Should New Zealand be trading maize forage on quality parameters?

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Executive Summary

Maize forage is essential to the productivity of the New Zealand dairy sector. It is easily ensiled and provides energy and fibre, which is essential to balance a pasture-based diet. An estimated 1,164,000 tonnes of maize forage was harvested in 2021. In the 2020/2021 season 24,500 hectares, or 45% of total maize forage planted, was grown off-farm and sold to a purchaser via a contract (Arable Industry Marketing Initiative, 2021a). Current contracts trade maize forage on dry weight and neglect most facets of forage quality, so the purchaser is unaware of the quality of the product they are receiving. Per cow consumption of maize silage is increasing, so the quality of maize forage becomes more influential and important to the purchaser. This report seeks to quantify the variation in maize forage quality in New Zealand and how the grower can influence it to enable trading maize forage on quality parameters.

Key findings:

- Growers can positively influence maize forage quality but are not rewarded by the purchaser, so it is not the priority in their decision-making.
- Starch is the critical influencer of maize forage quality.
- There is significant variation in maize forage quality in New Zealand. Starch content has been seen to range from 15 – 40%DM[1], neutral detergent fibre from 33.4 – 50%DM and metabolisable energy from 9.5 – 11.3 MJME/kg DM[2]. This variation creates significant differences in production potential for the purchaser.
- Maize forage quality can be influenced by hybrid choice, agronomic management, and the environment. The environment cannot be controlled, so strategies that create resilience in the growing system are essential.
- There is limited New Zealand-based data available for growers and advisors on how to influence maize forage quality.
- The common method of sampling maize forage for analysis is unlikely to cope with paddock variation, caused by a changing climate and variable soil types.

Recommendations:

- Research and provide educative resources on how agronomic decisions affect maize forage quality. This should be conducted by maize seed wholesalers and independent industry bodies, such as the Foundation for Arable Research (FAR).
- Create independent data comparing all commercially available maize hybrids for forage quality. This should be conducted by an independent industry body such as FAR or DairyNZ.
- Calibrate and certify the use of near-infrared spectrometry (NIR) in forage harvesters as an accurate measure of whole plant dry matter and quality parameters. Allow open entry to promote competition and innovation. This will need to be proven by the manufacturers and forage contracts amended by the Forage Trading Development Group.
- Create educative resources to extend the understanding of growers and purchasers on the accuracy of NIR technology as an assessment of quality parameters. This should be an industry approach, including DairyNZ, Federated Farmers, Contractors Association, FAR and the Forage Trading Development Group.

[1] % of dry matter
[2] Megajoules of metabolisable energy per kilogram of dry matter

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1.0 Introduction

Maize forage[3] is an integral part of the dairy industry in New Zealand. It is a high-yielding and high-energy crop that can be ensiled to create maize silage, which allows dairy farmers to maximise milk production through the season. The use of maize silage has increased over the past two decades. The average per cow consumption of maize silage has increased from 160kgDM[4]/cow/year in 2012 to 250kgDM/cow/year in 2021. In some cases, this is as high as 2000kg/cow/year. In the 2020/2021 season, 55,000 hectares of maize forage was harvested, which is up from an average of 48,400 hectares in the previous ten seasons (Arable Industry Marketing Initiative, 2021b; DairyNZ Limited & Livestock Improvement Corporation Limited, 2021).

Maize forage is often grown on-farm, but 24,500 hectares was grown off-farm and sold on contract in 2021 (Arable Industry Marketing Initiative, 2021a). With increasing imported feed costs and already high stocking rates making growing more area on farm difficult, the area of contract-grown maize forage could also see growth (DairyNZ Limited & Livestock Improvement Corporation Limited, 2021).

Most contract maize forage is sold to the purchaser on dry matter weight. There is little or no consideration of the quality, and the purchaser will have no indication of the quality of the delivered product. Most contracts will only discuss the requirement to ensure the forage is free of noxious weeds or chemical residues (Genetic Technologies Limited, 2019). Research shows that there is considerable variation in maize forage quality, with lower quality maize forage restricting milk production for the purchaser (Kolver et al., 2001). The variability in maize forage quality will become more significant with the impact of changing weather patterns.

Although increasing yields currently provides the greatest return for the grower, an increase in forage quality produces more milk revenue for the purchaser. A change in maize hybrid can increase milk revenue for the purchaser by $34 per tonne of maize forage (Kolver et al., 2003.). An increase in milk production of 6 – 12g milk solids per increase in MJME[5] can also be achieved (DairyNZ Limited, n.d.; Densley et. al, 2001). As maize silage consumption increases, the importance and impact of maize forage quality on milk yield will be critical. The issue is the grower can positively influence maize forage quality but is not rewarded for it, so it is not the priority in their decision-making.

This report seeks to understand the opportunity to promote the trading of maize forage on quality parameters rather than the current practice of just yield. It will investigate why the current maize forage trading model is used, what defines quality maize forage and if there is variation in quality within New Zealand. Lastly, the project will consider if maize forage quality parameters can be consistently influenced in the paddock and what market opportunities are available to trade maize forage on these parameters.

[3] Because the focus of this report is on selling maize as a standing crop rather than an ensiled product, the term maize forage will be widely used. Maize forage encompasses fresh material up to the point of harvest (Forage Trading Development Group, 2007), whereas maize silage references the finished product - maize forage that has been cut, stacked, and ensiled (DairyNZ Limited, 2022). When contracting maize forage, the grower is responsible for growing the forage, and the purchaser must harvest the forage and turn it into maize silage

[4] Kilograms of dry matter

[5] Megajoule of metabolisable energy

2.0 Aims and Objectives

This project aims to:

- Evaluate the opportunity to trade maize forage on quality parameters in New Zealand

The objectives of this project are to:

- Analyse the current maize forage trading model
- Classify what determines the quality of maize forage
- Measure maize forage quality in New Zealand and its variation
- Quantify how maize forage quality can be influenced
- Evaluate the current restrictions on trading maize forage on quality
- Propose pricing options for trading maize forage on quality parameters

3.0 Methodology

3.1 Literature Review

The main method of research was a literature review of available material on the feed value of maize forage and how maize forage quality can be influenced. The focus was to use New Zealand material, but international material was also used where required. Images and data not sourced to others are those of the author.

Initially outlining the current maize forage trading model is important as it provides context to why trading on quality parameters is possible. From there, defining maize forage quality is vital to allow us to select and measure the correct variables. The overall purpose was to then understand if there was variation in forage quality in New Zealand and to critically evaluate if this variation could be controlled and adjusted to enable growers to create forage to specification. It also sought to understand if there was quantitative and qualitative information readily available to help growers understand how to influence forage quality. To trade maize forage on quality parameters, understanding the cause and effect of agronomic strategies is paramount.

3.2 Semi-Structured Interviews

Semi-structured interviews with industry professionals and farmers that are involved with growing and purchasing maize forage were also used. Ten interviews were undertaken, with key themes derived using thematic analysis. The purpose was to help discover similarities or contrasting opinions to the literature review. Also, to delve deeper into restrictions hindering trading maize forage on quality parameters and how these could be overcome.

4.0 Literature Review

4.1 What does the current maize forage trading contract entail?

The trading of maize forage has continued to evolve over the last 25 years. During its inception, maize forage was traded on a per hectare basis. The purchaser and grower mutually agreed on a price per hectare for the forage. The yield was assumed and quality was not a factor. Although simple, either the grower or the purchaser would have missed out, but neither knew as there was no measurement.

Private businesses were set up to take fresh cuts of forage pre-harvest to determine yield, on which payment could be based. Although an improvement, crop variability and sample size meant that accuracy was not high. The Fair Trading Act (1986) criticised the robustness of the model, so the Forage Trading Development Group was developed to define the protocol to trade forage.

Most maize forage is now traded on cents per kilogram of dry matter (c/kgDM). The vehicles transporting the maize forage are weighed on certified scales to determine the wet weight of the harvested crop. Representative samples are taken from the transporting vehicles or the stack, and these are assessed to determine the dry matter. The total wet tonnage is multiplied by the dry matter percentage, with the resulting dry matter tonnage being what the grower is paid for (Forage Trading Development Group, 2007). There is limited reference to forage quality parameter requirements. Most reference is around ensuring the crop is free of toxic weeds and residual chemicals (Genetic Technologies Limited, 2019). A purchaser will therefore pay the same price for high-quality forage or poor-quality forage without knowing it.

A contract between a grower and purchaser is agreed and signed before harvest to allow the farmer to secure feed at a fixed price. This also ensures that the purchasers are covered by The Fair Trading Act (1986) and The Sales of Goods Act (1908) should any issues arise. Contracts can also be negotiated on the spot market when extra feed is required. These decisions are quick, requesting a tonnage and negotiating a price. Often the purchaser will not be aware of the location or quality of the crop. It is up to the goodwill of the contractor to provide something that is deemed as decent quality, even though there is no baseline for this. Quality is up to their interpretation, and many have a different perception of what that looks like.

On appraisal, the current contract benefits the grower as there is only one variable to control. Yield is a simple factor to influence with data available about economic returns from inputs. Although there are seasonal variations, long-term averages give surety around budgeting and income. The current contract also benefits the purchaser in that maize of generic quality is easy to source. Anyone can produce maize and the purchaser only pays for the yield they receive, so all risk is out of their hands. The downside for the grower is that they are not rewarded for producing high-quality forage, a product that will provide their purchaser with greater returns. Furthermore, the most prominent issue is that the purchaser's requirement for high-quality maize forage is not reflected or prioritised in the contract, so they enter a lottery for what product they will receive. Because the grower's income is focused on bulk yield, decisions may be made that jeopardise the quality of the maize forage.

4.2 What defines maize forage quality?

For most supplementary feeds in New Zealand, the variables of dry matter, metabolisable energy and crude protein are important. These factors are also important for determining maize forage quality. However, as the primary use of maize silage in New Zealand dairy systems is as a source of energy, starch content is the most crucial parameter (Kolver et al., 2001). Energy is the key nutritional component that influences milk production from maize forage, which can be influenced by lifting starch content (Densley et al., 2004).

There are two components of a maize plant. The grain and the stover. The stover consists of all other plant materials such as the stalk, leaves, centre of the cob and the leafy husk (Corson Maize, n.d.). The stover contains no starch and has low energy and low water-soluble carbohydrates. Because it is low quality, the stover's sole purpose is to provide fibre to the diet of ruminant animals. The maize grain influences the overall quality of maize forage, as it is high in starch and has low fibre, creating an energy-dense product. Therefore, a higher grain to stover ratio creates a higher quality maize product.

Schwaller (2018) also agreed that starch is the primary requirement for quality maize forage. It provides 1.5 times more energy than the stover of the plant. Densley et al. (2004) assessed the grain component as having 80% more energy than the stover. Starch influences whole plant digestibility, as starch is very digestible, which increases the overall metabolisable energy of the forage. Increases in starch and energy are therefore desired and should be a focus for growing quality maize forage (Kolver et al., 2001).

Although grain yield is key, because the stover can make up 45% - 70% of the forage, increases in stover quality through digestibility and reduction in fibre content can play a significant role. Wolf et al. (1993) and Villaver (1996) both agreed that the quality of stover is still vital for whole plant nutritional quality. Other literature agreed with the importance of stover quality but focussed on the importance of a higher grain: stover ratio. Fibre comprises both neutral detergent fibre (NDF) and acid detergent fibre (ADF), with the latter being the indigestible component of fibre. Feed with low ADF levels would indicate a high quality and highly digestible feed (Seales Winslow, n.d.).

Maize forage between 32 – 38% whole plant dry matter (WPDM) is also an essential requirement for quality. If maize forage is wetter, it will create inferior quality silage in the form of leachate and loss of valuable sugar and proteins. If the maize forage is drier than 38% WPDM, the digestibility of the stover and fibres is decreased, which results in reduced cow consumption (Corson Maize, 2022). Higher WPDM also means compaction of the stack is more complex, resulting in less stable maize silage.

Comparatively, Mahanna (2000) determined that maize forage of 28 – 35% WPDM was a target for standard quality. Ensiling forage below 30% WPDM would be difficult and result in quality losses during the ensiling process for the purchaser, so it could be considered poor-quality maize forage.

Based on the literature, the parameters listed in table 1 dictate standard maize forage quality in New Zealand.

Table 1: Target maize forage quality parameters in New Zealand. Adapted from Dairy New Zealand Limited (2021) and Genetic Technologies Limited (n.d.).

Forage Quality Parameter	Target
WPDM (%DM[6])	32 – 38
Metabolisable energy (MJME/kg DM[7])	10.5 – 11.5
Crude protein (%DM)	7 - 8
Acid detergent fibre (%DM)	25 - 35
Neutral detergent fibre (%DM)	35 – 45
Starch (%DM)	25 - 35

4.3 Is there variation in maize forage quality?

Data from Hill Laboratories (Hill Laboritories, 2022) showed a significant range in quality parameters for maize forage. When providing analysis, Hill Laboratories provide a median range of results. Any results that fall within this range are considered comparable to industry research and the average of all results gathered through their laboratory. Anything above or below this range could be considered as poor-quality or very high-quality maize forage. The median bandwidth has been depicted in table two. Significant differences across all quality parameters are shown, meaning that purchasers of maize forage are exposed to large gains and losses in milk revenue. The essential component of starch has a range of 15 – 40%DM, which is a 15% greater variation than the industry standard. Increasing forage quality from 10.5 to 11.5 MJME/kg DM has the potential to increase milk solids production by 9 – 18kgMS[8]/cow/year for a cow consuming 1500kgDM maize silage per year (DairyNZ Limited, n.d; Densley et al., 2001).

Table two also depicts six forage samples collected in the 2022 harvest season from Waikato maize forage. The results showed significant varaition in forage quality within a small pool of samples. Three samples were collected from a maize block with different forage hybrids and soil types. Three were collected from maize forage grown on-farm in three separate locations. Starch content was highly variable along with NDF. On-farm use of maize silage for the six farms where the forage was destined ranged from 450kg – 1550kgDM/cow/year. Those farms feeding higher levels of maize silage were exposed to more significant milk revenue fluctuation based on the quality of forage they purchased.

Wolf et al. (1993) also found that significant variation occurred between hybrids for stover quality. Millner et al. (2005) confirmed this with a range of stover metabolisable energy of 8.5 – 9.7 MJME/kg DM between seven different maize hybrids. Furthermore, Kolver et al. (2001) analysed 203 maize silage samples for silage quality. Although not linked to forage quality due to the ensiling process, it shows that large variability is present in maize silage, for which some of the influence can be credited to the forage supplied. Most importantly, metabolisable energy ranged from 7.5 – 13.6 MJME/kg DM, displaying a substantial variation in forage quality and milk yield potential.

[6] % of dry matter

[7] Megajoules of metabolisable energy per kilogram of dry matter

[8] Kilograms milk solids

Table 2: Variation observed in maize forage quality parameters from historical Hill Laboratories testing and on-farm case studies in the Waikato in the 2022 harvest season

Forage Quality Parameter	Hill Laboratories	Waikato 2022	Total variation
WPDM (%DM)	25 - 39	35.7 – 42.4	25 – 42.4
Metabolisable Energy (MJME/kg DM)	9.5 - 11	9.7 – 11.3	9.5 – 11.3
Crude Protein (%DM)	6 - 9	7.5 – 8.9	6 – 9
Acid Detergent Fibre (%DM)	25 - 35	20.4 – 28.1	20.4 – 35
Neutral Detergent Fibre (%DM)	35 - 50	33.4 – 44.6	33.4 – 50
Starch (%DM)	15 - 40	22.2 – 34.6	15 - 40

There is a consistent theme of variation in the literature, which has considerable implications for the purchaser. It is therefore in the purchaser's best interests to obtain higher quality maize forage. However, without testing the purchaser is not aware of what they are feeding. The publication of industry-standard targets for quality may give farmers a false perception of the extent of forage quality. On the upside, it provides a greater opportunity to create better and more consistent results. This creates opportunities for the purchaser for milk production and opportunities for the grower for revenue by creating forage to specification and seeking a premium for it.

4.4 Can maize forage quality be manipulated?

The previous section identified that variability in maize forage quality can be significant. Understanding what can cause this variability is essential so growers can adjust measures to ensure the production of high-quality maize forage. This section will focus on how growers can influence quality through the following factors that were identified and evaluated.

- Hybrid selection
- Environmental factors
- Management decisions

4.4.1 Hybrid selection

For the 2022/2023 growing season, 59 commercial maize hybrids are available from four maize wholesalers in New Zealand. There is currently no independent data or universal scale comparing these hybrids for forage quality. For example, Genetic Technologies provide a scoring system for their Pioneer hybrids for whole plant digestibility, starch, and sugar (Genetic Technologies Limited, 2022b). They provide a specific reference to the quantitative effect this has on quality when comparing one Pioneer hybrid with another when all other variables are equal. Corson Maize also provides a scoring system for forage protein, forage starch, whole plant digestibility and total energy when comparing their hybrids (Corson Maize, 2022). However, these scales cannot be used for comparison against alternative supplier scales. Genetic Technologies and Corson Maize have extensive trial programmes that focus on hybrid forage yield, with data being produced that compares competing companies' hybrids. There is no data available for comparing hybrid forage quality.

Kolver et al. (2003) state the "differences in maize hybrid quality accounted for $34 extra milk income per tonne of maize forage dry matter, whereas differences in hybrid yield had a much larger impact on milk income at $8672 per hectare maize grown." This is true from an on-farm point of view where forage yield has a considerable influence on profitability, but it negates two key points. Comparing the two variables on different metrics makes the effect of hybrid quality seem less substantial. Using an average maize forage yield of 21,000kgDM/ha[9] (Arable Industry Marketing Initiative, 2021a), maize

[9] Kilograms of dry matter per hectare

hybrid quality accounts for $714 extra milk income per hectare of maize forage grown. This is close to $8000 per hectare less than the effect hybrid yield has, but it is still profit in the pocket of the farmer by changing one factor.

Kolver et al. (2003) does state that with a 500-cow herd feeding 1250kgDM maize silage per day, because consumption is higher, the hybrid choice could influence overall profit by $21,000. The influence of maize forage quality will be more significant as usage rates increase on-farm. Some farms are feeding upwards of 1500 - 2000kgDM/cow/year. A 750-cow farm feeding 1500kgDM/cow/year of maize silage could see a return or loss of $38,250 by selecting a different maize hybrid.

It is important to consider that the difference in forage quality from hybrid choice could be more significant when selecting the hybrid most suitable for a particular farm environment (Kolver et al., 2003.). The research was also conducted in 2003. Since then, there have been increases in both forage and grain yield due to genetic gain (Genetic Technologies Limited, 2022a). Between 1930 and 2000, whole plant, stover and cob yields increased by 1.4%, 0.7% and 2.4% respectively (Lauer et al., 2001). It could be evaluated that quality between hybrids is now larger and the potential for the hybrid to influence quality is understated.

Kolver et al. (2003) also found that hybrids of long-maturity (greater than 105 days CRM[10]) have statistically less starch content than hybrids of ultrashort, short and medium maturity (<90, 90-97 and 98-105 days CRM). This is because hybrids of longer maturity have greater potential to accumulate plant height, which influences the grain: stover ratio in a less desirable way.

With forage quality being dictated by the grain: stover ratio (Kolver et. al, 2001; Corson Maize, n.d.), selecting hybrids that produce high grain yields is vital. This information is widely available through the supply of published company trial data. From 2014 to 2020, a maize hybrid evaluation trial was run by the FAR. This provided independent and replicated trial data that allowed farmers to make selections on forage and grain yield. Although this did not relate directly to forage quality, the ability to separate grain production provided material to conclude from.

In contrast, Villaver (1996) stated “the proportion of grain in the final yield was not a good indicator of forage quality.” This is contrary to what is widely published, as grain is completely digestible, which increases the overall digestibility of the crop (Lauer et al., 2001). The limitation of this report is it only covered seven hybrids with three replicates over a single growing season. It does raise that because stover makes up around 50 – 60% of the whole plant, stover digestibility still plays a significant factor in whole plant digestibility. This is more important when growers are using longer maturity hybrids, as the grain: stover ratio is typically lower. Currently, longer-maturity hybrids are used due to their higher yield potential than shorter maturity hybrids.

To support the importance of stover quality, Genetic Technologies have introduced a brown mid rib (BMR) forage hybrid to the New Zealand market. BMR is a naturally occurring variant in maize, which has lower grain yield but greater fibre digestibility. This leads to greater digestibility overall and higher feed consumption through the influence of the stover component. The introduction of BMR material is another opportunity for growers to positively influence the quality of their maize forage by hybrid selection.

[10] Comparative relative maturity

The reviewed literature has shown consensus that overall forage quality can be influenced through hybrid selection. This can be justified by all hybrids having their own genetic design. Although the effect is not significant, its importance is more relevant as consumption of maize silage increases. However, the influence of hybrids on forage quality is now understated with different genetics available. Choosing hybrids is also difficult with no independent comparative data. However, with grain yields consistently improving, the ability to influence starch levels and forage quality will be consistently achievable. A higher grain: stover ratio is the primary influencer of forage quality, but with the introduction of BMR material, there will be a focus on increasing the digestibility of the stover too.

4.4.2 Environmental factors

The impact of hybrid type on forage quality is less than the impact environment will have on parameters such as starch and digestibility (Thomas, 2017). The environment is seen to have three times the effect on fibre digestibility than hybrid selection (Pfister, 2017). Kolver et. al (2003) backed this with data showing significant changes in quality parameters of maize hybrids from the years 2000 to 2002. Starch content was statistically different and ranged from 25.5 – 34.6%DM between the three years. The timing and amount of rainfall and length and intensity of temperature have a significant impact on forage growth and the grain: stover ratio, for which most of this difference can be associated (Han et al., 2020).

Decadal variability of rainfall between November – April has increased in two Waikato locations over the past three decades, which makes rainfall unpredictable and management decisions around agronomic practices difficult. Heat stress days have followed a similar pattern of variability (Glassey et al., 2021). Kolver et al. (2001) stated that “with good management, forage quality can be very consistent.” On analysis, the greater variability of weather patterns will make forage quality more variable. Good management must progress to excellent management to ensure consistency in inconsistent environmental patterns.

Han et al. (2020) showed that a reduction in rainfall between vegetative growing stage six and tasselling, would result in reduced pollen activity, pollination rate and a reduction in the number of grains per ear and final grain yield. Therefore, selection of hybrid and planting time is important to provide the best chance of rainfall occurring at these critical stages. Growers in areas like Canterbury and Wairarapa with irrigation will have a greater opportunity to consistently influence forage quality due to managing water delivery and timing.

Environmental factors also include farm to farm differences. Densely et al. (2003) showed that within the same season, there were significant differences in quality parameters of maize forage from the same hybrids collected from various locations. Soil types vary from farm to farm and within a farm, and these soils have variations in water holding capacity. Ensuring that moisture is not limiting during reproductive stages is important to assist kernel and starch development (Ferreira & Brown, 2016). Maize grown on soils with lower water holding capacity and less predictable rainfall during reproductive stages are more likely to have issues maintaining consistent starch production. Below (n.d.) has shown that environmental factors have the most considerable impact on grain yield, with the potential to diminish grain yield by 4,400kg/ha.

It is clear to see that environmental challenges will have a significant impact on maize forage quality, more so than hybrid choice. Current data shows that there is rainfall and temperature variability in some areas of New Zealand (Glassey et al., 2021). Because environmental pressures are primarily out of the grower’s control, the environmental effect is harder to measure consistently. The ability to consistently influence quality will become more difficult. Management strategies to create resilience in the growing system will be paramount to minimise the risk and variation experienced each season.

4.4.3 Management decisions

The most significant management influence on forage quality is the timing of harvest. Current practice recommends harvesting maize forage between 32 – 38% WPDM. Most literature states that forage quality and milk yield potential are greatest when maize forage is harvested between 35-38% WPDM (Kolver et. al, 2001; Kolver et. al, 2003; Bal et. al, 1997). There is a direct correlation between WPDM and starch content. As WPDM increases, fibre digestibility decreases slightly, but this is outweighed by the dilution from the production of high-energy starch. Bal et al. (1997) shows in table three the effect WPDM has on starch and the energy of maize forage.

Table 3: Effect of WPDM on starch and energy in maize forage (Bal et. al. 1997).

WPDM (%)	31	32	35	42
Starch (%DM)	18.2	28.7	37.2	37.4
Energy (MJME/kg DM)	9.2	10.1	10.6	10.5

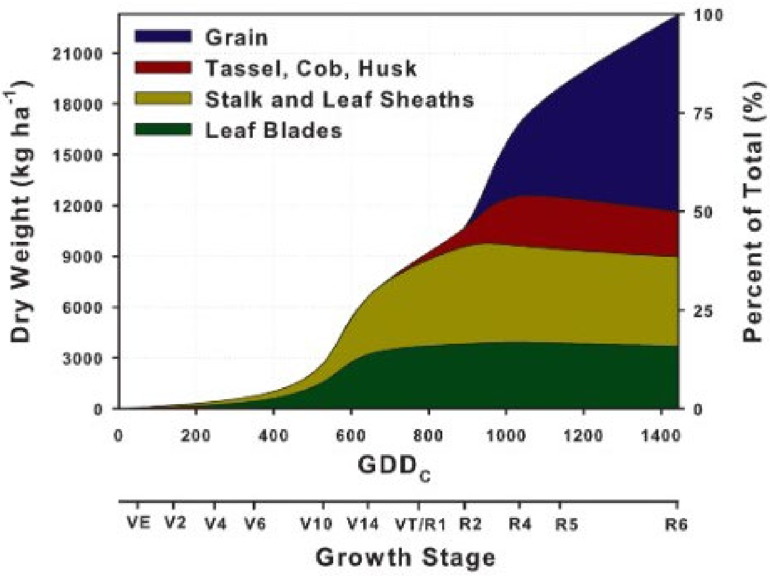

Figure 1: Dry weight partitioning of maize forage at different growth stages (Bender, Haegele, Ruffo, & Below, 2013)

This correlation is seen as the dry matter is solely partitioned towards grain after it has reached the reproductive stage of growth, which begins at tassling/ reproductive growth stage 1 (VT/R1) as shown in figure 1 (Bender et al., 2013). The rate of WPDM accumulation between 30% and 35% can average 150kg/ha/day. Assuming 0.4% WPDM accumulation per day, there is the potential to produce another 1,875kg/ha of grain during this period. Because no other components of the plant are accumulating yield, the delay of the harvest to between 30% and 38% WPDM will have a significant impact on the grain: stover ratio, total grain yield and starch content, and therefore overall forage quality.

However, overall digestibility can dramatically decline once WPDM goes above 40%. This has implications for creating quality silage due to poor compaction and fermentation in the stack. With WPDM typically increasing by 0.4 - 0.5% per day closer to harvest (Genetic Technologies Limited, 2019), and more in dry conditions, this has implications for ensuring harvest machinery is on time. Assessing WPDM in the paddock is done by eye, so human error is possible. If the contractor is delayed and the assessor has made an error in judgement, the potential for maize forage to go above the optimum WPDM is high. Industry-standard targets for WPDM are likely set between 32 – 38% to give the contractor a greater chance of harvesting at the correct time.

It could be argued that delaying harvest to between 35-38% WPDM is not the greatest benefit to forage quality. There can be occasions where full starch accumulation occurs before 35% WPDM. Delaying harvest would result in greater accumulation of fibre and lignin and a reduction in overall digestibility. Therefore, reference to forage quality could be stated as 'maximum forage quality is achieved when starch accumulation is greatest, and the plant is between 30 – 38% WPDM.'

A mechanical option to manipulate the quality of starch content per kilogram of maize forage is by adjusting the cutting height at harvest time. Because maize forage is traded on yield, efforts are made to remove all material from the paddock. The bottom stem is extremely low in starch but high in lignin and fibre, which provides it with the structure to stay standing. From 216 samples, increasing the cutting height from 100mm to 300mm increased the dry matter content of the forage by 1.5% and MJME/kg DM from 10.80 to 10.95 respectively. Increasing the cutting height from 100mm to 600mm increased the dry matter of the forage by 3.43% and MJME/kg DM from 10.80 to 11.21 respectively (Densley et al., 2001). This would have implications for the grower on how to deal with the material that is left behind and would result in higher dry matter forage, which may have implications when ensiling the forage.

Most New Zealand literature focuses on agronomic management strategies to influence the total yield of maize forage, such as planting populations, fertiliser inputs and input timings. There is less information published on how forage quality can be influenced through agronomic management compared to forage yield. Amongst the literature, there are varying views on the effect planting populations has on forage quality. Densley et al. (2003) showed that there was no significant effect on forage quality parameters by adjusting the planting population, besides a reduction in protein when increasing population. Ferreira et al. (2020) also showed planting population did not influence starch and sugar content but opposed Densley et al. (2003) findings with a change in NDF and ADF from the planting population. George and Fletcher (2009) also found that increasing plant population did not influence the proportion of grain in harvested forage.

Of importance though is that these recommendations are based on a single prescription. Variable rainfall and temperature have resulted in us seeing variability of yield and quality within a paddock of maize forage (Glassey et. al, 2021; Holmes, 2019). Maize seed wholesalers provide recommended planting populations for what can be considered as low, medium, and high yield environments. Generic recommendations may not achieve the maximum quality potential, as low yield potential areas within a paddock will not sustain planting populations based on the assumption the whole paddock has high yield potential. Variable-rate seeding would allow planting populations to change through the paddock based on yield expectations from previous seasons. A lower population in low yield expectations areas can positively influence the grain: stover ratio, therefore positively influencing the overall quality of the maize forage (Holmes, 2019).

Literature that is available also focuses on the effect management strategies have on total quality parameters per hectare of forage, rather than per kilogram of forage. Defining this is essential because to maximise forage quality, contract growers need to focus on influencing starch content per kilogram of forage rather than total starch per hectare.

> "Lower plant densities might produce a higher biomass per plant, but because of the reduced number of plants per unit area, the yield per unit land can be reduced *(Han et al., 2020)*"

On analysis of the comment from Han et al. (2020), a reduction of yield per unit land, in this case yield of starch per hectare, is perceived as bad. Although true in a total yield situation, when influencing quality of forage, we are focused on the starch per plant ratio or starch per unit land ratio. A mind set shift is required. A higher total starch weight per hectare will not always result in higher quality forage, as stover content could be higher too and dilute the starch gain. Increasing total starch per unit of land is still a focus and benefit if it does not negatively influence starch ratio per unit of land. Therefore, where literature states that a higher planting population will result in higher starch per hectare due to a greater number of plants and cobs, this does not always result in a greater content of starch per kilogram of forage.

On evaluation, there is an abundance of opportunities to influence maize forage quality through management decisions. Undoubtedly, influencing the time of harvest is the most practical and simple step for growers to positively influence maize forage quality for their purchaser. Of concern is the lack of statistical information available to growers and advisors on the size of the impact from these decisions. This makes selecting the opportunity with the greatest return difficult for the grower.

5.0 Semi-Structured Interviews

The overarching theme from the interviews was the importance of maize forage quality has been understated and is now more critical as maize silage consumption increases on-farm. Key topics around its importance were discussed to match the material found in the literature and their themes are analysed below.

5.1 What defines maize forage quality?

Those in the maize industry agree that grain is the significant influencer of maize forage quality. This determines milk yield as the grain content influences starch, digestibility and metabolisable energy of the final product. Some put extra emphasis on the importance of stover quality, but all saw its importance in overall forage quality.

Farmers who use high levels of maize forage have a better understanding of the importance of individual quality parameters, such as starch and fibre digestibility. It would be important to ensure consistency of knowledge transfer between low and high maize forage users, so everyone understands the important variables to look for.

With the consistency of messaging between the literature and first-hand experiences, there is a high level of confidence that starch is the biggest influencer in maize forage quality. Although stover quality still has a place, New Zealand’s dairy systems are deficient in energy and therefore require this to be supplemented through maize forage. On evaluation, the primary focus should be on increasing the grain: stover ratio to the greatest extent.

5.2 Is there variation in maize forage quality?

Both forms of research stated significant variation in maize forage quality. Industry professionals are involved with monitoring forage at the time of harvest, so they see a range of samples. This also gives them a greater ability to understand the cause and effect of influences on forage quality than an individual farmer who grows one crop per year.

Farmers also understand there is a variation in forage quality but to a lesser extent. Because maize forage is purchased and many do not visit the crop before harvest, their perception of forage quality is based on the colour of the delivered forage. When analysing this against literature, this is deceiving as it is not an accurate indicator of forage quality and milk yield potential. The purchasers are not informed of what they are purchasing, reducing the ability to increase milk production. It is important to address this to improve the purchaser's farm performance and whole industry performance.

Kolver et. al (2001) stated that maize forage can be consistent in quality. This is true in cases where environmental impacts and soil type variations are less extreme, as growers see issues with non-consistent maize forage quality within a paddock. Environmental pressures are likely to increase the variation in maize forage quality, with cases of poor-quality maize forage becoming more common if growers do not implement good agronomic practices.

5.3 Can maize forage quality be manipulated?

The interviewees provided unanimous support that maize forage quality can be influenced for better results. There was unanimity that the climate held the greatest influence, and this influenced whether hybrid or agronomic decisions would be expressed fully. This compares closely to work produced by Below (n.d.), with the climate being the most significant influencer of grain yield.

In contrast, there was a different emphasis put on other variables that influence maize forage quality. Because independent data is unavailable, the weighting of varied factors can only come down to first-hand experiences. Although this experience is valuable, without data integrity, these claims are hard to substantiate. This could lead to inaccurate recommendations being made in the industry, which is inefficient and costly.

The difference in forage quality of maize hybrids was more significant than what the literature stated, according to those involved in the industry. Since the literature has been published, there has been continual evolvement of maize hybrids targeting yield gains. This has meant longer maturity hybrids have been bred to maximise forage yield, resulting in a hybrid with a lower grain: stover ratio. The introduction of BMR material and focus on grain yield in other hybrids has resulted in hybrids that would be higher in quality. On evaluation, the potential increase in milk revenue for the purchaser of $34 per tonne of maize forage by changing forage hybrid (Kolver et al., 2003.) may be underestimated based on today's options.

Again, there was unanimous consensus that there is a considerable amount of data and information available on how to influence silage quality but significantly less on how to influence forage quality. There is a good amount of international data available but minimal data produced in New Zealand. This observation comes from those responsible for providing technical advice to farmers.

On critical analysis, this contradicts the idea that maize forage quality is easy to influence. The premise may be correct, but accessible data to make informed decisions is lacking, so influencing quality consistently can be difficult for those not educated on the topic. There appears to be a disconnect between industry professionals and farmers in this space and closing this would be paramount to ensure the grower understands the inputs required and the potential return for influencing maize forage quality.

Some of this can be explained due to seed sales and consumer demand being focused solely on forage yield, as the current trading model and on-farm profitability is centred around this. Part of the disconnect could also be explained as the market for trading on quality parameters is not present, so the information is not sought out by growers or provided by the industry. Whether growing maize forage on-farm or for contract, the topic of manipulating forage quality should be discussed and researched further as there are production benefits to be gained.

6.0 Findings and Discussion

This research project has confirmed three fundamental principles around maize forage quality in New Zealand.

- Grain is the key driver of quality.
- There is a significant variation in quality.
- Quality can be controlled through hybrid choice and agronomic decisions. It is also largely influenced by environmental factors.

The current maize trading model has a gap as it disregards aspects of maize forage quality and focuses on total yield, which the grower is paid on. Literature shows an increase in forage quality can positively increase milk production, but this is ignored in buying decisions. Without testing, farmers are unaware of the componentry of the forage they are feeding. The increase in consumption of maize silage means that maize forage quality has a greater influence on New Zealand's milk production capability.

"In future maize forage quality will become increasingly important for farmers buying in maize forage on a c/kg DM[11] basis and for maize silage users who are feeding high maize silage rates and/or targeting higher per cow performance." Densley et al. (2004)

"It would be expected that ranking of hybrids for quality will become more important as dairy farmers include higher amounts of maize silage." Kolver et al. (2003)

The literature shows that forage quality is of greater importance, but there has been little to reflect or promote this. New Zealand has been reminded of how vulnerable it is to global issues and how fragile the supply chain is. These issues have promoted the importance of quality homegrown feed and the need to increase productivity from inputs. Promoting the increase in maize forage quality could ensure New Zealand's dairy sector is more resilient to these changes. There is now an opportunity to promote higher-quality maize forage. Creating a new model that rewards growers for creating higher quality maize forage can be proposed to help develop this market and opportunity.

6.1 Structuring a new trading model

To trade maize forage on quality parameters, it has been evaluated that the following issues would need to be addressed.

6.1.1 Analysis of samples

There are currently multiple options for where maize forage samples can be analysed for quality parameters. These laboratories do not use the same calculations, reference points or technology when determining results for parameters, such as metabolisable energy. Cohesion between companies or deciding on a universal matrix is of importance.

[11] Cents per kilogram of dry matter

6.1.2 Selecting which parameter to trade on

Although starch is the key driver of maize forage quality, other parameters such as protein, neutral detergent fibre and acid detergent fibre still have a part to play. Creating a pricing matrix that just focuses on starch could cause unintended consequences, so starch content should be the main target with an emphasis on other variables included.

6.1.3 Sample collection

Both research methods clearly outline there was a variation in maize forage quality. Because most literature is pre-2010, the interviews focussed more on in-paddock variation. Even with the current trading model, getting an accurate representation of the WPDM is difficult. Environmental factors mean significant variability of WPDM and quality parameters of individual plants at harvest time. As an example, the WPDM of the maize forage in figure 2 ranged from 28% to 40%.

Figure 2: An example of in-paddock variation of WPDM in maize forage in Waikato, 2022.

Currently, the standard sampling method is collecting composite hand scoops from a selection of trucks. The Good Practice Guide for the Trading of Maize Forage states that a minimum of 14 samples are required for a 2% level of accuracy for WPDM. However, with in-paddock variation, it is likely this sampling method is not giving us a fair representation of the median WPDM. Representation can also be influenced by human error or bias based on where and when samples are collected. The industry should not be confident that current assessments will be accurate enough to manage this variation and provide accurate data for growers and purchasers.

The same issue will apply if trading maize forage on quality parameters. Ensuring a representative sample is obtained will guarantee the grower and purchaser are fairly paid for their product. As shown in figure 3, the transition to obtaining core samples from the forage stack pre-covering will allow for a greater level of accuracy. Ten core samples from the stack would allow a 1% level in accuracy for WPDM determination. When variability is an issue, transitioning to using stack cores should be minimum practice. Stack coring ensures that all forage material is well mixed and reduces the chance of operator bias too.

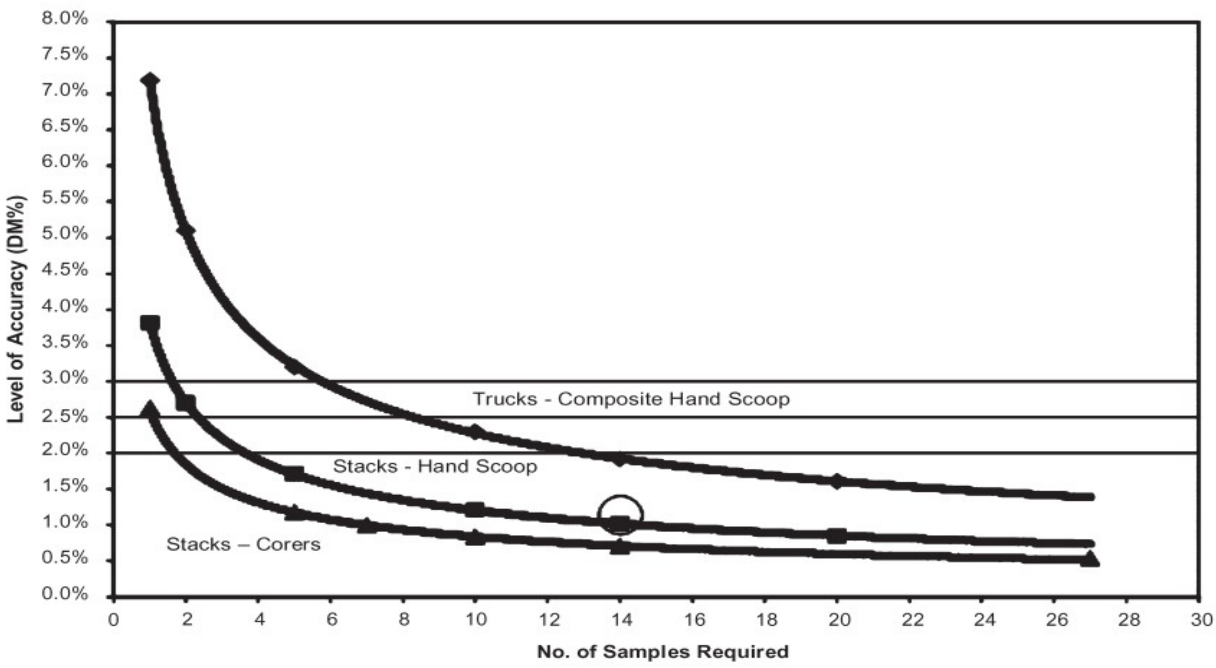

Figure 3: The correlation between the number of samples required and the level of accuracy to determine WPDM for maize forage via different methods at sampling time

An alternative option to gaining more precise analysis and a more representative sample could be with in-harvester technology. NIR technology involves using a sensor installed in the forage harvester that measures the fresh material passing through. NIR can measure WPDM and quality parameters, such as starch, fibre, and protein. These quality parameters are currently measured with NIR technology in New Zealand laboratories. The measurements are continuous as the forage harvester works, thus providing a greater representation of the paddock.

This technology must be calibrated to ensure readings match the laboratory analysis of the plant. Data sets for this calibration can be purchased, but these may be from international locations rather than local. Every season is different, so the ability to match what is occurring within a season may be compromised because it has not experienced those variables before. This technology would need to be certified as a proven method of analysis. Because there are multiple laboratories and different measurements, that process is more difficult, so further work would be required to ensure cohesion.

This technology is already installed in many harvesters in New Zealand, so uptake is simple. Different harvester manufacturers run different sensors though, so calibration on individual sensors would be essential. If one manufacturer is certified, it would be important to allow certification for others. This will allow competition and innovation in this space. There is no doubt this technology could provide efficiency gains for the representation of forage analysis and ensure trading on forage quality is achievable.

6.1.4 Trading on a number

The current contract is based on certified weights and measures. Both wet weight and dry weight are easily and legally determined with the use of certified weigh scales and dry matter testing through laboratories.

The Weights and Measures Act (1987) states;

“Subject to section 9, every person commits an offence who;

(a) …enters any contract, or engages in any dealing or transaction, by reference to any weight or measure other than a weight or measure of the metric system; or

(b) uses for trade any weight or measure other than a weight or measure of the metric system; or

(c) uses for trade any weighing or measuring instrument other than a weighing or measuring instrument which weighs or measures only by reference to weights or measures of the metric system.”

In laboratory feed testing, parameters such as starch, neutral detergent fibre and neutral detergent fibre are estimated through NIR technology. These results are then recorded as units of weight, such as g/kg DM[12] or a percentage of dry matter, which has been recorded as a unit of weight.

This would allow quality parameters to be traded, but the contract must accept that the parameters are estimated based on their percentage of dry matter. This estimation comes from a large pool of data that is continuously calibrated as new data is received. Acknowledgment of this must be clarified to growers, purchasers, and industry as we progress towards a more precise model. For the good of the industry, encouraging quality testing of all maize forage would assist in ensuring the estimation is continuously fine-tuned. This also puts more emphasis on the need to certify and calibrate NIR systems in forage harvesters with local data sets to provide confidence to the industry of its rigour in comparison to laboratory testing. Further investigation in this space will be required.

6.1.5 Technical information

For farmers and advisors to make informed decisions, access to data and technical information is paramount. Growers cannot confidently influence quality parameters if they do not understand the weighting of the variable they are adjusting. This research project has clearly shown there is limited New Zealand material available on how to influence maize forage quality.

There is the ability to influence maize forage quality through hybrid selection. However, there is limited statistical data from wholesale maize seed companies on the forage quality of their hybrids. One positive is they do have a trait performance guide based on the starch or energy production of their hybrids. However, these scales are not universal so cannot be used to compare one company’s hybrid with another. For maximum benefit of the grower and purchaser, independent data to compare hybrids for forage quality is essential.

A stringent trial protocol would be important to ensure accurate representation and replication. Companies may be reluctant to put their material forward for competition, but competition undoubtedly promotes innovation, which is for the betterment of the industry. The re-entry of maize hybrid evaluation trials run by the FAR for both forage yield and forage quality could be a major step in bridging this gap. Running a similar programme to the DairyNZ Forage Value Index, which compares commercially available ryegrass cultivars for yield, persistence, and quality, could be proposed as the platform has already been created (DairyNZ Limited, 2022).

There is also limited material available from wholesalers, retailers, and independent bodies on how to influence maize forage quality through agronomic practices, especially under a varied climate. Agronomic decisions are the largest variable growers can control, so understanding cause and effect would help resolve this. Because maize is either grown on-farm or sold on contract by weight, most

[12] Grams per kilogram dry matter

research and trial work focus is on influencing yield. Although there may be the opportunity to influence forage quality and generate returns by doing so, it is overshadowed by the yield factor, so information is harder to come by. A refocus of the industry would allow growers to be more confident about the switch. Again, trial work conducted by an industry body such as FAR would build confidence in the grower's mindset.

6.1.6 Pricing

Growers who can consistently create high-quality maize forage that generates greater returns for the purchaser should seek a premium. Two options for pricing the contract could include:

1.) Trading maize forage on cents per kilogram of dry matter (as per the current market rate and contract) and providing bonus payments for quality parameters that exceed industry standards

Examples:

- 0.5 cents per kilogram of dry matter bonus for every 1% increase in starch above 28%.
- 0.25 cents per kilogram of dry matter bonus for every 1% decrease in NDF below 40%.
- A grower creating maize forage with a starch content of 34.6% and NDF of 33.4% receives a base payment of 30c/kg DM and total bonus payments of 4.5c/kg DM.
- A 200-tonne contract is therefore grossing the grower and costing the purchaser $69,000 instead of $60,00 in a standard contract.

Benefits:

- Sets a target for growers to aim for and provides extra incentive to continuously improve when the incentive tipping point has been met.
- Ensures the grower recognises the importance of more than one parameter.
- Base payment ensures an income stream if the quality is challenged due to drought or other factors.
- More parameter incentives can be added.
- Allows an easy transition as growers are still comfortable with the yield basis.
- Rewards yield and quality.

Issues:

- A cut-off point means some miss bonus payments, even though they are creating decent quality maize forage.
- Those creating poor quality maize forage still receive the same base payment.
- Still has an underlying push for yield, which may compromise the focus on quality.

Options:

- Base payment could be set lower, with bonus payments kicking in earlier to separate the variation in quality further.

2.) Trade maize forage on total energy received (metabolisable energy multiplied by total yield) and pay per unit of MJME. For example, 2.85 cents/MJME

Examples:

- 11.2 MJME/kg DM x 20,000kg DM/ha[13] =224,000 MJME
  - 31.92c/kg DM or $6384/ha revenue
- 10.5 MJME/kg DM x 22,000kg DM/ha = 231,000 MJME
  - 29.93c/kg DM or $6583/ha revenue
- 11.5 MJME/kg DM x 24,000kg DM/ha = 276,000 MJME
  - 32.78c/kg DM or $7866/ha revenue

Benefits:

- Simple to calculate.
- Easier to calculate milk solids response off current data.
- The power of quality x yield creates high revenue potential.

Issues:

- Still a large emphasis on yield so other quality factors may be compromised.
- Focuses on total energy per area rather than a proportion of energy per kg of forage.
- Focuses only on energy so neglects other quality parameters.
- More volatile revenue potential.

With a lack of information on how different quality parameters influence milk yield, pricing each incentive is more complicated. In example one, it is important to consider if the grower requires extra inputs to generate the extra $9000 of revenue. Assuming a 21,000kgDM/ha yield, the contract forage came off 9.5 hectares, which would equate to extra revenue of $947/ha. With current growing costs equating to $3000/ha (Genetic Technologies Limited, 2022b), an increase in costs of 32% is unlikely based off our available strategies, therefore leaving a margin for the grower.

Considering will the purchaser produce milk revenue over and above the extra $45/tonne of forage purchased to warrant paying the premium. At a feeding level of 1250kg DM/cow and a $9.50/kgMS milk price, the breakeven would be an extra 5.92kgMS[14] produced per cow. Assuming metabolisable energy has increased from 10.1 to 10.6 MJME/kg DM (table 3), an increase in MS production of 6.95kg MS/cow/year[15] is likely. Milk return goes above the premium in this case, and there are other benefits not factored in from feeding higher quality maize forage. This is a calculation that would need to be completed by purchasers and growers each season to ensure they are both profiting from the change. For example, a drop in milk price to $5/kgMS would require a reset in pricing.

Option one would be the easiest way to transition from a contract focusing only on dry matter yield. It also ensures growers and purchasers are still focusing on the quality per unit of forage whilst still encouraging yield production. The availability of alternative feeds and milk prices will determine the capacity of purchasers to pay a premium. Regardless, there are productivity gains to be had by feeding higher quality maize silage no matter the rate.

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[13] Kilograms dry matter per hectare
[14] ($45T x 1.25Tcow)/$9.5kgMS
[15] ((10.6-10.1 MJME) x 1500kg DM)/108 (Densley, Miller, & Kolver, 2001)

7.0 Conclusions

With the area of maize forage planted and per cow consumption of maize silage likely to grow in the future, increasing the quality of maize forage can have a positive impact on farmer and industry milk production. With the current maize forage trading contract neglecting most facets of maize forage quality, there is an opportunity to promote the improvement of maize forage quality as controlled by the grower. The focus should primarily be on increasing the grain: stover ratio of the maize forage.

There are clear opportunities to manage and increase the quality of maize forage, through hybrid choice and agronomic decisions. However, the amount of information available for farmers and advisors is limited, so understanding the level of impact these decisions have is difficult. Creating a new contract based on quality parameters without technical information to support it would be difficult.

With the variety of quality parameters between farms and within paddocks, it is unlikely that the current sampling method would provide an accurate representation of the quality parameters for fair trading. Truck sampling struggles to ensure representation with the current contract trading on WPDM due to paddock variation. The use of stack sampling and technologies such as NIR can provide the opportunity for more material to be measured, ensuring a more accurate and representative sample.

To trade on quality, there is a need to extend the understanding of the accuracy of NIR results, even though they are based on estimations. Their results are recorded as certified weights and measures, and their accuracy continues to improve as more tests are undertaken. Growers and purchasers will need to be comfortable with this process. To enhance the process, encouraging quality testing of all maize forage would assist in ensuring the estimation is continuously fine-tuned.

Pricing a new contract is one area that would need industry involvement to help reach a consensus. Sticking to the current trading model but providing incentive payments for certain quality parameters will allow an easy transition. There is still a market for generic maize forage, so higher quality maize forage could be marketed as a premium product with a premium price. Creating a contract that will adjust to fluctuations in the price of milk and alternative feeds is vital.

Overall, New Zealand should be focusing on trading maize forage on quality parameters. There are clear productivity gains to be had for both growers and purchasers of maize forage. The report is also a reminder of how important quality is when growing maize forage. Because farmers trade on dry matter or grow on-farm and focus on yield, losing sight of quality is easy. There is an opportunity to positively influence maize forage quality, which will have a beneficial impact on the New Zealand dairy industry.

8.0 Recommendations

As a result of the findings of this report, the following recommendations should be actioned.

- Encourage purchasers of maize forage to use stack core sampling as a form of sample collection and complete quality analysis on all samples, even if trading on dry matter. This encouragement should be the responsibility of rural retailers and agricultural contractors.
- Calibrate and certify the use of NIR in forage harvesters for measuring WPDM and quality parameters for trading maize forage. Allow open competition to promote innovation and allow others to enter the market. This would need to be certified by the manufacturers of the equipment and alterations to the contract actioned by the Forage Trading Development Group.
- Create material to extend the understanding of growers and purchasers around the accuracy of NIR technology as an assessment of quality parameters. This should be an industry approach, including DairyNZ, Federated Farmers, Contractors Association, FAR and the Forage Trading Development Group.
- Research and provide resources on how agronomic decisions affect maize forage quality. This should be actioned by maize seed wholesalers and independent industry bodies, such as FAR.
- Create independent data comparing commercially available maize hybrids for forage quality. This should be actioned by FAR or an alternative independent industry body.
- Refine a pricing matrix that reflects extra inputs required by growers and the extra milk income potential for the purchaser. This requires an industry approach, and should include DairyNZ, FAR, the Forage Trading Development Group and key growers, advisors and purchasers of maize forage.

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