The amount of feed consumed by ruminants is the most determinant factor affecting performance and is arguably the most important aspect of dairy farming. Cows rely on feed to supply energy and nutrients for maintenance and replenishment of muscle and fat reserves, brain and organ function as well as the demands of gestation and milk production.

Within the sub-tropical environment, supplying lactating cows with sufficient energy to meet these requirements is challenging. The hot, often unpredictable weather patterns limit the crops that are suited to this environment, of which, few have the nutritional quality required for high production dairy systems.

The key limitation to feeding dairy cows in this sub-tropical region is feed quality. Quality broadly refers to the energy and desirable nutrient content of feeds, and the digestibility of that feed within the digestive tract of the ruminant.

Feed intake is regulated by various mechanisms in ruminant animals, but can be broadly summarised as physical and metabolic. Typically, in less intensive systems such as extensive beef grazing, forages have lower digestibilities and physical limitations to intake predominate. In intensive systems like dairy, nutrient requirements are higher, and consequently, feeds with higher digestibilities that supply more nutrients more quickly to animals are used. Within these systems it is likely that metabolic regulators limit intake.

To add to the difficulty of supplying high amounts of high-quality feed in the sub-tropical system, partial mixed ration (PMR) systems have become more prevalent in this area because of 1) unpredictable pasture growth 2) aiming to maintain year-round production and 3) to utilise lower cost feeds whilst increasing production. PMR systems utilise both fresh pasture and conserved forages and concentrates in the diet. The complexity in achieving high intakes is further exacerbated in these systems due to these distinctly different feed types. Fresh pastures usually have a low dry matter content, are high in protein and are highly digestible, whereas conserved forages, typically cereal silages, various types of hay and grains, are higher in dry matter, and serve as the major source of both rapidly and slowly fermentable carbohydrates. Both feed types (fresh and conserved) have distinctly different effects on rumination and metabolism.

Over the past few years, the C4Milk research team has undertaken several experiments that have worked to identify how intake is controlled in sub-tropical PMR dairy systems, with the aim to improve our understanding and make recommendations on how intake can be increased to supply sufficient energy and nutrients to high producing dairy cows.

Previous work has identified several mechanisms that increases intake in the two distinct feed types. Pasture quality is a major factor driving intake and can be manipulated primarily through
species selection, but also through grazing management practices. Briefly, intake is maximised in PMR systems by feeding high quality pastures at high allocations that allow cows to selectively graze the leaves of pasture as opposed to stems. The leaves contain more protein and are more digestible, which allows faster passage rate through the rumen and gastro-intestinal tract, subsequently increasing intake rate and overall intake. This relationship was consistent when the proportion of pasture in the diet ranged from 33 – 67 % of the whole diet, where cows consumed in excess of 20 kg of dry matter (DM) per day.

Another recent study investigated the effect on intake of the physical fibre attributes of the PMR. One key finding was the impact of fragility (brittleness) of the PMR on intake, with higher levels of fragility potentially positively correlated to increased DM intake. All treatments consumed similar levels of neutral detergent fibre (NDF), but the treatment with the lowest fragility had the lowest intake. The decline was likely driven by the increased time of rumination, particularly chewing, that was required to reduce particle sizes down to allow passage through the rumen. It was likely that the speed at which particles were broken down and digested was driving intake rather than a physical rumen fill limitation, as all treatments consumed similar levels of PMR with differences in pasture intake seen between treatments. This showed that the physical properties of the mix plays an important role in intake regulation, and more research is required in understanding the physical aspects of forages and how they can be managed at a commercial level.

The last study conducted took the results from the previous work and built upon those by looking at the effects of the nutrient composition or formulation of the PMR on intake in a sub-tropical dairy system. The aim of the study was to offer diets with similar physical characteristics and metabolisable energy levels, but differing in type of nutrient supplied. Diets were formulated to contain different proportions of starch, crude protein and fibre to assess how each of these distinct nutrients affected PMR and pasture intake.

Three PMR treatments (Table 1) were formulated with equal amounts of corn silage and lucerne hay as the forage component of the mix, but had varying quantities of barley grain, canola meal and soyhulls (used as a non-forage fibre source to increase the NDF level of the diet without altering the physical composition of the ration). Lucerne pasture was offered in areas large enough to allow cows to selectively graze the leaves of pasture to ensure allocation did not limit intake.

Nutrient values of feeds were taken immediately prior to the experiment and used in diet formulation software, where treatments were balanced to provide enough metabolisable energy (ME) for cows producing 35 L/day from 15.5 kg DM of PMR and 8 kg DM of lucerne pasture. The treatment diets are named according to their formulated level: low (L) or high (H), of dietary starch (S), crude protein (P) and NDF (F) content (% of DM) respectively:

- High Starch (HSLPLF) = 26.4% starch, 17.6% CP and 26.0% NDF;
- High Protein (LSHPLF) = 18.1% starch, 22.0% CP and 27.8% NDF;
- High Fibre (LSLPHF) = 17.6% starch, 16.7% CP and 35.2% NDF.

It was expected that the high starch (HSLPLF) diet would have the lowest intake due to the negative associated effects of starch on intake, and that the high protein (LSHPLF) treatment would have the highest intake due to an increase of microbial synthesis due to more protein available in the rumen and subsequently improved forage digestion.

The preliminary results showed that cows in the high starch treatment consumed less PMR (1.8 to 2.1 kg DM), and less pasture (2.1 to 3.3 kg DM) than the high protein and high fibre treatments (Figure 1). Total intake for the high starch group was 3.9 to 5.4 kg DM less than the high protein and high fibre groups respectively (Figure 1).
In ruminants, propionate is the primary fuel stimulating hepatic oxidation, which reduces the feeling of hunger in the animal. Diets high in starch, when broken down in the rumen, produce large volumes of propionate quickly and trigger hepatic oxidation in the liver, depressing hunger and consequently intake.

Table 2. Estimated mean nutrient intake (combined PMR and pasture, expressed as % DM) and rumen pH for each treatment. Neutral detergent fibre (NDF). Crude protein (CP).

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment</th>
<th>HSLPLF</th>
<th>LSHPLF</th>
<th>LSLPHF</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDF % DM</td>
<td>26.1</td>
<td>27.6</td>
<td>34.9</td>
<td></td>
</tr>
<tr>
<td>CP % DM</td>
<td>16.8</td>
<td>22.4</td>
<td>17.1</td>
<td></td>
</tr>
<tr>
<td>Starch % DM</td>
<td>28.1</td>
<td>17.0</td>
<td>17.2</td>
<td></td>
</tr>
<tr>
<td>Starch:Protein ratio</td>
<td>1.68:1</td>
<td>0.76:1</td>
<td>1.01:1</td>
<td></td>
</tr>
<tr>
<td>AM pH</td>
<td>7.22 ± 0.08</td>
<td>7.35 ± 0.07</td>
<td>7.11 ± 0.07</td>
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</tr>
<tr>
<td>PM pH</td>
<td>6.51 ± 0.18</td>
<td>6.33 ± 0.11</td>
<td>6.69 ± 0.14</td>
<td></td>
</tr>
</tbody>
</table>

1Nutrient values are estimated values using ration formulation software.
2AM pH sample was taken after cows had been on pasture overnight for at least 10 h (Mean values and standard error).
3PM pH sample was taken after cows had access to their PMR for at least 6 h (Mean values and standard error).

The targeted differences in nutrient content of the total diet for each treatment were achieved (Table 2, page 5), with slight differences due to cows in the high starch treatment consuming less PMR and pasture than targeted, and the high protein cows consuming more pasture. Total intake had a significant (P<0.01) negative linear relationship with starch:protein ratio. Only treatments with a starch:protein ratio <1.0:1 achieved their targeted intakes of 22.5 kg DM, and intake was highest when the starch:protein ratio was 0.71:1 (Figure 2, page 5).

The high starch diet had the highest starch:protein ratio with a total diet starch content of 28.1 % DM (Table 2, page 5) and non-structural carbohydrate (NSC; all rapidly fermentable carbohydrates) content of 31.7 % DM (data not shown) which would be considered high in commercial systems. Diets with high starch and NSC contents can cause sub-acute ruminal acidosis (SARA), where ruminal pH falls below 5.6 to 5.8. SARA typically leads to lower fibre digestion, milk fat and DM intake (DMI). Cows in the high starch treatment consumed less pasture than the other treatments, which could be due to compromised rumen function, as NDF digestion decreases as the starch content in the diet increases. Typically, cellulyolysis (the breakdown of cellulose) in the rumen declines when the pH drops below 6.0 to 6.2. However, in this study, cows in the high starch treatment recorded an average pH 6.51 after 6 hrs on PMR, which was slightly less acidic compared to cows in the high protein treatment where the pH was 6.33 (Table 2, page 5). This suggests that SARA and decreased cellulyolysis was not the cause of lower intakes. Further analysis of rumen bolus data is required to assess the full extent of the ruminal pH patterns over time for each treatment.

The decline in intake in the high starch treatment could be explained by the hepatic oxidation theory (HOT). HOT suggest that food intake is controlled by a signal from the liver to the brain that is stimulated by oxidation of various fuels. In ruminants, propionate is the primary fuel stimulating hepatic oxidation, which reduces the feeling of hunger in the animal. Diets high in starch, when broken down in the rumen, produce large volumes of propionate quickly and trigger hepatic oxidation in the liver, depressing hunger and consequently intake.

In this study, it is likely that intake was suppressed to some extent in the high starch diet due to a metabolic response (HOT) to high levels of starch in the diet, rather than effects associated with low rumen pH.

Further to the effects associated with high levels of starch, intake was also higher for cows in the high protein diet compared to the high fibre diet. These treatments consumed similar levels of starch and is therefore likely that a mechanism other than HOT affected intake. The high supply of CP allows for increased microbial synthesis in the rumen, leading to improved forage digestion, and may explain why cows in the high protein treatment consumed more pasture and total DM intake compared to the other treatments.

In the high starch treatment, almost all starch in the diet was supplied by the PMR. This caused a decrease in intake, likely explained by HOT, not only immediately whilst consuming the PMR, but also appeared to have carry over effects on intake as cows in that treatment also consumed less pasture than the high fibre treatment which contained a similar CP content but was lower in starch.

The results from this experiment support the hypothesis that intake in PMR systems is negatively affected by starch content in the PMR, and positively affected by crude protein.

Although PMR’s were formulated with similar ME levels, the form of energy had a significant effect on not only PMR intake, but has carry-over effects on pasture intake. The complexities of the interactions within and between feeds in PMR systems were highlighted in this experiment, and shows that the starch:protein ratio and starch content of the diet has a significant role on intake and should be considered when formulating diets. Further analysis is being conducted on the milk yield and composition responses and will be reported in future articles.