Beetroot Variety Isolation In Relation to Colour Pigmentation

Lydia Grant
Golden Circle Limited

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Level 7
179 Elizabeth Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399
E-Mail: horticulture@horticulture.com.au

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Project Leader : Lydia Grant
Golden Circle Limited
260 Earnshaw Road, Northgate

Frank Van Doore
Golden Circle Limited
260 Earnshaw Road, Northgate
Phone : (07) 3266 0620
(all correspondence relating to project, direct to Frank Van Doore)

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.

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 brixº prior to concentration when compared with raw beetroot start juice brixº 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 65ºbrix 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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