Hydroponic Fodder Production
An Analysis of the Practical and Commercial Opportunity
The New Zealand Merino Company, October 2011
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1. Executive Summary

Hydroponic fodder production involves supplying cereal grain with moisture and nutrients, all outside of a growing medium such as soil, and then harvesting the resulting green shoots and root mat. The grain responds to the supply of moisture and nutrients by sprouting and then producing a 200 – 250mm long vegetative green shoot with interwoven roots over a period of 5 to 8 days. At the end of the growing period the fodder is fed to livestock as a supplement in the same way that hay and silage are currently.

Hydroponic Fodder production systems are used in a number of different livestock systems internationally. Within the last 5 years there have been at least 3 fodder production sheds made operational in New Zealand. This report objectively investigates hydroponic fodder production systems and their applicability to New Zealand pastoral farming systems.

Specialist sheds are built for the production of hydroponic fodder. The climate within these sheds is actively controlled to ensure optimal growing conditions. A fodder shed measuring 10m x 13m will produce approximately 1 tonne of wet fodder per day.

Fodder sheds produce a large quantity of green fodder, with 1kg of grain producing 6 - 10kg of fodder sprouts. However, when this is converted back to a drymatter basis, there is a loss of approximately 12% of the total drymatter in the grain. This loss is due to the consumption of carbohydrates to produce energy within the grain during germination and other metabolic activities of the growing sprouts.

While energy content of the fodder (MJ ME /kg DM) is similar to that of the barley grain, there are some gains in protein and vitamin content of the fodder versus grain. Due to the costs of fodder production, energy (MJME) and protein are 4 and 1.9 times more expensive respectively in the fodder versus the grain. This is largely a function of the costs per kg DM for the fodder, which is $1.80 /kg DM, versus $0.44 / kg DM for the barley grain. Thus, fodder is expensive.

A number of studies have analysed animal responses to and performance on hydroponic fodder. These studies considered dairy cattle, pigs, beef cattle and poultry. The majority of these studies identified no advantage in feeding fodder, especially when it was used to replace grain. Some early research found improvements in production, which was attributed to a ‘grass juice factor’. A recent study found that steers supplemented with hydroponic barley sprouts performed better than expected, given the nutritional value of the feed. The researcher concluded that further trial work was required to better evaluate the performance potential of fodder. However, there would need to be major production improvements to overcome the economic constraints.

Given the high cost per kilogram of drymatter, inconclusive animal performance and labour requirements associated with hydroponic fodder production it is unlikely that fodder sheds will be established and utilised by a wide range of New Zealand farmers.
2. Introduction

The objective of this report is to provide an analysis of Novel Fodder Production systems and their applicability and potential benefits within New Zealand pastoral farming systems.

Novel Fodder Production systems are automated fodder production units that utilise hydroponic systems to sprout cereal grains, which then grow into green fodder in 5 to 8 days. This green fodder is then fed to supplement the diets of livestock to meet their nutritional requirements, in a similar way as hay and silage are commonly utilised within New Zealand pastoral farming systems.

This report provides some background on fodder production systems, analyses the feed value and economics of fodder production, and looks at their potential fit of this feed source to New Zealand pastoral livestock farming systems.

3. Hydroponic Fodder Production

3.1 Principles

Hydroponic fodder production involves supplying cereal grain with necessary moisture and nutrients, to enable germination and plant growth in the absence of a solid growing medium. The resulting green shoots and root mat are harvested and fed to livestock. The grain responds to the supply of moisture and nutrients by germinating, sprouting and then producing a 200 – 250mm long vegetative green shoot with interwoven roots within 5 to 8 days.

A range of cereals can be utilised for fodder production, including barley, oats, wheat and maize. The most commonly used cereal grain is barley. Barley fodder systems are the focus of the analysis within this report.

There are a range of chemical and structural changes that take place within the cereal grain through the hydroponic growing process. Activation of enzymes within the grain leads to hydrolysis of proteins, carbohydrates and lipids into their simpler components (Dung, Godwin, & Nolan, 2010). This hydrolysis increases the concentrations of amino acids, soluble sugars and fatty acids within the grain and resulting shoot (Chavan and Kadam, 1989).

The amount of sprouts produced (yield) and quality of the fodder is influenced by a number of factors including:

- Grain - grain quality, grain variety and treatments
- Growing environment - temperature, humidity and incidence of mould
- Management of the system - water quality and pH, soaking time, nutrient supply, depth and density of grain in troughs, and growing duration (Sneath and McIntosh, 2003).

Figure 1 below illustrates the transformation of barley grain to fodder ready to be fed at 7 days.
3.2 Hydroponic Fodder Production Systems

3.2.1 System Set Up

There are a number of sophisticated systems specially developed for the production of hydroponic fodder. One of the more common systems internationally, and one that is available in New Zealand is FodderTech (www.foddertech.com). Other systems include Fodder Factory, Green Feed Solutions and Fodder Solutions. Each of these are based largely on the same principles.

Purpose built sheds house the fodder production systems. A range of shed sizes are available, from 50m² to 300m². A mid sized unit, producing 1 tonne of wet fodder per day, will typically measure 10m x 13m. Fodder sheds consist of two areas – a growing area where the fodder is grown, and a pump area where grain is prepared for sowing and is where nutrient tanks, pumps and associated systems are located. In a 100sqm shed, the growing area represents approximately 70% of the total floor area (Carruthers, 2003).
The shed environment is actively controlled to ensure optimal temperatures and appropriate ventilation levels are maintained. Climate control consists of air conditioning units, and in colder environments, underfloor heating. The air conditioning and ventilation units can been seen in Figure 2, along the side wall of the shed.

The growing area of the shed consists of stacks of food quality PVC channels in which the grain is ‘sown’ and the fodder grows (see Figure 3 below). Each of these stands holds 28 trays measuring 4m long and 400mm wide. These trays are fed with nutrient nozzles which periodically supply a precise measure of nutrient solution to each individual tray. These nozzles are adjusted throughout the growing stages to supply the appropriate quantity of nutrient solution to each tray. This nutrient solution then flows through the bottom of the trays, which are set with a very slight fall, and is accessed by the grain and resulting roots. This is technique is commonly referred to as Nutrient Film Technique (NFT).

Nutrient solution that is not absorbed by the sown grains flows into a recirculating system that returns the solution back to the solution storage tank. This minimises wastage and optimises efficiency of water use within the system.
The pump area of the shed houses a range of equipment critical to the fodder shed. It is here that a mixing and storage tank for the nutrient solution is housed, along with pumps and the automation controls for climate as well as nutrient solution concentration, pH and temperature (Carruthers, 2003). A soaking tank, where grain is soaked in a nutrient solution for a day prior to sowing, also resides in this area. The soaking assists with the metabolism of reserve material in the grain and the use of those reserves for the growth and development of the fodder (Sneath and McIntosh, 2003).

3.2.2 System Operation

Sheds are commonly set-up so that the number of stacks is a multiple of the optimal harvest period for that system. For example, in an 8 day system there will be sections of fodder at eight different stages of growth. This allows one section to be harvested every day, and it is then resown immediately following harvest.

The daily operation of the fodder shed revolves around 6 main tasks:

1. Harvesting mature fodder
   Mature fodder is pulled out of the trays as a complete mat. It is commonly loaded on a cart and wheeled out the end of the fodder shed and loaded onto a vehicle or trailer for feeding.
2. Cleaning Trays
   It is critical that the trays and all equipment are thoroughly cleaned to reduce the risk of mould and other infections. A water blaster is commonly used to achieve this.

3. Sowing new grain
   New grain, which has been soaked for 24 hours, is sown into the trays. This grain is sown in an even layer 3cm deep.

4. Adjusting nutrient flows
   Nutrient flows are adjusted across each stack. The water and nutrient requirements of the growing fodder increases each day and thus the flow to each tray must be adjusted to ensure appropriate water and nutrient supply for the growing fodder. Small taps into each tray are adjusted to achieve this.

5. Topping up nutrient and acid supplies
   Nutrient is added to the nutrient tank via an automated system. The pH of the nutrient solution is also maintained via an automated system. Thus, there is a need to check that the supply of nutrient concentrate and acid is adequate to supply the systems needs. The exact make up of the various nutrient solutions used is not known. A comprehensive search failed to find adequate information on the make up of their nutrient mixes. A detailed chemical analysis of the mixes has not been completed within this study.

6. Feeding out
   The fodder is fed out to the appropriate stock class. This is commonly fed out in its mat form off the back of a ute or a feed wagon. A farmer in the Mackenzie Basin has trialled mulching the fodder first to improve utilisation by the sheep but observed no real advantage in utilisation.
The labour requirements of for fodder sheds depend largely on the level of automation within the system. The suggested daily labour requirement to operate a mid-sized system, producing 1 tonne of wet feed per day and based on the set up and operation outlined above varies from 2 to 4 hours per day (Sneath and McIntosh, 2003).

3.2.3 Mould

There are a number of challenges in producing hydroponic fodder. A common challenge that causes many problems for those with fodder sheds is mould. Given the warm moist environment within a fodder shed mould can easily take hold, ruin the crop and cause livestock health issues if fed. Thus, active management of mould risk is essential.

Mouldy sprouts have decreased livestock performance in trials (Myers, 1974), and has been known to result in animal deaths.

Mould is actively managed within sheds through pre treatment of the seed. Additives to the water are used for pre-soaking the grain to minimise the risk of mould. Shed hygiene is also important and thus considerable attention is paid to ensuring the growing trays are well cleaned following each crop and prior to the sowing of the new crop.

3.2.4 Environmental

There are both environmental advantages and disadvantages to the production and feeding of hydroponic fodder.
Hydroponic forage production systems are extremely water efficient. Water is reticulated within the system. Additionally, as the fodder is grown within a shed, there are nil losses of water due to evapotranspiration. Animals consume the majority of the water ‘used’, along with the feed.

An additional advantage is that there is zero leeching of nutrients in the growth and production of the fodder, unlike traditional feed supplement crops. Thus, nutrient use is significantly more efficient.

One negative impact associated with hydroponic fodder production is energy use. The climate control systems employed in fodder sheds use significant amounts of energy. This energy demand is increased markedly in the more challenging farming environments where fodder can provide benefits. The pumps associated with delivery of nutrient solution to the trays also have an energy demand.

### 3.3 Hydroponic Fodder Attribute Analysis

To compare the relative economic viability of fodder it is necessary to consider its nutritional attributes to analyse its value as a feed source for livestock.

The table below presents nutrient analyses for a range of feed types, including hydroponic fodder.

<table>
<thead>
<tr>
<th>Feed</th>
<th>Dry Matter (%)</th>
<th>Metabolisable Energy (MJME/kg DM)</th>
<th>Crude Protein (CP%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barley Grain</td>
<td>88</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Oats</td>
<td>91</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Barley Straw</td>
<td>89</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Pasture Silage</td>
<td>43</td>
<td>9</td>
<td>14</td>
</tr>
<tr>
<td>Pasture Hay</td>
<td>86</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Triticale Silage</td>
<td>42</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td><strong>Barley Fodder</strong></td>
<td><strong>9.9</strong></td>
<td><strong>11</strong></td>
<td><strong>24</strong></td>
</tr>
</tbody>
</table>

Source: Hinton (2007)

The following sections look at the major nutritional factors to be considered.

#### 3.3.1 Yield

There are a wide range of claims regarding to the productive yield of hydroponic fodder systems. These range from 6 to 10 times the weight of green fodder harvested relative to the weight of grain sown (Sneath and McIntosh, 2003).

The wet yield, while interesting, does not provide an accurate measure of the feed value of the fodder. To get an accurate understanding, there is a need to calculate the dry matter yield. The yield, on a Dry Matter (DM) basis, is dependant on the weight of sprouts grown from a given weight of grain and the DM% of the sprouts (Sneath and McIntosh, 2003).
An analysis completed on hydroponic fodder from a shed operated in the MacKenzie Basin showed a dry matter content of 9.9%. This means that for every tonne of fodder produced, there is 99kg of dry matter. Assuming a generous yield of eight times the weight of grain, this 1 tonne of green fodder would require 125kg of barley grain. Assuming the grain is 90% DM, this equates to an input of 112.5kg DM, for an output of 99kg DM. This is a loss of 12% of original DM weight and supports the findings of previous research. Dung et al. (2010) reported that there is no record of any cases where the DM yield of the sprouts was higher than that of the original grain.

The most positive finding is that reported by Sneath and McIntosh (2003) where they cite a study by Tudor, Smith & Shallcross (2003), which showed no change in DM from the sprouting. This study used 9kg of barley grain which produced 71.5 kg of sprouts in 6 days. With barley grain having a dry matter of 94.6% and the sprouts 11.9%, there was no change in total DM weight.

\[
\begin{align*}
9.0 \text{ kg grain} & \times 94.6\% \text{ DM} = 8.5 \text{ kg DM} \\
71.5 \text{ kg sprouts} & \times 11.9\% \text{ DM} = 8.5 \text{ kg DM}
\end{align*}
\]

The table below, from Sneath and McIntosh (2003), illustrates the effect of sprout DM and the weight of wet sprouts produced per kilogram of grain. This illustrates that to have a net gain in DM the fodder would need to have a DM% greater than 18% and a yield in excess of 9 times the input of grain.

**Table 2: Percentage DM change as influenced by sprout yield and DM, assuming the initial grain was 90% DM**

<table>
<thead>
<tr>
<th>DM%</th>
<th>Sprouts yield per unit input of grain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6</td>
</tr>
<tr>
<td>6%</td>
<td>-60%</td>
</tr>
<tr>
<td>8%</td>
<td>-47%</td>
</tr>
<tr>
<td>10%</td>
<td>-33%</td>
</tr>
<tr>
<td>12%</td>
<td>-20%</td>
</tr>
<tr>
<td>14%</td>
<td>-7%</td>
</tr>
<tr>
<td>16%</td>
<td>7%</td>
</tr>
<tr>
<td>18%</td>
<td>20%</td>
</tr>
<tr>
<td>20%</td>
<td>33%</td>
</tr>
</tbody>
</table>

The reasons for the loss in drymatter have been considered in a number of studies. The loss is likely due to the use of carbohydrates and energy within the grain for the metabolic activities of the growing plant, without any adequate replacement from photosynthesis of the young plant. Photosynthesis commences around day 5 when the chloroplasts are activated, but when harvesting a sprout at 7 or 8 days, there is not adequate time for any significant DM accumulation (Dung et al., 2010). Thus, the energy in the grain that is used for the metabolic activities is not adequately replaced through photosynthesis.

While the scientific literature shows no yield advantage in sprouting the grain versus the original grain, there are a wide range of comparisons that are made in the market for fodder production.
systems. One example is “The annual production in fresh sprouting fodder is the equivalent to the output of 120ha of grassland, all in just 130sq m” (Farmers Weekly, 2010).

3.3.2 Digestibility

Sneath and McIntosh (2003) report that there is conflicting evidence as to whether sprouting improves or reduces DM digestibility as compared to the raw grain. This comparison takes account of some basic processing of the grain. To optimise the utilisation of grains, they need to be processed e.g. rolled or cracked, to improve its digestibility. When grains are not processed, it is estimated that only 60% of the starch is digested (Sneath and McIntosh, 2003).

Dung et al. (2010) studied the in sacco digestibility of sprouted barley fodder visa vis grain. They found the loss of DM and no difference in in sacco digestibility disproved there being an advantage in sprouts rather than the original grain. They found that the initial degradation of the whole sprout was significantly higher than for cracked grain after six hours of incubation in the rumen, but from 12 – 96 hours there were no significant differences between the whole sprouts and cracked grain.

A significant difference existed in the digestibility of the shoot portion versus the root portion of the fodder. The plant shoots were easily degraded in the rumen. Dung et al. (2010) report that ruminant animals prefer diets that are leafy and non-stemmy and with leaves have a low to intermediate tensile strength. Some studies have show that a forage composition that leads to degradation to 1mm particle size encourages faster passage rate out of the rumen, leading to increased voluntary intake (Dung et al., 2010).

A study in 1992 measured the digestibility of barley grain and sprouts at differing ages. The results of this are presented below, and suggest that, other than at 4 days old, there is no real advantage in sprouting barley to improve digestibility.

<table>
<thead>
<tr>
<th>Table 3: The digestibility of barley sprouts of differing ages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Matter</td>
</tr>
<tr>
<td>Grain</td>
</tr>
<tr>
<td>4 days</td>
</tr>
<tr>
<td>6 days</td>
</tr>
<tr>
<td>8 days</td>
</tr>
</tbody>
</table>

Source: (Sneath and McIntosh, 2003)

3.3.3 Energy

While an analysis of DM provides a good indication of the ability of fodder production to produce feed, it is the detailed analysis of that feed that provides the most accurate analysis of the value of fodder relative to alternative feeds.
Processed grain (cracked) and sprouts are both highly digestible and nutritious feeds. The process of sprouting the grain turns the starch in the grain to sugars in the sprouts (Sneath and McIntosh, 2003).

Work by Dung et al. (2010) found that the energy value of the sprouts was also lower than that of the grain on a DM basis, with a gross energy loss of 2% recorded after comparing the sprouts with the original grain. In addition to this nutrient analysis, they also analysed the digestibility of the fodder versus original grain in situ. In line with the previously presented material, they found no significant difference in the digestibility and concluded loss of total DM without a significant improvement in digestibility, represents a considerable reduction in total digestible energy (Dung et al., 2010).

The energy content of fodder at a range of days post sprouting is presented below in Table 4.

A trial did find that steers did perform better than expected on a diet of sprouts and hay. In this work Tudor et al. (2003) questioned if sprouts may actually have a higher ME than measured by current testing methods. To date, there have been no further studies that have found similar results.

### 3.3.4 Protein

Protein is a critical element for animal growth and performance and is very important in analysing the feed value of fodder. The effect of sprouting on protein content isn’t clear, with some studies illustrating increases in protein, and others decreases in protein.

In one of the latest fodder studies, Dung et al. (2010) found crude protein, ash and all other minerals except potassium were higher in concentration on a DM basis in the sprouts than in the barley grain (Dung et al., 2010). This illustrates an advantage to the fodder.

Sneath and McIntosh (2003) propose that this is only an apparent increase in protein though and not a true increase. Their reasons for this are that the increase in protein is due to a decrease in dry weight through respiration during germination. This is only part of it though, with Morgan, Hunter & O’Haire (2002) stating that the increases in protein are “due partly to the absorption of nitrogen from the nutrients solution and to the concentration of nitrogenous compounds in a reduced mass of DM.”

Table 4 below presents an analysis of fodder of differing maturity, sourced from a fodder shed located in the Mackenzie Basin. This supports the findings above, with a decrease in MJ ME/kg DM in the fodder than the grain.
Table 4: Dry matter, ash and crude protein contents of 6, 8 and 10-day old barley grass mats

<table>
<thead>
<tr>
<th></th>
<th>Dry Matter (%)</th>
<th>Ash (g/kg DM)</th>
<th>Crude Protein (% DM)</th>
<th>Energy (MJ ME/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original grain</td>
<td>90</td>
<td>21</td>
<td>10.1</td>
<td>12.5</td>
</tr>
<tr>
<td>6 Day Fodder</td>
<td>21.4</td>
<td>28</td>
<td>13.8</td>
<td>13.7</td>
</tr>
<tr>
<td>8 Day Fodder</td>
<td>9.9</td>
<td>63</td>
<td>23.1</td>
<td>12.0</td>
</tr>
<tr>
<td>10 Day Fodder</td>
<td>9.1</td>
<td>68</td>
<td>24.3</td>
<td>11.4</td>
</tr>
</tbody>
</table>

The findings from this analysis above differed slightly from that presented in the literature, as shown in Table 5 below. Of significant interest is the considerable increase in protein, relative to that in the literature (24.3% DM vs 14.9% DM). The reason for this difference is unknown, but some increase in protein may be due to the content of the nutrient solution. This is an area that should be investigated further.

Sneath and McIntosh (2003) report that approximately half of the increase in percentage crude protein on a DM basis is due to a reduction in DM. This reduction in DM concentrates the weight of protein present, and thus falsely inflates any increase in protein content.

Table 5: Dry matter, ash and crude protein contents of seed and 4, 6 and 8-day old barley grass mats

<table>
<thead>
<tr>
<th></th>
<th>Dry Matter (% of input)</th>
<th>Ash (g/kg DM)</th>
<th>Crude Protein (% DM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original Seed</td>
<td>100</td>
<td>21</td>
<td>10.1</td>
</tr>
<tr>
<td>4 Day Old Fodder</td>
<td>96</td>
<td>22</td>
<td>10.8</td>
</tr>
<tr>
<td>6 Day Old Fodder</td>
<td>91</td>
<td>31</td>
<td>13.7</td>
</tr>
<tr>
<td>8 Day Old Fodder</td>
<td>84</td>
<td>53</td>
<td>14.9</td>
</tr>
</tbody>
</table>

Source: Morgan et al. (1992)

3.3.5 Vitamins

The vitamin content is generally improved by sprouting. This may make little difference to the feed value though, with Sneath and McIntosh (2003), reporting that the increases in individual vitamins are so small that its practical significance in meeting the nutritional requirements of cereal-based diets is difficult to evaluate in feeding trials.

The table below displays the quantitative changes in vitamin content of barley grain and 6 day old fodder. It is clearly evident that there is a significant increase in Vitamin content, but the value of that increase is not clear.

Table 6: Vitamin analysis of grain and 6 day old fodder

<table>
<thead>
<tr>
<th></th>
<th>Grain</th>
<th>Barley Fodder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin E</td>
<td>7.4</td>
<td>62.4</td>
</tr>
<tr>
<td>Beta – carotene</td>
<td>4.1</td>
<td>42.7</td>
</tr>
<tr>
<td>Biotin</td>
<td>0.16</td>
<td>1.15</td>
</tr>
<tr>
<td>Free Folic Acid</td>
<td>0.12</td>
<td>1.05</td>
</tr>
</tbody>
</table>

Source: Cuddeford (1989)
4. Animal Performance on Hydroponic Fodder

A wide range of trials to assess livestock performance on spouts have been conducted globally. These have included the performance of dairy cattle, beef cattle, pigs and poultry (Sneath and McIntosh, 2003).

In their comprehensive review of hydroponic fodder in relation to beef cattle, Sneath and McIntosh (2003) reported “Most of the trials on livestock performance from hydroponic sprouts show no advantage to including them in the diet, especially when it replaces highly nutritious feeds such as grain. From a theoretical perspective, performance improvements occur if the supplement supplies the primary limiting nutrient(s) or improve feed use efficiency such as the situation that Tudor et al. (2003) experienced with steers on protein deficient hay”.

Early research showed an increase in animal performance on fodder, which they put down to a grass juice factor (Kohler, Elvehjem, & Hart, 1938). This is supported by Finney (1982), who showed that hydroponic sprouts are a good source of nutrients contains a grass juice factor that leads to improved animal performance.

In contrast, some research has also shown that there is no improvement in animal performance with the feeding of hydroponic sprouts (Myers, 1974). In this case, when also coupled with DM losses, there is in fact a significant cost to feeding fodder relative to un-sprouted grain.

In a trial looking at the performance of feedlot calves fed on fodder, Fazaeli et al. (2011) found no significant difference in liveweight gain or feed conversion efficiency between a fodder diet and a control diet, consisting of barley grain. They concluded, given the costs associated with sprouting the grain and DM losses, that feeding hydroponic barley fodder to feedlot calves is not recommended. Tudor et al. (2003) have found that steers supplemented with hydroponic barley sprouts performed higher than expected for a period. They used barley sprouts to supplement steers on low protein hay. They found that steers fed on a restricted hay diet with 1.8 kg DM of barley sprouts over 48 days gained 1kg/head/day of liveweight gain and a 5:1 feed conversion ration. The same cattle fed for an additional 22 days given 1.5 kg DM of barley sprouts and ad lib hay gained 0.41 kg/head/day and a 22.8:1 feed conversion ration. They concluded that further work was required to better evaluate the performance potential of sprouts and the reasons for the response.

Mincera et al. (2009) conducted a trial in which they fed lactating Comisana sheep on hydroponically germinated oats. They found that the integration of hydroponic oats into the sheep diet did not modify the biochemical and haematological parameters, but did seem to produce an improvement in animal welfare and milk production. Marisco et al. (2009) completed a parallel study with goats. They also found no change in biochemical and haematological profiles. Unlike the sheep trial, they did not find any change in milk yield between those fed on hydroponic sprouts and those fed on traditional diets.

The findings of this review of animal performance are perplexing, with some showing positive results and others negative results or no results. For an accurate assessment to be made as to the potential value or animal response to fodder, a trial should be conducted on that specific species under the conditions that the fodder may be used. This should be compared with a control of the alternative
feeding regime in that system. This would provide a clear understanding of the animal response to
the feeding of fodder to be developed and if hydroponic fodder is an economic supplement feed
within that system.

5. **Economics of Hydroponic Fodder**

To adequately analyse the economics of hydroponic fodder production there is a need to place
fodder on an even comparison level to alternative supplements and feed stuffs.

In their comprehensive review of hydroponic fodder production for beef cattle, Sneath and
McIntosh (2003) analysed the value of fodder on a dry matter, energy and protein basis. Their
analysis has been adapted in this section to provide increased relevance to New Zealand pastoral
system.

5.1 **Dry Matter**

The analysis below, adapted from Sneath and McIntosh (2003), includes the predicted production of
a fodder shed and all associated costs, including interest and depreciation. This assumes an 8 fold
yield of fodder sprouts from an input of 100kg of barley grain.

<table>
<thead>
<tr>
<th>Put in Grain</th>
<th>X 8 yield increase in 6-8 days</th>
<th>Get out Sprouts</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 kg 'as fed'</td>
<td>800 kg 'as fed'</td>
<td></td>
</tr>
<tr>
<td>90 % DM</td>
<td>10% DM</td>
<td></td>
</tr>
<tr>
<td>10 kg water</td>
<td>720 kg water</td>
<td></td>
</tr>
<tr>
<td>90 kg DM</td>
<td>80 kg DM</td>
<td></td>
</tr>
</tbody>
</table>

**Daily input costs**

<table>
<thead>
<tr>
<th>Cost</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2.80</td>
<td>Nutrient</td>
</tr>
<tr>
<td>$0.85</td>
<td>Pump</td>
</tr>
<tr>
<td>$0.25</td>
<td>Cooler</td>
</tr>
<tr>
<td>$1.10</td>
<td>Gas heating</td>
</tr>
<tr>
<td>$40.00</td>
<td>Grain ($400/t)</td>
</tr>
<tr>
<td>$30.00</td>
<td>Labour</td>
</tr>
<tr>
<td>$41.10</td>
<td>Depreciation</td>
</tr>
<tr>
<td>$28.76</td>
<td>Interest</td>
</tr>
<tr>
<td>$144.86</td>
<td>Total Daily Cost</td>
</tr>
</tbody>
</table>

Cost/tonne on a dry matter basis = $144.86 per 80 kg DM = $1810.75 /t DM
Cost/tonne on an ‘as fed’ basis = $144.86 per 800kg wet = $181.08 /t ‘as fed’
This shows that the barley fodder costs in excess of four times the cost of the barley grain. The barley grain costs $444 per t DM, whereby the barley fodder costs $1,807. It should be noted that this analysis is solely based on the feeds on a DM basis and doesn’t take account of any animal performance differences.

### 5.2 Energy (MJ ME)

The energy of the product, in mega joules of metabolisable energy (MJME), is another factor that should be taken into account. The analysis below is also adapted from Sneath and McIntosh (2003).

<table>
<thead>
<tr>
<th>Grain In</th>
<th>Fodder Out</th>
<th>Cost Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>S/t DM</td>
<td>$444</td>
<td>$1,807</td>
</tr>
<tr>
<td>Energy MJ ME/kg DM</td>
<td>11.8</td>
<td>12</td>
</tr>
<tr>
<td>= cents/MJ ME</td>
<td>3.8</td>
<td>15.1</td>
</tr>
</tbody>
</table>

This analysis shows, that although there is a minor improvement in MJ ME/kg DM with the fodder, that is outweighed by the cost per kg DM, and thus hydroponic fodder is an expensive source of energy relative to the barley itself.

In looking at this, an earlier point should be noted. When grains are not processed (i.e. rolled or cracked), it is estimated that only 60% of the starch is digested (Sneath and McIntosh, 2003). Thus, fodder could be more economical relative to grain in the case where grain isn’t processed and this wastage due to poor digestibility is taken account of in the analysis.

### 5.3 Crude Protein Cost

The relative cost of the protein within the fodder is another important factor for consideration.

The analysis below in Table 9 shows that the crude protein within the fodder is relatively cheaper than the other factors analysed and presented here. This is largely a result of the significant improvement in crude protein content in the fodder relative to the grain.

<table>
<thead>
<tr>
<th>Grain In</th>
<th>Fodder Out</th>
<th>Cost Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>S/t DM</td>
<td>$444</td>
<td>$1,807</td>
</tr>
<tr>
<td>Crude Protein CP% DM</td>
<td>11</td>
<td>23.1</td>
</tr>
<tr>
<td>= $/kg CP DM</td>
<td>$4.04</td>
<td>$7.82</td>
</tr>
</tbody>
</table>
6. Potential for Hydroponic Fodder in New Zealand

Hydroponic fodder has gained a significant following overseas due to the ability of hydroponic fodder production systems to deliver a known quantity of green feed every day, no matter how dry, how wet, or how cold the season. From a high level this seems like a logical assessment to make, although digging into the data and scientific analysis that has been completed makes this a questionable judgement, based on feed production (on a DM basis), animal performance, and the economics of growing and feeding hydroponic fodder.

The key sectors that may be suited to the use of hydroponic fodder as a supplement include dairy, fine wool, lamb finishing, and beef cattle finishing systems.

The practical utilisation of hydroponic fodder as a feed stuff is also influenced by the volume of fodder a given class of livestock would need to consume. This will also determine the number of animals that a given fodder shed can support.

The table below, given the nutrient content of hydroponic barley fodder, presents the volume, both wet, and dry, that a given class of stock would need to consume. Fodder is 10% DM with an energy content of 12 MJME/kg DM.

<table>
<thead>
<tr>
<th>Table 10: Daily fodder supplementation requirements for livestock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fodder % of Diet</td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td>Lamb – 30kg growing 200g/day</td>
</tr>
<tr>
<td>Merino hoggets – 30kg growing 100g/day</td>
</tr>
<tr>
<td>Bull – 400kg growing 1.5kg/day</td>
</tr>
<tr>
<td>Dairy Cow – early lactation</td>
</tr>
</tbody>
</table>

It is clear to see that considerable volumes of wet fodder would need to be consumed to meet the energy needs of the livestock at the given levels of supplementation.

A number of the fodder shed manufacturers recommend sheep are supplemented with fodder at the level of 2% of their body weight as wet weight of fodder. Thus, a 60kg ewe should be fed 1.2 kg of wet fodder – at an energy requirement at maintenance of 10 MJ ME/day, this fodder would represent 14.4% of the ewes energy requirement.

Given the above calculations, a 1 tonne fodder shed could support 833 ewes fed at 2% of their body weight, or 252 merino hoggets that have 50% of their diet supplemented with fodder.

Another challenge for fodder production is the labour requirement. With most sheds taking between 2 – 4 hours per day, 7 days per week, to keep operational, this labour requirement would be a major consideration for farmers looking into fodder production. For the work and costs involved in fodder production, relatively small numbers of livestock can be supported.

While a significant amount of work has gone into the analysis of the production of hydroponic fodder, its nutritional value and the economics of its production, little to no work has looked at the
attributes of the final product produced by animals fed fodder. This is an area where there may be potential for fodder to deliver value, provided the attributes of the final product, for example lamb, were such that it generated a premium within the market. This would need to be associated with an appropriate branding strategy to extract any premiums from the market.

7. Conclusion

Hydroponic fodder production systems produce large quantities of green, palatable livestock feed. However, the research reviewed and analysis undertaken in this report indicates that there are challenges associated with the production and economic competitiveness of hydroponic fodder relative to alternative feed sources.

The costs associated with the establishment and daily operation of a fodder shed, coupled with drymatter yield losses during the sprouting make hydroponic fodder an expensive feed source. This, coupled with a lack of concrete evidence around animal performance on hydroponic fodder will limit the adoption of hydroponic fodder production systems.

There is an opportunity for some research to be undertaken to examine the performance of livestock on hydroponic fodder and the attributes of the final product. The production of a product with superior attributes that could generate significant premiums in top level markets may go some way in making hydroponic fodder an economic feed. This would have to be accompanied by a positive production response in the given class of livestock also.
References


