaines.

Betalain extracts can have a range of colours. The betalaines are divided into two groups, the betacyanines and betaxyanthines *(Coultate, 1995, p.142).* Betacyanin are the betalain pigments which appear violet to red, where as betaxyanthin pigments appear orange to yellow. “In most varieties of beetroot, the red pigment betanin is the predominant colouring compound, representing 75-90 per cent of the total colour present”*(Nielsen and Holst, 2005).*

Current commercial processes are able to produce natural colours from fruit and vegetable concentrates and further refine into highly concentrated viscous liquids and powders.

Characteristically betanins are known to be relatively unstable, sensitive to heat, light, oxygen and pH conditions, therefore when processing, provisions must be made to limit deterioration. Processing aids commonly are added during process to protect the sensitive pigment and limit deterioration. “In order to ensure optimum pigment and colour retention in betalainic foods, the particular time-temperature conditions during food manufacture must be carefully controlled”*(Herbach et al, 2006).*

Betanin content and shading dictates the end driving price, with higher betanin concentrates returning higher pricing than the lower betanin concentrates. The isolation of a particular variety to be grown specifically for higher pigment colour concentrate will in turn increase the demand for Australian grown beetroot. Significantly the development of this industry will benefit the Australian farming industry with considerable scope to export a high quality Australian beetroot concentrate.

Initial research completed at GCL during the 2006 beetroot season concluded beetroot variety does impact the level of colour pigment in extracted beetroot juice. Three specific varieties were isolated and identified as beetroot varieties with the potential to return high colour pigment in extracted beetroot juice. These beetroot varieties are identified as ‘*BT5004*’, ‘*Deep Detroit Red*’ and ‘*Pablo*’.

Beetroot variety isolation in relation to colour pigmentation was designed to determine the impact of variety, soil type and seasonality on the resulting colour pigment of beetroot juice.

4. MATERIALS AND METHODS

Season, Soil Type & Variety

Three selected beetroot varieties, ‘*BT5004*’, ‘*DDR*’ and ‘*Pablo*’ were cultivated on two sites located in the Lockyer Valley Qld, with planting sites varying in soil type, Site One - heavy black cracking clay, Site Two – light clay loam. Soil types were selected based on geographical soil variation typically found within the Lockyer Valley beetroot cultivation area. Additionally soil types were selected to assist the preliminary investigation of the correlation between soil type and colour recovery.

Each variety was planted on 0.7 hectares with the expectation to generate thirty Tonne upon maturity, with the planting configuration recorded by a GCL grower intergration representative. Planting configurations are governed by the time of season at planting as per GCL practices, with configurations varying dependant on time of year.

All cultivations were maintained in accordance with the GCL standard canning beetroot growing practices, with growers required to record all periods of fertilisation during crop establishment. Fertilisation records were retained for future development work, with the aim to investigate the impact of fertilisation periods on end colour recovery.

These trials were duplicated within two planting windows, to investigate the impact of seasonality. Planting windows are defined as Trial Plot A (Early Season)–Planted March and harvested during early July, Trial Plot B (Mid Season)-Planted early May/June and harvested during September/October.

Table 1: Planting/Harvesting Expected Plan

Season	Soil Type	Variety	Planting	Harvesting	Expected Tonnage
Trial Plot A	heavy black cracking clay	‘*BT5004*’	11th – 23rd March	11th – 23rd June	30 Tonne
		‘*DDR*’			30 Tonne
		‘*Pablo*’			30 Tonne
	light clay loam	‘*BT5004*’			30 Tonne
		‘*DDR*’			30 Tonne
		‘*Pablo*’			30 Tonne
Trial Plot B	heavy black cracking clay	‘*BT5004*’	30th April – 15th June	1st August – 15th September	30 Tonne
		‘*DDR*’			30 Tonne
		‘*Pablo*’			30 Tonne
	light clay loam	‘*BT5004*’			30 Tonne
		‘*DDR*’			30 Tonne
		‘*Pablo*’			30 Tonne

During the crop establishment of both Trial Plots, weather was monitored on a monthly basis *(Australian Government Bureau of Meteorology, Observations drawn from University Queensland Gatton {station 04700823})*.This information is retained for future development work, allowing the facilitation of preliminary investigation into the associated impact of colour yield versus weather conditions.

Monthly mean highest temperature and mean lowest temperature were recorded within these seasons. Similarly total rainfall for the area was also monitored and recorded (*Australian Government Bureau of Meteorology, Observations drawn from University Queensland Gatton {station 04700823}*).

Colour recovery versus paddock yield was compared using the following formulation:

- Betanin % @ 65ºBrix ÷ Paddock Yield x 100 (expressed as a percentage)

Harvesting, Processing and Recovery

Pre-Harvest

Prior to harvest a 10kg random sample of each variety was collected and assessed to provide an indication of expected receipt quality. Sample analysis, consisted of diameter measurement and betanin percentage determination. Measurement across the longest axis of the beetroot measured in millimeters (mm), determined the diameter.

Measurement of beetroot diameter prior to processing is of significant importance due to on-site processing limitations. Current specification specifies beetroot be no larger than 110mm across the longest axis.

Each beetroot variety was then processed on a laboratory scale replicating factory pilot line to produce beetroot juice samples for betanin analysis.

Each representative beetroot variety sample was:

- boiled in a steam kettle (replicating steam peeler – 10 seconds of steam).
- re-sized in a Robocoup Blender, to a fine particle beetroot pulp (replicating re-sizer).
- beetroot pulp was then pressed utilising a Para-Press, extracting juice (replicating belt press – time versus pressure).
- heated to 65ºC (extracted juice).
- acidified to a pH of 3.90 - 4.20 and filtered (extracted juice).

Beetroot juice was then analysed utilising a UV-VIS spectrophotometer, to determine betanin content *(Nilson, 1970).*

Post Harvest Processing

At harvest, beetroot was weighed and paddock yield (nett) was expressed as Tonne per hectare. This was calculated adopting the following formula:

- nett yield = nett tonnage ÷ area planted (hectares)

Maturation of beetroot was also calculated and expressed as number of days. Beetroot was then identified and isolated by variety in beetroot holding bays. All beetroot was processed including beetroot that were mis-shaped, elongated and diseased. A total of twelve factory production trials were completed to process all variants. This was governed by the following:

- on site limitation to process 30T per day utilising factory pilot line
- assurance no cross contamination of varieties between trials
- preference to process on day shift to ultilise experienced factory resources

Within one day of receipt, beetroot was processed utilising pre-existing equipment, this process involved beetroot cleaning, re-sizing, pressing, centrifuging and acidification. Beetroot juice was acidified to a nominated pH range of 3.90 – 4.10, aiming to reduce the deterioration of the extracted betanin pigments. The raw beetroot juice was then further filtered, pasteurised and concentrated to a nominated average brix of 65º, (see process flow chart).

Average beetroot diameter and processing through puts were recorded throughout all production trials. Weights were also monitored to assist in the calculation of processing yields and recoveries, to identify further process improvement requirements.

Data collection points are as follows:

- Beetroot prior to steam peeling
- Beetroot after steam peeling
- Extracted juice weight/Lt qty
- Beetroot concentrate weight/Lt qty

During the acidification of beetroot juice at the juice line holding tanks, acid addition rates were monitored for every trial and expressed as an average percent acid addition to achieve the targeted pH range.

Beetroot Process Flow Chart – Raw Material to Beetroot Concentrate

Beetroot Receipt

↓

Identified, Isolated, Record Weight

↓

Steam Peeled

↓

Bulk Holding

↓

Elevator Transfer

↓

Re-sizing Unit

↓

Press

↓

Centrifuge

↓

Juice Line Holding Tank → Acidification (pH Range 3.90-4.10)

↓

Transfer to Concentrator Area

↓

Transfer to Settling Tanks

↓

Pass through Frame Filter

↓

Transfer to Buffer Tanks

↓

Pasteurisation Process

↓

Concentration Process (aim 65°Brix)

↓

Pack to Drums

↓

Cold Room Storage - Blast Frozen (-18°C)

Laboratory Analysis

Internal laboratory analysis was conducted at GCL Northgate site, within the Research & Development, Main and Microbiological Laboratories.
Analysis included:

- brix° measurement
- betanin percentage (%) determination
- pH measurement
- oraganoleptic assessment
- microbiological assessment (concentrate only)

Collection of juice samples directly after centrifuge were retained and analysed for brix° and betanin content. These results represented the total start betanin content and were the basis to calculate the assumed betanin content in the final processed concentration. Calculation used due to varied start brix° of raw beetroot juice. Brix° was analyised using a calibrated refractometer.

Upon completion of concentration, samples were then evaluated for betanin content using a UV-VIS spectrophotometer. Samples were prepared in a 1 percent 0.05M phosphate buffer solution at a pH of 6.5. Diluted samples were then transferred into a 1cm cell and analysed at 538nm on a fixed wavelength reading *(Nilson, 1970)*. Brix and pH were also measured and recorded. Additionally end product organoleptic qualities were assessed, concentrate samples were evaluated by odour and taste.

Microbiological assessment of end beetroot concentrate included:

- Standard Plate Count (1ml sample plated on Plate Count Agar {PCA}).
- Yeast count (1ml sample spread plated on Dichlorin Rose-Bengal Chloramphenical medium – 1ml sample plated on Gyeme agar – for testing low water activity).
- Mould count (1ml sample spread plated on Dichlorin Rose-Bengal Chloramphenical medium – 1ml sample plated on Gyeme agar – for testing low water activity).

Each plated sample with the appropriate agar was set, inverted and incubated for 48hours at 30ºC. Once incubation was completed, plates were counted and evaluated in accordance to the following GCL standard microbiological specification:

- Excellent 0-4 cfu
- Good 5-20 cfu
- Satisfactory 21-40 cfu
- Poor 41-100 cfu
- Unsatisfactory >100 cfu

Additional Small Block Assessment

The evaluation of small block beetroot plantings, approximately 10kg allotments were assessed throughout the beetroot season. Samples were collected randomly within the small plantings. Beetroot variety identification were provided by a GCL grower intergration representative.

Varieties were assessed by:

- diameter – along the longest axis of the raw beetroot
- raw beetroot juice – Brix º
- betanin content determination of extracted beetroot juice

Laboratory scale equipment was ultilised to extract beetroot juice for analysis. This included beetroot being:

- boiled in a steam kettle (replicating steam peeler – 10 seconds of steam).
- re-sized in a Robocoup Blender, to a fine particle beetroot pulp (replicating re-sizer).
- beetroot pulp was then pressed utilising a Para-Press, extracting juice (replicating belt press – time versus pressure).
- heated extracted juice to 65ºC.
- acidified to a pH of 3.90 - 4.10 and filtered.

Beetroot juice was then analysed utilising a UV-VIS spectrophotometer, to determine betanin content *(Nilson, 1970).*

Each variety assessment consisted of betanin determination, Brixº reading, average beetroot diameter measurement and general sensory evaluation. Assumption used to calculate betanin at 65ºBrix concentrated form. Required assumption made due to absence of small scale bench equipment to replicate concentration process.

Extension Activities

During the later half of Trial Plot B, GCL engaged the expertise of a natural colour manufacturer to assist in the optimisation of colour recovery. Assistance was sought due to the betanin loss observed during the processing of Trial Plot A. This activity required the purchase of a laboratory scale vacuum concentrator, to replicate GCL concentration step. Samples were collected from harvested canning grade beetroot allotments at GCL holding bays, processed and evaluated on a laboratory bench scale.

Beetroot samples were then:

- boiled in a steam kettle (replicating steam peeler – 10 seconds of steam).
- re-sized in a Robocoup Blender, to a fine particle beetroot pulp (replicating re-sizer).
- beetroot pulp was then pressed utilising a Para-Press, extracting juice (replicating belt press – time versus pressure).

Beetroot juice samples were then:

- prepared – adding varied levels of antioxidant.
- concentrated – utilising a laboratory scale vacuum concentrator
- assessed – colour loss percentage

5. RESULTS

Growing

Planting Configurations

Table 2: Trail Plot A (early season) – planting configuration

Seedling Density	Seed Spacing	Seedbed Centres	Row Spacing	Seedbed Height	Row/Bed Spacing	Planting Depth
38/m²	4.2-5.9 (cm)	48-60cm	8cm	5-15cm	10cm	1.5cm

Table 3: Trial Plot B (mid season) – planting configuration

Seedling Density	Seed Spacing	Seedbed Centres	Row Spacing	Seedbed Height	Row/Bed Spacing	Planting Depth
33/m²	5-6.1 (cm)	48-60cm	8cm	5-15cm	10cm	1.5cm

Fertilisation Records

Table 4: Fertilisation Records (total) – Trial Plot A and Trail Plot B

	Trial Plot A-Early Season		**Trial Plot B-Mid Season**	
	Heavy Black Cracking Clay	Light Clay Loam	Heavy Black Cracking Clay	Light Clay Loam
‘*BT5004*’	300kg/ha	150kg/ha	300kg/ha	345kg/ha
‘*DDR*’	300kg/ha	150kg/ha	300kg/ha	345kg/ha
‘*Pablo*’	300kg/ha	150kg/ha	300kg/ha	345kg/ha

- Combination of fertilisers used, normal to GCL requirements

Weather Observations

Mean Temperatures

Figure 1: Weather Conditions – Mean Temperatures – Trial Plot A – Early Season (Observations were drawn from University of Queensland Gatton {Station 040082})

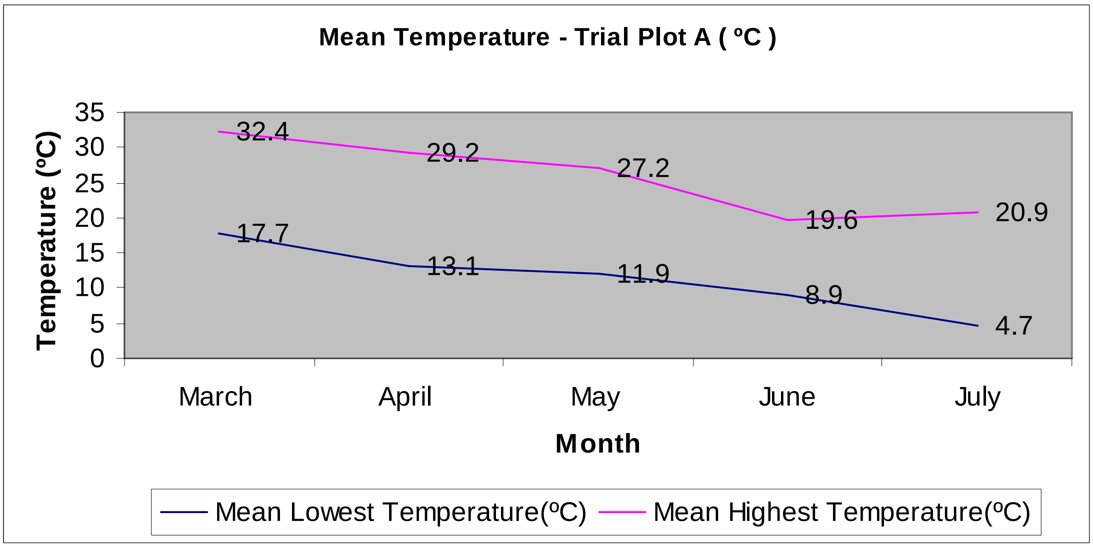
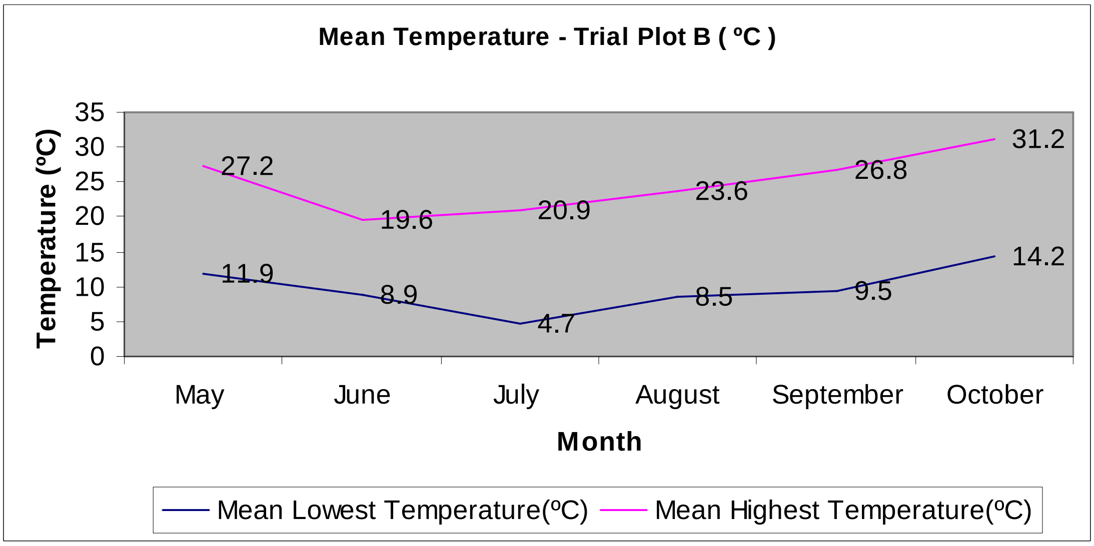


Figure 2: Weather Conditions – Mean Temperatures – Trial Plot B – Mid Season (Observations were drawn from University of Queensland Gatton {Station 040082})



Monthly Rainfall

Figure 3: Monthly Rainfall - Trial Plot A (Early Season)
(Observations were drawn from University of Queensland Gatton {Station 040082})

Total Rainfall Trial Plot A = 122.2mm

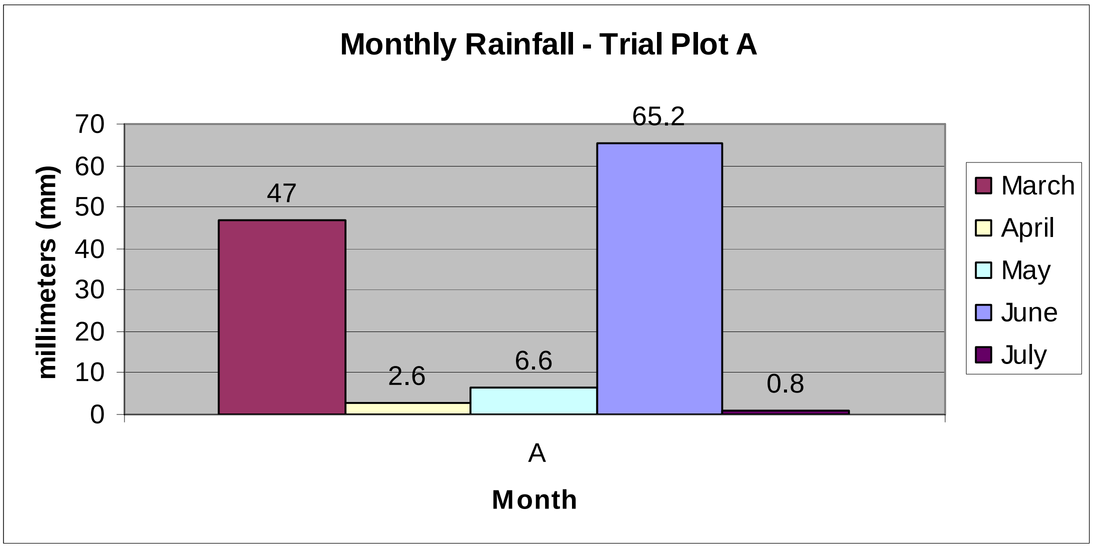
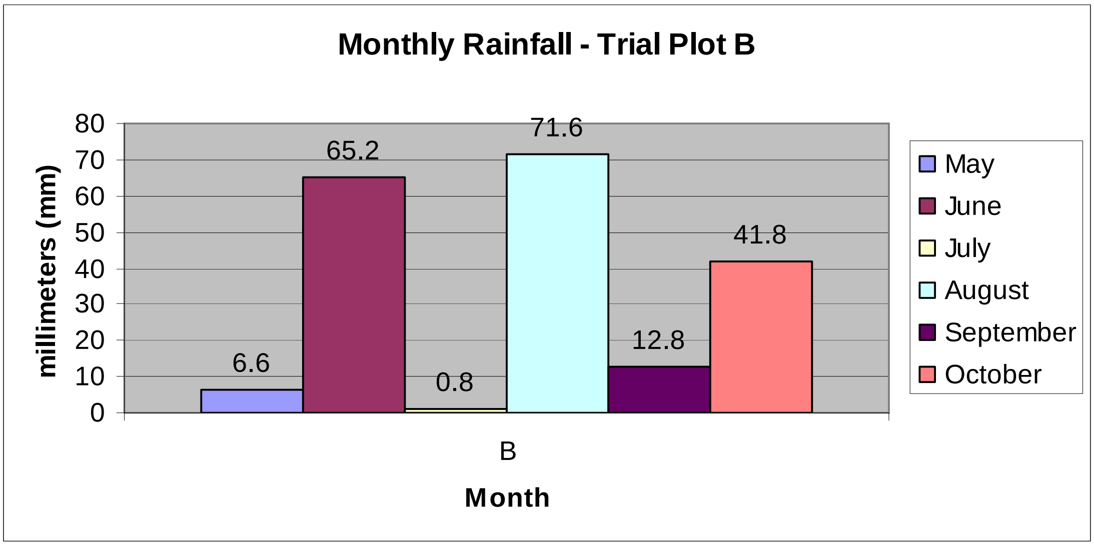


Figure 4: Monthly Rainfall – Trial Plot B (Mid Season)
(Observations were drawn from University of Queensland Gatton {Station 040082})

Total Rainfall Trial Plot B = 198.8mm



Harvesting, Processing & Recovery

Harvesting

Table 5: Pre-Harvest Variety Assessment – Betanin(%) and Diameter (mm)

	Trial Plot A-Early Season				**Trial Plot B-Mid Season**			
	Heavy Black Cracking Clay		Light Clay Loam		Heavy Black Cracking Clay		Light Clay Loam	
	Betanin	Diameter	Betanin	Diameter	Betanin	Diameter	Betanin	Diameter
'BT5004'	0.089	55	0.087	55	0.084	61	0.099	54
'DDR'	0.093	53	0.096	51	0.069	58	0.098	44
'Pablo'	0.074	51	0.103	55	0.072	57	0.082	47

- Diameter was averaged from ten raw beetroot from random sample
- Betanin % was determined from juiced random sample

Table 6: Beetroot Maturity & Average Diameter

	Trial Plot A-Early Season				**Trial Plot B-Mid Season ***			
	Heavy Black Cracking Clay		Light Clay Loam		Heavy Black Cracking Clay		Light Clay Loam	
	Maturity (days)	Diameter (mm)	Maturity (days)	Diameter (mm)	Maturity (days)	Diameter (mm)	Maturity (days)	Diameter (mm)
'BT5004'	117	61	107	43	140	56	142	88
'DDR'	112	55	109	52	140	58	143	72
'Pablo'	117	55	108	50	140	43	142	78

- Beetroot maturity determined as the period from planting to harvesting
- Average diameter monitored throughout processing. Average of 13 beetroot randomly selected off line

Table 7: Paddock Yield (Tonnes per hectare)

	Trial Plot A-Early Season		**Trial Plot B-Mid Season ***	
	Heavy Black Cracking Clay	Light Clay Loam	Heavy Black Cracking Clay	Light Clay Loam
'BT5004'	32.29	32.15	47.66	47.74
'DDR'	29.90	35.48	53.76	54.63
'Pablo'	33.04	35.58	48.08	58.12

* Traditionally known as a high yielding season, however a late harvest occurred due to machinery breakdown which impacted results.

Processing

Table 8: Processing – Trial Plot A – Early Season

		Heavy Black Cracking Clay			**Light Clay Loam**		
		'BT5004'	*'DDR'*	*'Pablo'*	*'BT5004'*	*'DDR'*	*'Pablo'*
Trial Plot A – Early Season	Receipt Weight (kg)	18900	17500	19340	19160	21140	21200
	Steam Peel Thru-Put (T/hr)	5.5	7	7.7	5.5	7	6
	Steam Peel – Recovery (%)	79	90	95	88	91	95
	Re-sizer start weight (kg)	14993	15671	18361	16897	19229	20178
	Re-sizer through put (T/hr)	6.7	7	5.7	7.8	8	7
	Beetroot lost to floor (%)	0.6	0.9	0.5	1	0.9	0.5
	Juice recovery at 10º Brix (%)	49	49	52	41	45	44
	Raw Beetroot/L concentrate (kg/L)	22	19	17	23	19	19

Table 9: Processing – Trial Plot B – Mid Season

Trial Plot B – Mid Season	Receipt Weight (kg)	25000	28200	25220	37720*	43160	45920
	Steam Peel Thru-put (T/hr)	6.6	5.8	5.9	n/a***	n/a***	n/a***
	Steam Peel – Recovery (%)	90	86	92	n/a**	81	92
	Re-sizer start weight (kg)	22395	24313	23100	20296	35030	42261
	Re-sizer through put (T/hr)	6.6	5.8	5.9	5	5	5
	Beetroot lost to floor (%)	2	0.9	1	0.4	1.5	1.3
	Juice recovery at 10º Brix (%)	71	72	67	52	68	64
	Raw Beetroot/L concentrate (kg/L)	13	13	13	15	13	13

* denotes start weight in-correct – product carried over
** denotes not all beetroot processed – carried beetroot over
*** denotes no throughputs recorded

Process Recovery by Variety – Trial Plot A

- ***SS denotes Single Strength***
- ***ºBx denotes Degree Brix***

Table 10: Recovery 'BT5004' – heavy black cracking clay (early season)

<table>
<tr><td rowspan="2">Steam Peeler</td><td>Start Weight (kg)</td><td>Finish Weight (kg)</td><td>% Recovery</td></tr>
<tr><td>18 900</td><td>14 993</td><td>79</td></tr>
<tr><td rowspan="4">Juicing Line</td><td>Start Weight (kg)</td><td colspan="2">Finish kg \ L</td></tr>
<tr><td rowspan="3">14 993</td><td colspan="2">9 806kg (based on average 7.3ºBx) \ 10 090L
(qty 10ºBx SS = 7365kg \ 7082L)</td></tr>
<tr><td colspan="2">Juice Recovery</td></tr>
<tr><td colspan="2">From 14 993kg =65% on 7.3ºBx (9806kg)
From 14 993kg = 49 % on 10ºBrix assumed SS (7365kg)</td></tr>
<tr><td rowspan="2">Concentrator</td><td>Start Qty</td><td>Finish Quantity Concentrate</td><td>Finish Quantity SS</td></tr>
<tr><td>10 090Lt @ 7.3ºBx
(average)</td><td>690 L @ 65.5ºBx
900kg @ 65.5ºBx</td><td>57 27Lt @ 10ºBx
5939kg @ 10ºBx</td></tr>
<tr><td>Raw Fruit – Concentrate</td><td colspan="3">Concentrate Recovery from Raw Beetroot = 0.021459T per 1L conc @ 65.5ºBrix</td></tr>
</table>

Table 11: Recovery 'DDR' – heavy black cracking clay (early season)

<table>
<tr><td rowspan="2">Steam Peeler</td><td>Start Weight (kg)</td><td>Finish Weight (kg)</td><td>% Recovery</td></tr>
<tr><td>17 500</td><td>15 671</td><td>89.5</td></tr>
<tr><td rowspan="4">Juicing Line</td><td>Start Weight (kg)</td><td colspan="2">Finish kg \ L</td></tr>
<tr><td rowspan="3">15 671</td><td colspan="2">10 691kg (based on average 7.2ºBx) \ 10 280L
(qty 10ºBx SS = 7 613kg \ 7 320L)</td></tr>
<tr><td colspan="2">Juice Recovery</td></tr>
<tr><td colspan="2">From 15 671kg =68% on 7.2ºBx (10 691kg)
From 15 671kg = 48.5% on 10ºBrix assumed SS (7 613kg)</td></tr>
<tr><td rowspan="2">Concentrator</td><td>Start Quantity</td><td>Finish Quantity Concentrate</td><td>Finish Quantity SS</td></tr>
<tr><td>15 671Lt @ 7.2ºBx
(average)</td><td>800 L @ 64.4ºBx
1049kg @ 64.4ºBx</td><td>6512 Lt @ 10ºBx
6753 kg @ 10ºBx</td></tr>
<tr><td>Raw Fruit – Concentrate</td><td colspan="3">Concentrate Recovery from Raw Beetroot = 0.01876T per 1L conc @ 64.4ºBrix</td></tr>
</table>

Table 12: Recovery 'Pablo' – heavy black cracking clay (early season)

Steam Peeler	**Start Weight (kg)**	**Finish Weight (kg)**	**% Recovery**
	19 340	18 361	94.9
Juicing Line	**Start Weight (kg)**	**Finish kg \ L**	
	18 361	12 485kg (based on average 7.6ºBx) \ 12 120L (qty 10ºBx SS = 9 489kg \ 9 124L)	
		Juice Recovery	
		From 18 361kg =67.9% on 7.6ºBx (12 485kg) From 18 361kg = 51.6% on 10ºBrix assumed SS (9 489kg)	
Concentrator	**Start Quantity**	**Finish Quantity Concentrate**	**Finish Quantity SS**
	12 120Lt @ 7.6ºBx (average)	1180 L @ 64.7ºBx 1549Kg @ 64.7ºBx	9 676 Lt @ 10ºBx 10034Lt @ 10ºBx
Raw Fruit – Concentrate	**Concentrate Recovery from Raw Beetroot = 0.01677T per 1L conc @ 64.7ºBx**		

Table 13: Recovery 'BT5004'- light clay loam (early season)

Steam Peeler	**Start Weight (kg)**	**Finish Weight (kg)**	**% Recovery**
	19 160	16 897	88.0
Juicing Line	**Start Weight (kg)**	**Finish kg \ L**	
	16 897	11 577kg (based on average 6.0ºBx) \ 11 350L (qty 10ºBx SS = 7082kg\ 6810L)	
		Juice Recovery	
		From 16 897kg = 68% on 6ºBx (11 577kg) From 16 897kg = 41% on 10ºBrix assumed SS (8890kg)	
Concentrator	**Start Qty**	**Finish Qty Concentrate**	**Finish Quantity SS**
	11 350L @ 6.0ºBx (average)	600L @ 65.5 ºBx 150L @ 65.5 ºBx	6225L @ 10ºBrix 6455kg @ 10ºBrix
Raw Fruit – Concentrate	**Concentrate Recovery from Raw Beetroot = 0.02309 T per 1L conc @ 65.5ºBrix**		

Table 14: Recovery 'DDR' – light clay loam (early season)

Steam Peeler	**Start Weight (kg)**	**Finish Weight (kg)**	**% Recovery**
	21 140	19 229	90.9
Juicing Line	**Start Weight (kg)**	**Finish kg \ L**	
	19229	13503kg (based on average 6.4ºBx) \ 13170L (qty 10ºBx SS = 8780kg \ 8443L)	
		Juice Recovery	
		From 19229kg =70% on 6.4ºBx (13503kg) From 19229kg = 45 % on 10ºBrix assumed SS (8780kg)	
Concentrator	**Start Qty**	**Finish Qty Concentrate**	**Finish Qty SS**
	@ 6.4ºBx (average)	1020 L @ 62.1ºBx 1325kg @ 62.1ºBx	8058Lt @ 10ºBx 8356kg @ 10ºBx
Raw Fruit – Concentrate	**Concentrate Recovery from Raw Beetroot = 0.01907T per 1L conc @ 62.1ºBrix**		

Table 15: Recovery 'Pablo' – light clay loam (early season)

<table>
<tr><td rowspan="2">Steam Peeler</td><td>Start Weight (kg)</td><td>Finish Weight (kg)</td><td>% Recovery</td></tr>
<tr><td>21 200</td><td>20 178</td><td>95</td></tr>
<tr><td rowspan="4">Juicing Line</td><td>Start Weight (kg)</td><td colspan="2">Finish kg \ L</td></tr>
<tr><td rowspan="3">20 178</td><td colspan="2">14 878kg (based on average 6.1ºBx) \ 14 528L
(qty 10ºBx SS = 8890kg \ 8 573L)</td></tr>
<tr><td colspan="2">Juice Recovery</td></tr>
<tr><td colspan="2">From 20 178kg =73% on 6.1ºBx (14878kg)
From 20 178kg = 44% on 10ºBrix assumed SS (8890kg)</td></tr>
<tr><td rowspan="2">Concentrator</td><td>Start Quantity</td><td>Finish Quantity Concentrate</td><td>Finish Quantity SS</td></tr>
<tr><td>14 528L @ 6.1ºBx (average)</td><td>900 L @ 62.8ºBx
1175kg @ 62.8ºBx</td><td>7110Lt @ 10ºBx
7373 kg @ 10ºBx</td></tr>
<tr><td>Raw Fruit – Concentrate</td><td colspan="3">Concentrate Recovery from Raw Beetroot = 0.01890T per 1L conc @ 62.8ºBrix</td></tr>
</table>

Process Recovery by Variety – Trial Plot B

Table 16: Recovery 'BT5004' – heavy black cracking clay (mid season)

Steam Peeler	**Start Weight (kg)**	**Finish Weight (kg)**	**% Recovery**
	25 000	22 395	90
Juicing Line	**Start Weight (kg)**	**Finish kg \ L**	
	22 395	18 961kg (based on average 8.4ºBx) \ 18 400L (qty 10ºBx SS = 15 927kg \ 15 358L)	
		Juice Recovery	
		84% on 8.4ºBx (22 395kg) 71% on 10ºBrix assumed SS (22 395kg)	
Concentrator	**Start Quantity**	**Finish Quantity Concentrate**	**Finish Quantity SS**
	18 400Lt @ 8.4ºBx (average)	1400 L @ 64.7ºBx (8.2X) 190lt @ 64.7ºBx (8.2X)	11 480 @ 10ºBx 1 558 @ 10ºBx
Raw Fruit – Concentrate	**Concentrate Recovery from Beetroot = 1T produces 77L conc @ 64.7ºBrix**		

Table 17: Recovery 'DDR' – heavy black cracking clay (mid season)

Steam Peeler	**Start Weight (kg)**	**Finish Weight (kg)**	**% Recovery**
	28 200	24 313	86
Juicing Line	**Start Weight (kg)**	**Finish kg \ L**	
	24 313	20 273kg \ 19 650L (based on average 8.7ºBx) (qty 10ºBx SS = 17 637kg \ 17 007L)	
		Juice Recovery	
		From 14 993kg =65% on 7.3ºBx (9806kg) From 14 993kg = 49 % on 10ºBrix assumed SS (7365kg)	
Concentrator	**Start Quantity**	**Finish Quantity Concentrate**	**Finish Quantity SS**
	19 650Lt @ 8.7ºBx (average)	1800 L @ 65.7ºBx 8.4X	15 120Lt @ 10ºBx
Raw Fruit – Concentrate	**Concentrate Recovery from Beetroot = 1T produces 73L concentrate @ 65.7ºBrix**		

Table 18: Recovery 'Pablo' – heavy black cracking clay (mid season)

Steam Peeler	**Start Weight (kg)**	**Finish Weight (kg)**	**% Recovery**
	25 220	23 100	92
Juicing Line	**Start Weight (kg)**	**Finish kg \ L**	
	23 100	15 854kg \ 15 300L (based on average 9.8ºBx) (qty 10ºBx SS = 15 534kg \ 14 979L)	
		Juice Recovery	
		68% on 9.8ºBx (23 100kg) 67% on 10ºBrix assumed SS (23 100kg)	
Concentrator	**Start Quantity**	**Finish Quantity Concentrate**	**Finish Quantity SS**
	15 300Lt @ 9.8ºBx (average)	1200 L @ 63.1ºBx (7.9X) 270L @ 59.8ºBx (7.4X)	9 480 Lt @ 10ºBx 1 998Lt @ 10ºBx
Raw Fruit – Concentrate	**Concentrate Recovery from Beetroot = 1T produces 77L conc @ 62.6ºBrix**		

Table 19: Recovery 'BT5004' – light clay loam (mid season)

Steam Peeler	**Start Weight (kg)**	**Finish Weight (kg)**	**% Recovery**
	Not established *	20 296	Not established
Juicing Line	**Start Weight (kg)**	**Finish kg\ L**	
	20 296	19 545kg (based on average 5.3ºBx) \ 19200L (qty 10ºBx SS = 10159kg \ 9796L)	
		Juice Recovery	
		From 20296kg =96% on 5.3ºBx (19545kg) From 20296kg = 52 % on 10ºBrix assumed SS (10159kg)	
Concentrator	**Start Quantity**	**Finish Quantity Concentrate**	**Finish Quantity Single Strength**
	@5.3 ºBx (average)	600 L @ 64.6ºBx 200L @ 62.0ºBx	4860 Lt @ 10ºBx 1560Lt @ 10ºBx
Raw Fruit – Concentrate	****Concentrate Recovery from S\Peeled Beetroot = 1T produces 65L conc @ 64.0ºBrix**		

* note: are unable to establish definite start weight due to beetroot carried over, due to production timing.
** raw fruit assumption from steam peeled weight due to start weight not established

Table 20: Recovery 'DDR' – heavy black cracking clay (mid season)

Steam Peeler	**Start Weight (kg)**	**Finish Weight (kg)**	**% Recovery**
	43 160	35 030	81.0
Juicing Line	**Start Weight (kg)**	**Finish Weight \ L**	
	35 030	41 513kg (based on average 5.8ºBx) \ 40 700L (qty 10ºBx SS = 24 078kg\ 23 217L)	
		Juice Recovery	
		From 35 030 118% on 5.8ºBx (41 513kg) From 35 030kg = 68% on 10ºBrix assumed SS (24078kg)	
Concentrator	**Start Quantity**	**Finish Quantity Concentrate**	**Finish Quantity SS**
	40 700L @ 5.8 ºBx (average)	1200L @ 62.5 ºBx (7.8X) 800L @ 53.7ºBx (7X) **Total = 2000L**	9360L @ 10ºBrix 5600L @ 10ºBrix
Raw Fruit – Concentrate	**Concentrate Recovery from Raw Beetroot = 1T = 76L conc @avg 59ºBrix**		

Table 21: Recovery 'Pablo' – heavy black cracking clay (mid season)

<table>
<tr><td rowspan="2">Steam Peeler</td><td>Start Weight (kg)</td><td>Finish Weight (kg)</td><td>% Recovery</td></tr>
<tr><td>45 920</td><td>42 261</td><td>92</td></tr>
<tr><td rowspan="4">Juicing Line</td><td>Start Weight (kg)</td><td colspan="2">Finish kg \ L</td></tr>
<tr><td rowspan="3">42 261</td><td colspan="2">49 564kg (based on average 5.5ºBx) \ 48 650L
(qty 10ºBx SS = 27 252kg \ 26 278L)</td></tr>
<tr><td colspan="2">Juice Recovery</td></tr>
<tr><td colspan="2">From 42 261kg =115% on 5.5ºBx (49 564kg)
From 42 261kg = 64% on 10ºBrix assumed SS (27 252kg)</td></tr>
<tr><td rowspan="2">Concentrator</td><td>Start Quantity</td><td>Finish Quantity Concentrate</td><td>Finish Quantity SS</td></tr>
<tr><td>48 650L @ 5.5ºBx
(average)</td><td>1600 L @ 64.2ºBx (8.1X)
600L @ 64.5ºBx (8.2X)
200L @ 61.4ºBx (7.6X)</td><td>12 960 Lt @ 10ºBx
4 920 Lt @ 10ºBx
1520Lt @10ºBx</td></tr>
<tr><td>Raw Fruit – Concentrate</td><td colspan="3">Concentrate Recovery from Raw Beetroot = 1T produces 72L conc @ 64.0ºBrix</td></tr>
</table>

Acidification

Table 22: Average Percent Acid Addition Per Batch Volume

Trial Plot	Soil Type	Beetroot Variety	Number of Batches	Average Acid Addition %
A (early season)	hbcc	*'BT5004'*	3	0.25
A (early season)	hbcc	*'DDR'*	3	0.23
A (early season)	hbcc	*'Pablo'*	3	0.24
A (early season)	lcl	*'BT5004'*	3	0.24
A (early season)	lcl	*'DDR'*	3	0.23
A (early season)	lcl	*'Pablo'*	4	0.20
B (mid season)	hbcc	*'BT5004'*	3	0.24
B (mid season)	hbcc	*'DDR'*	4	0.24
B (mid season)	hbcc	*'Pablo'*	3	0.24
B (mid season)	lcl	*'BT5004'*	3	0.17
B (mid season)	lcl	*'DDR'*	7	0.25
B (mid season)	lcl	*'Pablo'*	8	0.19

hbcc denotes heavy black cracking clay
lcl denotes light clay loam

Laboratory Analysis

Table 23: Average Raw Beetroot Brix°

	Trial Plot A-Early Season		Trial Plot B-Mid Season	
	Heavy Black Cracking Clay	Light Clay Loam	Heavy Black Cracking Clay	Light Clay Loam
'BT5004'	11.4	8.2	13.7	10.7
'DDR'	8.2	9.1	11.8	10.7
'Pablo'	11.7	8.5	12.9	9.8
Average Plot °Brix	10.4	8.6	12.8	10.4

- Average brix taken from 13 randomly selected beetroot which were juiced

Table 24: Betanin Recovery (percentage betanin)

	Trial Plot A–Early Season		Trial Plot B-Mid Season	
	Heavy Black Cracking Clay	Light Clay Loam	Heavy Black Cracking Clay	Light Clay Loam
'BT5004'	0.410	0.545	0.442	0.591
'DDR'	0.511	0.590	0.385	0.592
'Pablo'	0.536	0.436	0.377	0.759
Average Plot Betanin	0.486	0.523	0.401	0.647

- % betanin determined from beetroot juice at assumed 65°Brix

Table 25: Microbiological Assessment – End Concentrate1ml sample cfu

	Trial Plot A – Early Season					
	Heavy Black Cracking Clay			Light Clay Loam		
Variety	*'BT5004'*	*'DDR'*	*'Pablo'*	*'BT5004'*	*'DDR'*	*'Pablo'*
SPC (cfu)	0	0	0	0	0	0
Yeasts (cfu)	0	0	0	0	0	0
Moulds (cfu)	0	112	42	0	1	0
	Trial Plot B – Mid Season					
	Heavy Black Cracking Clay			**Light Clay Loam**		
Variety	*'BT5004'*	*'DDR'*	*'Pablo'*	*'BT5004'*	*'DDR'*	*'Pablo'*
SPC	2	8	7	3	5	0
Yeasts (cfu)	0	0	0	0	0	0
Moulds (cfu)	0	0	0	0	0	0

SPC = Standard Plate Count

- Assessed utilising standard GCL sampling, testing specifications

Summary Tables

Table 26: Summary Table – Trial Plot A - Average Diameter/Maturity/Betanin%

	Trial Plot A – Early Season					
	Heavy Black Cracking Clay			**Light Clay Loam**		
Variety	'*BT5004*'	'*DDR*'	'*Pablo*'	'*BT5004*'	'*DDR*'	'*Pablo*'
Average Diameter (mm)	61	55	55	43	52	50
Maturity (days)	117	112	117	107	109	108
Betanin %	0.410	0.511	0.536	0.545	0.590	0.436

- Diameter monitored throughout processing. Average of 13 beetroot randomly selected off line
- Beetroot maturity determined as the period from planting to harvesting
- % betanin determined from beetroot juice at assumed 65ºBrix

Table 27: Summary Table – Trial Plot B – Average Diameter/Maturity/Betanin %

	Trial Plot B – Mid Season					
	Heavy Black Cracking Clay			**Light Clay Loam**		
Variety	'*BT5004*'	'*DDR*'	'*Pablo*'	'*BT5004*'	'*DDR*'	'*Pablo*'
Average Diameter (mm)	56	58	43	88	72	78
Maturity (days)	140	140	140	142	143	142
Betanin %	0.422	0.385	0.377	0.591	0.592	0.759

- Diameter monitored throughout processing. Average of 13 beetroot randomly selected off line
- Beetroot maturity determined as the period from planting to harvesting
- % betanin determined from beetroot juice at assumed 65ºBrix

Table 28: Summary Table – Colour Recovery versus Paddock Yield (%)

	Trial Plot A-Early Season		**Trial Plot B-Mid Season**	
	Heavy Black Cracking Clay	Light Clay Loam	Heavy Black Cracking Clay	Light Clay Loam
'*BT5004*'	1.26	1.69	0.88	1.23
'*DDR*'	1.70	1.66	0.71	1.08
'*Pablo*'	1.62	1.22	0.78	1.30

- Expressed as percent - (Betanin % ÷ Paddock Yield % x 100)

Small Block Assessment

Table 29: Small Block Assessments

Variety	Diameter (mm)			Juice Brix° (Raw Beetroot)	% Betanin	% Betanin (Assumption at 65°Brix)
	Min	Max	Average			
Boro	43	71	55	12.1	0.101	0.545
Red Cloud	49	69	62	15.5	0.128	0.539
6006*	37	80	56	12.8	0.089	0.452
Taunus	27	35	30	10.0	0.082	0.533
5849*	34	80	59	11.3	0.083	0.477
6480*	33	65	55	11.0	0.075	0.443
6462*	35	67	53	9.0	0.049	0.354
6477*	25	55	37	9.5	0.071	0.486

* denotes variety identification number provided by seed company

Extension Activity

Table 30: Antioxidant Addition Evaluation

Trial	Blank	1	2	3	4
Acidification Dosage Rate (%)	0.2	0.2	0.2	0.2	0.2
Antioxidant Dosage Rate (%)	0	0	0	0.25	0.50
Weight of Juice (g)	-	103.46	100.18	100.3	100.03
Vacuum	-	nil	nil	nil	Nil
Rotary Speed (r/m)	-	120	120	120	120
Time (minutes)	-	45	45	45	45
Weight of Juice after Heating (grams)	-	Not tested	100.61	100.56	100.33
Loss of Colour (%)	-	6.53	13.77	-7.14	1.63

Result Analysis

Raw Beetroot Brix°- Beetroot grown in light clay loam soil, yielded on average lower brix° in raw extracted beetroot juice, *refer to table 26: Average Raw Beetroot Brix°.*

Betanin Recovery- When average plot betanin percentage recovery was compared across all four trial plots, *refer to table 27:Betanin Recovery (percentage recovery),* beetroot grown in light clay loam, on average yields higher betanin recovery consistently.

Microbiological Assessment- Results have indicated that current process has the capability to process an end beetroot concentrate product to an acceptable GCL quality of microbial standards. With the exception of Trial Plot A '*DDR*' which produced a result of an unacceptable mould count. After further investigation, hold times during this batch were prolonged which could account for the high count.*(refer to table 28: Microbiological Assessment – End Concentrate).*

Average Diameter/Maturity/Betanin%- (*refer to table 29 and 30: Average Diameter/Maturity/Betanin%).* '*Pablo*' cultivated in light clay loam soil with an average diameter of 78mm and a maturity of 142 days yielded the highest betanin recovery of 0.759%. The lowest betanin recovery recorded of 0.377%, also from the variety '*Pablo*' grown in heavy black cracking clay with an average diameter of 43mm and maturity of 140days.

Colour Recovery versus Paddock Yield- Variety '*DDR*' grown in heavy black cracking clay, Trial Plot A, yielded the highest colour recovery versus paddock yield. The lowest colour recovery versus paddock yield was also the variety '*DDR*', when grown in heavy black cracking clay, Trial Plot B – mid season, (*refer to table 31: Summary Table – Colour versus Paddock Yield).*

6. DISCUSSION

Season

Planting window Trial Plot A: consisting of six blocks, was harvested at a maturity of 107 to117 days, resulting with diameter readings ranging from 43mm to 60.5mm. An average of 63 percent of expected raw material tonnage was yielded from these blocks. Low paddock yields are common within this growing window and this was taken into consideration when planting for the expected tonnage required. However paddock yield were furthermore impacted, with un-seasonal higher temperatures and the additional lack of water supply to crop due to current drought conditions.

Planting window Trial Plot B: Machinery breakdown lead to the later harvest of Trial Plot B. Beetroot maturity was 140 to143 days, consequently diameters ranged from 42.8mm to 88mm. Compared to the range for Trial Plot A – 43mm to 60.5mm.

Traditionally this planting window is known to offer higher paddock yields when compared to early season plantings, due to the associated optimum growing conditions. However additionally with machinery breakdown, further compounded the expected yield the trial was to achieve.

Weather Conditions:

Beetroot planted during lower mean temperatures and mean temperatures at the lowest during the mid growth period, produced a higher betanin recovery. This indicates this growing window is suited for the growth of beetroot for betanin recovery. However the impact of weather conditions versus colour recovery would need further investigation to substantiate this observation.

Trial Plot A was planted during higher mean temperatures, with temperatures at the mean lowest at time of harvest.

Trial Plot B planting mean lowest temperature was during the middle of the growth cycle, with mean temperature highest at time of harvest. Trial Plot B also gained thirty nine percent more rain than Trial Plot A.

Soil Type

Early season light clay loam produced beetroot with a lower average beetroot diameter of 43mm, 52mm and 50mm for '*BT5004*', '*Deep Detroit Red*' and '*Pablo*' respectively. Within the same trial plot – heavy black cracking clay produced a higher beetroot diameter of 61mm, 55mm and 55mm for '*BT5004*', '*Deep Detroit Red*' and '*Pablo*' respectively.

Mid season, beetroot planted in heavy black cracking clay, produced a lower average beetroot diameter of 56mm ('*BT5004*'), 58mm ('*Deep Detroit Red*') and 43mm ('*Pablo*'). Where as within the same trial plot – light clay loam produced a higher beetroot diameter of 88mm ('*BT5004*'), 72mm ('*Deep Detroit Red*') and 78mm ('*Pablo*').

Beetroot grown in heavy black cracking clay, mid season produced a total lower betanin recovery.

Additionally heavy black cracking clay produced higher total soluble solids recovered in extracted beetroot juice when compared to light clay loam. It is noted that light clay loam produced a higher average diameter beetroot when compared to heavy black cracking soil.

Variety

Assessment of the three varieties provided inconsistent results across all twelve trial plots, with not one variety performing consistently when betanin percentage data was analysed. '*Pablo*' yielded the highest betanin pigment, followed by '*Deep Detroit Red*' then closely followed by '*BT5004*'.

Colour shade analysis conducted only on Trial Plot B samples indicated, slightly higher levels of yellow pigmentation. The '*Deep Detroit Red*' variety was identified as retaining the highest levels of yellow pigmentation.

Variety 1 –'BT5004': yielded a higher betanin content (assumed at end concentrated brix) – Trial Plot B, light clay loam with an average diameter of 88 mm. Lowest betanin content (assumed at end concentrated brix) resulted – Trial Plot A heavy black cracking clay, with an average diameter of 61mm. Total soluble solids were lower when grown in light clay loam soil. Additionally this variety has been identified as the lowest resulting pigment beetroot. It was observed that variety '*BT5004*' grew at a higher rate than all other varieties.

Variety 2 –'Deep Detroit Red'(DDR): yielded a lower betanin within Trial Plot A when compared to Trial Plot B, preferred soil type light clay loam. Highest colour pigment (assumed end concentrated brix) resulted when variety grown in light clay loam soil within the second planting window of Trial Plot B. Beetroot harvested from this planting recorded an average diameter of 72mm.

Lowest colour pigment (assumed end concentrated brix) resulted when variety grown in the second planting window – Trial Plot B in heavy black cracking clay, average diameter resulted in 58mm. Colour shade results indicate that '*Deep Detroit Red*' has the highest level of betaxyanthin pigments. Total soluble solids were lower when grown in light clay loam soil. Variety '*DDR*' is ranked second preferred variety for colour pigment.

Variety 3–'Pablo': preferred variety for colour pigmentation, yielding highest betanin content when grown light clay loam soil and planted/harvested within the Trial Plot B time frame. Beetroot harvested from this planting recorded an average diameter of 78mm. '*Pablo*' produced the lowest betanin content when grown within the identical trial plot in heavy black cracking clay, with an average diameter of 43mm.
Total soluble solids were lower when grown in light clay loam soil.

Summary: '*DDR*' yielded slightly highest consistent betanin preference, however this variety has higher levels of yellow pigmentation. '*Pablo*' retains the highest betanin percentage recovery, with shading of blue/purple.

Growing Practices

Fertilisation:
Fertiliser types and rates were used within standard GCL practices. Rates of fertilisation varied between both trial plots, governed by different fertilisers used on farm. Beetroot grown in Light Clay Loam, early season was fertilised at a lower rate and yielded a higher colour recovery across the plot. There was no data to support the correlation of fertilisation versus colour recovery.

Planting Configuration:
As mis-shaped beetroot have proven to be suitable for beetroot concentrate production, planting configuration could be accommodated to increase the amount of seeds planted in one cultivation area, dependant on the season.

Harvesting, Processing & Recovery

Owing to the machinery breakdown, no conclusive result regarding the optimum beetroot processing size can be established due to the variation in average diameter and maturity between early and mid trial plot plantings. This was impacted by the later harvest of the mid season plantings (*refer to tables 26 and 27 – Average Diameter/Maturity/Betanin %*).

Size of beetroot greatly impacted processing throughput, with larger beetroot blocking lines within the beetroot steam peeler facility, blocking lines on the elevator to the re-sizer and smaller beetroot lost to floor upon collection at the steam peeler and lost to floor when elevated to the re-sizer (*refer to tables 8 and 9 – Processing*).

Larger beetroot laboured the re-sizer, as the machinery used is not designed to process large amounts of fibrous material.

The particle size of beetroot pulp directly after the re-sizer was a large coarse size, which decreased the amount of available juice extracted from the pulp during pressing. Additionally beetroot pulp was difficult to pump across to the press due to the lack of available moisture. Therefore additional water was added to the collection tank so that beetroot pulp became a pumpable consistency. The addition of water contributed to the lower juice start brix° prior to concentration when compared with raw beetroot start juice brix° collected directed at the re-sizer prior to being deposited into the collection tanks.

Holding times within the juice tanks prior to concentration varied dependant on the steam peeler and re-sizer through-puts. Juice could not be concentrated until a certain volume was reached in the holding tanks, so that a deliverable amount could pass through the concentrator minimum process capacity. These tanks were heated and exposed to oxygen while waiting for required capacity which impacted betanin stability. Holding times in the presence of heat after periods of juice extraction, acidification and during filtration contributed to betanin deterioration. Recommendations are drawn from the assumed betanin at 65°brix calculation due to these conditions.

Additionally raw beetroot handling and distance between each functional operation also impacted effectiveness of process. With beetroot holding bays, steam peeler, juicing line and concentrator all in four separate areas of the factory. Operational throughputs, were adversely affected by these processing conditions and were less than optimum.

Processing equipment used on site demonstrated the key steps required to extract and concentrate beetroot juice however this process would require further refinement or re-modeling to optimize betanin recovery and avoid betanin deterioration. Prolonged holding times and excessive temperatures during process are contributing factors to the loss of betanin in the final concentrate form.

Due to the dark nature of the concentrate, the final achieved brix varied across all twelve trials. This was due to inaccurate readings on the in-line refractometers prior to packaging.

The average percentage acid addition across all twelve production trial juice batches was 0.23% per batch volume to achieve the target pH range prior to concentration.

Additional Small Block Assessment

Eight small variety assessments were completed on a laboratory bench top scale. All analysis resulted in no identification of potential new beetroot varieties for colour pigmentation development.

Extension Activities

Results have indicated the inclusion of an antioxidant directly after acidification will protect the colour shade of beetroot concentrate on a laboratory scale only.

7. MARKET ANALYSIS

A. Current Australian Market

Current imported beetroot concentrate usage for the Australian market has been disclosed as an approximate amount of 3 to 6 Tonne per annum. This volume requires clarification and further establishment of end use applications. Retail price for imported beetroot concentrate within the Australian market has been gauged at $15.00 to $18.00 per litre, volume dependant.

B. Global Market

The establishment of the global consumption of beetroot concentrate will outline the demand. This will allow the formation of a business case outlining the expected volumes an Australian beetroot concentrate could compete on a global scale. Three major international companies have been identified and have expressed interest to purchase an Australian beetroot concentrate. This expression of interest has identified for a beetroot concentrate to compete within the market, end product specification must be closely adhered to, with no tolerance for variation. Betanin content of the end beetroot concentrate must not be lower than the nominated commercial acceptance level.

C. Additionally

Evaluation of current available commercial beetroot concentrates resulted with a benchmark for Australian beetroot concentrates to compete with. Organoleptic assessment resulted with Australian concentrate producing higher levels of sodium in some extracts, which are commercially unacceptable. This indicates further refinement of concentrate is required ideally a dedicated facility to produce commercial grade concentrate for colour.

Currently the cost to produce a GCL 65ºBrix beetroot concentrate is $10.00per litre. This captures raw material, factory throughputs, labour and burden costs. The establishment of current global price is required to gauge whether this price will be competitive within the market.

8. CONCLUSION

A. Variety and Seasonality

Beetroot can be isolated by variety to yield higher colour pigmentation in raw extracted beetroot juice. '*Pablo*' with an average diameter of 78mm grown in light clay loam, within the mid season planting window, produced highest betanin content in raw extracted juice. However this variety did not consistently perform highest across all trial plantings.

'*Deep Detroit Red*' produced consistent results across trial plantings, with the exception of mid season – heavy black cracking clay. Furthermore results indicate that this particular variety has higher levels of betaxyanthin pigments. '*Deep Detroit Red*' is not recommended as a raw material source for the production of beetroot concentrate when producing for blue/purple shading, due to levels of yellow/orange pigmentation. However this variety could be utilised for the production of yellow/orange shaded concentrates.

'*BT5004*' preformed the lowest and is not recommended for future colour development work.

Seasonality marginally affected total betanin recovery when both trial plot data is compared.

B. Soil Type

Light clay loam consistently produced beetroot with lower soluble solids and higher betanin content, in contrast heavy black cracking clay produced beetroot with higher soluble solids and lower betanin content. Therefore selection of a beetroot yielding lower soluble solids grown in light clay loam will provide a higher betanin beetroot concentrate

All beetroot varieties in relation to betanin recovery preformed the lowest during Trial Plot B – mid season, grown in heavy black cracking clay.

C. Processing and Recovery

The pilot line utilised demonstrated the key steps required to clean, juice and concentrate beetroot. Further improvement to process is required to optimise juice recovery, betanin stability and to regulate operational throughput. Beetroot size did influence the effectiveness of process regarding throughput and general material handling.

The effectiveness of the inclusion of antioxidant within processing is required on a larger scale.

9. RECOMMENDATIONS

Larger scale trials are required to confirm findings, during the 2008 beetroot season with beetroot variety '*Pablo*', planting during mid season in light clay loam soil. Confirmation of these parameters, are essential to ensure a consistent result of high colour pigment in end concentrated product is achievable.

An expanded understanding the significance between raw beetroot soluble solids and betanin recovery in end concentrate, would be beneficial when selecting raw material to harvest for maximum betanin recovery. Selection of raw beetroot with lower soluble solids has been indicated to provide a higher betanin percentage in end concentrate form. Monitoring total soluble solids on a regular basis during beetroot maturation would identify how solids develop during growth.

Further development work is required to refine the processing of beetroot juice to end concentrate form. With particular focus in the areas of, optimum beetroot particle size for maximum juice recovery, through-put improvement, betanin stability during concentration. To achieve this, it would be of great benefit for GCL representatives to visit current international commercial processing plants with the aim to understand the technology involved to stabilise betalaines and maximise recovery.

To understand the commercial viability of the beetroot concentrate produced during these trials it is recommended that samples are submitted to various end product users for assessment. All associated feedback from potential buyers/consumers would determine end use acceptance and highlight required improvements. Findings would initiate the first step into the market analysis of Australian beetroot concentrate and its commercial viability.

It is recommended GCL to assess the suitability to include trial produced beetroot concentrate in new product development work. In addition to the scope to include Australian produced concentrate implementing the change to replace imported product.

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Appendix 1 – Process Flow Photos

1. Beetroot Receipt

2. Beetroot Transfer

3. Beetroot Steam Peeler

4. Beetroot Re-Sizer

5. Beetroot Press


6. Extracted Juice