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Sugar Beet

Preliminary feasibility of ethanol production from sugar beet in NE Tasmania

A report for the Rural Industries Research and Development Corporation

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Foreword

The aim of the project was to complete a preliminary economic and physical feasibility assessment of growing sugar beet for ethanol production in North Eastern Tasmania.

CSR expressed a commercial interest in expanding ethanol consumption as a renewable fuel. Sugar beet is one plant, capable of growing in cool, temperate Tasmania, with a demonstrated capacity of producing sugar that can then be used to produce ethanol. Previous studies by the Tasmanian Department of Agriculture in the 1980s showed that despite good yields, the industry at that time was not economically feasible. However advances in agronomic and production technologies, the utilisation of by-products for livestock production and the Federal Government's renewable fuels policy suggested the crop was worthy of reassessment.

This report examines the results of the economic and physical feasibility assessments to determine if ethanol production from sugar beet can provide a new industry for north-eastern Tasmania.

This project was funded by RIRDC, CSR Limited and the Department of Primary Industries, Water and Environment.

This report, an addition to RIRDC's diverse range of over 1,200 research publications, forms part of our Prospective New Industries R&D program, which aims to facilitate the development of new industries based on plants or plant products that have commercial potential for Australia.

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Tony Byrne
Acting Managing Director
Rural Industries Research and Development Corporation

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Rob McGregor and Martin Jones from CSR should also be thanked for their support and help in providing information. DPIWE is also grateful to Gary Fisher and Bob Reid for their help in obtaining seed and knowledge from our overseas counterparts.

Tyke Traicos from TD Chemicals prepared the animal feed study and Stuart Bowman undertook the gross margin analysis.

In particular, DPIWE would like to thank it's staff members whom where involved in the technical aspects of the agronomic trials. These people include; Stuart Smith, David Butler, Norma Harrison, Regan Parkinson, Brian Field, Jonathon Knox, Darryl Johnson and Brett Davies.

DPIWE is also grateful to its project advisory team, who consisted of; Michael Hart (DPIWE), Peter Simmul (DPIWE), Nick Van Den Bosch (Dorset Edge Group) and Robin Thompson (DPIWE)

Abbreviations

"CSR"	Colonial Sugar Refineries
"DPIWE"	Tasmanian Department of Primary Industries, Water and Environment

Contents

Executive Summary

Colonial Sugar Refineries (CSR) contracted the Tasmanian Department of Primary Industries, Water and Environment to evaluate the feasibility of growing sugar beet for ethanol production in North Eastern Tasmania. A preliminary project, the results of which are reported here addressed agronomic, economic, by–product and production system issues. The results of this project will be used to determine future research and development activities.

Economic Assessment by Gross Margin Analysis

A preliminary desktop economic assessment was made prior to the field trials, then refined at their completion, as new cost of production data was available. Two types of gross margins were assessed. The field trial gross margin used trial yields and a high-risk commercial gross margin encompassed all conceivable inputs and represented the worst case scenario. Both gross margins showed a good return to growers relative to many alternative crops available in this region.

Economic Assessment of By-Products

An assessment was made of the value of the by-products following beet processing. Advances in processing technology enable the pulp to be available as a high value animal feed. This pulp can be fed in the wet form or pressed and dried. The energy value of this feed is similar to that supplied by grain hence the retail price of both products should be comparable. A local market for the pulp was identified and if developed would result in significantly less feed grain being annually imported into Tasmania.

Agronomic Trials

Two main issues being time of sowing and varietal performance were evaluated in the agronomic trial. The results from the Scottsdale site are summarised below.

Sugar Content

Sugar (sucrose) content of the beet roots was determined by chemical analysis l. The overall average sucrose content of the beets was 18.27 %, which is optimum for ethanol production. Sucrose content differed between varieties with Ariana having the highest, followed by Latoya and then Roberta.

Root Yields

The combined average root yield for all varieties and sowing times was 77.0 t/ha. There were no differences in average yields between varieties. August sowing times had the highest combined yields (91.3 t/ha) and November had the lowest combined yields (56.6 t/ha). Later sowing times resulted in a reduction in root yields, which may have been overcome with earlier harvesting and increased irrigation.

Dry Matter

The overall mean dry matter percentage and production per hectare was 25.86% and 19.92 units respectively. Variety had no effect on dry matter percentage and dry matter tonnes per hectare. Sowing time had little effect on percentage dry matter, but dry matter tonnes per hectare decreased with lateness of sowing time.

Summary of results

- Average Root Yields - 77t/ha, with a range from 55 t/ha to 100t/ha.

- Average Sucrose Content - 18.27% with a range from 18.98% to 17.59% across sowing times and 18.25 to 16.75% across varieties.

- Plenty of room for improvement in root yields

Recommendations

At this stage, further development of an ethanol industry is subject to consideration by CSR in consultation with the Tasmanian Government. Consequently no further agronomic research is required at this time.

However the results from this study are a valuable benchmark and update in agronomic recommendations. If an ethanol industry were to be developed, then the results from this trial would be invaluable in increasing the potential success of the crop.

1. Introduction

The rural region around Scottsdale, in North Eastern Tasmania, has seen the decline in employment opportunities with the closure of a milk processing factory 3 years ago (20 jobs) and the closure of the Simplot potato processing factory (136 jobs). In a scan for other enterprises, production of sugar beet for ethanol offered a realistic alternative, given that there was a major Australian company who had commercial interest in expanding ethanol as a renewable fuel. Tasmania currently imports all motor vehicle fuels and ethanol is imported for use as a solvent in the poppy industry.

The Federal Government has a policy to encourage the use of renewable fuels although there has been much media speculation and mis-reporting regarding the suitability of ethanol as a fuel additive it is gaining acceptance particularly in Queensland. It is known that 10% ethanol can be used in fuel without adverse effect. Brazil uses 20 - 24% ethanol with some engine and fuel system modification and the EU recommends that a 5% ethanol mixture with petrol be adopted before 2010. Ethanol burns cleaner and more efficiently than petrol, resulting in less environmental pollution.

The introduction of an additional crop into this region, with an associated processing component, would lift employment and generate wealth in this regional community. A 20 million litre sugar beet to ethanol plant in USA is quoted as directly employing 25 people. Development of a sugar beet industry in the north-east has the potential to inject at leat $25m at the farm gate and directly employ about 30 people as process workers.
If the feasibility demonstrates that ethanol could be produced economically, the proposed plant would annually produce 40 million litres of ethanol and require 6,000 hectares of sugar beet crop. Additional value can be placed on the tops and fermented mash for stock-feed purposes. The combination of ethanol production and utilisation of plant tops and extracted mash for livestock feed appear to offer an attractive return for potential growers as well as reducing the importation of feed grain.

In 1980 the then Tasmanian Department of Agriculture conducted a series of field trials aimed at determining the yield and basic agronomic requirements for sugar beet production in Tasmania. This work concentrated on only one variety (Bush Mono G) and did not take into account the potential use of by products as animal feeds. Europe and North America have large sugar beet industries and associated research and extension programs. The literature from these areas suggests that agronomic and production technologies for sugar beet production have improved considerably over the past twenty years. Such advances have been concentrated on those aspects of production such as variety, weed control and product handling which are the main determinants of crop profitability. It was therefore necessary to apply these technologies to the Tasmanian environment and determine their local influence.

2. Objectives

Aims

- Determine suitable varieties and sowing times on the two major soil types in North-East Tasmania. Some observations and assessments of potential herbicides and equipment for harvesting and transporting sugar beet.
- To assess, via literature review, the value of sugar beet tops and pulp for animal production.
    1. Define the major equipment requirements, process description, capital, fixed and variable costs for the production of animal feed pellets from processed sugar beet waste.
- Update economic analysis for sugar beet and ethanol production in Tasmania.
- Recommendations based on technical and macro financial considerations regarding establishment of a commercial sugar beet industry for ethanol production in Tasmania.

3. Methodology

3.1 Agronomic Evaluation

Background

The field trial consisted of three replications of three sugar beet varieties by five sowing times on the two predominant soil types of the North East region. Observation and measurement of establishment, bolting, disease and pest incidence, plant form, yield of tops, roots and sugar and nutritional value of tops and extracted mash were made.

Animal performance to grazing sugar beet plants was assessed using material available at the conclusion of the agronomic assessments. A full report on nutrition status of sugar beet tops will be a separate publication. A literature review on animal performance with regards to sugar beet and fodder beet was compiled (Appendix).

Fodder beet was initially included as a potential source for ethanol production, but assessment was changed to that as a potential new animal forage crop. A report on fodder beet results is a separate publication.

Preparation

Two trial sites were chosen in north-east Tasmania to represent the major cropping soil types. The sites were located at Scottsdale, a traditional vegetable cropping region and Waterhouse, which although traditionally grazing, has moved into potato cropping.

The Waterhouse area is dominated by sandy soils derived from wind blown sands, while the Scottsdale area consists of gradational, well-structured red Ferrosol soil formed from basalt rock. Sites were also considered on the availability of irrigation and size of trial area available.

Soil tests were taken from both sites and fertiliser applied, so as to ensure non-limiting nutrition. The fertiliser used was 6:14:14 at 300kg/ha applied at sowing

Prior to planting the sites were sprayed with 1.35 kg/ha of Glyphosate and rotary-hoed before planting. Both sites were sown using the DPIWE's Oyard cone seeder drill. All seed was tested for germination prior to sowing so as the sowing rate could be adjusted accordingly.

Scottsdale Trial Site

The site at Scottsdale was located at Glenn Moore's property 'The Hope'. The property consists of fertile red Ferrosol soils, which have been used intensively for vegetable production. Ferrosol soils generally consist of a clay loam topsoil overlying a light to light-medium clay subsoil. These soils are well structured (provided good soil management is maintained) and well draining.

The Scottsdale region is well known for its intensive vegetable production, being primarily onions, potatoes and carrots, with poppies and pyrethrum an addition in recent years. Other farming enterprises in the area include dairying, beef, sheep meat and wool production. The trial area totalled 1.2 hectares, with plot sizes of $160m^2$.

Waterhouse Trial Site

The site at Waterhouse was located at Ken Lette's property 'Dunlin'. Soil types in the Waterhouse region can be quite variable and range from sands to clays to duplex soils. The soil in the trial area was quite variable, but dominated by a shallow ground-water podzol (Podosol), known locally as a Thorpe Sand, which is derived from wind blown sands. These soils tend to be weakly structured sandy loam to loamy sand topsoils, occasionally with deep A_2 horizons. Heavy sandy soil types were found in the trial site, that overlayed a medium to heavy clay subsoil.

Sheep and beef grazing have traditionally dominated the Waterhouse area. Potatoes have become part of the cropping rotation in recent years with the introduction of centre pivot irrigators. The sandy soils enable harvesting to proceed throughout winter. On a lesser scale cereals, poppies, forage crops and some speciality vegetable crops are starting to be grown. Cropping is restricted by lack of available irrigation water. The trial area was 0.6 hectares, with plot sizes of $80m^2$.

For both sites, there were five sowing times. The reason for evaluation of sowing times was to assess the effect of sowing time on final yield and to determine whether an extended period of harvesting and sowing of the sugar beet is possible. The sowing times were approximately monthly from July through to November. The three varieties used in the trial were Ariana, Latoya and Roberta, obtained from the Sugar Beet Seed Company in the U.K.

For both sites nutrition and water were managed as to be non-limiting to sugar beet production (however at the Scottsdale site, water was required elsewhere on the property, so water may have been limited in the last months of growing). Herbicide products used on the trial were those registered for use on beets in Australia. At this stage, other herbicides were not used due to the lack of registration or the inability to import the particular chemical. A herbicide trial had been considered but was abandoned due to lack of resources.

Spraying regime

The spraying regime for both trial sites was as follows;

Pre-sowing Sprays

Glyphosate @ 3l/ha

Pre-emergent Sprays

Herbicide
Betanal @2l/ha

Insecticide
Dimethoate

<u>Post-emergent Sprays</u>

Herbicide

2 to 3 sprays of Betanal @ 5L/ha
2 to 3 sprays of Tramat @ 2L/ha
Select @ 1L/ha (as required if grass weeds were a problem)
Lontrel @ 250ml/ha (as required if thistles were a problem)

Insecticide

SlugOut Slug pellets @ 200g/100m2
2 sprays of Dimethoate @

Fungicide

1 spray of Triadimefon @ 1L/ha (Scottsdale site only)

A small additional variety trial and a comparison of sowing rates was also sown at Waterhouse using seed received after the initial trial was planted. These newly released varieties were Cinderella, Giovanna, Dominika, Wildcat and Stallion, obtained through Danisco Seeds.

Observations and measurements of establishment, seedling vigour, bolting, disease and pest incidence, yield of tops and roots (kg/ha), sugar content and dry matter (%) of tops and roots were made. Seedling vigour was estimated

Observations of seedling vigour were made subjectively on a scale of 0 to 10 (0 Poor, 10, Excellent). Establishment was a visual estimate of density, with the actual recording of surviving plant density taking place at harvest. Bolting of mature plants was recorded with time of bolting, variety, size of bolted stem and number of stems. Disease and pest incidence was observed and any damage recorded.

The trial area was harvested using a twin row potato digger, which lifted the beets out of the ground. The tops and crown were separated to simulate what would be harvested under normal commercial harvesting operations. A $16m^2$ harvesting area was used.

The tops and roots of the beets were weighed and counted. Further analysis for dry matter and sugar content, were conducted using a sample of 3 beets from each plot. Analytical Services Tasmania conducted sugar content analysis at the University of Tasmania, while dry matter was assessed at the DPIWE's laboratories at Mt Pleasant. The method of sugar content analysis is as follows;

Analysis of sugars by HPLC

Instruments

Pump:	Varian 9012
Injector:	Varian 9100 Autosampler
Detector:	Shimadzu RID-6A Refractive index detector
Column:	Prevail Carbohydrate ES 150 x 4.6mm 5µm

Conditions

Mobile Phase:	75% Acetonitrile: 25% MilliQ water
Injection Volume:	100µL
Flow Rate:	1.0mL/min

Sample Preparation

A thin, complete, transverse section is cut from each beet, approximately midway along its length. Another section, crossing the diameter of the beet, is taken from the previous section to approximately 3.3 grams. Each sample submitted composed of three beets, so each beet contributed to the total of approximately 10 grams as a composite of each sample location. The cut samples were immediately placed in a 250mL Schott glass bottle, to which, 100mL of 80% Methanol was added.

Each sample was transferred to a clean 250mL vessel and blended for 60 seconds on a Sorvall Omni Mixer (Inverted high speed blender). The resultant blended sample was then transferred to its original vessel, capped and sonicated for 10 minutes to rupture the cells. The samples were allowed to cool, then passed through a 0.2µm syringe filter into 2mL HPLX vials for analysis. The samples were then compared against accurately weighed and diluted pure sucrose standard.

All yield and measurement data was statistically analysed using Genstat.

Investigation of potential drilling and harvesting equipment is currently under way.
At the conclusion of each trial, the property owners stock was allowed onto the remaining beets to help clear the paddock, before the trial area was fully sprayed out. To ensure the incidence of nitrate poisoning was minimised, all tops cut during the harvest were removed from the grazing area.

3.2 Economic and By-product Feasibility Assessments

Tyke Traicos, an independent consultant from TD Chemicals in Queensland was contracted to undertake the assessment of the value of by-products. Results were presented in a report (21). DPIWE economist, Stuart Bowman, calculated gross margins.

4. Results

4.1 Agronomic Evaluation

4.1.1 Waterhouse Evaluation Trial

As previously stated, the trial site was seriously affected by a root rot disease called *Fusarium*. The physical signs of the disease was discovered in early January when wilting of leaves and extensive root rot became evident. Previous root rots were minimal in the population prior to this time. Generally all crops will have some root rot due to rapid growth, insect damage causing splitting of the roots, which allows disease to infect. Samples were sent to the Department's plant pathologist for diagnosis in February. Although the trial was officially stopped at this point, observations were still made until May. A surprising result that despite no irrigation, some plots managed to recover slightly. However it was decided that yield and other data collected from this site was not scientifically valid. The only sugar beet variety that showed no signs of disease was Cinderella, which produced 81 t/ha.

1.

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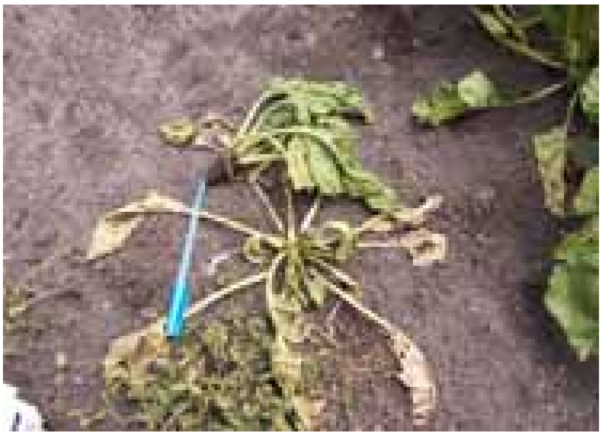

3.

Figure 1: Cinderella Sugar Beet Variety.
Figure 2: Plant affected by Fusarium.
Figure 3: The Waterhouse trial site

The trial had initial problems with the first two sowing times (July, August), having to be resown due to waterlogging. This waterlogging is also a possible cause of the *Fusarium* disease that later affected the crop. Plants produced from sowing times from September to October showed good emergence and vigour. Emergence was found to be at least three days earlier than at the Scottsdale site. Vigour was also better at this site with seedlings reaching their 12-leaf stage a week earlier than seedlings from the same sowing times at the Scottsdale trial site.

The waterlogging in early August also caused a small amount of salinisation on a number of plots. As sugar beet is a maritime plant (and therefore reasonably tolerant of salt) the effect on populations was minimal, apart from areas where a salt crust had emerged. On the plots where seedlings were emerging, their vigour was hindered somewhat by the crust and a dramatic loss of seedlings occurred.

Insect damage was minimal at this site.

4.1.2 Scottsdale Evaluation Trial

Yield

There were initial concerns with germination and density at this site. Despite germination being tested, germination in the field was quite varied. Some plant counts were taken, with numbers generally lower than the desired 8 plants/m2. Despite density not being optimum, it can be seen from the yields that this did not cause major problems with yields at the Scottsdale site reaching 90 to 100t/ha.

Figure 4: Scottsdale trial site

Disease

Plants at the Scottsdale trial site were infected with two fungal diseases namely Powdery Mildew and Leaf Rust, but there was no major affect on final yields. They were effectively controlled with Triadimefon @ 1L/ha and no specific treatment respectively. Leaf Rust affected different sowing times to varying degrees. As the trial was close to harvest at time of infection, no fungicide was applied. The trial was also to be fed off to cattle so we wished to minimise any residue problems.

Insects

Leaf miners and slugs were the major insect pests at Scottsdale. A preventative application of slug pellets was applied when slugs were observed, although no damage had been seen. Despite leaf miners attacking the foliage, it was determined that due to the minimal damage it caused that they posed no threat to yields. Consequently the next stage of foliage grew and no further sign of damage was seen.

Sugar Content

The overall average sugar content (as % sucrose) of the sugar beet roots was determined to be 18.27%. Sucrose content differed between varieties with Ariana having the highest, followed by Latoya and then Roberta (Table 1). Previous trials conducted by the Department had an average sugar content of 17.7%. Sugar content did decrease slightly with later sowing times from an average of 18.98 for the July sowing times to 17.59% sucrose for the November sowing times (Table 2).

Table 1: Sucrose content compared to variety

Variety	*Average Sucrose % (w/w)*	*Significance*
Ariana	19.8	a
Latoya	18.25	b
Roberta	16.77	c
	LSD = 0.673	

Table 2: Sucrose content compared to sowing time

Sowing Time	*Average Sucrose (%) (w/w)*	*Significance*
August	18.98	a
July	18.71	b
September	18.1	b
October	17.98	b
November	17.59	c
	LSD = 0.869	

As shown in Table 3, where the effects of sowing time and variety are combined, the Ariana variety had very high sucrose content, followed closely by Latoya.

Variety	*Sowing Time*	*Average Sucrose (%)*	*Significance*
Ariana	August	20.47	a
Ariana	September	19.97	ac
Ariana	July	19.8	acd
Ariana	November	19.58	acde
Latoya	August	19.53	acdef
Latoya	July	19.27	acdefg
Ariana	October	19.17	acdefgh
Latoya	October	18.03	bfghi
Latoya	September	17.73	bhi
Roberta	July	17.07	bi
Roberta	August	16.93	bi
Roberta	October	16.73	bi
Latoya	November	16.68	bi
Roberta	September	16.6	bi
Roberta	November	16.5	bi
		LSD = 1.505	

Root Yields

The combined average root yield for all varieties and sowing times was 77.0 t/ha. There were no significant differences in average yields between varieties (Table 4).

Table 4: Root yield (t/ha) compared to variety

Variety	*Average t/ha*	*Significance*
Ariana	76.1	a
Latoya	80.8	a
Roberta	73.9	a
	LSD = 11.09	

Table 5: Root yield (t/ha) compared to sowing time

Sowing Time	*Average t/ha*	*Significance*
August	91.3	a
July	82.7	ab
October	77.6	ab
September	76.5	b
November	56.6	c
	LSD = 14.32	

However for sowing times there were a number of significant differences. As seen from Table 5, August sowing times had the highest yields (91.3 t/ha), which were significantly higher than the September (77.6 t/ha) and November (56.6 t/ha) combined yields. Overall November did poorly with all other sowing times having significantly higher yields.

The effect of sowing time and variety was analysed for any further affects (Table 6). Again the November sowing time had a dramatic effect on overall root yield, with yields being below the desired 70t/ha.

Table 6: Root yield (t/ha) compared to the combination of sowing time and variety

Variety	*Sowing Time*	*Average t/ha*	*Significance*
Latoya	August	100.4	a
Ariana	August	92.4	ac
Latoya	September	84.9	acd
Latoya	July	83.8	acde
Ariana	July	82.4	acdef
Roberta	July	82	acdefg
Latoya	October	81.5	acdefgh
Roberta	August	81.1	acdefghi
Roberta	October	78.5	acdefghij
Roberta	September	73.4	bcdefghij
Ariana	October	72.8	bcdefghij
Ariana	September	71.3	bcdefghij
Ariana	November	61.7	bdefghij
Roberta	November	54.6	bj
Latoya	November	53.5	b
		LSD = 24.79	

Figure 5: Harvested sugar beets

Dry Matter

The overall DM percentage was 25.86 % and the DM yield 19.92 t/ha. Despite Latoya recording a significantly lower DM % (Table 7), variety generally had no effect on DM t/ha (Table 8).

Table 7: Dry Matter (%) compared to variety

Variety	*Average DM(%)*	*Significance*
Ariana	26.21	a
Latoya	25.28	b
Roberta	26.08	a
	LSD = 0.751	

Table 8: Dry matter (t/ha) compared to variety

Variety	*Average DM t/ha*	*Significance*
Latoya	20.4	a
Ariana	19.95	a
Roberta	19.42	a
	LSD = 1.464	

Table 9: Dry matter (%) compared to sowing time

Sowing Time	*Average DM (%)*	*Significance*
August	26.6	a
November	26.05	a
July	25.99	a
October	25.69	ab
September	24.95	b
	LSD = 0.97	

Table 10: Dry matter (t/ha) compared to sowing time

Sowing Time	*Average DM t/ha*	*Significance*
July	24.5	a
August	21.38	b
September	19.93	b
October	19.09	cd
November	14.71	e
	LSD = 1.89	

There was a significant reduction in DM % for the September sowing times, however sowing time overall does not seem to have a major effect on this characteristic (Table 9). However for DM t/ha, there was a trend to decrease with later sowing time (Table 10). November sowing times had significantly lower DM t/ha than the other sowing times. July sowing times were had significantly higher DM t/ha than the other sowing times, while August and September sowing times were higher than October and November.

Despite a number of significant differences, there is no evident trend arising from the combination of sowing time and variety for dry matter percentage (Table 11).

Table 11: Dry matter (%) compared to sowing time and variety

Variety	*Sowing Time*	*Average DM (%)*	*Significance*
Roberta	August	27.63	a
Ariana	July	27.04	ac
Ariana	November	26.71	acd
Ariana	August	26.48	acde
Ariana	October	26.37	acdef
Roberta	July	25.93	bcdef
Roberta	November	25.89	bcdef
Latoya	August	25.7	bcdef
Roberta	October	25.66	bcdef
Latoya	November	25.55	bcdef
Roberta	September	25.29	bdef
Latoya	September	25.11	bdef
Latoya	October	25.06	bdef
Latoya	July	25.01	bef
Ariana	September	24.45	b
		LSD = 1.68	

Table 12: Dry matter (t/ha) compared to sowing time and variety

Variety	*Sowing Time*	*Average DM t/ha*	*Significance*
Latoya	August	25.83	a
Ariana	August	24.53	ac
Roberta	August	23.16	acd
Ariana	July	22.12	cde
Latoya	September	21.24	bdef
Roberta	July	21.18	bdefg
Latoya	July	20.83	bdefgh
Latoya	October	20.41	bdefghi
Roberta	October	20.13	befghij
Ariana	October	19.26	befghijk
Roberta	September	18.55	bfghijkl
Ariana	September	17.47	bijklm
Ariana	November	16.38	bklm
Roberta	November	14.06	b
Latoya	November	13.69	b
		LSD = 3.274	

However for dry matter yield there is a general trend with the later sowing times showing the lowest yields. As seen with the effect of sowing time on root yields, there is a similar effect occurring with DM t/ha (Table 12).

Population Density at Harvest

Although some initial plant counts were taken after germination, it was not continued as some problems with drilling had occurred. The germination percentages tested at DPIWE before sowing for the three varieties are as follows;

Ariana:
Germination = 84.5%
1000 Seed Weight = 42.4g

Roberta:
Germination = 86.5%
1000 Seed Weight = 42.3g

Latoya:
Germination = 85.5%
1000 Seed Weight = 40.5g

Sowing rates were modified to allow for these germination percentages drilling problems led to uneven spacing in the rows. Therefore plant counts were not continued.

Population density was subsequently estimated by counting plants present at harvest. Given the harvested area was 24m^2 and the desired plant density was 8 plants/m^2, each harvested area there should have supported around 192 plants (if 100% germination). To calculate the germination percentage for each variety, the population number taken at harvest was recorded as a percentage of the total plants possible if 100% germination. Therefore from Table 13, it can be seen that Latoya and Roberta performed reasonably well, whilst Ariana was relatively low. The earlier sowing times of July and August also performed well (Table 14).

Table 13: Plant density compared to variety

Variety	*Average Plant Density No.*	*Population Density %*	*Significance*
Ariana	142	73.9	a
Latoya	155.9	81.2	ab
Roberta	160	83.3	b
	LSD = 16.44		

Table 14: Plant density compared to sowing time

Sowing Time	*Average Plant Density*	*Population Density %*	*Significance*
August	175.8	91.5	a
July	161.7	84.2	ac
October	146.2	76.1	bc
November	141.2	73.5	bc
September	138.2	72.0	bc
	LSD = 21.23		

Table 15: Sowing time / variety plant densities

Variety	*Sowing Time*	*Average Sample No.*	*Significance*
Roberta	July	195	a
Latoya	August	179.3	ac
Latoya	July	170	acd
Ariana	July	162.3	acde
Latoya	September	156.3	bcdef
Roberta	November	153.7	bcdefg
Roberta	August	153	bcdefg
Ariana	August	152.7	bcdefg
Roberta	October	151.7	bcdefg
Roberta	September	146.7	bcdefg
Latoya	October	144	bcdefg
Ariana	November	140.3	bdefg
Ariana	September	135.7	bdefg
Latoya	November	129.7	befg
Ariana	October	119	g
		LSD = 36.77	

Beet size characteristics

The overall average length of the beets was 25.41 and 12.39 cm in diameter (measured at the widest portion of the root). There was no significant difference between varieties for diameter and length (Tables 16 and 17).

Table 16: Variety Root Diameter (cm)

Variety	*Average Root Diameter (cm)*	*Significance*
Ariana	12.17	a
Latoya	12.83	a
Roberta	12.19	a
	LSD = 1.085	

Table 17: Variety Root Lengths (cm)

Variety	*Average Root Lengths (cm)*	*Significance*
Ariana	25.99	ab
Latoya	26.38	ab
Roberta	23.85	b
	LSD = 1.727	

Despite significant differences in root lengths, there is no obvious trend emerging between the early and late sowing times (Table 18). July sowing times were significantly larger in root diameter than September and November sowing times (Table 19).

Table 18: Sowing Time Root Length (cm)

Sowing Time	*Average Root Length (cm)*	*Significance*
October	26.9	a
July	26.12	ac
September	25.36	abc
August	24.61	abc
November	24.04	b
	LSD = 2.045	

Table 19: Sowing Time Root Diameter (cm)

Sowing Time	*Average Root Diameter (cm)*	*Significance*
July	13.37	a
October	12.89	ac
August	12.37	abc
September	12.02	bc
November	11.32	b
	LSD = 1.344	

Despite a number of significant differences, there is no evident trend emerging between sowing time and variety on root length or root diameter (Table 20 and 21).

Table 20: Sowing Time / Variety Root Length (cm)

Variety	*Sowing Time*	*Average Root Length (cm)*	*Significance*
Ariana	October	27.97	a
Latoya	October	27.33	ac
Latoya	August	26.87	acd
Ariana	July	26.83	acde
Roberta	July	26.43	acdef
Latoya	November	26.33	acdefg
Latoya	September	26.27	acdefgh
Ariana	September	25.6	acdefghi
Ariana	August	25.57	acdefghij
Roberta	October	25.4	acdefghijk
Latoya	July	25.08	acdefghijkl
Roberta	September	24.2	bcdefghijkl
Ariana	November	24	bcdefghijkl
Roberta	November	21.8	bl
Roberta	August	21.4	b
		LSD = 3.542	

Table 21: Sowing Time / Variety Root Diameter (cm)

Variety	*Sowing Time*	*Average Root Diameter (cm)*	*Significance*
Roberta	July	14.15	a
Latoya	July	13.52	ac
Latoya	October	13.4	acd
Roberta	October	12.68	acde
Latoya	August	12.65	acdef
Ariana	August	12.62	acdefg
Ariana	October	12.6	acdefgh
Latoya	September	12.5	abcdefgh
Ariana	July	12.45	abcdefgh
Latoya	November	12.08	abcdefgh
Roberta	September	12.03	abcdefgh
Roberta	August	11.83	abcdefgh
Ariana	November	11.63	bcdefgh
Ariana	September	11.53	bcdefgh
Roberta	November	10.23	b
		LSD = 2.328	

Boltings

The majority of bolting plants occurred in the two early sowing times of July and August. Compared to the fodder beet that was planted with the sugar beet trial, bolting was fairly minimal (Table 22).

Table 22: Bolting sugar beet plants

Sowing Time	*No. of bolted plants*
July	18
August	2
September	0
October	0
November	0

Figure 6: Bolted fodder beet plants

4.2 Value of Sugar Beet and Fodder Beet as an animal feed

A literature review was compiled that investigated the value of sugar beet and fodder beet, plus the by-products of ethanol production for animal feed. A summary of this report and the recommendations are as follows;

Summary

- After the extraction of sugar, there are five main types of by-products that can be produced (wet pulp, pressed pulp, dried beet pulp, molassed dried beet pulp and beet molasses), all of which are an effective and nutritious source of animal feed.
- Sugar beet and fodder beet has been extensively used in Europe and the U.K as a source of feed. If the nutrient deficiencies of both are corrected (ie. low protein), they could provide a suitable alternative to many traditional feeds such as grain.
- Sugar beet and fodder beets have a high yield potential in terms of energy available for lactation when compared to cereals. The other benefit seen from the data is the replacement of high starch cereals in the ration with sugar beet pulp. This would reduce the demand for grain imports into Tasmania.
- Although fodder beet has been tried by a few growers in the state in past years, there remains an opportunity for dairy and red meat producers to incorporate fodder beet as a feed crop.
- The curing of beet tops to reduce the level of nitrate and oxalic acid in leaves may prove to be difficult due to Tasmanian conditions. With the majority of sugar beet harvesting carried out in the winter months, the tops may not be able to dry properly. Drying facilities like those seen in Europe are required (Frappell, 1980).
- Fodder beets have been specifically bred for animal feed purposes, so their nitrate content is lower than sugar beet. It would be advisable however to graze the tops of the fodder beet whilst attached to the roots by using temporary fencing to restrict grazing area.
- The use of tops and silage from sugar and fodder beet may be limited due to the amount of labour required and the level of knowledge required to utilise these feeds effectively. Good extension would have to be provided to encourage growers to take advantage of the left-over tops either as a feed or as a green manure crop.
- Some experiments explained in the review were for stock in production systems quite different to those seen in Australia. For instance, housing sheep during winter would mean that their maintenance requirements and thus production would be quite different to open grazing stock.

Recommendations

- Legislation covering the use of these feeds in Australia will need to be investigated. Beet used for animal feeds is subject to strict legislation in the EU.
- Experiments with the commercial forms of sugar beet feeds need to be undertaken to ascertain their nutritive value and whether they have a role in Australian agriculture.
- No data is available on the effect of sugar and fodder beet on wool production and with this being one of the major industries in Tasmania, it is essential that at least preliminary investigations are undertaken.

4.3 Economic Assessment

Value of the By-Products

Recommendations from the study concluded that;

- Beet pulp is generally distributed in the forms of wet, pressed, dried and molassed. Each has economic and logistical features, which will determine the optimisation product distribution range. Its use in human foods is also possible.
- A process design including flowsheet, mass balance and major equipment specification was prepared. Capital costs were estimated from $3.7 milllion (pressed pulp) to $8.4 million (pressed, dried and pelletised pulp).
- Variable costs ranged from $0.11 to $17.56 per tonne pulp processed and fixed costs $445 000 to $555 000 per annum.
- It is recommended that these product options and costs be evaluated in cash flow analyses to determine the optimal product mix.

The full report can be found in the appendix 3

Gross margins

Two gross margins were formulated after the trial was finished; one based on actual trial costs and the other assuming a high input high -risk scenario. These results together with similar analyses for other cash crops (such as poppies and potatoes) are included in the appendix. The trial cost scenario can be considered as very close to what a commercial crop could produce.

The gross margins for the trial, when compared to other crops grown in the Scottsdale and Waterhouse region are as follows:

Table 23: Gross margins of sugar beet compared to locally grown crops

	Average	*Good*
Crop	$/ha	$/ha
Sugar Beet - Trial	5421	6282
Sugar Beet - High Risk	5930	7440
Potatos (Processing)	4033	5211
Carrots	4184	-
Onions	3756	-
Poppies	3359	-

Average $/ha are based on long term yield and price averages, while the good 4/ha represent good yields and prices that may occur from time to time depending on the current economic conditions. As can be seed from Table 23, the gross margins are better than poppies and potato crops (both considered high value). However with transport costs an unknown factor, as would depend on the location of the factory and the mode of transport as to the final cost. Harvesting costs may also need re-evaluating.

5. Discussion

5.1 Agronomic Evaluation Trials

5.1.1 Waterhouse Trial Site

A major causal factor for the *Fusarium* root disease at the Waterhouse trial site most likely would have been waterlogging in early August. The disease was most likely triggered by the warmer conditions in November-December. Combined with irrigation spray and general movement this could have ultimately led to its spread throughout the site.

The reason for poor emergence of the November sowing times is unclear. It may have been an early victim of the disease with seedlings being much more vulnerable to disease attack than adult plants. No sign of insect damage was present.

Despite minimal results being available, if trials were to be continued in the north-east, a trial at Waterhouse would need to be included based on emergence and vigour observations. Disease prevention management would be implemented to reduce the likelihood of the trial being affected again. These would include raised beds, resistant varieties, adequate drainage and rotations. One major factor that could cause a concern is the abundance of potato crops in the district. A number of diseases can be passed between sugar beet and potatoes. If potato growers were to grow sugar beet, care would have to be taken to ensure that the beet crop was not planted following a potato crop and vice versa.

5.1.2 Scottsdale Trial Site

Results suggest that good yields are easily attainable in the Scottsdale region. Previous trials in the region have also resulted in similar root yields. Whether these yields can actually be increased further with improvements in weed control, better varieties and earlier harvesting remains to be seen.

There was a general decrease in root yields with sowing times, with November sowing time performing quite poorly. Due to irrigation constrains the trial may have not received the optimum supply for unlimited growth. Trials in the early 1980s did show a reduction in root yields of around 20 t/ha when dry-land crops were compared with irrigated crops. It could be possible that irrigation may have limited the potential of the later sowing times of October and November. There is another possibility that a frost could have occurred before the plants had reached their full size, which can lead to a reduction in yields, as well as affecting sugar contents.

As the trial was primarily to look at the effect of sowing times on yields, the results from the last two sowing times warrant further work. The question that remains is that whether improved watering would have increased yields comparable to those of the earlier sowing time.

Compared to traditional sugar beet growing countries, our yield results are quite good. For 2003, the USA average was 56.1 t/ha (USDA, 2004), compared with our trial average of 77.7 t/ha. UK yields were 55.78 t/ha in 2002 (National Statistics, 2004) and Ireland yields were 50t/ha in the 2003/2004 period (The Department of Food and Agriculture, 2004). However, a larger commercial scale trial would determine the yield under normal field situations.

Sugar Content

The combined average sugar content of 18.27% is slightly higher than the 17.7% from previous departmental trials. High sucrose contents can cause problems for ethanol processing. However as the combination of variety and sowing time treatments are from a relatively small harvest area, it would be conceivable that these levels would be lower over a larger area.

There are a number of possible reasons for the increase in sugar levels. Due to earlier sowing time treatments being left in the ground until the later sowing times were ready for harvest, it is possible that in this period of time sugar levels may have risen. The significant difference in sugar content between the July and November sowing times is 1.12 % sucrose. In addition, a number of frosts were experienced prior to harvest. American farmers tend to wait 6 weeks after a frost before harvesting as this is thought to raise sugar levels. Whether this occurred in this situation would require further evaluation, although at least two frosts were recorded in the period between March and July. However in a normal commercial sugar beet crop harvesting probably would have occurred at an earlier stage (eg. February to April).

Agronomy

With a number of weeds causing concern at both sites, further herbicides will need to be evaluated. It was surprising that the yields were so good, despite the high population of *Amaranthus spp.*, *Polygonum aviculare* and *Solanum nigrum* at the Scottsdale site. *Solanum nigrum* was also a major weed at the Waterhouse site. However, to ensure further increases in yield, it is essential that weeds be managed.

Using knowledge of local farmers, combined with a longer fallow period could help to overcome any weed problems in the future.

With only a minor amount of bolting in sugar beet varieties seen at Scottsdale, there is no evidence to suggest that sowing times would be a problem. Techniques in other sugar beet areas involve wick wiping the bolted heads to prevent any seed set. It would be envisioned that a similar technique would be used here.

Population densities suggest that improvements in ensuring good establishment and vigour are required. A major factor is ensuring that any seed provided for the trial is of the highest quality, as there was a concern with the varieties used that they may have been more than 1 year old. In addition, most commercial sugar beet crops used specialised sowing equipment. Further trials with a range of varieties and slight modifications to sowing rates would provide an indication of the potential yield that could be produced.

Figure 7: Sugar Beet Plant

5.2 Economic Assessments

Value of the by-products

The report conducted by Tyke Traicos suggested that sugar beet by-products could increase the value of sugar beet to CSR. The value of this by-product would be similar to feed grains. There is also a large feedlot in Tasmania, which not only could take all by-product produced, but could store on site in bunkers. If the feedlot was unable to take the feed for whatever reason, the many dairy farmers around the state would be another willing buyer.

Gross Margins

Advances in chemicals and varieties over th last twenty years have made sugar beet a more attractive proposition to Tasmanian growers. In a good season, returns could be around $5000/ha, while in what would be considered a very bad season (and also very unlikely if good management is used) then returns may be around $2000/ha down to a dismal $500/ha. This is still very attractive to many growers, despite not quite being at the level of potato prices or a good poppy crop.

Figure 8: Healthy plants at the Waterhouse site

6. Recommendations

The results from the Scottsdale trial show the sugar beet can be easily grown in this region.

Despite the good results, there is plenty of room for improvement.

There is still scope for improvement in root yields, therefore further agronomic trials at Scottsdale are warranted. These would include;

- A large scale variety trial (only three were tested in this trial, many more are available)
- Further herbicide evaluation
- Small scale sowing rate and sowing method trials.

With the setback in trial results from the Waterhouse region, it is imperative that another trial be conducted in the area to provide comparative data to the Scottsdale trial results. The combination of initial observations and hand harvested yield results suggest that Waterhouse will be able to provide similar yields. Trials to be conducted at Waterhouse would include;

- Sowing time trial (1 variety only)
- A large scale variety trial which would also implement various disease control measures (e.g. raised beds and resistant cultivars)

If further trials were to be undertaken, then a number of resources are required.
These include;

- A professional harvesting team for small plot work (Available from two local companies)
- Additional technical assistance
- The use of a commercial size harvester for bulk harvesting

Figure 9: A gigantic sugar beet has the final word

7. References

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8. Appendices

8.1 Literature Review - The effect of Sugar Beet and Fodder Beet on animal production - Implications for Tasmania

Introduction

Fodder beet, mangolds and sugar beet are all members of the species *Beta vulgaris*. For this report however, we will only be discussing the feed attributes of fodder beet and sugar beet. Sugar beet is mainly used for commercial sugar production, but can be fed to stock. Fodder beet has been widely used for stock feed in the Europe and the U.K, particularly in the Netherlands and Denmark. In addition to beef and cattle, sugar beet can be fed to swine, horses, poultry, as well as for stock feed. Fodder beet can also be fed to swine and goats.

The three kinds of beet differ in dry matter content, crude protein and sugar content;

Mangolds	-	Low in dry matter and sugar content and high in crude protein
Fodder Beet	-	Intermediate levels of dry matter and sugar content between Mangolds and Sugar Beet
Sugar Beet	-	High in dry matter and sugar content and low in crude protein

Uses

Sugar beet is mainly grown for sugar production, but can be used as animal feed. All the components of the sugar beet can be used for feed; crown, tops and roots. It can be prepared in a variety of ways; chopped, dried, dehydrated, as silage, chopped or feed whole. After the sugar extraction process, the by-products of beet pulp and beet molasses are formed and which can be processed into pellets or used in silage.

Sugar beet contains about 16 to 18% sucrose (Fillipic, 2001) and approximately 23 % dry matter (Woodman, 1957).

When sugar beet is harvested the crowns are cut off, as these contain salts which affect the recovery of sugar from the juice (Morrison, 1950). The tops consist of the crown and leaves and generally have a lower dry matter than the roots. For a crop with a root yield of 50 tonnes per hectare, about 35 to 40 tonnes per hectare of tops (Frappell, 1980). The tops can be strip grazed in the field by cattle and sheep, windrowed and grazed, transported to a feeding yard or ensiled. Unfortunately grazing the tops can led to a reduction in the sugar yield (Frappell, 1980).

Jaggard (1989) explains the two methods of windrowing and direct loading used by U.K growers. There are two ways to windrow; putting three to six rows into one with a multi-row harvester or, using a dump box on a single row harvester, leaving large windrows at right angles to beet rows. Tops in windrows can be picked up by a front end loader, a top elevator, or a self-pick-up trailer; in all cases a shallow layer of tops should be left on the ground to reduce soil contamination. Loading the tops direct into trailers decreases soil contamination but causes an increase in the amount of effluent if they are used to make silage. Flail-type toppers can be used, but the crown and some stalk will be left behind. Independent toper harvesters are ideal and can chop up the tops if required. Chopped tops are easier to transport and convert to silage, while unchopped tops are better for feeding fresh. A forage harvester can be used if flail speed is reduced to 800 - 1000 rpm.

The cut tops need to be left in the paddock for two to three days to cure as it contains some potentially toxic compounds (Jaggard, 1989). However the report by Frappell (1980) it is recommended that the wilted tops should be left 6 to 7 days. Oxalates are present in the leaves of sugar beet as oxalic acid and can cause poisoning in cattle and sheep (Morrison, 1950). The beet tops are also quite laxative and can cause scouring, so they must be fed in small amounts. Feeding a high calcium mineral can reduce scouring (Lardy and Anderson, 1999). Also the smaller beets left behind after harvesting can cause choking in some stock. Nitrates are also present in the tops of sugar beet tops and can also cause poisoning in stock. Nitrates are converted to nitrites in the rumen by microbes. However when the nitrite level in the rumen exceeds the microbes capacity to convert it to ammonia, excess nitrite will be absorbed into the bloodstream and combine with haemoglobin (Agrifacts, 1991). The methoglobin formed is unable to carry oxygen and the animal will begin to suffer from oxygen starvation. Oestrogen levels can also increase in sugar beet leaves, especially in the autumn (Massey University). Soil contamination is also a problem and will affect the proper utilisation of the feed by the stock. There has also been reports of the betaine in the leaves causing a fishy flavour in milk (Frappell, 1980). The tops are quite low in nutrients. Beet tops should only be used as an extender of another forage source, not as the principal forage crop (Lardy and Anderson, 1999). However with proper feeding management, the adverse effects of the tops can be avoided.

Beet tops can be made into silage, effectively reducing the nitrate levels. Six tonnes of silage can be produced (using a 17.5% dry matter variety) per 10 tonnes of tops (Jaggard, 1989). Tops must also be finely chopped to allow for tight packaging to stimulate proper anaerobic conditions needed for fermentation (Frappell, 2980). From the Frappell's report (1980), it was suggested that from 225 000 tonnes fresh weight or 36 000 tonnes dry weight of sugar beet tops that 125 000 tonnes of silage could be produced. It is not as laxative as the fresh beet tops, but again must be fed in small amounts. It also benefits from the addition of limestone. As the silage can also taint the milk of dairy cows, it should be feed after milking and with a high phosphorus mineral supplement (Jaggard, 1989).

Beet pulp is the fibrous residue that is left after the sugar has been extracted from the sugar beet. It is highly palatable due to the processing rupturing the plant cells (Schroeder, 1999). Up to 3 kg/cow/day can be fed (Gurung, 2002). Pulp can be processed into three basic products; dried molassed beet pulp, molassed pressed pulp and pressed pulp

The moist pulp, which has a dry matter content of approximately 10%, has a high water content, thus making it expensive and difficult to transport long distances (Visser and Hindle, 1990). By pressing or drying the pulp, transport costs can be reduced, ensiling characteristics are improved and the dry matter increases to between 18 and 25% (Visser and Hindle, 1990).

Dried pulp is high in fibre, but deficient in fat, phosphorus, carotene and certain B vitamins (Morrison, 1950). High fibre feeds are quite beneficial for the rumen as it can provide certain physical and chemical characteristics to the rumen, that in turn will avoid digestive problems such as acidosis and depressed appetite (Bhattacharya and Sleiman, 1970). The bulkiness of this feed could also prevent low milk fat syndrome when used with high concentrate rations by controlling the proportion of volatile fatty acids in order for proper milk fat synthesis (Bhattacharya and Lubbadah, 1970).

Beet pulp is also low in protein, so a source of protein such a barley or corn should be added to the ration. Shreds can be produced from the dried pulp and has the benefit of being quite light. Shreds also can be easily mixed into a ration. It contains 90 to 92% dry matter (Hollysugar, 2000). From the shredded beet pulp, pellets can also be made. This allows for ease of transport from the factory. Pellets have a similar dry matter content to the shreds. About 1 tonne of sugar beet can produce up to 110 pounds (or 50 kg) of pulp pellets (New Mexico State University, Website)

In the U.K, only those farmers that are close to the factory, will be able use pressed pulp. According to Hollysugar (2000), the pressed pulp can be either "top dressed" on to corn ensilage or fed directly to production animals and contains a dry matter content of 22 to 28%.

Beet pulp has a crude fibre content of 18%, but low crude protein and phosphorus levels (McDonald et al 1971). Due to the low crude protein, it needs to be supplemented with a protein source, especially if being used to replace grass silage. It is particularly useful in silage due to its absorbancy. Beet pulp can absorb up to 4 times it's weight in water.

According to Lardy and Anderson (1999), beet pulp can be used as an energy supplement for gestating or lactating cows, as an ingredient in background diets, or as a roughage source in finishing diets. It can make up to 50% of a dairy concentrate or replace 15 to 25% of the forage dry matter in the diet (Schroeder, 1999).

Beet molasses is produced from the extracted pulp and has a dry matter content of 70 - 75 % (McDonald et al, 1971). Of this 70 to 75%, 50% is sugars (Dwyer, 2001). It also contains about 2- 4 % of betaine, a useful amine for humans and animals. However molassed sugar beet feed is not recommended for feeding to simple stomached animals such as sheep, pigs or horses (Hollysugar, 2000).
Molasses can also be added to the shredded pulp before drying to produce a carbohydrate rich feed - dried molassed beet pulp. Similar to the beet tops, beet molasses are very laxative. Molasses can be used in the manufacture of pellets as it improves palatability and helps to bind the ingredients. It is rich in soluble sugar and is often used as an additive in silage making. (McDonald et al, 1971). It is also used for the production of citric acid, vinegar, yeast, antibiotics, cattle feed sweetner chemicals and pharmacuticals (AgMRC, 2003). Unlike sugar cane, sugar beet molasses are net eaten by humans, simply due to its bad taste (Filipic, 2001).

Fodder beet has been bred with the specific purpose of animal consumption. The main difference between sugar beet and fodder beet is a reduction in sugar content and increase in dry matter. However up to 70% of the dry matter in fodder beet is sugar, which could potentially produce ethanol as well (Roberts and Martindale, 1988).

Fodder beet is extensively used in the Northern Hemisphere and is considered to;

- have the highest yield potential
- be a reliable performer year after year
- produce high quality feed year after year

and can save up to 2 kg of concentrates per day through supplementation (Roberts & Martindale, 1988).

Fodder beet has a dry matter content between 160 and 220g/kg depending on variety and stage of growth at harvesting, a high metabolizable energy content between 11.6 and 13.1 MJ/kg DM and a crude protein content of between 60 and 75 g/kg DM(Roberts and Martindale, 1990). Fodder beet can have medium to high dry matter varieties. McDonald et al (1971) reports that the medium dry matter varieties can contain from 14 to 18 per cent, while the high dry matter varieties can contain up to 22 percent. Generally the fodder beet varieties currently available have dry matters between 12 and 22%. Up to 12 tonnes of dry matter per hectare can be produced from the roots and 2 – 5 tonnes DM per hectare from the tops (Fisher et al, 1994).

Fodder beet roots and tops can be eaten in a similar manner to sugar beet. The tops can be grazed directly or ensiled, similar to sugar beet. Ensiling can be difficult due to the low dry matter content of the tops (110 g/kg) (Roberts and Martindale, 1988). The sugar content of ensiled fodder beet tops is considerably lower than fodder beet roots, but on the other hand contain three times as much protein than the roots and are often fed in combination (Roberts and Martindale, 1988). Ensiled chopped beet has been found to be a safer option, due to the effluent being released gradually and for a prolonged period of time, compared with the tops (Roberts and Martindale, 1988).

As for sugar beet tops, it is recommended that the tops are allowed to wilt for 2 to 3 days, before extensive grazing by sheep or cattle. Animals should also have access to grass or another forage source. McDonald et al (1971) explains that care is required when feeding high dry matter fodder beet to cattle, as excessive intakes can cause digestive upsets, hypocalcaemia and even death. It is thought that the oxalic acid present in the leaf is the culprit.

Fodder beet can be fed as either a concentrate or a forage replacer. It involves more labour than other conventional feeds, as it needs to be stored, cleaned and sometimes chopped up. It has the benefit of increasing the level of total dry matter intake when included in the ration (Roberts and Martindale, 1990). As crude protein is low, it needs to be supplemented with a rumen undegradable protein like barley or soyabean meal (Roberts and Bax (1988). It can also be feed as a supplement to grass and maize silage, with the addition of a protein supplement (Roberts and Martindale, 1988). It can be fed with or without concentrates, but the addition of concentrates will increase milk yield (Dwyer, 2001).

There are different varieties of fodder beet available, which contain a range of dry matters from low, medium to high. High dry matter varieties are generally not nutritionally better, however the high dry matter content does reduce the overall bulk of roots required for a given yield of dry matter (Roberts & Martindale, 1988). With 70% of the dry matter as sugar, it is assumed that a high dry matter variety would have a higher sugar level that a low dry matter variety. That has been suggested by Clark et al (1987) who reported that the water soluble carbohydrates (i.e. sugar) content was significantly higher in the high dry matter varieties than in the low dry matter varieties.

Composition and Nutritive Value of Sugar Beet and Fodder Beet

The main advantage of sugar and fodder beet is their yield potential. Up to 113 000 MJ NEL per hectare can be produced, compared with only 56 000 MJ NEL per hectare for cereals (Deininger et al, 1996). NEL is net energy lactation, the amount of energy contained in the food that can be used for milk synthesis. Sugar and fodder beet are highly digestible, with an energy content equal to that of concentrates (approximately 7.5 MJ NEL per kg dry matter of energy) (Deininger et al, 1996).

A study conducted by DPIWE in 1978 indicated that the feed value of sugar beet tops was similar to late spring pasture growth (Frappell, 1980). The nutritive values are shown below;

Dry Matter Content (%)	17.8
Protein Content (%) DM	12.3
Organic Matter Digestibility (%)	83
Ash Content (%) DM	15.4

Tables 1 and 2 contain values on the composition and nutrients available in various forms of sugar beet and fodder beet feeds.

Effect on Animal Performance

Sugar Beet

Depending on the form of sugar beet fed to animal (e.g. molassed, chopped), it can have a variety of effects on the rumen metabolism. Sugar beet is generally high in fibre and low in starch. Barley on the other hand is high in starch and low in fibre. The one disadvantage of a high starch cereal, such as barley is that it can lower the ruminal pH which can cause reduction of the digestion of cellulose-based dietary components and the production of soft fat (Mandebvu, 1999). Replacing the high starch cereal with a high energy feed such as molassed sugar beet pulp can reduce this effect. There has also been indications that sugar beet pulp can increase the efficiency of microbial N synthesis (O'Mara et al., 1996).

Dairy Cattle

There has been a considerable amount of experimental data on the use of sugar beet and fodder beet in dairy cattle rations. Due to the high value of milk production, farmers are prepared to spend more on feed and concentrates than the conventional sheep and beef farmer. Silage and concentrates are regularly fed and rations are carefully calculated. With lactation being important to the overall milk production, energy requirements need to be met for optimum performance. Compound feeds are fed as supplements to roughage-based diets to meet the energy requirements of early lactation (Visser et al, 1991). Moist ensiled products such as ensiled pressed pulp or brewer’s grains can partially replace concentrates. However this can have a negative effect on rumen fermentation, as the ensiling process uses some of the feeds energy to produce volatile fatty acids and lactic acid, which then can not be used by the rumen micro-organisms.

The effect of dried sugar beet pulp on the intake and production of dairy cows, was examined by Castle et al (1966). In combination with silage and concentrates, different levels of sugar beet pulp were fed (6 and 12 lb of pulp*). Dry matter weight consumed each day increased with increasing amounts of pulp. The dry weight of other feeds consumed also declined with the increase in pulp, with silage the most effected. Daily milk yields increased by 0.55 lb milk/lb extra S.E. (Starch Equivalents) between no pulp and 12 lb of pulp. Fat percentages did not differ, but solids not fat percentage increased significantly between no pulp and 12 lbs. The average liveweights were significantly higher with the addition of pulp. Lactose percentage did not differ between the treatments. Most importantly there was no adverse effect on milk taste.

Bhattacharya and Sleiman (1971) examined the feeding value of dried beet pulp for milk production. A ration contained 55% beet pulp was compared with a standard mix of 57% barley for the effect on milk yield, fat content and body weight change. There was no significant difference in change of body weight, milk yield and fat content between the two treatments. Therefore, the dried beet pulp at 55% was just as effective for production in dairy cows as the barley ration. When 4% fat was added to the fat deficient ration, which consisted of 50% beet pulp, milk yield was increased by 7.5%. Bhattacharya and Sleiman (1971) suggest that this beneficial effect of fat addition is due to an efficient energy utilisation of the ration.

Corn is another form of feed commonly used in dairy rations. Bhattacharya and Lubbadah (1970) examined the effect of replacing corn in a high concentrate dairy ration with dried beet pulp on milk yield and composition and body weight gain. Similar to the previous experiment, there was no significant difference in body weight gain, milk yield and composition.

Castle (1972) did a similar experiment of replacing barley with dried molassed sugar beet pulp on an equal dry matter basis. The amount of barley and sugar beet pulp in the ration varied from 0 to 80%. The total daily dry matter intake, mean milk yield, solids-not-fat content, volatile fatty acid proportion and crude protein were not significantly different from each other. However water intake was significantly increased as the proportion of dried pulp replacing the barley increased. This result suggested that dried molassed sugar beet has a similar feeding value to barley on a dry matter basis.

When fed as a supplement to grass silage, Castle et al (1981) again found that beet pulp and barley had a similar feeding value. In this experiment, the perennial ryegrass silage was supplemented with soyabean meal as a control treatment and in conjuction with the barley and sugar beet pulp. Dry intake of the silage was not significantly different between treatments. In addition, fat, solids-not-fat, crude protein and lactose concentration in the milk, as well as liveweights were not significantly different. Again the water intake was significantly higher on the beet pulp treatments, but not as high as Castle’s (1977) previous experiment where hay was the primary source of fed. Obviously from these two experiments, it can be seen that access to drinking water is essential when feeding beet pulp.

When compared with maize as a fed, significant differences have been seen. Visser and Hindle (1990) undertook a series of experiments which evaluated dried beet pulp, ensiled pressed beet pulp and maize silage as substitutes for concentrates in dairy cow rations. The factors examined included; feeding value, feed intake, milk production, milk composition, fermentation patterns and ruminal degredation. The dried beet pulp had a total dry matter intake was significantly different to the other treatments, with intake higher than the other treatments for the majority of the experiment (Figure). The ensiled pressed pulp has a low dry matter content, so lactating cows would have had trouble consuming the feed. Net energy intake for the dried beet pulp was significantly higher than the pressed pulp, with both pulp diets significantly higher than the maize diet. Milk yield remained constant between the groups. Although there was no significant differences in milk fat yield and percentage, the maize ration did have a slightly higher fat percentage. For milk protein yield and percentage, there were no significant differences, but the maize silage had the lowest protein yield and percentage. The pH and concentration of volatile fatty acids were not significantly different between treatments, but the branched chain fatty acids and ammonia concentrations were higher for the maize silage diet. Osmolality, lactic acid and the nonglucogenic glucogenic ratio (NGR) also did not differ significantly between the treatments. Overall the differences in rumen fermentation were small between the three diets.

A similar experiment was conducted by Phipps et al (2003) examined the incremental replacement of cereal grain with sugar beet feed in a maize-based on dry matter intake, milk yield, milk composition and milk constituents of lactating cows. The sugar beet feed was a commercially available product by Trident Feeds. Cracked wheat and sugar beet feed were fed at ratios of 240:0, 180:60, 120:120 and 60:180 g/kg of dry matter. There was a significant positive linear effect in dry matter intake, with the increase in sugar beet ratio in the ration. At 120 and 180g/kg of DM, the dry matter intake was 1-2 kg lower than the lower levels of sugar bet feed. Therefore wheat could be supplemented up to the 120 g/kg of DM of the sugar beet feed without compromising overall milk production and yield. Mean milk yield, milk composition and yield of milk constituents did not significantly differ between treatments.

Another product from Trident Feeds, is Grainbeet, a mixture of 1 part Molassed Sugar Beet Feed and 5 parts brewers grains, on a fresh weight basis (Trident Feeds, 2003). It has been reported that it can replace concentrates with no effect on production and at a lower cost (Perrott, 1993). Perrott (1993) reports that when it replaced half the forage (grass silage or straw) that the Grainbeet increased milk production. Bulls on Grainbeet reached their target weight 6 weeks earlier than bulls on a silage/concentrate ration, with an average liveweight gain of 1.6 kg/day.

Concentrator seperator dried beet pulp (or concentrated steffen filtrate) is a another form of beet pulp, which contains more crude protein and ash, but less sugar (Weidmeir et al, 1993). With new technology, more sugar can be extracted from beet molasses, leading to this new product. Weidmeir et al (1993) analysed the effect of this form of dried beet pulp on nutrient digestibility, milk production and preference in dairy cattle. A ration containing 20% CSB pulp was compared to a control ration of 20% molassed dried beet pulp. Cows fed the CSB produced significantly less milk daily and 3.5% more fat corrected milk than the control. This was due to the CSB having a lower total digestible nutrients and dry matter intake. This was expected as the diets were not isocaloric (similar energy content). Feed efficiency was also lower for the CSB ration. Milk fat, protein, lactose and solid-not-fat percentages were not significantly different between treatments. Cattle showed no preference between the 20% dried beet pulp ration or the CSB ration at 10 or 15%. However, when CSB was fed at 30%, the cattle preferred the 20% dried beet pulp. Overall, the CSB contained less energy and was unpalatable at high concentrations in the ration than the standard dried beet pulp.

A previous study by Ronning and Bath (1962) which compared the CSB, dried beet pulp and molassed dried beet pulp on milk production. A basal diet was fed at a restricted and full ration with or without the three forms of beet pulp. Milk production was not significantly different among the full rations, but was reduced by 5 lb (or 1.85 kg) when restricted. While milk fat percentage was not affected, the solids-not-fat percentage decreased significantly in the restricted basal ration. Liveweight and butterfat did not show any significant differences. Compared with the experiment by Weidmeir et al (1993), there was no problem with palatability of the CSB.

It is recommended that when beet pulp is ensiled that it is used as a secondary forage source. In an experiment by Ferris and Mayne (1994), beet was included with grass silage either as part of the ration at 20, 35 and 45 % or ensiled with the grass at 40, 80 and 120 kg of pulp. For both forms of beet pulp in the diet, dry matter intake, milk fat and protein increased as the level of pulp increased. Milk fat and protein yields were higher when the pulp was supplemented in the diet rather than ensiled. This is due to the loss of metabolisable energy and nutrients during the ensiling process. If the nutrient loss can be minimised, then overall feed efficiency will improve. The results of this experiment suggest that the supplementation of beet pulp with the silage would not only be a simpler option, but have a better feed efficiency than an ensiled beet pulp / grass blend. The main benefit from ensiling beet pulp is that it eliminates storage, cleaning and feeding problems, such as putrefaction whilst being stored in clamps.

When sugar beet is ensiled with maize, the results are more encouraging. 'Pulp'n'Maize' is another product of Trident Feeds, made by ensiling molassed sugar beet pulp with maize at 10% fresh weight (Bell et al, 2000). Bell et al (2000) evaluated 'Pulp'n'Maize' for its effect on milk production. The four treatments were grass silage, grass silage/'Pulp'n'Maize', grass silage/maize silage/molassed sugar beet pulp and grass silage/maize silage. Milk yield and lactose was significantly higher for the 'Pulp'n'Maize' treatment compared to the two silage treatments (without any form of pulp added). Milk fat and protein was significantly higher for the treatments containing pulp. Forage dry matter intake was also significantly higher for the treatments containing pulp. From these results, the ensiled beet pulp and maize provided a production benefit over grass silage and the grass/maize silage mix.

When grass silage is fed, there can be problems with digestion of the feed is of marginal quality. Silage can cause a solid mass of digesta in the rumen that can cause a reduction digestion and therefore a reduction in intake. Pressed pulp is another source of fibrous stock feed. Humpheries et al (2003) examined pressed pulp as an alternative fibre source for lactating dairy cows. When grass silage was replaced with pressed pulp at 30 %, total dry matter intake was improved up to 41 %. The pressed pulp also increased the bolus chewing time and chews per bolus significantly. The rumen mat density was also reduced at 30 % pressed pulp, but not significantly. However, the pressed pulp provided an improved rumen environment for fibre utilisation. For marginal quality grass silage, pressed pulp could be used to improve overall digestibility.

A similar experiment conducted by Murphy (1986) compared ensiled pressed pulp fed with grass silage, as a substitute for barley in the concentrate or as additional energy. The treatments were barley and soyabean meal (B/S), soya bean meal and pulp (PP/S) or barley, soyabean meal and pulp (B/S + PP). For the B/S + PP treatment, milk yields, daily fat yield, protein yield, lactose and total intake were significantly higher than the other two treatments. Protein concentration was significantly higher for the B/S + PP treatment compared to the PP/S treatment. Overall, the ensiled pressed pulp dry matter was found to have a similar feeding value to barley dry matter and proved a good response when added as an additional energy source. .

Deininger et al (1996) examined the effect of beet mash silage on milk production. Beet mash allows for easier handling and increased efficiency of silage production. Cows were fed roughage with either a standard concentrate or a sugar beet mash silage (20.4 % dry matter) of equal energy content. Daily milk yield was significantly lower in the group fed the beet mash silage. Milk composition and fat did not differ significantly between the treatments. The benefit of the beet mash to farmers would be the ability to produce on farm (providing they have the equipment) reducing the need for a commercial concentrate.

Beef Cattle

Sugar beet is not as widely used as a feed for beef cattle as it has been for dairy cattle. In beef production the main emphasis is on weight gain.

Sugar beet tops can be grazed by cattle. Selman (1984-86) reports liveweight gains per head of between 0.27 and 1.29 kg over a period of 11 years. Park et al (2000) examined the use of sugar beet pulp on yearling steers in comparison with corn silage. When beet pulp replaced part of the corn silage, their average daily gain was higher, but not significant. This was mainly due to the higher energy content of the beet pulp. Dry matter intake was considerably lower for the beet pulp treatment, possibly due to the lower dry matter content of the pulp compared to the corn silage. Although there was a reduction in dry matter intake, overall feed conversion was improved with the inclusion of beet pulp in the ration.

A similar experiment conducted by Rush (2000) evaluated the effect of three levels of beet pulp (15, 35 or 50% of the ration) replacing corn silage on growing calves. Calves fed the beet pulp gained weight faster on the same amount of feed. The beet pulp provided better feed utilization, possibly due to a higher level of energy than corn. The best feed efficiency was at 35 % of the ration, with intake and gain negatively affected at 50 %.

As with sheep and dairy cow rations, pressed pulp will replace a barley/soya bean meal based ration. Marsh et al (2001) examined the value of feeding pressed sugar beet pulp ensiled with dried maize distillers grains on the performance of fast finishing suckled bulls. This sugar beet mix is another product from Trident Feeds, commercially known as Praize. There were no differences between the treatments, which shows that the Praize feed can replace the standard barley/soya bean ration with no affect on performance.

Cordiez et al (2003) looked at various farm produced and commercial feeds as part of the diet of young bulls. Dried beet pulp was the main ingredient in all of the treatments, with supplementary compound feed added at three levels (0.65, 0.75 and 1%). Daily gains were fairly constant for the three treatments. When there was a decrease compound feed percentage then intake of beet pulp would increase. However total consumption of dry feed per liveweight gain was constant, therefore the energy value of the three treatments were similar.

Sheep

Crawshaw (1990) tested the digestability of a commercial dried molassed sugar beet feed from Trident Feeds in the UK on adapted sheep and in the laboratory. Molassed sugar beet is a mixture of beet pulp and beet molasses. The product was found to have a high nutritive value. Metabolisable energy was 12.5 MJ/kg, and digestible crude protein was 86 g/kg. Barley has a digestible crude protein content of 99g/kg and is digested more quickly. This suggest barley may be utilise less efficiently than the molassed sugar beet feed, particularly in diets based on silage.

Crawshaw (1992) went on to test the effect of feeding molassed sugarbeet feed (MSBF) to ewes fed on silage diets, early weaned lambs, silage fed lambs and lambs finished at grass. By including MSBF in the diets of ewes and lambs, there were economic and nutritional benefits and was found to be safer and more effective than rolled barley.

Through good nutrition, growers can maximise the number of lambs produced per ewe. Perrott (1994) examined the effect of substituting barley or a compound feed with the molassed sugar beet feed (MSBF) again supplied by Trident Feeds in the UK. This was fed together with grass silage, barley straw or fishmeal. Silage intake was 6% higher in ewes fed MSBF instead of barley. In the last week of pregnancy, this increased to 9% giving an extra metabolisable energy intake of 1MJ/day. Birthweights and growth rates were similar, with the MSBF group in better condition. MSBF costs were lower than other feeds by 8%.

Chapple et al (2000) examined the effect on ewe and lamb performance of feeding sugar beet feeds with distillers grains (explain) to March-lambing ewes rearing twin lambs at pasture. The supplements were 80:20 rolled barley/soya bean meal, 50:50 maize distillers/molassed sugar beet feed or 50:50 barley distillers/molassed sugar beet feed. Although initial liveweights on the maize distillers / sugar beet mix was lower than those on the barley distillers / sugar beet mix, ewe liveweights were all similar at the end of the experiment. Therefore a ration of 50:50 maize distillers and sugar beet mix or a 50:50 barley distillers and sugar beet mix will replace a rolled barley / soya bean ration when fed to lactating ewes suckling twin lambs without affecting the ewe or lambs performance.

Field beans were then evaluated by Chapple et al (2001) as a source of protein instead of soya bean meal. Soya bean meal is imported into the U.K. and can not be traced back. Twin bearing ewes were fed barley straw ad libitum with four supplements; 80:20 whole barley/soya bean meal, 70:30 barley distillers/molassed sugar beet feed, 50:30:20 barley distillers/molassed sugar beet feed and beans or a 50:30:20 maize distillersmolassed sugar beet feed and beans. Similar to the previous experiment, ewes fed maize distillers/sugar beet feed and beans had significantly lighter liveweights than the barley distillers/molassed sugar beet feed. However at the end of the experiment, all the ewes were of similar liveweights. The 70:30 barley distillers/molassed sugar beet mix could then replace the whole barley/soya bean mix without affecting the performance of the ewes and lambs. However the substitution of beans to replace the distillers grains, led to ewe weight loss during pregnancy and smaller lambs at birth. However the weight loss was seen with the other treatments and at the end of the experiment there were no long-term detrimental effects.

From these experiments, distillers grains/sugar beet feeds have been found to be an acceptable replacement for the standard whole barley/soya bean feed commonly used in the U.K.

Chapple et al (1998) evaluated the effects on ewe and lamb performance of feeding sugar beet feeds with higher levels of distillers grains to January-lambing ewes on straw based and big-bale silage systems during pregnancy and early lactation.

In this experiment the straw was supplemented with a mix of sugar beet pulp and maize distillers grain and compared with a compound feed containing 20% crude protein. The silage was supplemented with a barley distillers / sugar beet pulp mix and compared with a compound feed containing 18% crude protein. For the twin bearing ewes fed baled grass silage, the 60:40 barley distillers / sugar beet mix could adequaetly replace the 18% crude protein compound feed with no effect on ewe and lamb performance. However the 70:30 maize distillers / sugar beet mix fed to the ewes on the straw diet resulted in lower birth rates and reduced growth rates in lambs when compared with the 20% crude protein compound feed. (TABLES??)

Experiments by Chapple et al (1998, 1999, 2000, 2001, 2003?) had examined the effect molassed sugar beet feeds has on ewe and lamb performance. However the beet pulp can also be pressed and ensiled. Trident feeds is a U.K producer of animal feeds and has a number of products based on sugar beet by-products. Praize is an ensiled mix of pressed sugar beet pulp and dried maize distillers grains (Trident Feeds?). Chapple et al (2003) compared ewe and lamb performance when March-lambing ewes were fed on a straw based system and supplemented with a standard cereal/protein mix, 2 dried sugar beet pulp/protein mixes and Praize. The supplements were; a 70:30 rolled wheat/rapeseed meal, 60:40 maize distillers/molassed sugar beet feed, 78:22 molassed sugar beet feed/soya bean meal or a 80:20 ensiled sugar beet pulp/dried maize distillers feed. Similar to the previous experiments, ewes lost weight during pregnancy, but gained it again at the end of pregnancy. The ensiled mix was found to be an adequate replacement for the other three supplements without affecting ewe or lamb performance.

Dried beet pulp can be fed as a sole source of energy in the ration or supplemented with grain due to its high energy. Dried beet pulp can be pelleted making it not only more affordable, but also increases the intake by stock. Bhattacharya et al (1971, 1975) undertook a number of studies looking at the dried beet pulp in rations for dairy, beef and sheep. Bhattacharya et al (1975) examined the effects of feeding dried beet pulp as a sole source of energy replacing a grain or a grain residue in a high concentrate ration on feed intake, energy utilization, growth performance, carcass quality and rumen fermentation in growing and fattening wether lambs. The rations consisted of either; 90% corn grain, 90% dried beet pulp, 45% corn and 45% beet pulp or 45% wheat bran and 45% beet pulp. The lambs fed beet pulp gained more weight and required less feed per unit of gain than those on the corn grain ration. When urea was added and the beet pulp was pelleted, the weight gain and feed efficiency was increased compared to the other rations. Lambs finished on beet pulp alone were 7 kg heavier than those on the corn ration. Beet pulp also ha the highest carcass quality, dressing percentage, rear leg weight, *longissimus* muscle area and fat thickness when compared to the other rations. In addition intake of the beet pulp pellets was the highest compared to the other rations. Therefore, the benefits of pelleting beet pulp does not only include ease of transport, but better feed intake. In taste tests of the meat quality beet pulp and the corn and beet pulp ration outperformed the other rations. It is also recommended to supplement the beet pulp with phosphorus (Jordan, 1990).

Evaluation of sugar beet feed mixes as a fed for finishing lambs. Minter et al (1999) investigated the effects of various types of feeds, including Grainbeet, another product from Trident Feeds containing sugar beet by-products. The feed mixes were; Molassed sugar beet feed and distillers barley dark grains, whole barley and distillers barley dark grain, a commercial concentrate and Grainbeet. Grain beet consists of 200 g/kg molassed sugar beet feed and 600g/kg brewers grain). The lambs on the concentrate diet achieved a significantly higher final liveweight, daily liveweight gain and carcass weight than the other treatments and were also on trial for a shorter period of time. However the feed cost/lamb were reduced for the Grainbeet diet when compared with the commercial concentrate. The main implication for growers is that, although the Grainbeet could replace the concentrate, it may take up to 10 - 20 days longer to reach the optimum weight. Therefore growers would have to modify their management in order for the lambs to be ready for a target sale date.

Ensiled pressed sugar beet pulp was also evaluated as a feed for finishing lambs. Pattinson et al (2001) evaluated the Praize feed from Trident Feeds. Liveweights were similar at the start of the trial and at slaughter for both treatments. The control group which was fed a barley/soya ration took less time to reach the slaughter date and had a higher daily liveweight gain when compared to the Praize diet. Again Praize was found to be a cheaper alternative to the conventional feed. Similar to the previous experiment, the pros and cons of each feed must be considered in the management system.

Fodder Beet

Fodder beet can contain up to 13 t DM per ha (Fitzgerald, 1983) and has been found to have replacement value relative to concentrates of 81% to 91% in sheep trials (Fitzgerald, 1979).

A good crop of fodder beet can produce the same amount of energy as a 5 t/ha barley crop (at 850 g/kg DM) at a lower cost. The following table also includes contractor costs for sowing and harvesting into the growing costs

Table 3: A comparison of the energy costs of fodder beet and spring barley

	Fodder Beet	*Spring Barley*
Utilisable DM yield (t/ha)	12	4.25
Utilisable energy yield (GJ/ha)	142	55
Growing cost ($/ha)	1385.51	624.1
Energy cost ($/GJ)	9.74	11.23

Effect of fodder beet and its by-products on rumen metabolism

Sabri et al (1988) carried out two experiments with sheep to evaluate the effect fodder beet had on rumen function. In the first experiment, hay was supplemented with fodder beet, barley/maize or sugar beet shreds. The mean rumen pH for the fodder beet diet was 6.34 and intermediate between the barley/maize at 6.2 and the sugar beet shreds at 6.38. There was no significant difference in rumen concentration of total volatile fatty acids (VFA). However there were significant effects for the concentrations of acetate and propionic acid. In the second experiment, the rate of *in sacco* organic matter (OM) disappearance of the three supplements were compared in sheep given a high forage diet. There were highly significant differences in rates of OM disappearance for the supplements. The initial rate of fermentation of fodder beet was significantly greater than for the barley/maize diet, but caused less rumen disturbance. This is mainly due to the bulky fodder beet being eaten over a period of several hours while the barley/maize diet was eaten within 30 minutes.

Dairy Cattle

Similar to sugar beet, fodder beet can also be used to substitute barley and silage. Due to its wide use in Europe and the U.K, there have been a number of experiments evaluating its performance.

Straw/hay is a bulky fibrous feed and can cause a reduction in appetite and nutrient intake in cows (Castle et al, 1961). The physical form and low digestibility of straw/hay limit the appetite, therefore limiting the intake of nutrients and dry matter, affecting milk production (Roberts and Bax, 1988). Castle et al (1961) examined the addition of fodder beet with a basal diet of hay and grass silage. 30 and 60 lb (11.1 and 22.2 kg) of fodder beet were added to the grass and silage ration. For every 1 lb (0.37 kg) of additional fodder beet dry matter eaten, there was a decline in the intake of the basal ration of 0.45 lb. The silage also declined by 2.8 lb as the proportion of fodder beet increased. However the total dry matter intake was increased with the addition of fodder beet. Milk yields did increase by 0.9 lb of milk per 1 lb of extra S.E. given between the basal ration and 30 lb fodder beet ration. The fat percentage did not differ significantly but solids-not-fat percentage was significantly different for the 60 lb fodder beet ration. The percentage of liveweight gain was significantly increased by 0.6 % as the level of fodder beet in the ration increased.

In a similar experiment, Roberts and Bax (1988) evaluated the substitution of barley by fodder beet in a straw diet and the partial substitution of silage by fodder beet. Overall dry matter intake was similar, although straw intake was reduced in the fodder beet treatment. Liveweights showed no significant differences. Roberts and Bax (1988) suggested that if fodder beet is fed with straw, then additional protein would be required. As protein levels are adequate in silage based diets, then fodder beet could be used provided it was cost effective to do so. These two experiments suggest that fodder beet could be useful addition for Tasmanian dairy feed rations considering recent reductions in availability of these feeds.

As an addition to silage, fodder beet can increase intake and improve milk composition. Roberts (1987) examined the effect of feeding two levels of fodder beet (2 or 4 kg DM daily) with grass silage. Mean milk yield, liveweights and condition scores were not significantly different between treatments. Milk fat and protein were significantly increased as fodder beet levels increased. Similar to previous experiments (e.g., Castle et al., 1961, 1963) total dry matter increased with increasing fodder beet inclusion.

Fodder beet can also be fed with concentrates similar to sugar beet. In an experiment by Sabri and Roberts (1988), fodder beet was feed at three different dry matter levels (0,2 and 4 kg DM) with two levels of concentrate (4 and 8 kg DM). As seen with the straw/silage substitution experiments, silage dry matter intake was decreased, but total dry matter intake was increased with fodder beet. There was no significant effects on milk yield or milk composition with fodder beet addition. However milk protein was significantly increased with fodder beet addition. This would be due largely to the increase in total ME intake. The crude protein content of the diet was quite low and it was suggested that this may of prevented any differences in milk yield and composition.

To examine this effect, Fisher et al (1994) examined the effect of feeding fodder beet and concentrates with three different crude protein contents on early and late lactating dairy cows. For the early lactating cows, fodder beet increased milk yield, composition and constituent yield and significantly increased milk protein content. There was a decrease in silage dry matter intake seen with both early and lactating cows, but a corresponding increase in total dry matter intake with the addition of fodder beet. This agrees with the reports of Roberts (1987) and Sabri and Roberts (1988). When the crude protein content of the concentrates was increased, silage dry matter intake was increased (significantly with the late lactating cows). Total dry matter intakes also increased (significantly for early lactating cows). Although milk composition was not significantly changed in this experiment (except for milk protein in early lactating cows), the benefits of fodder beet fed with concentrates and the addition can be seen by the increase in dry matter intake. The crude protein contents used in this experiment, was between a range of 129 – 244 g/kg DM.

Fodder beet can be used to replace concentrates in the diet, particularly in Denmark where it has been reported to give up to 35 kg of milk per day (Roberts and Martindale, 1988). In an experiment by McIlmoyle et al (2000), fodder beet replaced concentrate in a grass silage. Dry matter digestibility and energy was significantly higher with inclusion of fodder beet. Milk yield was significantly higher, but overall milk energy was not influenced by fodder beet in the diet.

Whole chopped fodder beet can be ensiled quite effectively and due to its high energy can produce higher growth rates from smaller amounts of feed. When supplemented with barley for a protein source, liveweight gains of 1.12 and 1.4 kg/day have been reported (Roberts & Martindale, 1988).

Beef Cattle

Fodder beet has been found to be a suitable alternative to barley in feeding rations. MacDearmid and Kay (1977) compared diets of chopped fodder beet at differing organic matters with rolled barley as the balance with whole fodder beet. Steers of an initial liveweight of 150 to 250 kg were used. The value of fodder beet dry matter was found to be 87% of that of barley dry matter. There were no differences in killing-out percentage, carcass classification or subcutaneous fat colour between the different treatments. There were no significant differences in intake and gains from whole or chopped beet.

In a similar experiment by Selman (1983) evaluated chopped and whole fodder beet with or without barley on the performance of finishing cattle. The cattle on the whole fodder beet/barley diet finished 13 days earlier and had a higher killing-out percentage. Chopping the fodder beet and the addition of barley increased the daily gain. There has been conflicting evidence on whether fodder beet should be fed whole or chopped. It is recommended for younger cattle (below 250 kg liveweight) that the fodder beet should be chopped (Roberts & Martindale, 1988).

Anderson (1976) reported that carcase percentage of bone, fat and lean was unaffected in diets, when fodder beet was increased in the diet at the expense of barley. However the barley diet produced higher intra-muscular fat and greater tenderness than a fodder beet diet.

Fodder beet roots can also be used to supplement grass silage, providing additional protein is given. Drennan (1977) evaluated the use of fodder beet roots as a supplement to grass silage for fattening steers. Fodder beet roots were found to be quite comparable to rolled barley as a supplement for silage.

Sheep

Experimental data on sheep indicate that lambs and ewes can be fed with fodder beet (preferably chopped). However, there was very little information on its effect on rams, wethers or weaner lambs.

A study was carried out at Knockbeg Sheep Unit, Ireland by the Teagasc Research Centre on early lamb production systems. Fodder beet and sugar beet were evaluated as feeding options for early lambing flocks (Flanagan, 1999). The effect of chopped fodder beet on lactating ewes and subsequent lambing growth rates was examined (Flanagan, 1999). Due to a harsh winter climate and grass deficits, ewes and lambs are often housed indoors. The management system developed showed that ewes consume over 2 kg of root DM/head/day. This resulted in a predictable lamb growth rate of approximately 300 g/day from birth to 5 weeks.

Lamb performance was measured using a number of different feeding options. January lambing ewes were fed either an Italian ryegrass or forage rape from late January to March. The lambs were then finished on permanent pasture til April/May. Another group of ewes were housed 8 weeks after lambing and offered silage or fodder beet *ad libitum* supplemented with concentrates. Their lambs were early weaned and finished indoors on all-concentrates or on chopped fodder beet supplemented with concentrates (Flanagan, 1999). The lamb growth rate on the indoor diet of fodder beet and concentrates was lower than on grazed grass, but the difference was not significant (Flanagan, 1999). However the lambs on the fodder beet diet did produce heavier carcasses due to a longer feeding period.

An evaluation of fodder beet as the main diet for ewes post-lambing was undertaken for four years. Ewes were housed for 6 weeks post lambing and fed chopped fodder beet *ad libitum* (Flanagan, 1999). The performance of the early born lambs reared on housed ewes fed a fodder beet diet were evaluated, as well as the performance of the lambs finished on either a grazed pasture or early weaned on fodder beet and concentrates. The voluntary intake by ewes of chopped fodder beet increased rapidly to 2.17 kg DM/ewe/day at 2 weeks post-lambing and remained at this level (Flanagan, 1999). At a metabolisable energy value of 12.5 MJ/kg DM (Fitzgerald, 1983), the fodder beet had the potential to supply nearly all of the energy requirements of a 70 kg ewe in early lactation. This was also supported by the fact that ewe liveweight increased between mid pregnancy and 5 weeks post-lambing. Brown (1978 - 86) reported that whole and chopped fodder beet can supply between 50 and 60 % of ewe dry matter intake in the last seven weeks of pregnancy.

Protein supplementation was also lower than expected due to unexpected high intake of fodder beet. Increasing the protein supplement has been reported to increase lamb growth rates (Sheehan and Hanrahan, 1989). However increasing the protein level in this trial provided no effect on growth rates. Housing the flock for 5 to 6 weeks after lambing and by feeding a fodder beet diet and finishing on grazed pasture, lambs were finished for slaughter at a younger age. However a protein supplement should be supplied regardless. Clarke (2003) states that lactating ewes can eat up to 14 kg of fresh beet per day, but this must be supplemented with a protein like soya.

Options for Tasmania

Overall the results show why sugar beet and fodder beet has been extensively used in Europe and the U.K as a source of feed. If the nutrient deficiencies of both are corrected (i.e. low protein), they could provide a suitable alternative to many traditional feeds such as grain.

Feed cereals an important supplementary feed for a majority of Tasmanian producers, with nearly half of the total requirement imported from the mainland. In recent years when drought has hit the mainland, Tasmanian growers, particularly dairy producers have been hard hit by a dramatic increase in the price of grain locally. As stated in the nutrition section, sugar and fodder beet have a high yield potential in terms of energy available for lactation when compared to cereals. The other benefit seen from the data is the replacement of high starch cereals in the ration with sugar beet pulp. This would also reduce the demand for imported grain.

Sugar beet has an added benefit for growers with the usefulness of its by-products as a source of animal feed. With farmers continually looking for good sources of stock feed as well as providing income, this could help increase the attractiveness of this crop to new growers. As yet, the exact sugar content of current fodder beet varieties is not fully known. If this was found to contain a sugar level suitable for ethanol production, then fodder beet could be the viable alternative.

Although fodder beet has been tried by a few growers in the state, there remains an opportunity for dairy producers to incorporate the fodder beet as a feed crop. From previous studies conducted by the DPIWE it would not be economical for dairy growers in the rich kraznozems areas of the state to grow sugar beet (for ethanol and a feed crop) as the returns would not match those received through poppy and vegetable crops. However fodder beet could be an option for further study.

The oxalate levels were higher than in the U.K. Although varieties change over time, the varieties of today would have similar feed values and nutritive characteristics.

Human consumption is also an option, with the sugar beet plant quite similar to silver beet. The young tops and roots can be eaten, with the roots being somewhat an acquired taste. The roots can be used in coleslaw or baked (Frappell, 1980).

The curing of beet tops to reduce the level of nitrate and oxalic acid in leaves may prove to be difficult due to Tasmanian conditions. With the majority of harvesting carried out in the winter months, the tops may not be able to dry properly. Drying facilities like those seen in Europe are required (Frappell, 1980).

The use of tops and silage from sugar and fodder beet may be limited due to the amount of labour required and the level of knowledge required to utilise these feeds effectively. Good extension would have to be provided to encourage growers to take advantage of the by-products of the crop.

Some experiments explained in this review were for stock in production systems quite different to those seen in Australia. For instance, housing sheep during winter would mean that their requirements would be quite different to open grazing stock.

No data is available on the effect of sugar and fodder beet on wool production and with this one of the major industries in Tasmania, it is essential that at least preliminary investigations are undertaken.

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8.2. Animal Feed Pellet Study, Beet Fuel Ethanol

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Animal feed pellet plant study. Beet fuel ethanol

Preliminary Draft

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Contents

Summary and Conclusions

1.1 Introduction

The Tasmanian Government and CSR Distilleries is currently reviewing the feasibility of ethanol production from sugar beet in Tasmania. One key factor in the economic viability of the project is the value of the animal feed co-products. Following TD Chemical PTY LTD's (TD) contribution in 2001 to the project (Feasibility study – Reference 2), it has been requested by the Government Department of Primary Industries, Water and Environment (DPIWE) to compile this report covering the costs of animal feed pellet production.

1.2 Objectives

The study is designed to:

- Define the major equipment requirements, process description, capital, fixed and variable costs for the production of animal feed pellets, the co-product of a 40 ML per annum beet fuel ethanol distillery.

- Include available animal feed pellet product options, and the sensitivity of the plant viability to variations in throughput (a ready market for part of the unprocessed fresh by-products may be possible).

1.3 Principal Assumptions

- The expected beet pulp analysis will be similar to those in the European and American industries.

1.4 Conclusions and Recommendations

1.4.1 Beet pulp is generally distributed in the forms of Wet, Pressed, Dried and Molassed. Each has economic and logistical features which will determine the optimisation product distribution range. Its use in human foods is also possible. [Section 3].

1.4.2 A process design including flowsheet, mass balance and major equipment specification was prepared. [Section 4]

1.4.3 Capital costs were estimated from $3.7 milllion (pressed pulp) to $8.4 million (pressed, dried and pelletised pulp). Variable costs ranged from $0.11 to $17.56 per tonne pulp and fixed costs, $445 000 to $555 000 per annum. [Section 5]

1.4.4 It is recommended that these product options and costs be evaluated in cash flow analyses to determine the optimal product mix.

2. Comment

This study has identified opportunities for significant ethanol value addition through several beet pulp animal feed options. TD is able to assist with the next stage of this project.

3. Product Options

3.1 Literature search

A wide search was made of the options available for the manufacture of animal feed by-products of the sugar beet ethanol production process. The product range identified is drawn from works published by European, US and Australian authors. Technology found is as recent as 1998.

3.2 Introduction

The beet pulp remaining after the extraction of sugar has long been recognised as a valuable animal feed. Its key feature as a good source of highly digestible fibre and energy. Whilst it has always been a particularly valuable feed for ruminants, its use for non-ruminants, especially pigs, is rapidly developing. A new market for beet pulp is a fibrous ingredient for human consumption (section 3.4).

3.3 Animal feeds

Four feeds are most frequently produced:

Wet Pulp

Wet pulp is the exhausted beet cossettes, after sucrose extraction. Dry substance is low (6-12 per cent) and shelf life is short (50 per cent of its food value is lost in six month's storage).

Benefits are:

- It's content of sugar per unit dry substance is the highest of all forms of beet pulp
- It can be ensiled without additives
- It carries no processing cost, and can be transported directly from the extraction plant.
- It's nutrients provided are energy and fibre.

Disadvantages are:

- Short shelf life (high storage losses)
- High transport cost per tonne feed value
- Difficult to handle in conventional storage facilities
- Liquid run-off needs to be contained (high BOD_5)

Wet pulp is still extensively used in some countries, such as Denmark.

Pressed Pulp

Wet pulp is de-watered in heavy presses to Pressed Pulp, containing 18-30 per cent dry substance.

Benefits are:

- Reduced transport costs
- Higher density makes it more attractive as a (high performance) animal feed
- Can be fed fresh (5-7 day shelf life)
- High energy and low protein supplementary feed for ruminants. Excellent feed for horses
- Increasing usage in pig feeds (especially for sows). Pressed pulp promotes sow welfare and health.
- Environmentally beneficial for ruminant and pig feed, in that nitrogen and phosphorus excretions are reduced.
- Lower production costs than Dried Pulps (reduced energy usage)

Disadvantages are:

- Limited shelf life

Outlook:

In Europe, 50 per cent of the pressed pulp is used directly on the farm (either fresh or ensiled). In the UK, US, Japan and Germany, the majority of the pulp is dried to manufacture a range of products. Future pressed pulp production is expected to outstrip that of dried beet pulp as less manufacturing energy is used. Molasses pressed pulp (mixture, including minerals) is also promoted.

Dried Beet Pulp

Pressed pulp can be dried alone, or combined with molasses or stillage, and then dried. It resembles coarse tobacco, and is known as shredded or dried beet pulp. In most countries it is pelletised and conditioned with steam or water in pellets of diameter varying from 5-6 mm to 12-14 mm (refer Figure 1). Dry substance content is 87-92 per cent, with molassed pellets above 92 per cent (to eliminate sticking problems).

In the UK and Ireland, dried pulp is sold to the farms for direct feeding to calves and in particular, to sheep.

Advantages are:

- Ease of mixing
- Low cost (before pelletising)

Disadvantages:

- Higher transport costs than pellets (200-250 kg/m^3 bulk density)

Pellet advantages:

- Lower transport costs (610-690 kg/m^3 bulk density)
- Pneumatic bulk handling and automatic feeding system systems on farms.

Molasses Beet Pulp

The addition point of molasses does affect the nutritional and handling qualities of dried beet pulp. Post-drier addition reduces the ruminant protein degradability from 0.9 to 0.55, compared with a 0.6 to 0.07 degradability in drying plain pulp. Additives including ammonia, ammonium sulphate and urea are used to raise nitrogen content of the pulp.

Legislation

Animal feeds produced from beet are subject to more stringent legislation in the EU than in other parts of the world.

Analysis, feeding values and applications

Table 1 compares the three major pulp products. The prime nutrients are energy and fibre. The fibre is highly digestible by both ruminants and non-ruminants. Traditionally, the main use of beet pulp has been to feed dairy cows. Table 2 summarises the energy values of pulp, molasses and molasses residues.

Table 1. Typical sugarbeet pulp products analysis

Analysis	Units	Pressed Pulp	Dried Unmolassed Pulp	Dried Molassed Pulp
Dry substance	%	18-30	87-92	>92
Crude protein	G/kg DS	104	99	130
Oil (ether extract)	"	9	8	
Acid ether extract	"		7	7
MAD fibre	"		208	137
NDF (ash free)	"		543	356
NDFam (ash free)	"		498	301
Acid detergent fibre (ashed)	"	287	186	
Total ash	"	40-80	40-90	70-100
ME ruminants	MJ/kg DS	12.3	12.7	12
NE lactation	"	7.2	7.6	8
Gross energy	"		17.1	16.5
DE pigs	"		9.3	19
Cellulose	g/kg DS		224	153
Starch	"		6	38
Water Soluble carbohydrates	"		26	220
Total sugar	"		70-90	140
NCD	"		786	854
RFP	"		780	818
Calcium	"		8.1	9.8
Phosphorus	"		0.9	0.6
Magnesium	"		1.9	1.5
Potassium	"		7.1	18.2
Sodium	"		1.2	5.5

*Table 2. Energy data of pulp, molasses, and molasses residues according to **DLS-feeding values***

Feed supplement	**Energy Value MJ/kg DS**	
	ME	**NEL**
Wet Pulp (silage, 14% DS)	11.7	7.23
Pressed Pulp (silage, 22% DS)	11.87	7.4
Corn Silage (23% DS)	10.51	6.31
Cane Molasses	12.09	7.81
Beet Molasses (63% sugar DS)	12.29	7.88
Dried Beet Pulp (non molassed)	11.93	7.43
Molassed dried beet pulp	12.09	7.61
Beet Cossettes	12.47	7.93
Citrus Residue	12.29	7.71
Winter Barley	12.84	8.08

3.4 Human Consumption

Beet fibre has been identified as being suitable for application in a wide range of foods. Due to its vulnerability to destruction by moulds and other sources of infection, the direct processing of the pulp during the beet campaign is required. The product, at 90 per cent DS and 73 per cent dietary fibre, competes well with cereal fibre in that due to its high water holding capacity, in addition to its fibre value to the human body, it has functional value in the production of many foods such as bread and processed meats. It is also well suited to extrusion mixtures, frying coatings and muesli. The composition of a typical product is summarised in Table 3.

Table 3. Typical exhausted cossettes dry substance analysis

Component	**Per Cent**	**Dietary Fibre**
Hemicellulose	32	+
Pectin	24	+
Cellulose	20	+
Lignin	4	+
Protein	12	
Sugar	4	
Minerals	4	
Fat	0.3	

4. Process design

4.1 Introduction

The design is made for an ethanol production of 40ML per anum, equivalent to 400000 tonnes beet. This equates to a dried pulp production rate of 160 tonnes per day for the 180 day harvest (refer Appendix 1). The process is based on recent European and US publications. It is noted that major equipment design choices can vary (e.g. horizontal versus vertical presses, and fuel gas versus superheated steam driers), depending on the main process equipment vendor selection. Wherever possible, the design was aligned with that prepared in TD' 2001 study (Reference 2).

4.2 Process description

- The process flowsheet prepared is in Figure 1.
- Beet cossettes, after sucrose extraction, discharge from the diffuser D101 as wet pulp. This could be distributed to nearby farms in its wet form, but due to the bulk storage and effluent run-off problems incurred, it has been ignored for this study.
- The wet pulp is conveyed (K106), sometimes in a free water removal screen, to the mechanical presses (M102). These can be either of the vertical or horizontal design, and reduce the water in the pulp from 90 to 80 per cent. The press water is screened (S106) and pumped (P105) via a heater (E109) to the diffuser supply water tank, from where it is used to assist in cossette sucrose extraction.
- The Pressed pulp is then either conveyed to T103, the tank-loading bin, or mixed with nutrients and fed to E108, the pulp drier.
- Pulp drying can be either by superheated steam or by direct gas or oil firing. Draft is normally induced, with co-current parallel flow (direct firing) to minimise pulp overheating and burning. Horizontal designs contain sufficient baffles to drop the pulp through the hot flue gases as the drum rotates. These drums are mounted perfectly level, so that as the drum rotates, alternately lifting and dropping the pulp, the pulp is progressively moved forward through the drum only by the flow of the drying gases. A typical unit will be 3 metres in diameter, and 15 metres long, to process the planned 2500 tonnes beet per day. Energy savings can be achieved by recirculating the stack gases (after dust separation cyclones). These are important as of the total energy used by the entire beet factory, approximately 30 per cent is the drying of the pulp. Allowance for higher efficiency options will be made in section 5, the economic criteria.
- The dried pulp can be marketed in either its loose or pelletised form. Loose pulp can be either bagged (typically 25 or 50 kg), or warehouse bulk stored for distribution.
- Allowance has been made for pulp value addition through the usage of stillage (calcium, magnesium and potassium salts), yeast separated from the stillage (protein) and urea (nitrogen).
- Pulp outloading has assumed to be by road, and allowance for process storage has been made in section 5.

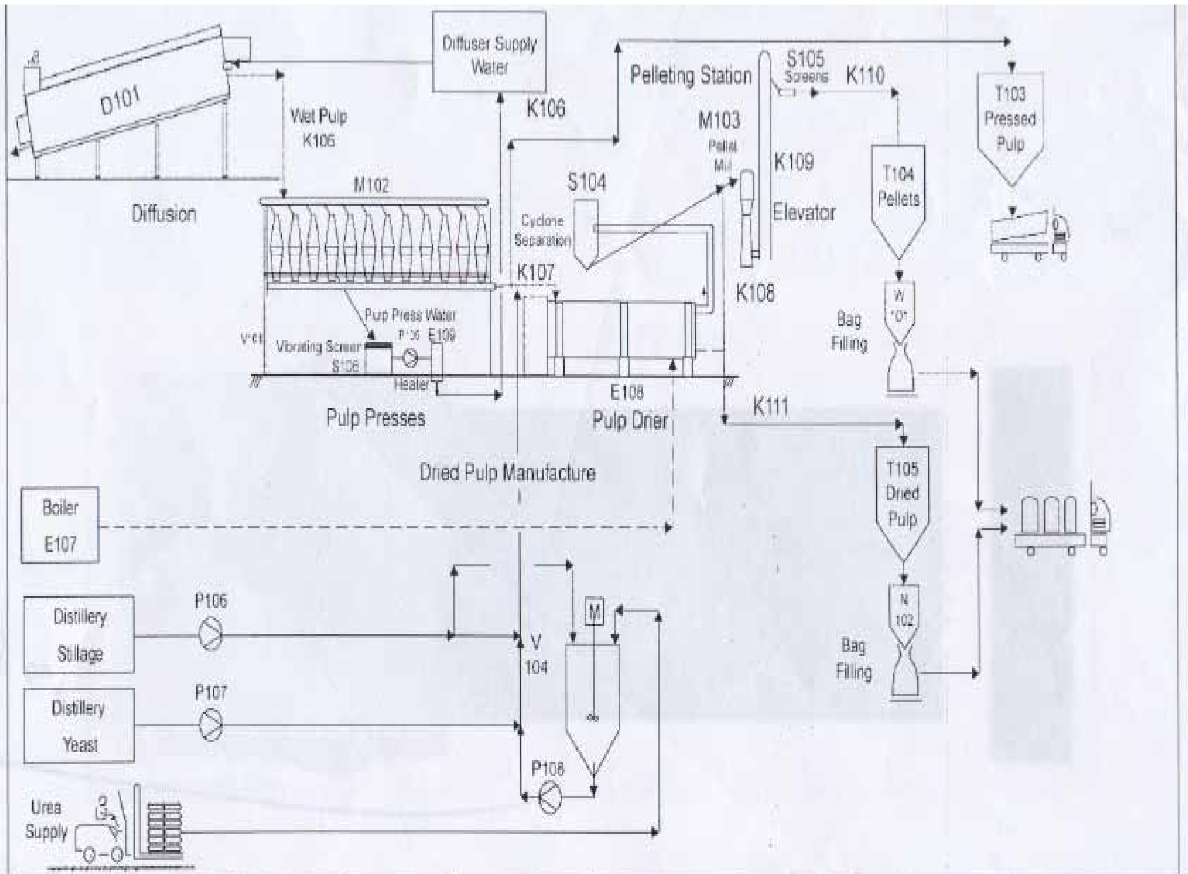
4.3 Equipment specifications

The major equipment specifications were prepared using the calculations in Appendix I (mass balance) and are summarised in Table 4. These were used to calculate the capital and variable costs listed in section 5. A typical pelletising mill arrangement is in Figure 2.

Table 4. Major equipment specifications. Animal feed plant.

Tag	Number off	Description	Capacity	Specification
M102	1	Pulp press	20 t/hour	Vertical or horizontal
E108	1	Drier and cyclones	Evap 15t/hour	Vertical or horizontal
M103	1	Pellet mill	15t/hour	
T103	1	Pressed pulp bin	$500m^3$	
T104	1	Pellet bin	$25m^3$	
T105	1	Dried pulp bin	$70m^3$	
V104	1	Nutrient mix tank	$5m^3$	
P105	1	Press water pump	5kW	S.S.304
E109	1	Press water heater	3000kW	SS316
P106-8	3	Nutrient pumps	2kW	
W101-2	2	Bagging weigh bins	$0.25m^3$	

Figure 1. Process flowsheet. Animal feeds. 20 tonnes/hour



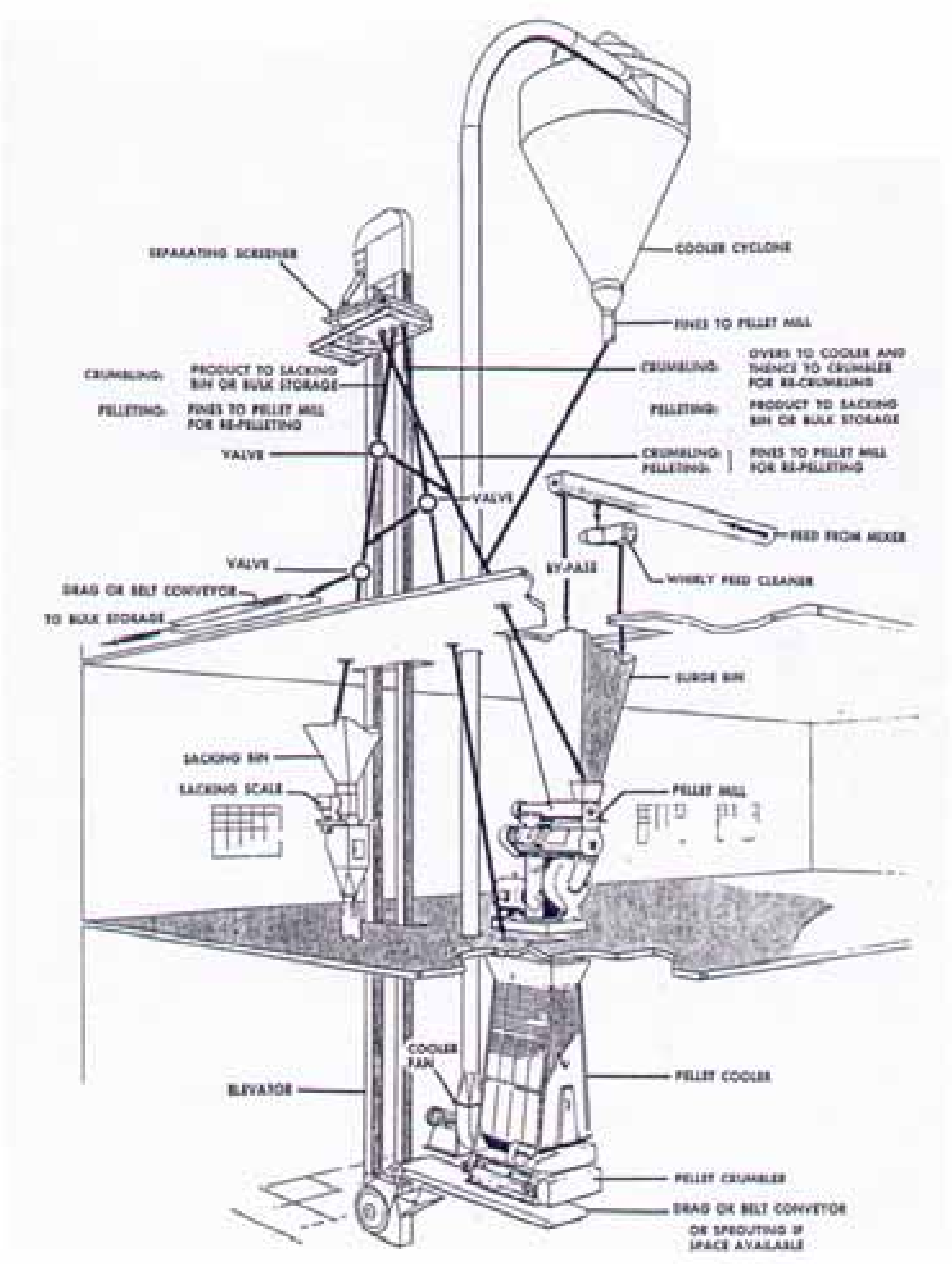
Tag	D101	M102	E108	M103	V104	T103
Description	Diffuser	Presses	Drier	Mill	Mixing tank	Storage
Service	Cossettes	Pulp	Pulp	Pulp Pellets	Urea	Pressed Pulp
Capacity	100 t/h	20 t/h	14 t/h	20 t/h	5 m^3	500 m^3
Material	cs	ss	cs	ss	cs	ss
Tag	T104-5	W101-2	K106-111	S104-6	P105	P106-9
Description	Bins	Scales	Conveyers	Screens/separators	Pump	Pumps
Service	Pellets/Pulp	Pellets/Pulp	Pulp/Pellets	Pulp	Raw Water	Nutrients
Capacity	25 - 70 m^3	20 t/h	50 t/h	50	20 t/h	5 t/h
Material	cs	ss	cs	cs	ss	ss

TD Chemicals PTY LTD

Process Flowsheet
Animal Feeds
20 tonnes/hour

09.06.03 PT Traicos

Figure 2. General arrangement. Pulp pellet mill.



(Reference 1)

5. Economic criteria

5.1 Capital costs

In order to assess the impact on the project profitability of alternative product manufacture, three options were considered. The minimal effect on capital of eliminating the nutrient addition was not considered.

Scheme	**Pulp products**
1	Pressed, dried and pellets
2	Pressed and dried
3	Pressed

Table 5. Capital Budget Estimates. $ '000. 400 000 tonnes beet per annum

Item	**Description**	**Scheme**		
		1	**2**	**3**
1	Pulp press	1400	1400	1400
2	Drier	1700	1700	0
3	Pellet mill	530	0	0
4	Product bins	200	75	225
5	Mixing tank	12	12	12
6	Pumps and conveyers	77	77	40
7	Piping and installation	800	650	340
8	Electrics and instruments	950	780	400
9	Structures	1000	800	450
10	Engineering design	550	450	250
11	Project management	280	230	150
12	Sub Total	7497	6174	3267
13	Contingency	903	746	393
14	**Grand Total**	**8400**	**6920**	**3660**

5.2 Variable costs

These are summarised in Table 6. The utility costs are based on the 2001 TD report (Reference 2). No allowance has been made for product distribution costs.

Table 6. Variable cost summary.

Item	Material	Units	Cost $ per unit	Usage per tonne			Cost $ per tonne product scheme		
				Scheme			Scheme		
				1	2	3	1	2	3
1	Steam	Tonnes	10.00	1.0	1.0	0	10.00	10.00	0
2	Electricity	kWh	0.054	140	140	2	7.56	7.56	0.11
3	Total	-	-	-	-	-	17.56	17.56	0.11

5.3 Fixed costs

It is assumed that the animal feed plant is integral with the beet distillery, enabling the sharing of all services and overheads. One operator per shift, and the equivalent of one maintenance technician will be required.

Table 7. Fixed Cost Summary. $ '000 per annum

Item	Description	Scheme		
		1	2	3
1	Shift personnel (4)	285	285	285
2	Overheads (invoice, rent, admin)	80	70	40
3	Maintenance (2% of plant machinery value)	110	95	50
4	Management, marketing and technical services	80	75	70
5	**Total**	**555**	**525**	**445**

6. References

1. *McGinnis R.A. (1982). Beet sugar technology. 3rd Edition. 1982*
2. *Traicos P.T. (2001). Feasibility study. Sugar beet fuel ethanol. Tasmania. CSR Distilleries. 18 December 2001.*
3. *Van der Poel PW, Schiweck and Schwartz T (1998). Sugar Technology. Beet and cane sugar manufacture. 1998*

7. Appendix:

Appendix 1: Mass balance. Animal feed plant. 10 tonnes/hour. Tonnes per day

Process		Stream	Sugars	Non sugars (soluble)	Pulp/Protein (insoluble)	Water	Total
Pressing	In	Wet pulp	7.4	40.0	114.4	1456.2	1618.0
	Out	Pressed pulp	1.8	3.6	114.4	319.8	466.6
		Press water	5.6	36.4	0	1136.4	1151.4
Mixing	In	Pressed pulp	1.8	3.6	27.0	319.8	466.6
		Yeast	0	0	168.4	40.6	67.6
	Out	Drier feed	1.8	3.6	168.4	360.4	534.2
Drying	In	Drier feed	1.8	3.6	168.4	360.4	534.2
	Out	Dried pulp	1.8	3.6	168.4	19.3	193.1
		Water vapour	0	0	0	341.1	341.1

8.3. Gross margins of comparative crops in Tasmania

4.19 Sugar Beet

			$/ha		Your Estimate
ENTERPRISE OUTPUT			Average	Good	
Beet					
Yield:	85	tonnes/ha			
	95	tonnes/ha			
Price:	$90	/tonne, depending on size, bruise free and rejects.	7650	8550	.............…
Tops					
Yield:	6.4	tonnes DM/ha			
	9.0	tonnes DM/ha			
Price:	$0.06	/kg DM	384	540	.............…
Pulp					
Yield:	8.5	tonnes DM/ha			
	9.5	tonnes DM/ha			
Price:	$250	/tonne	2125	2375	.............…
Total Enterprise Output	#####		**10159**	**11465**	**..........…**

VARIABLE COSTS										
Materials:										
Seed			4	kg/ha	@	$80	/kg	320	320	....
Fertiliser										
Pre-Spread:										
Superphosphate				t/ha	@	$240	/tonne		0	.............…
Side-Dressing:										
Urea				kg/ha	@	$507	/tonne		0	.............…
Muriate of Potash				kg/ha	@	$506	/tonne		0	.............…
At Planting:										
4:6:7			0.6	t/ha	@	$329	/tonne	197	197	.............…
Cartage			0.6	t/ha	@	$13.50	/tonne	8	8	.............…
Weed Control										
Pre-cultivation -										
glyphosate*	1	spray	3	l/ha	@	$8.50	/litre	26	26	.............…
dicamba*	1	spray	250	ml/ha	@	$18.10	/litre	5	5	.............…
Post Plant -										
phenmedipham	1	spray	5	l/ha	@	$74.70	/litre	374	374	.............…
	2	spray	2	l/ha	@	$74.70	/litre	299	299	.............…
ethofumasate	2	spray	2	l/ha	@	$100.00	/litre	400	400	.............…
select	1	spray	0.25	l/ha	@	$134.75	/litre	34	34	.............…
Lontrel	1	spray	0.75	l/ha	@	$76.34	/litre	57	57	.............…
Pre-harvest -										
diquat 200v**	0	spray	2	l/ha	@	$20.75	/litre	0	0	.............…
paraquat 250v**	0	spray	2	l/ha	@	$17.40	/litre	0	0	.............…
Disease Control										
mancozeb 800w***		sprays	2.5	kg/ha	@	$7.60	/kg	0		.............…
mancozeb 800w***		sprays	2.5	kg/ha	@	$7.60	/kg		0	.............…
metalaxyl/mancozeb40/640***		sprays	2.5	kg/ha	@	$37.00	/kg	0	0	....
difenoconazole		sprays	500	ml/ha	@	$139.00	/l	0	0	.............…
triadimefon	1	sprays	1	l/ha	@	$8.00	/l	8	8	....
Pest Control										
chlorpyrifos	0	sprays	700	ml/ha	@	$19.90	/l	0	0	.............…
dimethoate	1	sprays	1	l/ha	@	$9.75	/l	10	10	.............…
Tractor and Plant:										
# Land Preparation****			10.3	hr/ha	@	$6.55	/hr	67	67	.............…
# Weed Control	8	sprays	0.6	hr/ha	@	$3.53	/hr	17	17	....
# Disease and Pest Control	2	sprays	0.6	hr/ha	@	$3.53	/hr	4	4	....
Repairs, Maintenance & Lubrication on operations										....
Contract Operations:										
Tissue Analysis 14 ha	0	analysis			@	$45.00	each	0	0	.............…

						Average	Good	Your Estimate
Soil Analysis	14 ha	1 analysis	@	$30.00	/field	2	2	....
Precision air seeding		1 drilling	@	$72.50		73	73	....
Disease Control (includes Pest Control)		0 aerial sprays	@	$34.00	/ha	0		....
		0 aerial sprays	@	$34.00	/ha		0	....
Pest Control	included in disease control							
Harvest	$16 /t	plus labour	@		/tonne	1360	1520	....
Cartage to factory			@	$15.00	/tonne	1275	1425	....
Drying Cost								
Irrigation:								
Water Price		150 mm/ha	@	$50.00	/Ml	75		....
Water Price		250 mm/ha	@	$50.00	/Ml		125	....
Running costs		150 mm/ha	@	$21.31	/25 mm	128		....
Running costs		250 mm/ha	@	$21.31	/25 mm		213	....
Total Variable Costs						**4,738**	**5,183**	**................**
GROSS MARGIN						**5,421**	**6,282**	**..............**
Gross Margin per 25 mm of water applied						904	628	

*, **&*** Combined sprayings.

**** Land preparation is assumed to consist of 1 mouldboard ploughing, 2 tyne cultivations, 1 roterra and 1 agrow ploughing.

Fuel cost only.

This budget provides only an indication of returns. It should not be used as a basis for price negotiations.

4.19 Sugar Beet (C'ontd)

ALLOCATED OVERHEAD COSTS

These Overhead Costs are based on the Model Farm assumptions outlined in the Appendices.

					O/head Cost per ha Average $	Good $	Your Estimate $
Interest on preHarvest Variable Costs	6 months	@	10%	p.a.	101	106	....
Pasture re-establishment contribution	10 months	@	264.92	/ha	22	22	....
Tractor and Plant							
Land preparation							
- Tractor	10.3 hr/ha	@	14.15	/hr	146	146	....
- Mouldboard plough	3 hr/ha	@	6.66	/hr	20	20	....
- Tyne cultivator	2 hr/ha	@	2.09	/hr	4	4	....
- Roterra	2.3 hr/ha	@	14.75	/hr	34	34	....
- Agrow plough	3 hr/ha	@	7.19	/hr	22	22	....
Weed Control							
- Tractor	4.8 hr/ha	@	9.14	/hr	44	44	....
- Boom Spray	4.8 hr/ha	@	2.63	/hr	13	13	....
Pest Control							
- Tractor	1.2 hr/ha	@	9.14	/hr	11	11	....
- Boom Spray	1.2 hr/ha	@	2.63	/hr	3	3	....
Irrigation							
- Tractor	2.75 hr/ha	@	9.14	/hr	25	25	....
- Annual capital costs of system	150 mm/ha	@	20.79	/25mm	125		....
	250 mm/ha	@	20.79	/25mm		208	
Permanent Labour							
Tractor operations incl. irrigation	19.05 hr/ha	@	13.68	/hr	261	261	....
- includes allowances for superannuation contribution and leave loading.							
Total Allocated Overhead Costs					**830**	**917**	**................**
ENTERPRISE CONTRIBUTION					**4,591**	**5,365**	**...........**
Enterprise Contribution per 25 mm of water applied					765	536	

SENSITIVITY ANALYSIS (Parametric Budget)

Shows the effects of yield per hectare and potato price
on Gross Margin and Enterprise Contribution per hectare.

Average Crop

Gross Margin - $/ha

Average Price per tonne		Yield - tonnes per hectare		
		Low	Expected	Good
$		75.0	85.0	95.0
81	10% decrease	**3906**	**4656**	**5406**
90		**4581**	**5421**	**6261**
99	10% increase	**5256**	**6186**	**7116**

Enterprise Contribution - $/ha

Average Price per tonne		Yield - tonnes per hectare		
		Low	Expected	Good
$		75.0	85.0	95.0
81	10% decrease	**3076**	**3826**	**4576**
90		**3751**	**4591**	**5431**
99	10% increase	**4426**	**5356**	**6286**

Good Crop

Gross Margin - $/ha

Average Price per tonne		Yield - tonnes per hectare		
		Low	Expected	Good
$		85.0	95.0	105.0
81	10% decrease	**4677**	**5427**	**6177**
90		**5442**	**6282**	**7122**
99	10% increase	**6207**	**7137**	**8067**

Enterprise Contribution - $/ha

Average Price per tonne		Yield - tonnes per hectare		
		Low	Expected	Good
$		85.0	95.0	105.0
81	10% decrease	**3760**	**4510**	**5260**
90		**4525**	**5365**	**6205**
99	10% increase	**5290**	**6220**	**7150**

This budget provides only an indication of returns. It should not be used as a basis for price negotiations.

Sugar Beet – High Risk Gross Margin

4.19 Sugar Beet

			$/ha Average	$/ha Good	Your Estimate
ENTERPRISE OUTPUT					
Beet					
Yield:	50	tonnes/ha			
	60	tonnes/ha			
Price:	$90	/tonne, depending on size, bruise free and rejects.	4500	5400	....
Tops					
Yield:	3.0	tonnes DM/ha			
	9.0	tonnes DM/ha			
Price:	$0.06	/kg DM	180	540	....
Pulp					
Yield:	5	tonnes DM/ha			
	6	tonnes DM/ha			
Price:	$250	/tonne	1250	1500	....
Total Enterprise Output			**5930**	**7440**	**.............**

						Average	Good	Your Estimate
VARIABLE COSTS								
Materials:								
Seed		4 kg/ha	@	$80	/kg	320	320	....
Fertiliser								
Pre-Spread:								
Superphosphate		1.0 t/ha	@	$240	/tonne		240	....
Side-Dressing:								
Urea		500 kg/ha	@	$507	/tonne		254	....
Muriate of Potash		500 kg/ha	@	$506	/tonne		253	....
At Planting:								
4:6:7		0.6 t/ha	@	$329	/tonne	197	197	....
Cartage		0.6 t/ha	@	$13.50	/tonne	8	8	....
Weed Control								
Pre-cultivation -								
glyphosate*	2 spray	3 l/ha	@	$8.50	/litre	51	51	....
dicamba*	2 spray	250 ml/ha	@	$18.10	/litre	9	9	....
Post Plant -								
phenmedipham	1 spray	5 l/ha	@	$74.70	/litre	374	374	....
	2 spray	2 l/ha	@	$74.70	/litre	299	299	....
ethofumasate	2 spray	2 l/ha	@	$100.00	/litre	400	400	....
select	1 spray	0.25 l/ha	@	$134.75	/litre	34	34	....
Lontrel	1 spray	0.75 l/ha	@	$76.34	/litre	57	57	....
Pre-harvest -								
diquat 200v**	1 spray	2 l/ha	@	$20.75	/litre	42	42	....
paraquat 250v**	1 spray	2 l/ha	@	$17.40	/litre	35	35	....
Disease Control								
mancozeb 800w***	1 sprays	2.5 kg/ha	@	$7.60	/kg	19		....
mancozeb 800w***	1 sprays	2.5 kg/ha	@	$7.60	/kg		19	....
metalaxyl/mancozeb40/640***	sprays	2.5 kg/ha	@	$37.00	/kg	0	0	....
difenoconazole	sprays	500 ml/ha	@	$139.00	/l	0	0	....
triadimefon	2 sprays	1 l/ha	@	$8.00	/l	16	16	....
Pest Control								
chlorpyrifos	0 sprays	700 ml/ha	@	$19.90	/l	0	0	....
dimethoate	3 sprays	1 l/ha	@	$9.75	/l	29	29	....
Tractor and Plant:								
# Land Preparation****		10.3 hr/ha	@	$6.55	/hr	67	67	....
# Weed Control	10 sprays	0.6 hr/ha	@	$3.53	/hr	21	21	....
# Disease and Pest Control	7 sprays	0.6 hr/ha	@	$3.53	/hr	15	15	....
Repairs, Maintenance & Lubrication on operations								....
Contract Operations:								
Tissue Analysis 14 ha	0 analysis		@	$45.00	each	0	0	....

Soil Analysis	14 ha	1 analysis	@	$30.00	/field	2	2	....
Precision air seeding		1 drilling	@	$72.50		73	73	....
Disease Control (includes Pest Control)		1 aerial sprays	@	$34.00	/ha	34		....
		1 aerial sprays	@	$34.00	/ha		34	....
Pest Control	included in disease control							
Harvest	$16 /t	plus labour	@		/tonne	800	960	....
Cartage to factory			@	$15.00	/tonne	750	900	....
Drying Cost								
Irrigation:								
Water Price		150 mm/ha	@	$50.00	/Ml	75		....
Water Price		250 mm/ha	@	$50.00	/Ml		125	....
Running costs		150 mm/ha	@	$21.31	/25 mm	128		....
Running costs		250 mm/ha	@	$21.31	/25 mm		213	....
Total Variable Costs						**3,855**	**5,047**	....
GROSS MARGIN						**2,075**	**2,393**	....
Gross Margin per 25 mm of water applied						346	239	

*, **&*** Combined sprayings.

**** Land preparation is assumed to consist of 1 mouldboard ploughing, 2 tyne cultivations, 1 roterra and 1 agrow ploughing.

Fuel cost only.

This budget provides only an indication of returns. It should not be used as a basis for price negotiations.

4.19 Sugar Beet (C'ontd)

ALLOCATED OVERHEAD COSTS

These Overhead Costs are based on the Model Farm assumptions outlined in the Appendices.

					O/head Cost per ha Average $	O/head Cost per ha Good $	Your Estimate $
Interest on preHarvest Variable Costs	6 months	@	10% p.a.		112	153	....
Pasture re-establishment contribution	10 months	@	264.92	/ha	22	22	....
Tractor and Plant							
Land preparation							
- Tractor	10.3 hr/ha	@	14.15	/hr	146	146	....
- Mouldboard plough	3 hr/ha	@	6.66	/hr	20	20	....
- Tyne cultivator	2 hr/ha	@	2.09	/hr	4	4	....
- Roterra	2.3 hr/ha	@	14.75	/hr	34	34	....
- Agrow plough	3 hr/ha	@	7.19	/hr	22	22	....
Weed Control							
- Tractor	6 hr/ha	@	9.14	/hr	55	55	....
- Boom Spray	6 hr/ha	@	2.63	/hr	16	16	....
Pest Control							
- Tractor	4.2 hr/ha	@	9.14	/hr	38	38	....
- Boom Spray	4.2 hr/ha	@	2.63	/hr	11	11	....
Irrigation							
- Tractor	2.75 hr/ha	@	9.14	/hr	25	25	....
- Annual capital costs of system	150 mm/ha	@	20.79	/25mm	125		....
	250 mm/ha	@	20.79	/25mm		208	....
Permanent Labour							
Tractor operations incl. irrigation	23.25 hr/ha	@	13.68	/hr	318	318	....
- includes allowances for superannuation contribution and leave loading.							
Total Allocated Overhead Costs					**947**	**1,072**	....
ENTERPRISE CONTRIBUTION					**1,128**	**1,321**	....
Enterprise Contribution per 25 mm of water applied					188	132	

SENSITIVITY ANALYSIS (Parametric Budget)

Shows the effects of yield per hectare and potato price
on Gross Margin and Enterprise Contribution per hectare.

Average Crop

Gross Margin - $/ha

Average Price per tonne		Yield - tonnes per hectare		
		Low	Expected	Good
$		40.0	50.0	60.0
81	10% decrease	**875**	**1625**	**2375**
90		**1235**	**2075**	**2915**
99	10% increase	**1595**	**2525**	**3455**

Enterprise Contribution - $/ha

Average Price per tonne		Yield - tonnes per hectare		
		Low	Expected	Good
$		40.0	50.0	60.0
81	10% decrease	**678**	**678**	**678**
90		**1128**	**1128**	**1128**
99	10% increase	**1578**	**1578**	**1578**

Good Crop

Gross Margin - $/ha

Average Price per tonne		Yield - tonnes per hectare		
		Low	Expected	Good
$		50.0	60.0	70.0
81	10% decrease	**1103**	**1853**	**2603**
90		**1553**	**2393**	**3233**
99	10% increase	**2003**	**2933**	**3863**

Enterprise Contribution - $/ha

Average Price per tonne		Yield - tonnes per hectare		
		Low	Expected	Good
$		50.0	60.0	70.0
81	10% decrease	**31**	**781**	**1531**
90		**481**	**1321**	**2161**
99	10% increase	**931**	**1861**	**2791**

This budget provides only an indication of returns. It should not be used as a basis for price negotiations.