Australian Oaten Hay

aexco.com.au

Nutritional Assessment of Australian Cereal Forages

AEXCO

2024

Aknowledgements

Research undertaken by Scibus one of Australia's leading dairy nutrition and science-based advisors

This project is supported through funding from AgriFutures An Australian Government Research and Development Corporation and the Australian Government's Agricultural Trade and Market Access Cooperation (ATMAC) program.

Table of Contents

1. Executive summary

This report was commissioned by AEXCO, the peak body for export hay in Australia and AgriFutures, an Australian Government research and development organisation. Funding from AgriFutures and the Australian Government's Agricultural Trade and Market Access Cooperation (ATMAC) program supported this report.

The objective of this study is to provide pre-competitive technical assessments that identifies the value proposition for new export customers and removes the lack of technical knowledge as a barrier of entry for Australian export fodder. This was undertaken by evaluating the role of Australian oat hay in diets across Asia and MENA Gulf States.

As one of the leading ruminant nutritionists in Australia, Ian Lean Adj. Prof. BCSc. DVSc PhD. MANZCVS of the company Scibus was selected to undertake this study.

Information on 66 Australian oat hay samples was obtained from wet chemical analysis at the Cumberland Valley Analytical Laboratory. This information was augmented with >500 samples of cereal hays and >470 samples of oat hay to provide a larger database for comparisons with other feeds.

Australian oat hays are lower in total lignin than those from North America and have higher NFC and markedly higher WSC and ESC and lower starch. All measures of fibre quality are more favourable for ruminal fermentation than the North American hays

The inclusion of Australian oat hay into diets in China, Philippines, Indonesia, South Korea, Taiwan, Vietnam and Saudi Arabia was tested using diets and commodity prices obtained from these regions.

For each country, diets were evaluated for dairy cows that were in late gestation (260 days pregnant; far-off drys), dairy cows just prior to calving (270 days pregnant; pre-fresh), high producing dairy cows in peak lactation (100 days in milk), and pregnant cows in later lactation (240 days in milk; 160 days pregnant, dairy heifers of 4 and 13 months of age and in beef diets for steers being backgrounded (>1 kg/day gain) and in the feedlot steers (>1.66 kg/day gain).

The evaluations assessed dairy cows producing from 15,000 to 6,600 L per lactation and the beef feedlot gains of >1.7 kg per day. This range meant that high producing cows were modelled to produce from 55 to 35 L per day in early lactation and from 35 to 25 L per day in mid to late lactation.

The modelling approaches used are based on the Cornell Net Protein and Carbohydrate System which is recognized as one the most robust means of evaluating the complex interactions of diets with cattle production. The models were developed using CPM Dairy (3.0.8) and RU.M.EN Nutritional Dynamic Software (Version 3.12.1.01a). These models allow for interactions among substrates and the effects of rates of degradation of substrates such as carbohydrates, proteins and fibre fractions on cattle production and can evaluate the economic impacts of diet.

When Australian oat hay was evaluated for inclusion in diets, the inclusion resulted in lower diet costs and increased profit in most evaluations with a range in benefit from modest to large.

Limitations on the diet modelling resulting from expected fluctuations in commodity pricing, quality and availability were addressed by simulation modelling using @Risk software.

Variation in international traded commodity prices, information on forage quality from extensive feed libraries and those in the nutrition models were used. Variation in the availability of home-grown forages were considered.

The following summary integrates the findings from the Saudi Arabian and Chinese modelling. A more nuanced discussion is provided in the body of the document. The modelling is based on the standard deviations (SD) in feed pricing and quality.

Oat hay inclusion in diets tested was relatively insensitive to changes in the price of corn grain. A lower price favoured Australian oat hay inclusion that was slightly higher in fibre.

Similarly whole cottonseed price had little effect on the inclusion of oat hay in most diets, but when the price was 1.5 SD lower than average oat hay inclusion reduced.

Inclusions of oat hay decreased slightly with increased price of soyabean or cottonseed meal but was relatively insensitive to the pricing. However, sunflower meal 1 SD below reduced oat hay use in the Chinese diet, but at average prices the sunflower meal did not enter the diet.

Increased palm oil price favoured a hay slightly lower in fibre and a 1 SD reduction in price of palm oil reduced oat hay inclusion for the UAE diet as this allowed less use of grain and less need for more fibrous feeds.

A decrease of 1 SD in alfalfa price reduced inclusion of oat hay by 75%, but no alfalfa hay entered diets at the average historical pricing differentials and oat hay inclusion was not sensitive to better alfalfa quality. Most diets had availability of high protein commodities (whole cottonseed, soyabean meal, canola meal) meaning that protein sources other than alfalfa were available. Consequently, the better fibre digestion characteristics favoured oat hay inclusion over alfalfa hay based on the pricing of the mix of commodities.

Oat hay inclusions were insensitive to the price of Rhodes grass hay and was only displaced if the Rhodes grass hay was of 2 SD better quality.

If Timothy hay of 1 SD better quality was available at the same purchase price, it would reduce oat hay use by 90%. Timothy hays of lesser quality than 1 SD better than average did not enter diets.

Oat hay inclusion was sensitive to the availability of maize silage, however, this sensitivity highlights the important role of the purchased hay reducing exposure to agronomic and silage making risks for farms.

Access to other protein sources such as wheat dried distillers grains reduced inclusion of alfalfa hay and increased oat hay inclusion.

The quality and availability of local forages was a key determinant of oat hay inclusion.

Oat hay attributes should not be considered merely as nutritional components but the total nutritional package and also be considered in terms of agronomic risk and disease risk mitigation.

Abbreviations

AEXCO - Australian Exporters Company

ADF – Acid detergent fibre

ADICP – Acid detergent insoluble crude protein

aNDFom – Neutral Detergent fibre in organic matter

AOAC – American association of analytical chemists

@Risk - Palisade's analytics software for simulation modelling

ASEAN - Association of Southeast Asian Nations

CF – Crude fibre

CP – Crude protein

CPMDairy - Cornell Pennsylvania Miner nutrition program

CVAS – Cumberland Valley Analytical Services

DairyOne – New York Dairy Herd Improvement Laboratory

DCAD – Dietary cation anion difference

DM – Dry matter

ESC – Ethanol soluble carbohydrate

ME – Metabolisable energy

MENA - Middle East and North Africa

NDF – Neutral detergent fibre

NDFd – Neutral detergent fibre digestibility

NDICP - Neutral detergent insoluble crude protein

NDS – RU.M.EN nutritional software

NFC – Non-Fibre Carbohydrates

NSC – Non Structural Carbohydrates

Oat hay – refers only to Australian oat hays in this document unless specified

SD – Standard deviation

UAE – United Arab Emirates

uNDFom – Undegraded neutral detergent fibre in organic matter

WSC – Water soluble carbohydrate

2. The analytical results for Australian hays

2.1. The Australian data

2.1.1 Introduction

The objectives of this work were to evaluate the role of Australian oat hays in diets across Asia and MENA Gulf States using samples of hay obtained from a single season and characterised by wet chemistry analysis at a single feed laboratory.

The fibre breakdown characteristics of the hays were considered important to have tested by analytical chemical methods in order to provide the most accurate evaluation of the hay qualities in terms of fibre. Further aspects of carbohydrate chemistry were evaluated by determination of the water-soluble carbohydrate (WSC) and ethanol soluble carbohydrate (ESC) fractions.

The chemical determinations of the oat hays were used to provide estimates for different classes of oat hay that could be tested for inclusion and benefit in diets considered representative for cattle production the Asian and MENA Gulf States.

To consider volatility in commodity price, quality and availability, a series of simulation studies was undertaken to robustly evaluate the response of oat hay inclusion to changes in the economic environment. All the simulation studies in this document are based on Australian oat hay.

2.1.2 Materials

A total of 66 oat hay samples were sent from Australia to the Cumberland Valley Analytical Services Laboratory (CVAS) for wet chemistry analysis. Hay exporters provided these samples from their hay inventory and were asked to include equal proportions of high, medium and low grade export hay. Of these samples, 14, 24, and 28 were from South Australia, Victoria, and Western Australia, respectively. These samples were primarily from year 2023 with 1 sample from 2021 and 7 from the 2022 production year.

2.2 Some basic descriptions

The following Figures support Table 1 providing summary information on the 66 oat hay samples submitted to Cumberland Valley Analytical Services for analysis.

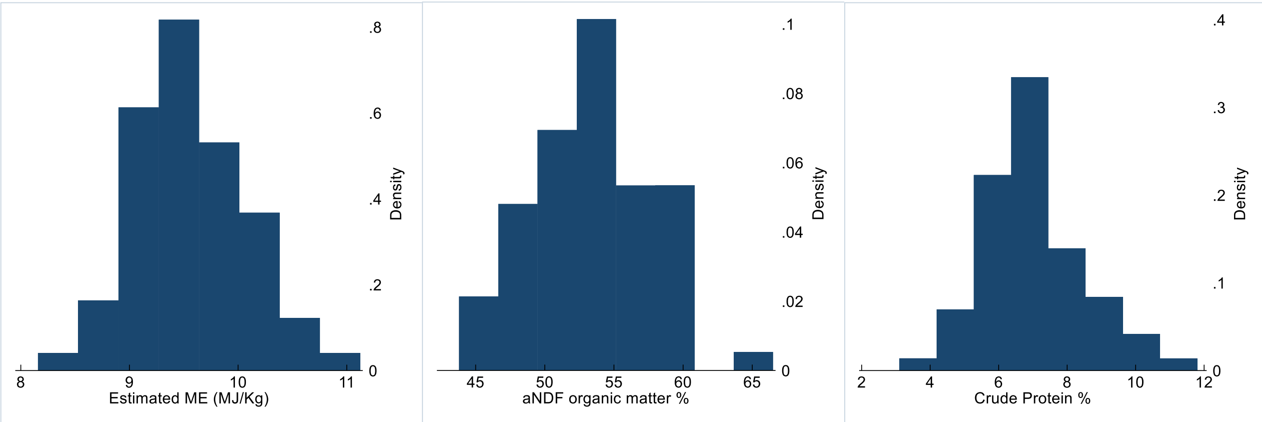


Figure 1. A. Estimated ME (MJ/Kg), B. aNDF organic matter percentage and C. Crude Protein % for AEXCO data (n = 66 samples of oat hay)

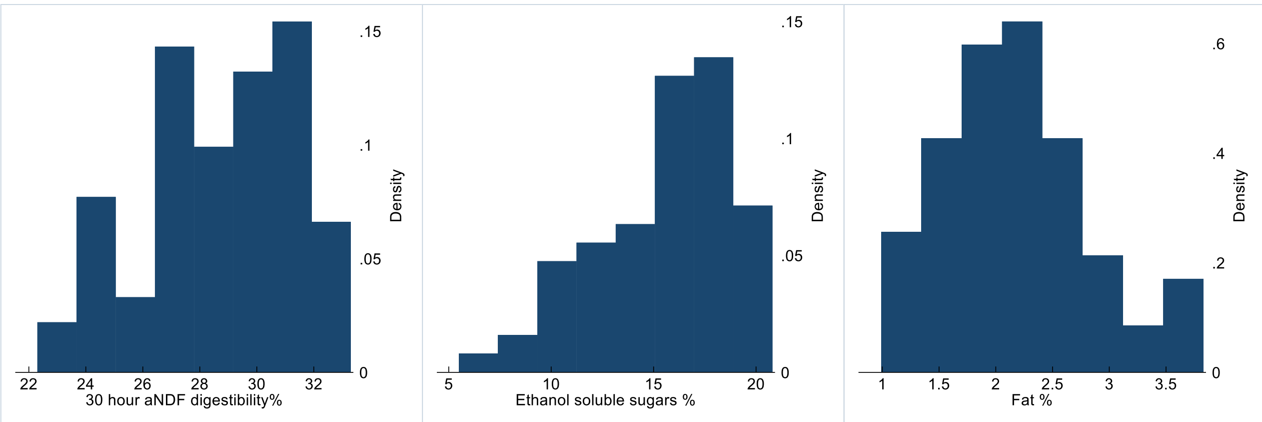


Figure 2. A. Estimated 30 hour aNDF organic matter digestibility percentage B. Ethanol soluble sugars and C. Crude fat % for AEXCO data (n = 66 samples of oat hay)

These samples can be compared to those from the Extended data, and data on North American oat hay from the CVAS and Dairy One Laboratories in Table 7. Notably, results from the AEXCO samples (Table 1A) are very similar to those of the Extended data (Table 1B).

It is notable that the Australian oat hays are lower in total lignin than the estimates from North America, have higher NFC and markedly higher WSC and ESC and lower starch. Also, all measures of fibre quality are more favourable than for the North American hays (See Section 6).

Table 1A. Chemical analysis of 66 Australian oat hay samples from a single season (2023).

Variable (% of DM unless otherwise stated)	Observations	Mean	Std. dev.	Min	Max
Dry matter	66	90.70	1.18	85.50	92.80
Crude Protein	66	7.02	1.56	3.10	11.80
Acid Detergent Insoluble Crude Protein	66	0.59	0.13	0.39	0.94
Neutral Detergent Insoluble Crude Protein	66	10.60	2.18	6.60	16.80
Acid Detergent Fibre	66	32.30	3.55	24.50	42.20
Neutral Detergent Fibre in organic matter	66	53.42	4.48	43.80	66.50
Lignin	66	4.05	0.67	2.95	5.91
Non Fibre Carbohydrates	66	31.99	6.47	19.20	62.30
Starch	66	3.03	1.77	0.50	7.40
Ethanol soluble sugars SC (Simple Sugars)	66	15.50	3.28	5.50	20.80
Water-Soluble Carbohydrates	66	17.77	2.97	10.90	24.60
Crude fat	66	2.17	0.69	0.99	3.83
Relative Feed Value	66	109.8	13.04	77.00	137.0
Ash	66	6.43	1.64	3.39	11.47
Ca	66	0.20	0.05	0.09	0.32
P	66	0.15	0.03	0.09	0.23
Mg	66	0.11	0.02	0.07	0.18
K	66	1.30	0.40	0.63	2.39
S	66	0.10	0.03	0.04	0.17
Na	66	0.51	0.27	0.15	1.47
Cl	66	1.06	0.45	0.29	2.60
DCAD, meq/100g	66	19.41	11.93	-1.30	52.80
Fe, ppm	66	148.6	122.1	51.00	595.0
Mn, ppm	66	55.86	22.32	22.00	141.0
Zn, ppm	66	15.58	7.06	6.00	63.00
30 hr NDF digestibility in organic matter, % of OM	66	28.74	2.68	22.30	33.30
30 hr Undegraded NDF in organic matter, % of OM	66	24.71	3.80	17.10	34.80
30 hr NDF degraded in organic matter, % of NDF	66	53.92	4.62	41.6	63.70
30 hr Undegraded NDF in organic matter, % of NDF	66	46.08	4.62	36.30	58.40
120 hr NDF digestibility in organic matter, % of OM	66	36.96	2.92	30.6	46.20
120 hr Undegraded NDF in organic matter, % of OM	66	16.49	2.82	10.10	22.80
120 hr NDF degraded in organic matter, % of NDF	66	69.28	3.75	62.50	78.80
120 hr Undegraded NDF in organic matter, % of NDF	66	30.72	3.75	21.20	37.50
240 hr NDF degraded, % of NDF	66	43.35	2.72	37.42	51.98
Estimated Metabolizable Energy, MJ/kg	66	9.58	0.50	8.16	11.12

Table 1B. Chemical analysis of 476 Australian oat hay samples.

Variable (% of DM)	Observations	Mean	Std dev.	Min	Max
Dry matter	476	89.13	0.81	86.90	92.10
Crude Protein	476	7.28	1.42	4.10	12.70
Acid Detergent Insoluble Crude Protein	476	0.55	0.10	0.30	0.90
Neutral Detergent Insoluble Crude Protein	476	1.31	0.39	0.60	2.80
Acid Detergent Fibre	476	31.87	3.27	23.90	42.50
Neutral Detergent Fibre in organic matter	476	52.30	4.79	42.00	66.00
Lignin	476	2.68	0.70	0.40	5.40
Non Fibre Carbohydrates	476	33.97	4.34	19.50	43.40
Starch	476	2.50	1.43	0.20	8.70
Ethanol soluble sugars SC (Simple Sugars)	476	14.10	2.20	2.30	18.40
Water-Soluble Carbohydrates	476	24.19	5.54	6.00	36.00
Crude fat	476	2.19	0.31	1.60	3.50
Relative Feed Value	476	115.35	14.66	78.00	154.0
Ash	476	5.61	1.46	1.50	10.30
Ca	476	0.24	0.08	0.01	0.58
P	476	0.22	0.03	0.12	0.35
Mg	476	0.16	0.03	0.02	0.30
K	476	1.52	0.40	0.42	2.86
S	476	0.14	0.04	0.01	0.28
Na					
Cl	476	0.95	0.26	0.24	2.00
In vitro Digestibility 24 hr	476	67.74	4.92	50.00	81.00
In vitro Digestibility 48 hr	476	75.52	3.66	66.00	86.00
Neutral Detergent Fibre Digestibility 24 hr	476	38.48	5.64	1.00	57.00
Neutral Detergent Fibre Digestibility 48 hr	476	53.23	4.65	42.00	67.00
30 hr Undegraded NDF in organic matter, % of OM	476	25.30	5.88	8.10	40.80
30 hr NDF degraded, % of NDF	476	50.81	7.88	29.30	79.20
120 hr Undegraded NDF in organic matter, % of OM	476	17.40	3.47	8.00	28.50
120 hr NDF degraded, % of NDF	476	65.89	5.53	44.50	79.60
240 hr Undegraded NDF in organic matter, % of OM	476	15.17	3.34	6.70	25.70
240 hr NDF degraded, % of NDF	476	70.30	5.37	49.60	84.10
Estimated Metabolizable Energy, MJ/kg	476	9.63	0.65	7.42	10.79

3. Diet modelling results

3.1 Modelling materials and methods

The modelling to provide estimates of the comparative nutritional values of oat hays, based on the AEXCO database was undertaken on several levels.

Diets and diet costs and market information were obtained from numerous sources including diets formulated by Scibus for international markets including China, South Korea and the Philippines. Diets were obtained from other nutritional advisors for Saudi Arabia, China, UAE, Vietnam, Indonesia and Taiwan.

The prices for feeds used in the modelling were obtained as part of the diets received or were based on local information sources and cross validated through AEXCO, based on prices of oat hay sold into the markets, and all markets had information from independent advisors. Milk prices were obtained as part of the diets received and were cross-validated using market data available on the internet (See sources). Similarly, beef prices were advised or obtained from market data available on the internet (See sources).

All older diets had prices updated to provide current pricing. Where diets were received, the nutritional qualities for the various feeds in the existing model were accepted and where these data were not present, feed bank data for the nutritional modelling programs were used and supplemented with the information obtained from CVAS and DairyOne laboratory libraries.

Four different oat hay specifications were generated by averaging the nutritional profiles of oat hays from the AEXCO analyses at CVAS.

- Three highly ranked oat hays (on estimated metabolisable energy basis) were combined to provide *a high-quality first quartile hay* (52 NDF 34 NFC 25 WSC), and
- similarly a *second quartile hay* (58 NDF 26 NFC 23 WSC),
- a *3rd quartile* (58 NDF 26 NFC 17 WSC) and
- a hay from the *4th quartile* (62 NDF 23 NFC 9 WSC) were synthesised.

The selections were from approximately the top 15 oat hays, the 15 to 30 ranked, the 30 to 55 ranked and from the 11 lowest ranked hays, respectively. These were priced slightly differently in the diets, but consistently with the local market, to provide approximately $US10 difference between each category, that is with a $40 range. The details on the nutritional attributes of the 4 different hays are provided in Supplemental Table 7. These were the 4 hays used for modelling.

Diets were formulated using CPMDairy (Version 3.08 Cornell Pennsylvania Miner) (**CPM**) or RU.M.EN NDS software (Reggio Emelia, Italy) (**NDS**) with the choice of software used being primarily determined by the source of the diet. For example, there were existing CPM files for China, South Korea, UAE, whereas there were existing NDS files for Vietnam and the Philippines.

New files were created for Taiwan in CPM as the pricing used was based on China, whereas Indonesia and the Philippines were created in NDS. Environmental conditions were not greatly adjusted for season and cow, heifer and steer sizes were estimated for each country and maintained invariable for direct comparison diets.

The following diets were formulated for each region,

- pre-calving, far-off dry cow (260 days of gestation) and close up cow (pre-fresh; 270 days of gestation),
- high producing cows (100 days in milk) which varied for peak production with region, but included diets for cows production up to 15,000 L per 305d,
- lower producing cows (240 days in milk; 160 days pregnant),
- young heifers aged 4 months (most gaining 0.77 kg/day) and older heifers 13 months old (most >0.8 kg/day gain),
- beef backgrounder steers (>1 kg/day gain) and feedlot steers (>1.66 kg/day gain).

For each animal by region, diets were created that provided the opportunity for oat hays to be included in the diet and for identical conditions with no oat hay availability. The milk production profile for the Saudi Arabia modelling was targeted at 15000 L per lactation. Hence for these diets both the peak lactation and later lactation diets were for highly productive cows doing 55L milk per day at peak and 35 L per day in later lactation. The milk production targets for Indonesia 8000 L and the Philippines 6600 L were lower than for the China (9000 L, 10000 L), Korea (10000 L) and Taiwan herds (10000 L). Consequently, these cows had lower per cow per day production than those for Saudi Arabia.

The two nutritional programs (CPM and NDS) have optimiser functions that reduce the risk of formulator bias. However, the optimisers function very differently, both with strengths and weaknesses. In most cases optimisation was achieved, however, there were some situations that required a loosening of constraints either for feed availability or for nutritional attributes of the diet. These situations required reformulation to ensure that diets were directly comparable. On some occasions, the optimised diets were considered suboptimal, as a result of an inappropriate inclusion level of a feed (for example limestone) due to the optimisation process and these were also reformulated to ensure the integrity of the evaluation.

The modelling approaches used both (CPM and NDS) are based on the Cornell Net Protein and Carbohydrate System which is recognized as one the most robust means of evaluating the complex interactions of diets with cattle production. These models allow for interactions among substrates and the effects of rates of degradation of substrates such as carbohydrates, proteins and fibre fractions on cattle production and can evaluate the economic impacts of diet (Fox et al., 2004; Van Amburgh et al., 2015).

After formulation, the diets were provided to two independent, highly qualified, nutritional advisors for assessment to ensure the integrity of the formulations. Diets with anomalies were reformulated.

Strengths of the modelling approach is that it ensured that the value of oat hays were tested in a real-world context using rations that were current or in the recent past from the different regions. The rations were sufficiently varied to provide a range of availability and amounts of dietary commodities, hence substrates, ingredients and prices that would identify the value of the oat hays to producers.

3.2 Limitations to the evaluations

It was difficult to obtain full details of diets in terms of feed quality, pricing and income for some areas. This highlights a limitation to the modelling, in general, as differences in feed availability, environment, attitudes to risk, financial backing ensure that any particular diet may not be fully representative of the region from which it is derived. This challenge was addressed, in part, by the simulation modelling detailed in section 6.2.

3.3 Dry cows

The following are the results for the pre-calving far-off and close-up (Pre-Fresh cows) by region. The cows were evaluated at 260 days of gestation for the far-off and 270 days of gestation for the close-up cows. Weights of cows differ with region and identical values were used for close up interventions for the oat hay or non-oat hay rations.

Table 2. Summary of the models evaluating potential for inclusion of oat hays in pre-calving far-off and close-up dry cow diets. *Cells in green are the diet comparisons that showed a benefit of using oat hay.*

Country	Far off cows			Close up cows		
	Oat hay rations	No oat hay	Difference	Oat hay rations	No oat hay	Difference
Saudi Arabia						
Riyal/cow/day	11.82	11.82	0	19.73	29.05*	-9.32
Weight gain (kg)	0.18	0.18	0	0		0
Korea						
$US/cow/day	4.31	4.47	-0.16	4.05	4.26	-0 .21
Weight gain (kg)	0	0	0	0	0	0
Vietnam						
Dong/cow/day	113823	111742	2081	143659	145506	-1847
Weight gain (kg)	0.2	0.32	-0.12	0.53	0.53	0
Taiwan						
$T/cow/day	22.4	22.4	0	20.05	20.05	0
Weight gain (kg)	0.07	0.07	0	0.07	0.07	0
Indonesia						
Rupiah/cow/day	41,931	46,250	-5,220	61,580	59,690	-18
Weight gain (kg)	0	0	0	0.25	0.32	-0.07
China						
$US/cow/day	2.42	2.45	-0.03	2.42	2.45	-0.03
Weight gain (kg)	0.05	0.05	0	0.05	0.05	0
China 2						
RMB/cow/day	27.43	27.61	-0.18	18.36	18.36	0
Weight gain (kg)	0.05	0.05	0	0.02	0.02	0
Philippines						
$US/cow/day	1.67	1.54	0.13	2.71	2.71	0
Weight gain (kg)	0.28	0.27	0.01	0.22	0.22	0

*Solution requires adjustments: v high Calcium
Where prices are identical, no oat hay was included in the diet.

Summary: For the far-off cows there were modest reductions in costs of feeding for Korea, Indonesia and China. For Vietnam there was increased cost but greater weight gain and for the Philippines there were modest increased costs, but cows had higher weight gains for an optimised oat hay diet. Oat hay did not enter the far-off diets for Saudi Arabia and Taiwan. The close-up cows had reductions in costs for Saudi Arabia and this diet would not solve without an additional forage source such as oat hay providing evidence of the importance of the oat hay to the diet. Korea, Vietnam and one Chinese farm had lower costs of feeding with the inclusion of oat hay.

3.4 Lactating cows

The following are the results for the high producing and lower producing cows by region. The high cows were evaluated at 100 days of lactation and lower producers at 240 days of lactation being 160 days in calf. Weights of cows differ with region and identical values were used for the oat hay or non-oat hay rations. Higher production cows up to 15000 L per lactation were assessed with 55 L per day production at 100 days in milk where appropriate. Where prices are identical, no oat hay was included in the diet.

Table 3. Summary of the models evaluating potential for inclusion of oat hays in diets for peak milk production and for later lactation or lower production cow diets. *Cells in green are the diet comparisons that showed a benefit of using oat hay.*

Country	High cow			Low cow		
	Oat hay rations	No oat hay	Difference	Oat hay rations	No oat hay	Difference
Saudi Arabia						
Costs Riyal/cow/day	46.18	48.01	-1.83	41.71	43.43	-1.72
Income over feed costs	80.32	78.49	1.83	73.29	71.57	1.72
Korea						
Costs $US/cow/day	11.68	11.74	-0.06	8.78	9.13	-0.35
Income over feed costs	29.32	29.26	0.06	15.82	15.47	0.35
Vietnam						
Costs Dong/cow/day	385,018	385,018	0	321,656.1	321,849.7	-193.6
L/ cow/day	39.9	39.33	0.57	28.6	28.8	-0.2
Taiwan						
Costs $T/cow/day	253.3	253.3	0	186.41	186.41	0
Income over feed costs	2535	2571	0	2,104	2,043	61
Indonesia						
Costs Rupiah/cow/day	229,556	227,673	1,883	172,212	163,600	8,608
L/ cow/day	40.0	39.3	0.7	30.2	29.2	1
China						
Costs $US/cow/day	7.98	8.14	-0.16	6.03	6.16	-0.13
L/ cow/day	20.37	20.21	0.16	12.87	12.74	0.13
China 2						
Costs RMB/cow/day	68.38	70.11	-1.73	49.25	51.34	-2.09
Income over feed costs	154.62	152.89	1.73	84.55	82.46	2.09
Philippines						
Costs $US/cow/day	5.26	5.26	0	3.28	3.28	0
L/ cow/day	32.3	32.3*	0	18.2	18.2	0

*Not solved @ 9kg maize silage and needs oat to solve

For the high cows that are in early lactation, the milk L/cow/day varied from 30 L to 55 L based on local production. There was a spread from 35L to 15 L per day for the low cow production.

Where prices are identical, no oat hay was included in the diet.

Summary: For the lactating cow diets it was difficult to confirm some milk prices, hence diets are reported as L/ per cow per day and for income over feed costs which is a prime metric for farm profit. The high producing cows had greater income over feed costs with oat hay inclusion for Saudi Arabia which was modelled for 55L per cow per day production. The Saudi Arabian results are strongly supported by use of oat hay in large, high producing herds from United Arab Emirates (ATMAC Report: Market assessment UAE).

Vietnam, Korea, Indonesia and China all had higher profit or milk production from feeding oat hays. For Taiwan there was no benefit from including oat hay in the diet but for the Philippines the diet would not solve without the providing an additional forage source, in this case oat hay. The Taiwan results are influenced by the good availability of low cost locally produced forage.

Perhaps unsurprisingly, results for the lower producing cows were identical in direction, but lower in magnitude than those for the high producing cows with the exception of the Philippines high cows that could not solve without the inclusion of oat hay. One Chinese herd was lower producing, the other high producing.

3.5 Heifer diets

The following are the results for young heifer and older heifer diets. The young heifers aged 4 months (most gaining 0.77 kg/day), older heifers 13 months old (most >0.8 kg/day gain). Weights of heifers were consistent for region and identical values were used for feeds in the oat hay or non-oat hay rations. Where prices are identical, no oat hay was included in the diet.

Table 4. Summary of the models evaluating potential for inclusion of oat hays in diets for 4-month old and 13-month old growing heifers. *Cells in green are the diet comparisons that showed a benefit of using oat hay.*

Country	4-month-old Heifer			13-month-old Heifer		
	Oat hay rations	No oat hay	Difference	Oat hay rations	No oat hay	Difference
Saudi Arabia						
Riyal/cow/day	7.06	7.06	0	3.77	3.77	0
Weight gain (kg)	1.1	1.1	0	0.76	0.76	0
Korea						
$US/cow/day	3.58	3.67	-0.09	1.55	1.58	-0.03
Weight gain (kg)	0.93	0.94	-0.01	0.71	0.76	-0.05
Vietnam						
Dong/cow/day	62966	62966	0	33909.9	38833.8	-4923.9
Weight gain (kg)	0.73	0.73	0	0.9	0.84	0.06
Taiwan						
$T/cow/day	16.97	16.97	0	6.53	6.53	0
Weight gain (kg)	0.78	0.78	0	0.78	0.78	0
Indonesia						
Rupiah/cow/day	27,610	27,610	0	38,310	38,310	0
Weight gain (kg)	0.75	0.75	0	1.06	1.06	0
China						
$US/cow/day	2.3	2.62	-0.32	1.08	1.11	-0.03
Weight gain (kg)	1.2	1.1	0.1	0.72	0.72	0
China 2						
RMB/cow/day	17.62	20.12	-2.5	8.29	8.33	-0.04
Weight gain (kg)	0.96	0.96	0	0.87	0.86	0.01
Philippines						
$US/cow/day	1.76	1.69	0.07	0.9	0.94	-0.04
Weight gain (kg)	0.9	0.9*	0	0.76	0.78	-0.02

* Not solved without oat hay
Where prices are identical, no oat hay was included in the diet.

Summary: For older heifers, there was not a notable response to oat hay availability. While profit was greater in Korea and China, oat hay did not enter diet elsewhere although the Philippines diet would not optimise without oat hay. For younger heifers, oat hay was incorporated for all regions except Taiwan. However, the diet in Indonesia was optimised at a slightly higher cost, but with slightly higher weight gain.

3.6 Beef diets

The following are the results for backgrounder and feedlot diets. The backgrounder weights varied with market as did the feedlot entry weights, however, the feedlot diet was formulated towards a 100 to 120-feeding period. Weight gains for backgrounder steers were targeted at >1 kg/day gain and for feedlot steers >1.66 kg/day gain and identical values were used for feeds in the oat hay or non-oat hay rations. Where prices are identical, no oat hay was included in the diet.

Table 5. Summary of the models evaluating potential for inclusion of oat hays in diets for beef backgrounder and beef feedlot diets on cost of ration and weight gain (kg) per head. *Cells in green are the diet comparisons that showed a benefit of using oat hay.*

Country	Backgrounder Beef			Finisher Beef		
	Oat hay rations	No oat hay	Difference	Oat hay rations	No oat hay	Difference
Saudi Arabia						
Riyal/head/day	13.29	16.6	-3.31	16.48	16.48	0
Weight gain (kg)	1.1	1	0.1	2	2	0
Korea						
$US/ head /day	3.44	3.58	-0.14	4.15	4.35	-0.2
Weight gain (kg)	1.1	1.1	0	1.7	1.7	0
Vietnam						
Dong/ head /day	93,653	91,117	2,536	102,638	88,479	14,159
Weight gain (kg)	1.5	1.4	0.1	1.8	1.8	0
Taiwan						
$T/ head /day	98,811	97,000	1,811	125,574	126,000	-426
Weight gain (kg)	1.01	0.96	0.05	1.724	1.724	0
Indonesia						
Rupiah/ head /day	50,311	49,531	780	70,484	79,423	-8,608
Weight gain (kg)	1.03	0.82	0.19	1.62	1.47	0.15
China						
$US/ head /day	2.06	2.06	0	2.05	2.05	0
Weight gain (kg)	1.4	1.4	0	1.66	1.66	0
China 2						
RMB/ head /day	18.18	18.29	-0.11	26.06	26.06	0
Weight gain (kg)	1.2	1.2	0	1.7	1.66	0.04
Philippines						
$US/ head /day	1.41	1.41	0	1.73	1.73	0
Weight gain (kg)	1	1	0	1.8	1.8	0

Where prices are identical, no oat hay was included in the diet.

Summary: For the backgrounder cattle, the cost of feeding was reduced for Saudi Arabia, Korea and one China diet. The diets for Indonesia, Vietnam and Taiwan the oat hay diets were more expensive but weight gain was better. Other diets did not include oat hay. For the feedlot cattle, differences in costs and gain were small with the exception of Vietnam for which the costs of feeding were lower with oat hay.

4. Modelling factors that influence oat hay inclusion

It is obvious that the many factors that influence diets on farm vary substantially, but these also vary in predictable ways. Availability of low-cost local forage, such as tropical grasses, limited uptake of oat hay. Access to lower cost protein or non-protein nitrogen sources, increased uptake of oat hay and reduced the inclusion of alfalfa (lucerne) hay in the diets.

The goal of the following modelling was to develop more robust methods to account for;

- Anticipated fluctuations in input costs based on commodity fluctuations,
- Availability of critical inputs such as silages, protein meals and non-protein nitrogen sources,
- Variation in feed values.

The simulations provide a robust evaluation in a risk-based context to evaluate the likely inclusion of oat hay in the diet. The materials and methods used for this modelling are detailed in Section 6.

Figures 4 to 6 and 8 to 11 are the results from diet evaluations showing oat hay inclusions, displayed as percentage inclusion in the dry matter of diets, stemming from changes over a range of 4 Standard Deviations in alternative commodity pricing while oaten hay pricing remains constant. The normalised price associated with each Standard Deviation of the alternative ingredient is itemised with each graph. The Y– axis of the figures shows the proportion (with 1 being the maximum) of the 10,000 simulation results for each percentage inclusion of oat hay. The upper X-axis provides the 90% confidence interval for inclusion of the oat hay. The 90% confidence interval shows that 90% of the simulations include oat hay at the percentages in that range. The process of simulation modelling provides the best means of considering the effects of volatility in price or availability on oat hay inclusions in diets.

The modelling still has some practical limitations. For example, availability of low cost locally grown forage limited or obviated the inclusion of imported hays. The practical caveats around tropical forages in particular, need to be considered as these are difficult to preserve and are difficult to maintain in a highly digestible state for harvest due to rapid growth and have a propensity for mycotoxin contamination (Aranega, 2022; Anon 2024). These factors may inhibit their use in high producing and lactating cow diets due to adverse effects (Rodrigues, 2014). These issues are well understood by experienced nutritional advisors. Consequently, the inclusion of oat hay and other forages may be more attractive than a nutritional evaluation by modelling may suggest. The concern about anti-nutritional factors also applies to corn silage in some climates where delays in harvest, in particular, may increase mycotoxin loads.

The simulation results for changes in price and availability of different feeds are shown in Figures 4 to 11.

4.1 Results of changes in feed pricing and availability

4.1.1 Diets for the UAE

The modelling process provided an evaluation of the proportion of inclusion for oat hays as the price or availability of another commodity varied. The @Risk distributions shown in Figures 4 to 6 are based on a total oat hay inclusion in the diet and allow for an adjustment between the different oat hays by modelling using only the dominant hay quality that was selected in the optimized models.

The optimisation was based on holding the price of the oat hays constant and changing the price of the commodity tested in the diet by 1 and 2 SD greater and below the mean price of the commodity over the past approximately 10 years using a normalized distribution (Figure 3). Values that differ by more than 2 SD from the mean in either direction represent only 2.5% of prices and those that differ by more than 1 SD in either direction represent less than 16% of prices. Further, one might anticipate changes in the pricing of the oat hay in response to market pressures or opportunities that would alter the proportion included.

For example, if a shift in pricing of a commodity resulted in an optimized solution with a hay of higher or lower feed value, the amount of hay included was adjusted for by modelling. Specifically, for example, with an increased cost of cottonseed, the oat hay inclusion changed from second quartile to third quartile oat hay with a lower percentage inclusion in the diet. Hence the distribution estimated reflected a higher inclusion of oat hay than for the lower quality inclusion. Such changes are noted in the legends for the Figures 4 to 6.

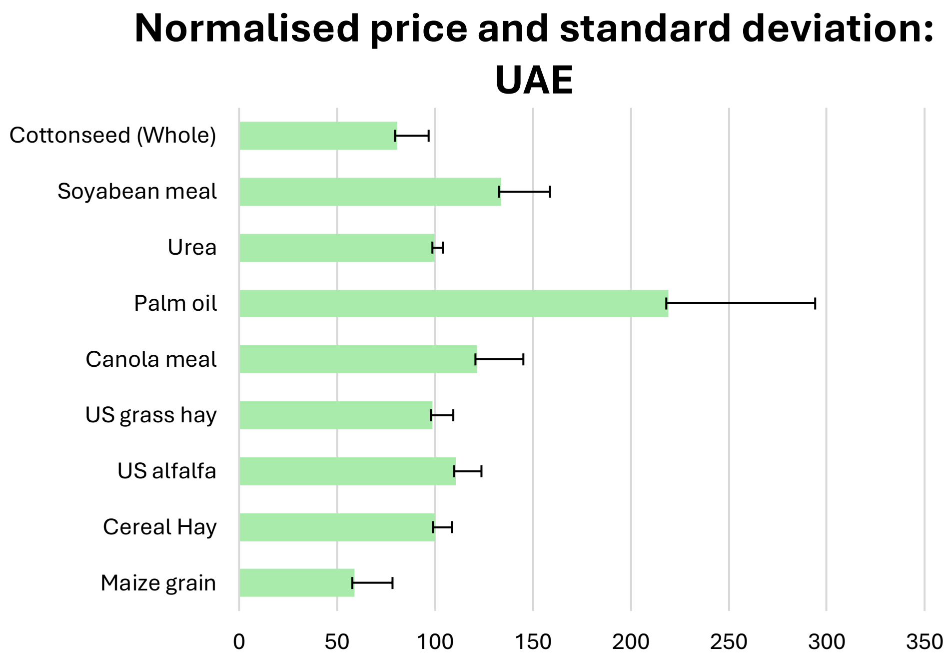


Figure 3. The Y axis is the commodity evaluated and the X axis provides prices for commodities in the UAE diets providing a normalised mean (average) based on cereal hay pricing and standard deviation from commodity fluctuation data but on a normalised basis. Oat (Cereal) hay is the reference at 100.

4.1.2 Changes in feed price

Figure 4 A shows the effect of change in corn price on the inclusion of oat hay. With a higher price for flaked corn, inclusion of second quartile quality oat hay was favoured and less total oat hay was required. When only second quartile quality oat hay was evaluated the distribution shows that the inclusion is relatively insensitive to changes in maize price, lying between 10 and 20% of the diet DM inclusion.

While inclusion of oat hay was relatively insensitive to changes in the price of corn, Figure 4B demonstrates insensitivity of oat hay inclusion to marked change in whole cottonseed price. There was, however, a change in oat hay quality from second quartile quality to third quartile quality as cottonseed price increased.

The findings reinforce an important role of oat hay in providing high quality fibre in the diet to assist in proving rumen stability when rapidly fermentable carbohydrates such as flaked maize are able to be increased in the diet on a cost efficacy basis. Interestingly, the similar insensitivity of oat hay to whole cottonseed indicates the overall importance of the nutritive values of oat hay when a feed high in fats, protein and fibre is more available.

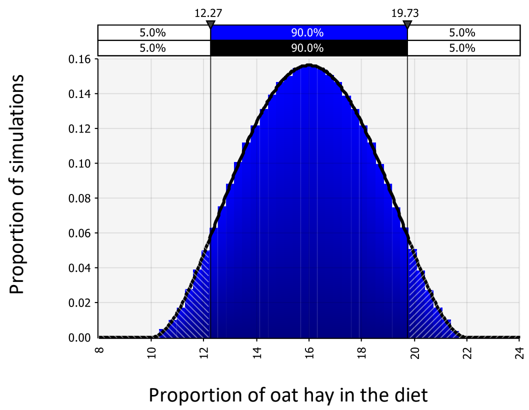


Figure 4A. Sensitivity of oat hay inclusion to changes in price of maize in UAE diets

The Y axis indicates the frequency of inclusion of oat hay in the diet and the X axis is the proportion of dry matter included. Change in inclusion of third quartile quality oat hay as dry matter % of the diet over a range of 4 standard deviations in maize price ($normalised 19.5 per SD; Figure 3). Third quartile quality oat hay was included when the price of corn was below or at average, and second quartile quality when at average maize price or greater.

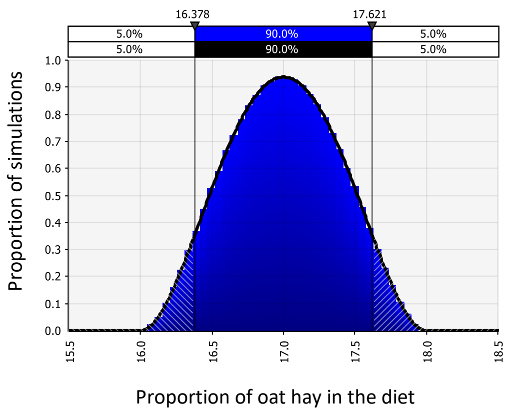


Figure 4B. Sensitivity of oat hay inclusion to changes in price of whole cottonseed in UAE diets

The Y axis indicates the frequency of inclusion of oat hay in the diet and the X axis is the proportion of dry matter included. Change in inclusion of oat hay as dry matter % of the diet over a range of 4 standard deviations ($normalised 16 per SD; Figure 3) in whole cottonseed price. Second quartile quality oat hay was included when the price was below or at average and third quartile quality when at average whole cottonseed price or greater.

As soyabean meal price increased inclusion of oat hay declined and the inclusion altered from third quartile quality to second quartile quality hays. Figure 5 A shows the third quartile quality oat hay inclusions. If prices for soyabean meal were 1SD greater average or greater second quartile quality oat hay was included at 12.5% of dietary DM.

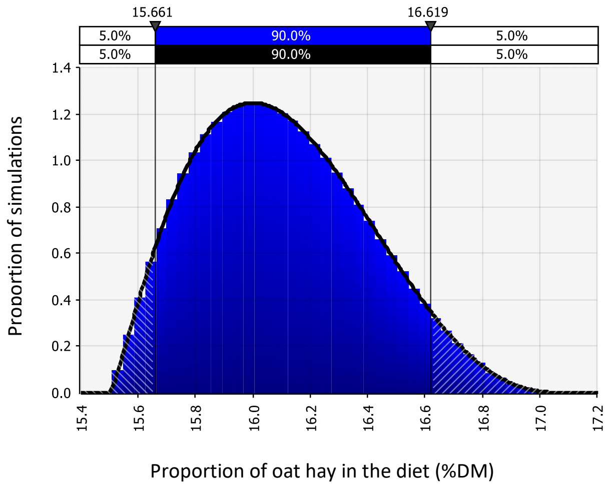


Figure 5 A. Sensitivity of oat hay inclusion to changes in price of soyabean meal in UAE diets

The Y axis indicates the frequency of inclusion of oat hay in the diet and the X axis is the proportion of dry matter included. This figure shows change in inclusion of third quartile quality oat hay as dry matter % of the diet over a range of 2 standard deviations from average to 2 SD below average soyabean meal price ($normalised 25.1 per SD; Figure 3). Third quartile quality oat hay was included when the price of soyabean meal was less than or at average and second quartile quality when at average soyabean meal price or greater.

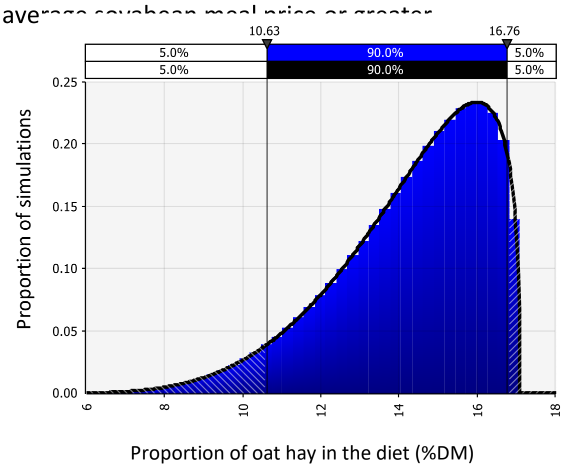


Figure 5 B. Sensitivity of oat hay inclusion to changes in price of palm oil in UAE diets

The Y axis indicates the frequency of inclusion of oat hay in the diet and the X axis is the proportion of dry matter included. Change in inclusion of total oat hay as dry matter % of the diet over a range of 4 standard deviations in palm oil price ($normalised 75 per SD; Figure 3). As the price of palm oil increased, the third quartile quality oat hay was not included but the second quartile quality hay increased.

The effect of palm oil pricing on oat hay inclusion is complex as with the average situation third quartile quality oat hay was included in the diet at 16%, however, increased price of palm favoured the inclusion of second quartile quality oat hay at 13.8% to 16.7% of the diet. A reduction of 1 SD in palm price resulted in a reduction to 5% inclusion of the third quartile quality oat and inclusion of alfalfa hay.

For alfalfa hay price, at the average case, that is current price differentials, no alfalfa was included in the diet. A decrease in price of 1 standard deviation in alfalfa hay price resulted in approximately a 75% reduction in oat hay inclusion. This did not alter if the price of alfalfa hay decreased by another standard deviation. An increased price for alfalfa greater the current differential did not result in inclusion of alfalfa in the diets.

The oat hay inclusions were insensitive to changes in the price of Rhodes grass with a partial displacement 50% of the third quartile oat hay only once the price of Rhodes grass hay was 2 SD below average that is approximately <2.5% of the time and if the oat hay price was simultaneously at the average price.

4.1.3 Feed quality and availability

The availability of corn silage greatly influenced the inclusion of oat hay. If 12 kg DM corn silage was available, no oat hay entered the diet, however, when no corn silage was available the diet included second quartile quality oat hay (12% of DM) and 19% of the DM as third quartile quality oat hay (Figure 6).

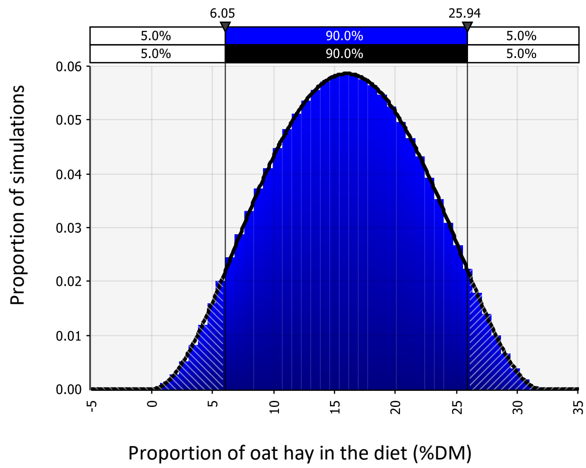


Figure 6. Sensitivity of oat hay inclusion to changes in availability of maize silage in UAE diets

The Y axis indicates the frequency of inclusion of oat hay in the diet and the X axis is the proportion of dry matter included. A. Change in inclusion of total oat hay as dry matter % of the diet over a range of 0 to 12 kg of dry matter of maize silage. The inclusion of oat hay in the diet increased as less silage was available.

Alfalfa hay of lesser quality did not enter the diets if it had the same purchase price, and a 1 SD better quality alfalfa hay (Supplementary Table 2), was included at 2.8% of the diet with a similar reduction in the oat hay use, indicating that oat hay inclusion was robust to 1 SD better alfalfa hay quality at a similar pricing differential (that is 11% higher than second quartile quality oat hay).

If Timothy hay was available of 1 SD better quality and at the same price, it would displace 90% of the oat hay in the diet and for timothy hay 2 SD greater average, all oat hay was displaced. However, Timothy hays of lesser quality did not enter the diet.

4.1.4 Risk mitigation

Figure 6 identifies the sensitivity of oat hay inclusion to that of alternate forages. However, this also highlights the potential for oat hay to reduce exposure to risk for enterprises. For example, if 12 kg of dry matter of maize silage were fed to 1000 milking head each day (representing approximately 1200 lactations per annum), the 12 tonne of dry matter per day requirement represents approximately a 0.5 HA planting of a productive maize crop (24 tonne of DM per HA) and therefore a planting of approximately 180 HA assuming no use of maize silage in dry or young stock. This planting has the potential for enterprise risks in terms of investment and possible crop failure or quality failures. Oat hay provides an opportunity to secure forage and manage risk.

A second area of risk mitigation noted above is the ability to reduce the risk of acidosis and take advantage of changes in the price of rapidly fermentable carbohydrates such as maize grain.

4.2 Chinese diets

Figure 7 provides the normalised values for commodities for the Chinese modelling.

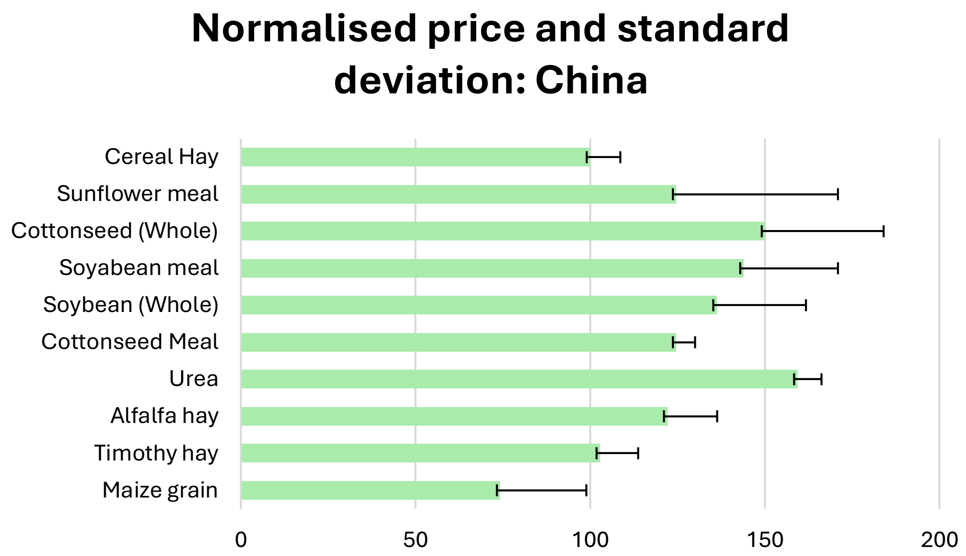


Figure 7. Pricing for commodities in China diets providing a normalised mean (average) and standard deviation based on cereal hay pricing. Oat (Cereal) hay has a normalised price of 100.

Total inclusions of oat hay at 11 to 12% of dietary DM were insensitive to decreases in the price of corn grain, but the inclusions increased markedly when corn grain increased in price. When corn price was lower than average (normalised mean) the inclusion of the fourth quartile quality oat hay was favoured, but from average to greater the third quartile quality oat hay was selected. There was <1% difference in DM inclusion between the fourth quartile quality and third quartile-quality oat hay inclusion when the same diet constraints were tested. Figure 8A shows the response in third quartile quality oat hay to corn price increases. Responses to increased costs of cottonseed meal demonstrated slightly increased use of oat hay including the use of the fourth quartile quality hay in small amounts (3 to 4% inclusion) with an increase of 1 SD and 2 SD in cottonseed meal, respectively. Total oat hay use increased from 11.6 to 14% of the DM with increases of 1 and 2 SD in the price of cottonseed meal. Soyabean meal use increased in the diet with the higher price for cottonseed meal. Overall, decreases in cottonseed meal prices below the average had little effect on the inclusions of oat hay, which decreased from the average to 2 SD below average by less than 1 % of the diet DM.

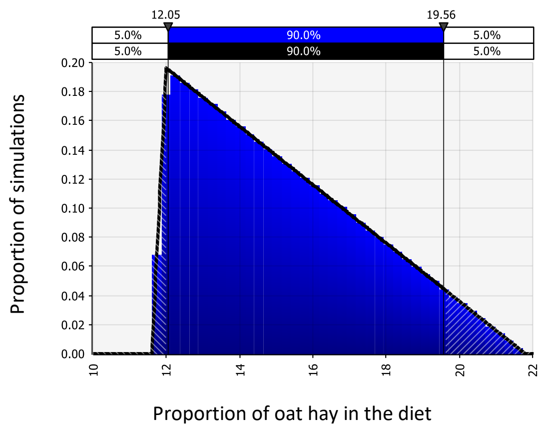


Figure 8A. Sensitivity of oat hay inclusion to changes in price of corn grain in Chinese diets

The Y axis indicates the frequency of inclusion of oat hay in the diet and the X axis is the proportion of dry matter included. Change in inclusion of total oat hay as dry matter % of the diet over a range of 2 standard deviations increase in corn grain price. As the price of corn grain increased from the average, the use of oat hay increased.

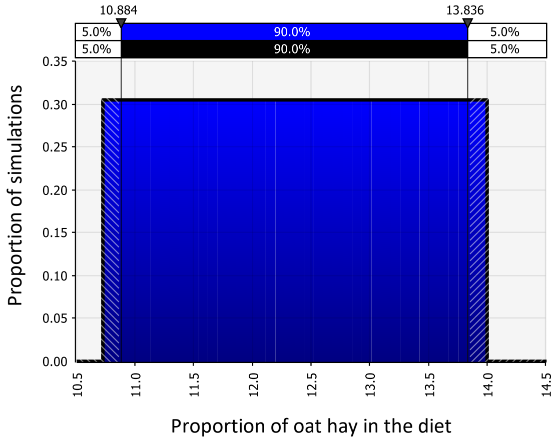


Figure 8B. Sensitivity of oat hay inclusion to changes in price of cottonseed meal in Chinese diets

The Y axis indicates the frequency of inclusion of oat hay in the diet and the X axis is the proportion of dry matter included. Shows the lack of change in inclusion of total oat hay as dry matter % of the diet over a range of 4 SD variation in costs of cottonseed meal. As costs for cottonseed meal increased, there was a small increase in inclusion of fourth quartile quality oat hay as well as the third quartile quality oat hay.

When whole cottonseed was cheaper than 1.5 SD below average, it displaced much of the oat hay from the diet and leaving only 4% DM oat hay, however, even with cottonseed priced 1 SD below the mean oat hay was in the ration at 11.5% and cottonseed was not included. This inclusion level of oat hay of approximately 12% of DMI stayed static at high prices of cottonseed. Figure 9A displays oat hay responses to change in cottonseed prices from 2 SD below average to the average price.

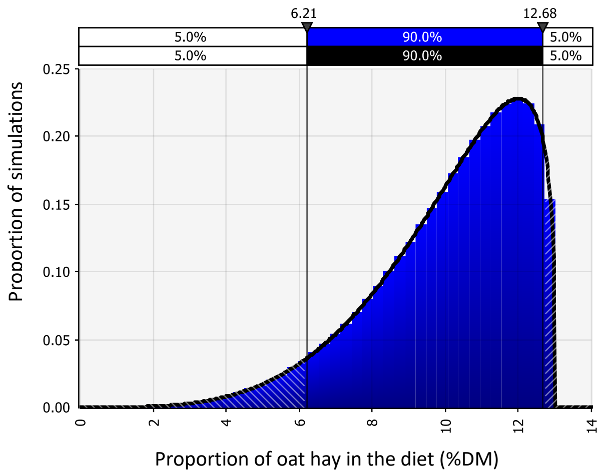


Figure 9A. Sensitivity of oat hay inclusion to changes in price of whole cottonseed in Chinese diets

The Y axis indicates the frequency of inclusion of oat hay in the diet and the X axis is the proportion of dry matter included. Change in inclusion of total oat hay as dry matter % of the diet over a range of 2 standard deviations increase in whole cottonseed price from 2 SD below to the average price. As the price of whole cottonseed increased from 2 SD below average to the average price, the use of oat hay increased until the average price at which point it became static in the diet.

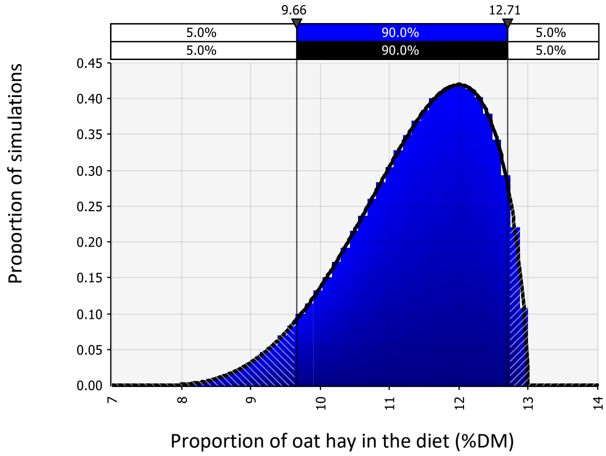


Figure 9B. Sensitivity of oat hay inclusion to changes in price of whole soyabean in Chinese diets

The Y axis indicates the frequency of inclusion of oat hay in the diet and the X axis is the proportion of dry matter included. Shows the change in inclusion of total oat hay as dry matter % of the diet over a range of 4 SD variation in costs of whole soyabean, showing a nearly linear increase in inclusion over the range with the distribution weighted to the mean price of soyabean.

Oat hay use increased with increases in price of whole soyabean (Figure 9B). With very low prices of whole soyabean the inclusions were with the fourth quartile quality oat hay and from the average price upwards the inclusion was with third quartile quality oat hay, however, the amount of oat hay in the diet for this range was relatively insensitive to changes in the soyabean price.

Inclusions of oat hay increased from 7% to 11% of the diet DM up to the average pricing for soyabean meal but were not sensitive to further increases in the price of soyabean meal. Figure 10A shows the increase in inclusion of the range from 2SD below average to the average price of soyabean meal. When sunflower meal was priced at 1 SD below average, oat hay did not enter the diet, however, oat hay increased in the diet until the average price for sunflower meal was reached and sunflower meal was not included in the ration. Figure 10B shows the distribution for sunflower meal priced 1 SD below average to the average price and indicates a sensitivity of oat hay inclusion to decreases in sunflower price.

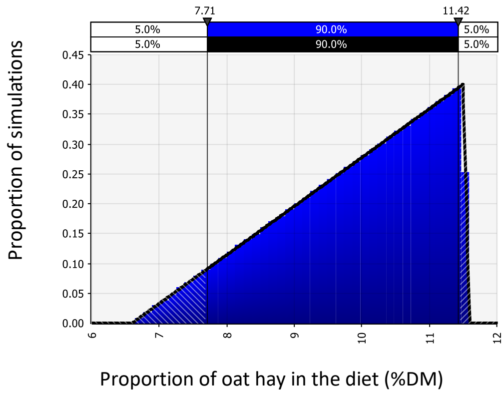


Figure 10A. Sensitivity of oat hay inclusion to changes in price of soyabean meal in Chinese diets

The Y axis indicates the frequency of inclusion of oat hay in the diet and the X axis is the proportion of dry matter included. A. Change in inclusion of total oat hay as dry matter % of the diet over a range of 2 standard deviations increase in soyabean meal price from 2 SD below to the average price. As the price of soyabean meal increased from 2 SD below average to the average price, the use of oat hay increased from 6.7% of the diet dry matter until the average price at which point it became static in the diet at approximately 12% of diet dry matter.

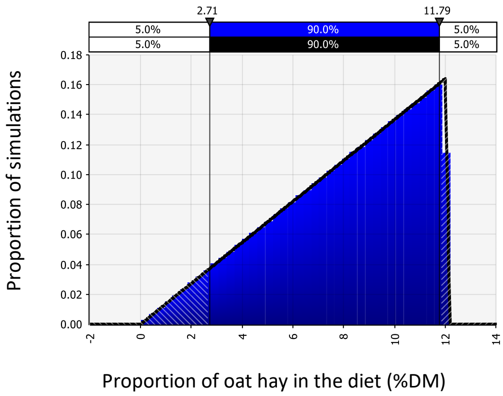


Figure 10B. Sensitivity of oat hay inclusion to changes in price of sunflower meal in Chinese diets

The Y axis indicates the frequency of inclusion of oat hay in the diet and the X axis is the proportion of dry matter included. Shows the change in inclusion of total oat hay as dry matter % of the diet over a range of 1 SD variation in costs of sunflower meal, showing a nearly linear change in inclusion over the range.

The China diets were insensitive to a change of 1 standard deviation greater or below the average quality of the either oat or alfalfa hay, indicating that the oat hays delivered the nutrients required in the most probable price range.

A decrease of one standard deviation from the average price of timothy hay resulted in the replacement of oat hay in the diet with timothy hay. No timothy was included in the average price scenario nor with increased costs of timothy hay.

Figure 11 shows that the amount of oat hay included in the diet was very responsive to the amount of maize silage available over a range from 0 corn silage to more than 10 kg of DM with a base of 7kg available.

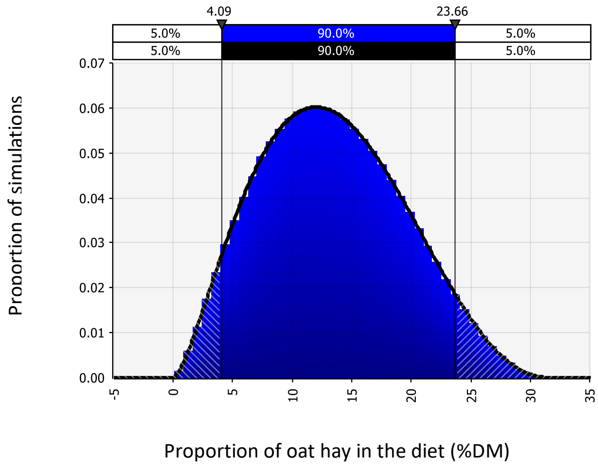


Figure 11. Sensitivity of oat hay inclusion to changes in price of maize silage in Chinese diets

The Y axis indicates the frequency of inclusion of oat hay in the diet and the X axis is the proportion of dry matter included. The change in inclusion of total oat hay as dry matter % of the diet over a range of no corn silage available in which the oat hay inclusion is high to having in excess of 10 kg of DM of maize silage available when very little or no oat hay is included in the diet.

Summary of Chinese modelling

The Chinese modelling is very consistent with the findings overall that the use of oat hays is limited by the availability of local forage, but is consistently included at similar proportions in the diet despite quite large changes in pricing of many other commodities. The oat hay inclusion was sensitive to reductions in sunflower meal price. The inclusions of oat hay were also influenced by prices of competing fibre sources but the nutritional attributes of the oat hay were superior when compared to alfalfa or timothy hays that were of 1 SD higher quality than normal.

5. Export hay data – An extended database

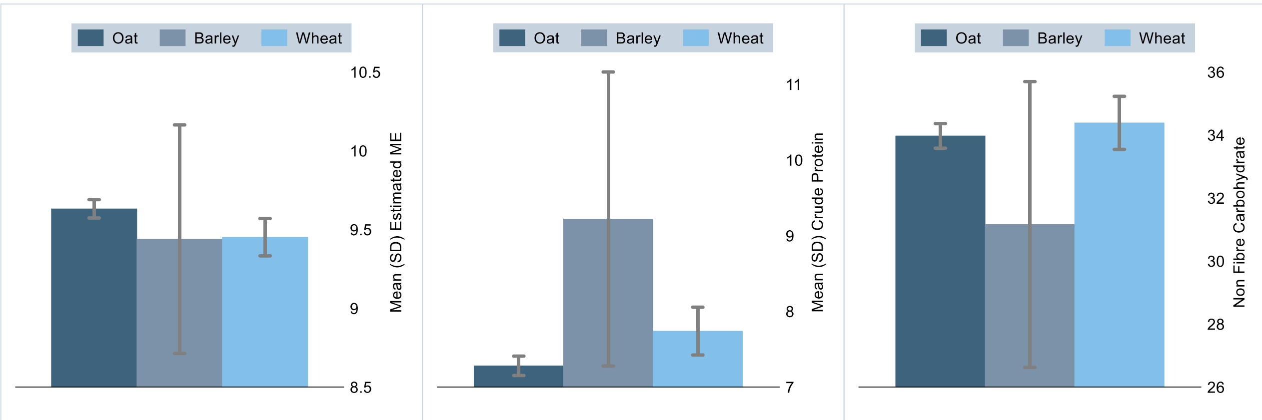
The following provides a description of more than 500 Australian hays. The source of the information comes from a single export producer who has provided a high-quality database of hay tested through a single laboratory (DairyOne New York DHIA Laboratory). The samples are drawn from each lot of the entire inventory of hay of all grades from across three states purchased by the exporter. A comparison with competitor products (Alfalfa hay and Timothy hay from the USA – see supplementary Tables 10 and 11) is based on information from the DairyOne New York DHIA Laboratory database and information supplied from CVAS.

The materials and methods used by CVAS are provided in Section 6 of this document. The data provided include potentially important insights including the results of standard analytical procedures for determining the nutritional value of feeds and analytical estimates of rates of digestion and fibre residues that are useful for nutritional modelling. The Supplemental Tables (1 to 3) provide information on these hays and some evaluation of the components that are valuable in describing nutritional value.

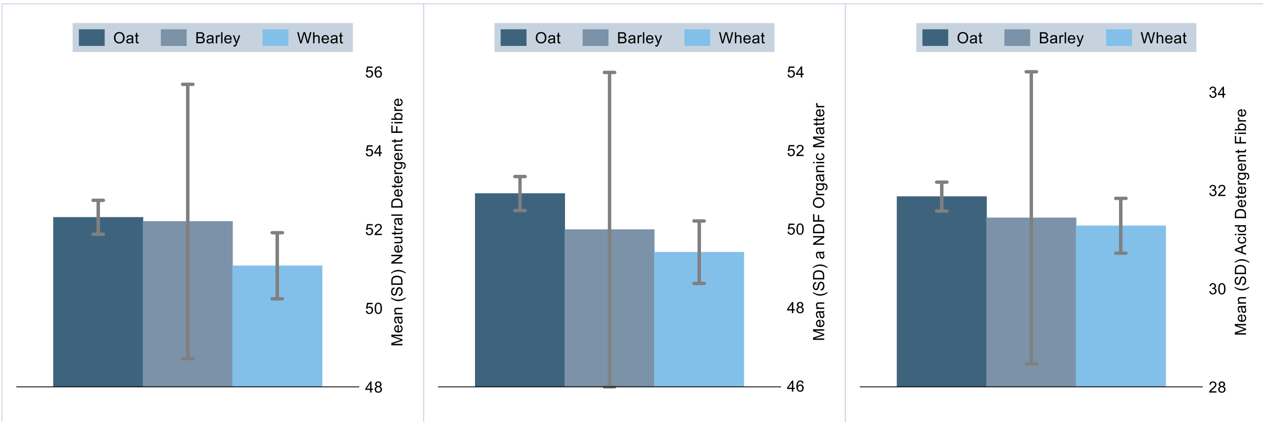
5.1 Comparison among hay types

Of the 535 hay samples evaluated in the Extended data set, Barley hay samples (5) were less than 1%, Oat hay (476) 89% and Wheat hay was 10% of the samples. The source of hays was 65% Bowmans and 35% Brookton with all being from the 2021 crop. Comparisons may be valid between the Oat hay and Wheat hays for these samples, but there is a lot less evidence for the Barley hay and this is only documented to provide some indication of the feed value.

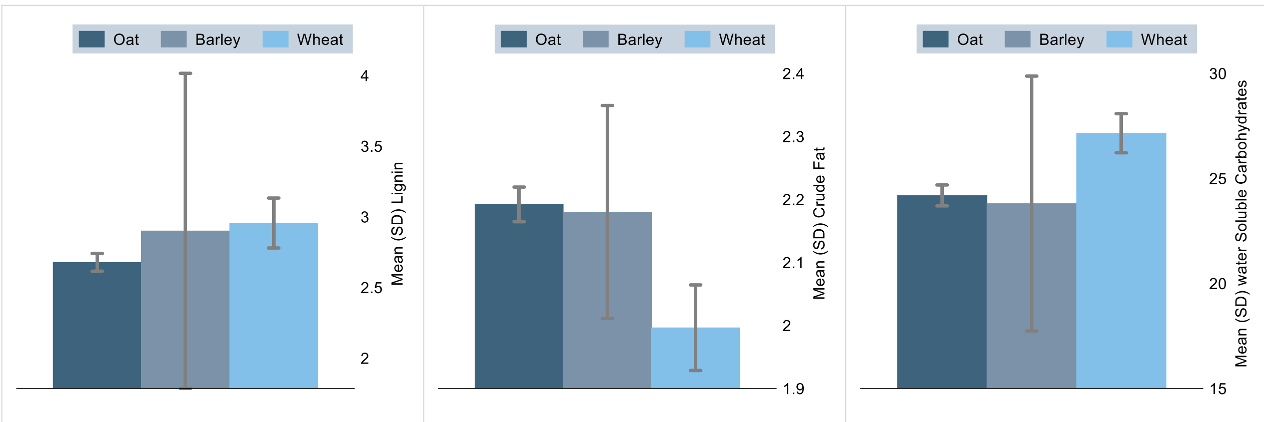
The statistical methods applied to the feed analysis data (Figures 12 to 26) was an analysis of variance to compare the different hays and the results provided graphically are as means and SD of the data.



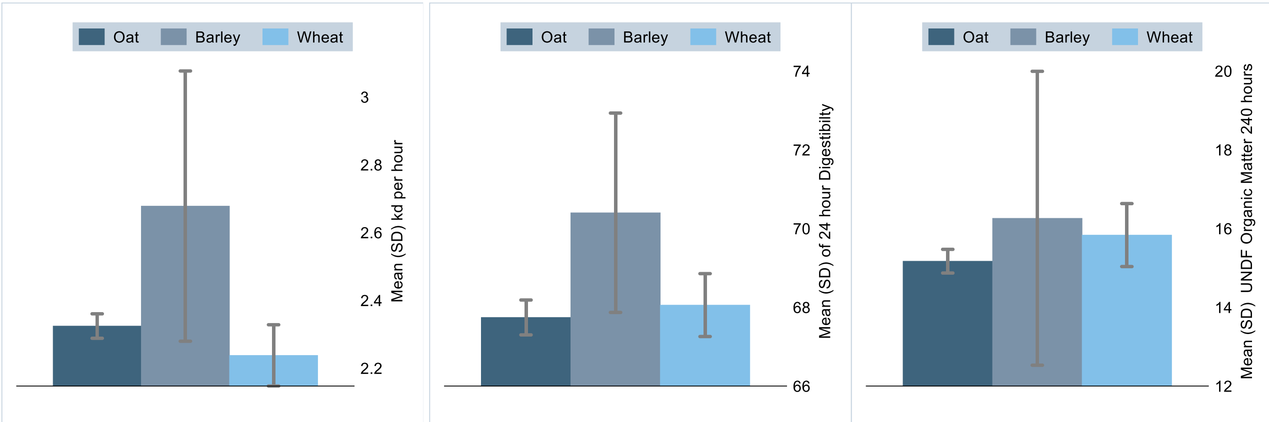
Figures (12 to 14). Mean and standard deviation (error bars) of estimated metabolisable energy (MJ), percentage crude protein and non-fibre carbohydrate for Oat, Barley and Wheat hays. All 3 hays do not differ in estimated ME (P >0.1) or non-fibre carbohydrate (P>0.2), but all hays differ in crude protein (P<0.01).



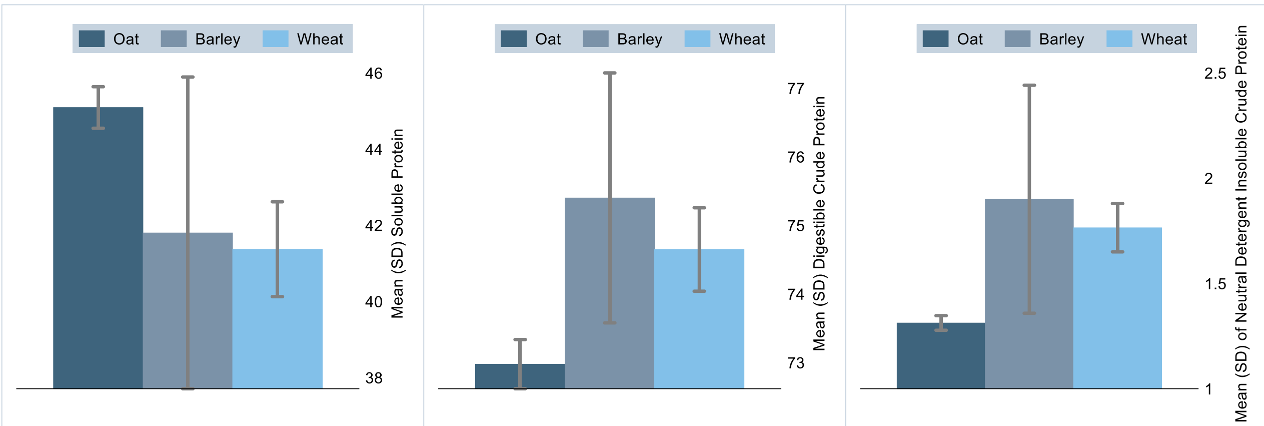
Figures (15 to 17). Mean and standard deviation (error bars) of neutral detergent fibre, neutral detergent fibre as a percentage of organic matter, and acid detergent fibre for Oat, Barley and Wheat hays. All 3 hays do not differ in estimated neutral detergent fibre (NDF) (P >0.2) or acid detergent fibre (ADF) (>0.4) but differ in neutral detergent fibre as a percentage of organic matter (P>0.1), with Oat and Wheat hays differing (P<0.05).



Figures (18 to 20). Mean and standard deviation (error bars) of lignin, percentages crude fat and water-soluble carbohydrate for Oat, Barley and Wheat hays. The hays differ in lignin (P <0.05) with Oat hay being lower than Wheat, and also differ in crude fat (P >0.01) with Oat higher in crude fat than Wheat. Water-soluble carbohydrates were higher in Wheat than Oat hay (P<0.01). Postscript – the wheat hay results may be biased as they are more likely to be from frosted grain crops



Figures (21 to 23). Mean and standard deviation (error bars) of rate of degradation (kd/hr), 24-hour digestibility and undigested neutral detergent fibre as percentage of organic matter at 240 hours, for Oat, Barley and Wheat hays. The Barley hay has a greater rate of degradation (kd/hr) than the other hays (P <0.05). All 3 hays do not differ in 24-hour digestibility and undigested neutral detergent fibre as a percentage of organic matter at 240-hours (P >0.2).



Figures (24 to 26). Mean and standard deviation (error bars) soluble crude protein, degradable crude protein, and neutral detergent fibre insoluble crude protein as a percentage for Oat, Barley and Wheat hays. The Oat hay has a greater soluble protein than the other hays (P <0.01) and is higher than Wheat hay but is lower in degradable crude protein than (P <0.01) the other hays and specifically lower than Wheat by approximately 2%. Wheat and Barley hays are higher in neutral detergent fibre insoluble crude protein (P<0.01) than Oat hay but do not differ in acid detergent fibre and insoluble crude protein (P >0.2) (not shown in Figures).

5.2 Summary of Hay Analyses

The 535 samples provide a strong evidence base for evaluating differences in Oat and Wheat hay but little evidence around Barley hay. Differences among the hays indicate likely differences in performance. While the estimated ME content did not differ among hays (Figure 12), only 1 Wheat hay was ranked in the top 30 for this analysis. Given the disproportionate number of Oat hays to Wheat hays, this does not indicate that the Wheat hays will be less satisfactory in diets.

The crude protein content of the 3 hays differed, although the numeric differences are modest with Barley 9.2, Wheat 7.7 and Oat 7.3% (Figure 13). The non-fibre CHO contents did not differ (Figure 14), nor do the NDF (Figure 15) and ADF (Figure 17); however, the aNDFom differed (Figure 16; P <0.1) with Wheat hay containing 49.4 and Oat hay 50.9%. Despite that finding, the hays differed in lignin content (Figure 17) with Wheat hay containing more 2.9% than Oat hay 2.7%, but the 24-hour digestibility (Figure 22) and 240-hour uNDF (Figure 23) did not differ among hays. The limited number of Barley hay determinations had a higher rate of degradation per hour than the other two hays (Figure 21). Consequently, there is little to differentiate the hays on a fibre content and degradation basis.

Interestingly, there are differences in the crude fat content (Figure 19), with Oat hay being 0.2% greater than Wheat, but Oat hay was 3% lower in water-soluble CHO content (Figure 20). Most of the difference in WSC was attributable to a difference in fructans that were 2.9% higher in Wheat than Oat hay. The fat content was approximately 2% of the hays, but WSC was approximately 25% indicating a readily available energy source for microbial fermentation. The increased soluble crude protein by approximately 4% (Figure 24) for Oat hay is not consistent with a reduction of approximately 2% in degradable crude protein (Figure 25) but consistent with an increase in neutral detergent insoluble crude protein (0.5%) compared to Wheat hay (Figure 26).

6. Comparative aspects of oat hay, alfalfa hay and timothy hay sourced from North America

Figure 27 shows comparisons among the oat hays sourced from Australia and North American based on the Extended data for oat hay and the information obtained from the DairyOne and CVAS feed laboratories (Table 6).

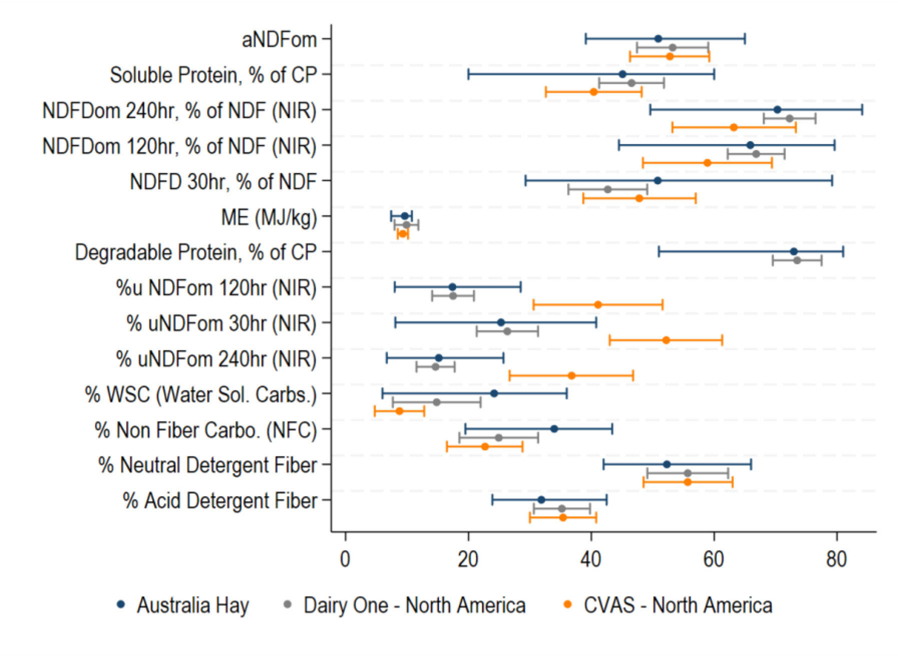
While many of the nutritional qualities are comparable, there are also notable differences. In particular, the fibre components differ with the lower percentage of lignin, ADF, NDF, and aNDFom than the North American estimates. Further, the degradability of the NDF was higher at 30 hours and similar or higher at 120 and 240 hours than the oat hays from North America. The undegraded NDF was similar or lower at 240 hours, and the non-fibre carbohydrates were higher by 9 to 11% for the Australian oat hays, with water-soluble (WSC) and ethanol soluble carbohydrates (ESC) being higher in the Australian hays. The starch was lower in the Australian hay samples indicating the probability of being harvested earlier than the North American hays, a finding consistent with the fibre and other carbohydrate findings. The ash content was a little lower in the Australian hays. While the analytical methods differ slightly between laboratories, the Australian and CVAS estimates are from the same laboratory. The DairyOne results can also be compared directly with the Extended results in Table 1B.

Table 6. A comparison of oat hays from North America and Australia.

Nutrient (% of DM)	Australian			US -DairyOne			US- CVAS		
	N	Average	SD	N	Average	SD	N	Average	SD
Lignin	476	2.678	0.697	130	4.155	1.004	4498	5.14	1.12
Acid Detergent Fibre	476	31.871	3.271	169	35.214	4.571	6483	35.4	5.42
Neutral Detergent Fibre	476	52.305	4.79	140	55.697	6.572	6491	55.7	7.27
Neutral Detergent Fibre in organic matter	476	50.899	4.810	29	53.236	5.803	6528	52.8	6.41
Neutral Detergent Fibre degraded 30hr, % of NDF	476	50.808	7.878	51	42.686	6.415	2046	47.8	9.11
Neutral Detergent Fibre in organic matter degraded 120hr, % of NDF (NIR)	476	65.887	5.534	27	66.836	4.629	6572	58.9	10.5
Neutral Detergent Fibre in organic matter degraded 240hr, % of NDF (NIR)	476	70.302	5.366	27	72.287	4.211	6574	63.2	10.1
Undegraded Neutral Detergent Fibre in organic matter degraded 240hr (NIR), % of NDF*	476	15.170	3.340	27	14.644	3.105	6574	36.8	10.1
Non Fibre Carbohydrate	476	33.972	4.341	142	24.935	6.408	4837	22.7	6.16
Ethanol soluble sugars SC (Simple Sugars)	476	14.100	2.197	138	9.663	4.187	4454	7.66	3.58
Water Soluble Carbohydrates	476	24.187	5.538	135	14.83	7.142	6584	8.77	4.02
Starch	476	2.504	1.426	141	3.72	4.021	5181	7.98	6.25
Ash	476	5.613	1.456	133	7.701	2.775	4875	8.66	2.57

*CVAS report as % NDF undegraded

A.



B.

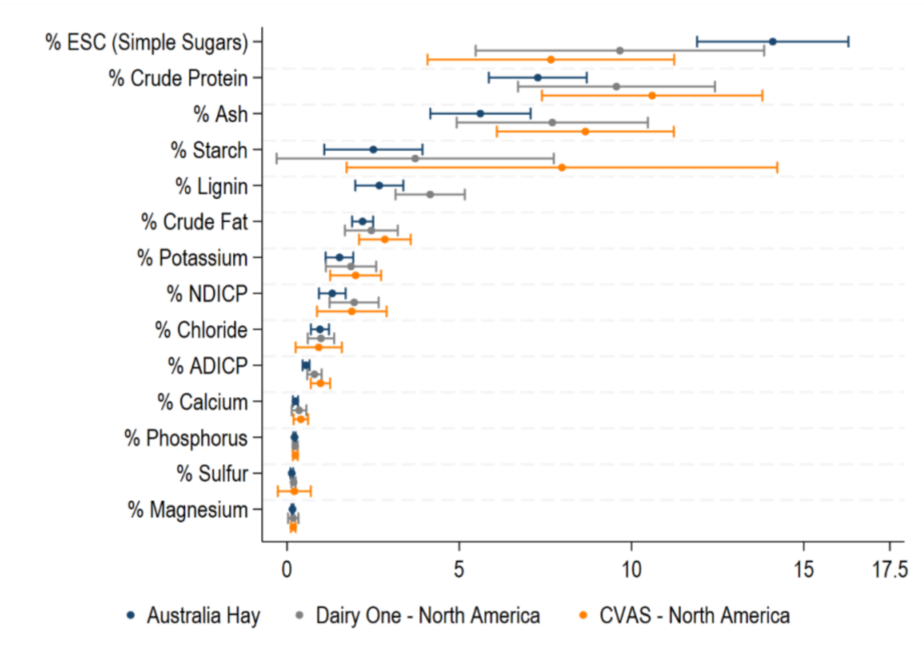


Figure 27. Nutrient contents (mean plus or minus 1 SD) of oat hay samples from Australia and North America tested at Dairy New York Dairy One Herd Improvement Laboratory and Cumberland Valley Analytical Services Laboratory. A. Higher concentration nutrients B. Lower concentration nutrients.

6.1 Statistical Materials and Methods

All analysis was undertaken using Stata V18 (StataCorp, Texas). Initial investigations for both data sets included histograms to evaluate the normality of the data. No variables in the Extended data set required transformation as these approximated normal distributions. Analysis of differences among hay types was conducted by analysis of variance and pairwise examination for differences among hay types. Descriptions of the differences among hay types were graphed by mean and standard deviation for each group.

For investigation of feed components that would best describe the estimated metabolisable energy or degradable and undegradable fibre fractions at 120 hours for the feeds multiple linear regression was used. Linear regression plots were used to evaluate linearity assumptions and to identify potential outliers. One outlying variable was removed for magnesium content. Predictions of fibre degradability and undegraded aNDF organic matter at 120 hours made involving sulphur were significantly quadratic and the quadratic effect of sulphur was included in models. Effects of hay type were tested as a fixed and as a random effect in a mixed linear model.

6.2 Modelling to provide a robust assessment of oat hay

Notwithstanding the rigour of comparative analytical evaluation of Australian oat hays from the Extended database, from AEXCO and data obtained from CVAS and DairyOne, and diet analysis, further evaluation was applied.

Lactating cow diets from China and UAE were used as a template for developing @RISK (Palisade Company LLC, Ithaca, NY, USA) models to evaluate the merit of inclusion of oat hay when prices or quality of other commodities fluctuate. The @Risk program provides a means of Monte Carlo modelling to allow for simulation of risks such as fluctuation in relative pricing of commodities or feed quality.

Key components for this were inputs on fluctuations in commodity prices using oat hays as a benchmark and evaluating inputs and pricing around the typical distributions of variations in feed prices and providing different scenarios for feed availability. The prices for commodities over period of approximately 10 years were sourced (See Sources). The values of the oat hays were held constant at the values used in the diets; these were historically near average.

Further, the sensitivity of oat hay inclusion to the quality of alfalfa and timothy hay was tested to provide a robust series of sensitivity analyses. Variations in feed quality were provided using the data from DairyOne and CVAS laboratory analysis of > 100,000 alfalfa samples and > 2300 timothy hay samples. Hays of plus or minus one standard deviation in quality were modelled with a price adjustment on the low- and high-quality hays, similar to that used for the oat hay modelling, that is differing by $US10 per category with the difference in dollars normalised to the reference oat hays. Data from this were used to provide an input to @RISK to describe scenarios that were favourable or unfavourable to the inclusion of oat hays. Not all responses were suited to modelling and these are reported in the results. For a number of interventions, the type of oat hay selected changed and this effect is described in results.

Figures 3 and 7 describe the economic distributions and the normalized values of feeds used in the modelling. Local prices of milk and commodities will vary and prices that were used were from original diets or current commodity and milk pricing.

6.3 Laboratory methods for wet chemistry: CVAS analysis of the AEXCO samples

The wet chemistry methodology was as follows: DM of forages (Goering and Van Soest, 1970), , NDF with the addition of amylase and sodium sulfite (Van Soest et al., 1991), acid detergent fiber (ADF; Method 973.18; AOAC, 2000), ash (Method 942.05; AOAC, 2000), lignin (Goering and Van Soest, 1970) with modifications described at **https://www.foragelab.com/Resources/Lab-Procedures** (Cumberland Valley Analytical Services, 2021), crude fat (Method 2003.05; AOAC International, 2006), crude protein (CP; Method 990.03; AOAC, 2000) using a Leco FP-528 Nitrogen Combustion Analyzer (Leco Corporation, St. Joseph, MO), soluble CP (Krishnamoorthy et al., 1982), starch (Hall, 2009), sugar (DuBois et al., 1956), a complete mineral panel (Method 985.01; AOAC, 2000; using a Perkin Elmer 5300 DV ICP, Perkin Elmer, Shelton, CT), sulfur was analysed by a Leco S632 Sulfur Combustion Analyzer (Leco Corporation) using Leco Organic Application Note “Sulfur and Carbon in Plant, Feed, Grain, and Flour” Form 203-821-321, 5/08-REV1, and chloride was analysed by sample extraction with 0.5% nitric acid and analysed by potentiometric titration with silver nitrate using a Brinkman Metrohm 848 Titrino Plus (Brinkmann Instruments Inc., Westbury, NY).

6.4 Laboratory methods for wet chemistry: DairyOne analysis

Wet chemistry techniques were as follows: DM (AOAC 2000; method 930.15), NDF (Van Soest et al., 1991), CP (AOAC 2000; method 990.03), soluble protein (Cornell sodium borate-sodium phosphate buffer procedure), crude fat (AOAC 2000; method 2003.05), ash (AOAC 2000; method 942.05), lignin (AOAC 2000; method 973.18), ADF (AOAC 2000; method 973.18), acid and neutral detergent insoluble crude protein (ADICP and NDICP; Leco TruMac N Macro Determinator; Leco Corp., St. Joseph, MI), starch (YSI 2700 SELECT Biochemistry Analyzer; YSI Inc., Yellow Springs, OH), WSC (Hoover and Miller-Webster, 1998), ethanol-soluble carbohydrate (Hall et al., 1999). The NFC was calculated as 100 - (%NDF + %CP + %Fat + %Ash).

7. Recommendations for AEXCO and AgriFutures

7.1 Building robust extension

It became clear as this project progressed that there is a need to educate the hay exporting and growing community on the potential roles of oat hay in the diet of the target markets. While each component of the nutritional quality of the oat hay is important to understand, particularly in regard to the limitations of other feeds that may enter the diet, it is the integrated value of the feed that determines whether it enters a diet or not. Therefore, the education needs to be directed to evaluating the nutritional and antinutritional values of oat hay and competitor feeds for different classes of stock and different markets. There is the opportunity to do this in conjunction with other exporters of feed. Target audience – primarily sales staff.

7.2 Integrating agronomic and genetic strategies with nutritional quality

The limited exploration of the effects of agronomic practices on feed attributes provided evidence that there are potentially quite substantial effects. The difference in entry into diets of the different hays indicated that it is critical to understand which hays will perform best in which diets. There is a substantial potential to improve market penetration indicated by the different inclusions of oat hay into the diets examined in this document. These inclusions include opportunities for hays of high quality but lesser nutritional quality ie higher in fibre, but lower in sugars. Better understandings of cultivar attributes, effects of growing conditions, including effects of soils and fertiliser should allow targeting of specific markets. This requires a long-term commitment to research in the area and a need to integrate that with nutritional modelling and market feedback. Target audience – ultimately hay producers.

7.3 Small lot-holder opportunities

In many of the Asian markets, the majority of cattle are held by small lot-holders who have limited land, numbers of cattle and resources. The physical requirements for sourcing tropical grasses that contain dry matter contents of 10-20% and variability of quality in the grasses is a major limitation to productivity. In contrast oat hay is ~88% dry matter, transportable and predictable. It has greater keeping quality and lower mycotoxin risk. It has many superior nutritional qualities. A program to develop awareness and sales to small lot holders should be considered.

8. Supplementary information

8.1 Nutritional specifications for oat hays

Supplemental Table 1. Oat hay specifications used in nutritional modelling

Variable (% of DM)	Quartile 1 52 NDF 25WC	Quartile 2 58 NDF 23 WSC	Quartile 3 58 NDF 17 WSC	Quartile 4 62 NDF 9 WSC
Dry matter, %	91.23	90.15	91.67	90.63
Crude Protein	5.87	6.63	7.33	6.50
Available Crude Protein	5.87	6.63	7.33	6.50
Soluble Protein	2.47	3.15	3.23	2.50
Acid Detergent Insoluble Crude Protein	0.60	0.62	0.66	0.60
Neutral Detergent Insoluble Crude Protein	0.69	0.73	0.82	0.79
Acid Detergent Fibre	30.53	32.90	35.20	37.17
Neutral Detergent Fibre	52.83	53.73	58.43	63.13
Neutral Detergent Fibre in organic matter	52.07	52.80	57.70	61.90
Lignin	4.37	3.81	4.62	5.41
30 hr NDF digestibility in organic matter, % of OM	26.73	29.53	30.50	29.33
30 hr Undegraded NDF in organic matter, % of OM	25.33	23.28	27.20	32.57
30 hr degraded NDF in organic matter, % of NDF	51.47	55.93	53.00	47.27
30 hr Undegraded NDF in organic matter, % of NDF	48.53	44.08	47.00	52.73
120 hr NDF digestibility in organic matter, % of OM	35.17	37.95	40.07	41.50
120 hr Undegraded NDF in organic matter, % of OM	16.90	14.85	17.63	20.40
120 hr NDF digestibility in organic matter, % of NDF	67.63	71.95	69.47	66.90
120 hr Undegraded NDF in organic matter, % of NDF	32.37	28.05	30.53	33.10
240 hr NDF digestibility in organic matter, % of OM	41.68	44.28	46.25	47.59
Ethanol soluble sugars SC (Simple Sugars)	16.97	18.03	13.33	7.27
Water-Soluble Carbohydrates	25.00	23.31	16.70	8.50
Starch	4.33	1.98	2.20	3.37
Crude fat	2.65	1.65	2.40	1.91
Net Energy Lactation, Mcal/lb	0.71	0.65	0.62	0.59
Estimated ME, MJ/kg	10.48	9.57	9.15	8.70
Relative Feed Value	115.00	110.00	98.33	89.00
Non Fibre Carbohydrates	45.20	33.20	25.90	23.30
Non Structural Carbohydrates	21.30	20.00	15.53	10.63
Dietary Cation Anion Difference, Meq/100g	12.77	25.13	17.50	11.57
Ash	4.14	6.35	6.93	6.75
Ca	0.19	0.19	0.21	0.21

Variable (% of DM)	Quartile 1 52 NDF 25WC	Quartile 2 58 NDF 23 WSC	Quartile 3 58 NDF 17 WSC	Quartile 4 62 NDF 9 WSC
P	0.16	0.16	0.14	0.17
Mg	0.11	0.11	0.10	0.09
K	1.02	1.26	1.40	1.09
S	0.08	0.09	0.11	0.10
Na	0.35	0.49	0.60	0.27
Cl	0.85	0.81	1.34	0.79
Fe, ppm	118.3	123.8	84.00	86.33
Mn, ppm	54.00	44.50	43.00	37.33
Zn, ppm	16.00	15.50	11.33	10.67
Cu, ppm	3.67	3.25	4.00	4.00

8.2 Supplementary information: Extended Data

Supplemental Table 2. Nutritional analysis of awned wheat hay

Variable (% of DM)	Observations	Mean	Std. dev.	Minimum	Maximum
Dry matter, %	42	88.86	0.78	87.20	91.50
Crude Protein	42	7.64	1.04	5.30	10.20
Available Crude Protein	42	7.05	1.04	4.70	9.60
Acid Detergent Insoluble Crude Protein	42	0.59	0.08	0.40	0.70
Soluble Protein	42	41.43	4.81	26.00	47.00
Neutral Detergent Insoluble Crude Protein	42	1.70	0.35	1.10	2.70
Acid Detergent Fibre	42	31.20	1.26	29.10	34.30
Neutral Detergent Fibre	42	50.74	1.73	47.00	55.00
Lignin	42	2.98	0.63	1.30	4.10
Non Fibre Carbohydrates	42	34.86	2.18	29.60	39.60
Starch	42	1.24	0.66	0.30	2.90
Water-Soluble Carbohydrates	42	27.71	2.64	21.00	33.00
Ethanol soluble sugars SC (Simple Sugars)	42	14.29	1.11	11.70	16.90
Crude fat	42	1.96	0.17	1.60	2.30
Ash	42	6.61	1.11	4.90	9.80
Relative Feed Value	42	118.90	5.51	107.00	131.00
Ca	42	0.25	0.04	0.16	0.34
P	42	0.20	0.03	0.16	0.27
Mg	42	0.15	0.02	0.12	0.20
K	42	1.41	0.19	0.97	1.82
S	42	0.14	0.02	0.08	0.17
Cl	42	0.54	0.13	0.37	1.04
In vitro digestibility 24 hr	42	67.67	1.63	64.00	71.00
In vitro digestibility 48 hr	42	73.93	1.67	70.00	78.00
NDF digestibility 24 hr	42	36.17	3.08	30.00	46.00
NDF digestibility 48 hr	42	48.55	3.29	43.00	58.00
Breakdown Kd/hr	42	2.14	0.24	1.68	2.88
Neutral Detergent Fibre in organic matter	42	49.12	1.64	45.20	52.30
30 hr Undegraded NDF in organic matter, % of OM	42	23.80	1.69	21.10	28.40
120 hr Undegraded NDF in organic matter, % of OM	42	19.09	1.80	15.60	24.00
240 hr Undegraded NDF in organic matter, % of OM	42	16.35	1.72	12.70	21.90
30 hr NDF digestibility in organic matter, % of OM	42	51.59	2.80	43.90	58.00
120 hr NDF digestibility in organic matter, % of OM	42	61.09	3.96	50.40	69.30
240 hr NDF digestibility in organic matter, % of OM	42	66.68	3.70	54.60	74.90

Variable (% of DM)	Observations	Mean	Std. dev.	Minimum	Maximum
Estimated ME, MJ/kg	42	9.49	0.27	8.76	10.11

Supplemental Table 3. Nutritional analysis of awnless wheat hay

Variable (% of DM)	Observations	Mean	Std. dev.	Minimum	Maximum
Dry matter	10	89.11	0.78	87.50	90.30
Crude Protein	10	8.36	1.52	5.60	10.40
Available Crude Protein	10	7.93	1.57	5.10	10.20
Acid Detergent Insoluble Crude Protein	10	0.49	0.10	0.30	0.60
Soluble Protein	10	41.20	4.61	32.00	47.00
Neutral Detergent Insoluble Crude Protein	10	2.17	0.49	1.40	2.80
Acid Detergent Fibre	10	30.39	2.97	23.30	34.20
Neutral Detergent Fibre	10	50.70	5.01	38.00	55.00
Lignin	10	2.62	0.44	1.80	3.40
Non Fibre Carbohydrates	10	34.05	4.50	28.70	43.30
Starch	10	1.99	0.86	1.10	3.70
Water-Soluble Carbohydrates	10	25.50	5.25	20.00	36.00
Ethanol soluble sugars SC (Simple Sugars)	10	14.36	2.47	11.50	20.20
Crude fat	10	2.24	0.32	1.70	2.60
Ash	10	6.80	0.72	6.00	8.50
Relative Feed Value	10	121.30	19.35	106.00	173.00
Ca	10	0.27	0.07	0.19	0.42
P	10	0.24	0.03	0.21	0.29
Mg	10	0.18	0.04	0.12	0.24
K	10	1.68	0.25	1.19	1.98
S	10	0.15	0.04	0.08	0.20
Cl	10	0.57	0.19	0.31	0.83
In vitro digestibility 24 hr	10	71.00	4.22	67.00	80.00
In vitro digestibility 48 hr	10	77.40	3.84	73.00	85.00
NDF digestibility 24 hr	10	42.90	4.91	33.00	51.00
NDF digestibility 48 hr	10	55.70	5.10	45.00	63.00
Breakdown Kd/hr	10	2.61	0.41	1.84	3.39
Neutral Detergent Fibre in organic matter	10	48.98	4.64	36.70	52.30
30 hr Undegraded NDF in organic matter, % of OM	10	19.87	3.98	13.10	26.10
120 hr Undegraded NDF in organic matter, % of OM	10	14.36	3.77	9.60	21.30
240 hr Undegraded NDF in organic matter, % of OM	10	12.26	3.48	8.10	19.40
30 hr NDF digestibility in organic matter, % of OM	10	59.67	6.04	49.40	67.10
120 hr NDF digestibility in organic matter, % of OM	10	70.70	7.02	59.30	80.50
240 hr NDF digestibility in organic matter, % of OM	10	75.05	6.29	63.00	83.50
Estimated ME, MJ/kg	10	9.57	0.62	8.76	10.79

Supplemental Table 4. Nutritional analysis of barley hay

Variable (% of DM)	Observations	Mean	Std. dev.	Minimum	Maximum
Dry matter, %	5	89.80	0.95	88.50	90.70
Crude Protein	5	9.22	2.21	6.80	11.60
Available Crude Protein	5	8.68	2.20	6.20	11.10
Acid Detergent Insoluble Crude Protein	5	0.56	0.11	0.40	0.70
Soluble Protein	5	41.80	4.66	35.00	47.00
Neutral Detergent Insoluble Crude Protein	5	1.90	0.62	1.00	2.50
Acid Detergent Fibre	5	31.44	3.38	26.70	36.20
Neutral Detergent Fibre	5	52.20	3.96	47.00	58.00
Lignin	5	2.90	1.27	1.00	4.50
Non Fibre Carbohydrates	5	31.16	5.16	24.40	38.70
Starch	5	1.78	0.94	0.60	2.80
Water-Soluble Carbohydrates	5	23.80	6.91	15.00	34.00
Ethanol soluble sugars SC (Simple Sugars)	5	13.64	1.89	11.10	16.00
Crude fat	5	2.18	0.19	1.90	2.40
Ash	5	7.10	0.89	6.10	8.40
Relative Feed Value	5	115.40	13.32	97.00	134.00
Ca	5	0.20	0.08	0.15	0.34
P	5	0.23	0.06	0.14	0.30
Mg	5	0.16	0.04	0.10	0.19
K	5	2.07	0.53	1.40	2.77
S	5	0.17	0.03	0.13	0.20
Cl	5	1.04	0.17	0.83	1.18
In vitro digestibility 24 hr	5	70.40	2.88	66.00	74.00
In vitro digestibility 48 hr	5	77.40	2.88	73.00	81.00
NDF digestibility 24 hr	5	43.00	4.85	36.00	49.00
NDF digestibility 48 hr	5	56.80	4.82	51.00	63.00
Breakdown Kd/hr	5	2.68	0.45	2.18	3.38
Neutral Detergent Fibre in organic matter	5	49.98	4.56	44.30	56.80
30 hr Undegraded NDF in organic matter, % of OM	5	22.88	4.51	18.80	30.50
120 hr Undegraded NDF in organic matter, % of OM	5	17.44	3.90	13.00	21.40
240 hr Undegraded NDF in organic matter, % of OM	5	16.26	4.25	10.80	20.20
30 hr NDF digestibility in organic matter, % of OM	5	54.32	6.56	46.40	61.50
120 hr NDF digestibility in organic matter, % of OM	5	64.96	8.28	55.30	74.70
240 hr NDF digestibility in organic matter, % of OM	5	67.24	8.99	57.20	78.80
Estimated ME, MJ/kg	5	9.44	0.83	8.09	10.11

Supplemental Table 5. Nutritional analysis comparison of Australian oat hay with alfalfa hay tested at two different laboratories

Item (% of DM)	Australian oat hay			Alfalfa hay US DairyOne			Alfalfa hay US CVAS		
	N	Mean	Std deviation	N	Mean	Std deviation	N	Mean	Std deviation
Dry Matter, %	476	89.13	0.81	11287	90.40	1.49	189613	90.00	2.67
Crude Protein	476	7.28	1.42	11095	21.16	2.58	185516	20.30	3.29
Adjusted Protein	476	7.28	1.42				107536	20.40	3.42
Soluble Protein	476	45.09	6.05	10167	45.45	5.78	174492	41.40	6.85
Acid Detergent Insoluble Crude Protein	476	0.55	0.10	10092	1.51	0.20	165285	1.38	0.28
Neutral Detergent Insoluble Crude Protein	476	1.31	0.39	10092	3.91	0.62	165840	2.32	0.91
Degradable Protein, % of CP	476	72.98	3.98	10071	76.10	2.12	174489	14.40	2.49
Lignin	476	2.68	0.70	10466	6.29	1.01	167568	6.77	1.16
Acid Detergent Fibre	476	31.87	3.27	11193	30.06	3.97	183978	32.00	4.89
Neutral Detergent Fiber	476	52.30	4.79	10644	37.23	4.84	184619	39.00	7.29
Neutral Detergent Fibre in organic matter	476	50.90	4.81	605	38.23	5.88	185719	37.20	6.96
30 hr NDF digestibility in organic matter, % of NDF*	476	50.81	7.88	2587	41.68	5.68	88222	43.60	5.31
120 hr NDF in organic matter digestibility, % of NDF*	476	65.89	5.53	535	43.32	7.47	186827	48.60	6.51
240 hr NDF in organic matter digestibility, % of NDF*	476	70.30	5.37	535	45.83	7.61	186884	51.00	6.80
30 hr Undegraded NDF in organic matter, % of OM*	476	25.30	5.88	535	23.05	4.85	88162	19.89	2.71

Item (% of DM)	Australian oat hay			Alfalfa hay US DairyOne			Alfalfa hay US CVAS		
	N	Mean	Std deviation	N	Mean	Std deviation	N	Mean	Std deviation
120 hr Undegraded NDF in organic matter, % of OM*	476	17.40	3.47	535	21.70	4.86	186827	20.05	3.35
240 hr Undegraded NDF in organic matter, % of OM*	476	15.17	3.34	535	20.77	4.88	186884	19.11	2.65
Ethanol Soluble Carbohydrates	476	14.10	2.20	10555	6.59	1.57	166305	7.35	2.20
Water Soluble Carbohydrates	476	24.19	5.54	10536	8.38	1.97	187056	9.19	2.53
Starch	476	2.50	1.43	10589	0.90	0.54	156483	2.08	1.19
Crude Fat	476	2.19	0.31	10469	2.42	0.41	167542	2.32	0.44
Ash	476	5.61	1.46	10515	10.96	1.70	176480	10.60	1.91
Calcium	476	0.24	0.08	10794	1.55	0.29	174431	1.50	0.33
Phosphorus	476	0.22	0.03	10794	0.27	0.04	174466	0.28	0.06
Magnesium	476	0.16	0.03	10659	0.36	0.09	174448	0.33	0.09
Potassium	476	1.52	0.40	10666	2.37	0.54	174342	2.60	0.72
Sulphur	476	0.14	0.04	10228	0.34	0.05	93679	0.30	0.09
Sodium				1049	0.22	0.21	52324	0.19	0.18
Chloride	476	0.95	0.26	10136	0.83	0.34	20325	0.70	0.36

*CVAS reported as %NDF. Adjusted to % NDF in OM for undegraded fraction

Supplemental Table 6. Nutritional analysis of timothy hay from CVAS laboratory

Item (% of DM)	N	Mean	Standard deviation
Dry Matter, %	2997	89.1	2.43
Crude Protein	2951	9.74	3.02
Soluble Protein	2871	32.4	6.41
Acid Detergent Insoluble Crude Protein	2828	1.12	0.25
Neutral Detergent Insoluble Crude Protein	2831	2.86	1.04
Degradable Protein, % of CP	2871	6.47	2.03
Lignin	2823	5.6	1.25
Acid Detergent Fibre	2947	38.5	3.84
Neutral Detergent Fibre	2956	60.9	6.18
Neutral Detergent Fibre in organic matter	2974	58.2	6.14
30 hr NDF digestibility % of NDF	1114	52.9	8.41
120 hr NDF digestibility % of NDF	2974	59	8.86
240 hr NDF digestibility % of NDF	2974	62	9.12
30 hr Undegraded NDF % of NDF	1114	47.1	8.42
120 hr Undegraded NDF % of NDF	2974	41	8.86
240 hr Undegraded NDF % of NDF	2974	38	9.12
Ethanol Soluble Carbohydrates	2741	8.12	2.47
Water Soluble Carbohydrates	2974	12.2	3.23
Starch	2738	2.27	0.9
Crude Fat	2845	2.59	0.47
Ash	2891	6.53	2
Calcium	2890	0.46	0.23
Phosphorus	2890	0.21	0.06
Magnesium	2889	0.18	0.06
Potassium	2886	1.74	0.56
Sulphur	1440	0.17	0.04
Sodium	1186	0.04	0.08
Chloride	476	0.43	0.3

Supplemental Table 7. Nutritional analysis of the oat hays modelled

Item (% of DM)	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Dry Matter, %	91.23	90.15	91.67	90.63
Crude Protein	5.87	6.63	7.33	6.50
Soluble Protein	2.47	3.15	3.23	2.50
Soluble Protein % of CP	42.47	47.68	43.57	38.43
Acid Detergent Insoluble Crude Protein	0.60	0.62	0.66	0.60
Acid Detergent Insoluble Crude Protein	10.50	9.38	9.67	9.17
Neutral Detergent Insoluble Crude Protein	0.69	0.73	0.82	0.79
Neutral Detergent Insoluble Crude Protein	11.93	11.03	11.87	12.30
Degradable Protein, % of CP	4.20	4.90	5.30	4.53
Acid Detergent Fibre	30.53	32.90	35.20	37.17
Neutral Detergent Fiber	52.83	53.73	58.43	63.13
Neutral Detergent Fibre in organic matter	52.07	52.80	57.70	61.90
Lignin	4.37	3.81	4.62	5.41
30 hr NDF digestibility in organic matter, % of NDF	51.47	55.93	53.00	47.27
30 hr Undegraded NDF in organic matter, % of NDF	48.53	44.08	47.00	52.73
120 hr NDF digestibility in organic matter, % of NDF	67.63	71.95	69.47	66.90
120 hr Undegraded NDF in organic matter, % of NDF	32.37	28.05	30.53	33.10
240 hr NDF digestibility in organic matter, % of NDF	41.68	44.28	46.25	47.59
Ethanol Soluble Carbohydrates	16.97	18.03	13.33	7.27
Starch	4.33	1.98	2.20	3.37
Crude Fat	2.65	1.65	2.40	1.91
Total digestible nutrients	68.43	62.90	60.37	57.47
Net energy lactation Mcal/lb	0.71	0.65	0.62	0.59
Relative Feed value	115.00	110.00	98.33	89.00
Non fiber carbohydrates %	45.20	33.20	25.90	23.30
Non structural carbohydrates %	21.30	20.00	15.53	10.63

Item (% of DM)	Quartile 1	Quartile 2	Quartile 3	Quartile 4
DCAD Meq/kg	12.77	25.13	17.50	11.57
Ash %	4.14	6.35	6.93	6.75
Calcium %	0.19	0.19	0.21	0.21
Phosphorus %	0.16	0.16	0.14	0.17
Magnesium %	0.11	0.11	0.10	0.09
Potassium %	1.02	1.26	1.40	1.09
Sulfur %	0.08	0.09	0.11	0.10
Sodium %	0.35	0.49	0.60	0.27
Chlorine %	0.85	0.81	1.34	0.79
Iron ppm	118.33	123.75	84.00	86.33
Manganese ppm	54.00	44.50	43.00	37.33
Zinc ppm	16.00	15.50	11.33	10.67
Copper ppm	3.67	3.25	4.00	4.00
Metabolizable energy MJ/kg	10.48	9.57	9.15	8.70

9. Information sources

Bramley E. pers comm

Charteris Hough J. pers comm

Elders Rural, pers comm

Guerrin P. pers comm

Hass H. pers comm

Johnstone J. pers comm

Lawson R. pers comm

Peace C. pers comm

Posada V. pers comm

Routledge S. pers comm

Weber D. per comm

Wirth T. pers comm

10. References

Agricultural Trade and Market Access Cooperation program. ATMAC market assessment of the UAE 2023.

AOAC. 2000. Official methods of analysis of AOAC international, AOAC Arlington, VA.

AOAC. 2006. Official methods of analysis of AOAC international, AOAC Arlington, VA.

Anon (2024) DFM-Firmenich. Global Mycotoxin Survey. January – June 2024.

Aranega, J. P., and C. A. Oliveira. 2022. Occurrence of mycotoxins in pastures: A systematic review. Quality Assurance and Safety of Crops & Foods 14:135-144.

Australian Bureau of Agriculture and Research Economics (2024) Agricultural Commodities September 2024, Hay Price Index

Australian Bureau of Agriculture and Research Economics (2024) Agricultural Commodities September 2023/4 Coarse Grain Commodities

Canola Council of Canada. 2024. https://www.canolacouncil.org/markets-stats/exports/ay price index

Cumberland Valley Analytical Services. 2021. Resources - lab procedures No. 2021.

DuBois, M., K. A. Gilles, J. K. Hamilton, P. A. Rebers, and F. Smith. 1956. Colorimetric method for determination of sugars and related substances. Analytical Chemistry 28:350-356. doi:10.1021/ac60111a017

Farm-gate Milk Prices, China. 2024. https://www.clal.it/en/index.php?section=latte_cina

Federal Reserve Bank of St. Louis. 2024. **https://fred.stlouisfed.org** accessed 21/10/2024 (numerous commodity prices)

Fertilizer Australia. 2024. Global Fertiliser Prices. **https://fertilizer.org.au/about-fertiliser/the-fertiliser-industry/global-feriliser-prices**

Fox DG, Tedeschi LO, Tylutki TP, Russell JB, Van Amburgh ME, Chase LE, Pell AN, Overton TR. The Cornell Net Carbohydrate and Protein System model for evaluating herd nutrition and nutrient excretion. Animal Feed Science and Technology. 2004 Feb 10;112(1-4):29-78.

Goering, H. K., and P. J. Van Soest. 1970. Forage fiber analyses (apparatus, reagents, procedures, and some applications). U.S. Agricultural Research Service.

Hall, M. B. 2009. Determination of starch, including maltooligosaccharides, in animal feeds: Comparison of methods and a method recommended for AOAC collaborative study. J AOAC Int 92:42-49.

Hall, M. B., W. H. Hoover, J. P. Jennings, and T. K. M. Webster. 1999. A method for partitioning neutral detergent-soluble carbohydrates. J. Sci. Food Agric. 79:2079-2086. doi:10.1002/(sici)1097-0010(199912)79:15<2079::aid-jsfa502>3.0.co;2-z.

Hoover, W. H. and T. K. Miller-Webster. 1998. Nutrient analysis of feedstuffs including carbohydrates. Animal sci. Report no. 1, divison of animal and veterinary science,. West Virginia University. Morgantown, WV, USA.

Korea JoongAng Daily. 2024. Milk prices to remain fixed with dairy industry agreement. **https://koreajoongangdaily.joins.com/news/2024-07-30/business/industry/Milk-prices-to-remain-fixed-with-dairy-industry-agreement/2101819**

Krishnamoorthy, U., T. V. Muscato, C. J. Sniffen, and P. J. Van Soest. 1982. Nitrogen fractions in selected feedstuffs. Journal of Dairy Science 65:217-225. doi:**https://doi.org/10.3168/jds.S0022-0302(82)82180-2**

Index mundi. 2024. Soybean Meal Futures.

https://www.indexmundi.com/commodities/?commodity=soybean-meal&months=180

National Sunflower Association. 2024. Historical Prices/Values. **https://www.sunflowernsa.com/stats/historical-prices-values/**

Nutrien Ag Solutions : Fertiliser Product Range 2024

Rodrigues, I. 2014. A review on the effects of mycotoxins in dairy ruminants. Anim. Prod. Sci. 54:1155-1165.

Statista. 2024. Average monthly producer price for beef cattle in Indonesia in 2022. **https://www.statista.com/statistics/1340967/indonesia-average-monthly-producer-price-for-beef-cattle/**

The Global Economy.com. 2024. Taiwan: Meat prices. **https://www.theglobaleconomy.com/Taiwan/meat_prices_wb/**

Van Amburgh ME, Collao-Saenz EA, Higgs RJ, Ross DA, Recktenwald EB, Raffrenato E, Chase LE, Overton TR, Mills JK, Foskolos A. The Cornell Net Carbohydrate and Protein System: Updates to the model and evaluation of version 6.5. Journal of Dairy Science. 2015 Sep 1;98(9):6361-80.

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597. doi:10.3168/jds.S0022-0302(91)78551-2

Appendix

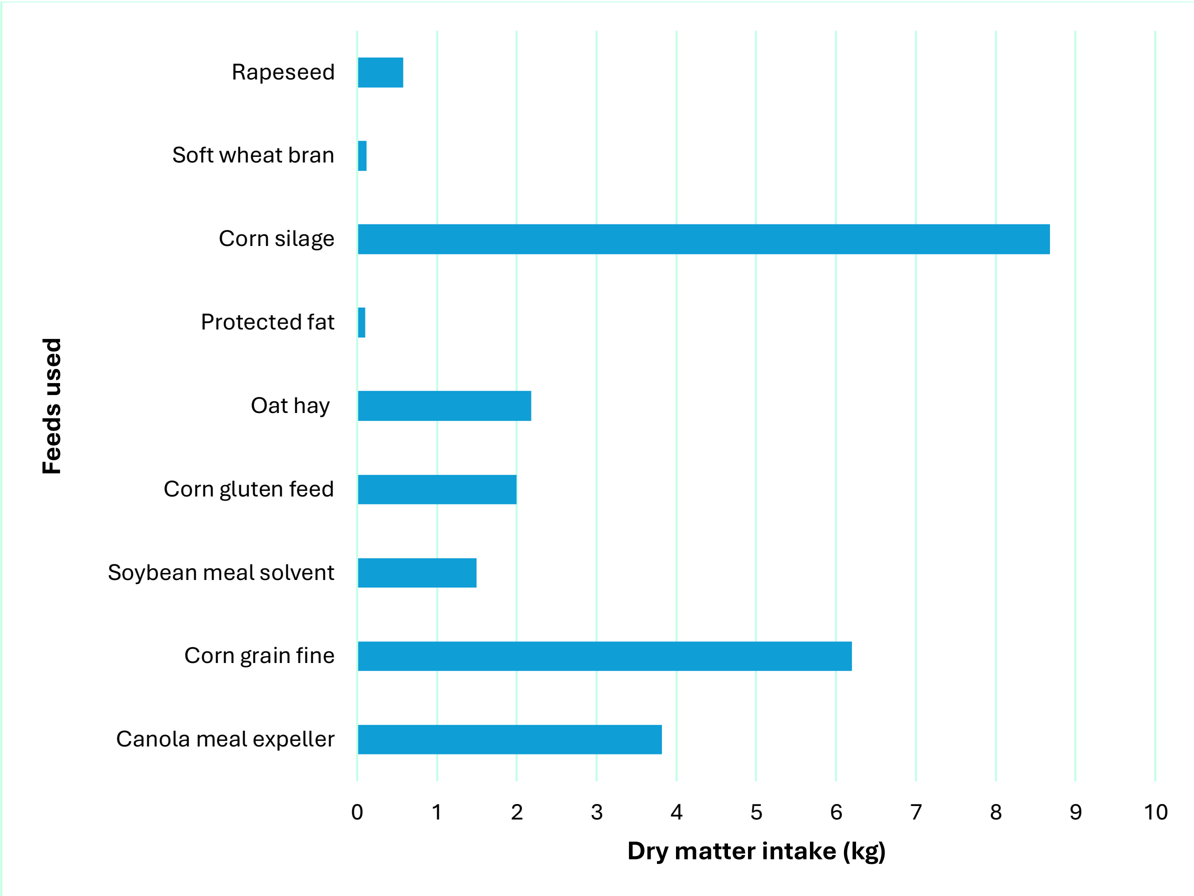
The following provide details on the feeds included for one diet for each modelling exercise or country. Feeds left out of the diets are not included in the detail. Most diets had alfalfa hay, timothy, fescue or Rhodes grass hays available as well as other concentrates and commodities. All mineral additives, buffers or feed additives used by the dairies were fixed to the levels used or identical between diets formulated with or without oat hay. The mineral contents are not included in all the diets or graphs.

Indonesian high cow early lactation diet

While the oat hay inclusion in this diet is relatively small, the inclusion had marked effects on the rest of the diet compared to not using oat hay with changes in inclusions of canola, urea, corn silage, gluten feed and most other commodities.

Appendix Table 1. Feed ingredients and amounts included in Indonesian high cow early lactation diet

Ingredients	Cost normalized	DM (%)	As fed (kg/d)	DM (kg/d)
Canola meal expeller	200.0	90.0	4.25	3.82
Corn grain fine	95.0	88.0	7.95	7.00
Soybean meal solvent	359	90.0	1.67	1.50
Sodium bicarbonate	282	99.0	0.19	0.19
Magnesium oxide	148	98.0	0.05	0.05
Salt	56	99.5	0.15	0.15
Limestone	56	99.5	0.12	0.12
Dicalcium phosphate	113	95.5	0.10	0.10
Mineral premix	211	99.5	0.01	0.01
Corn gluten feed	68	88.5	2.26	2.00
Oat hay	100.0	91.6	2.51	2.18
Protected fat	660	99.5	0.10	0.10
Corn silage	93	27	32.53	8.68
Soft wheat bran	88.3	88.3	0.12	0.11
Rapeseed	155	94.3	0.61	0.58



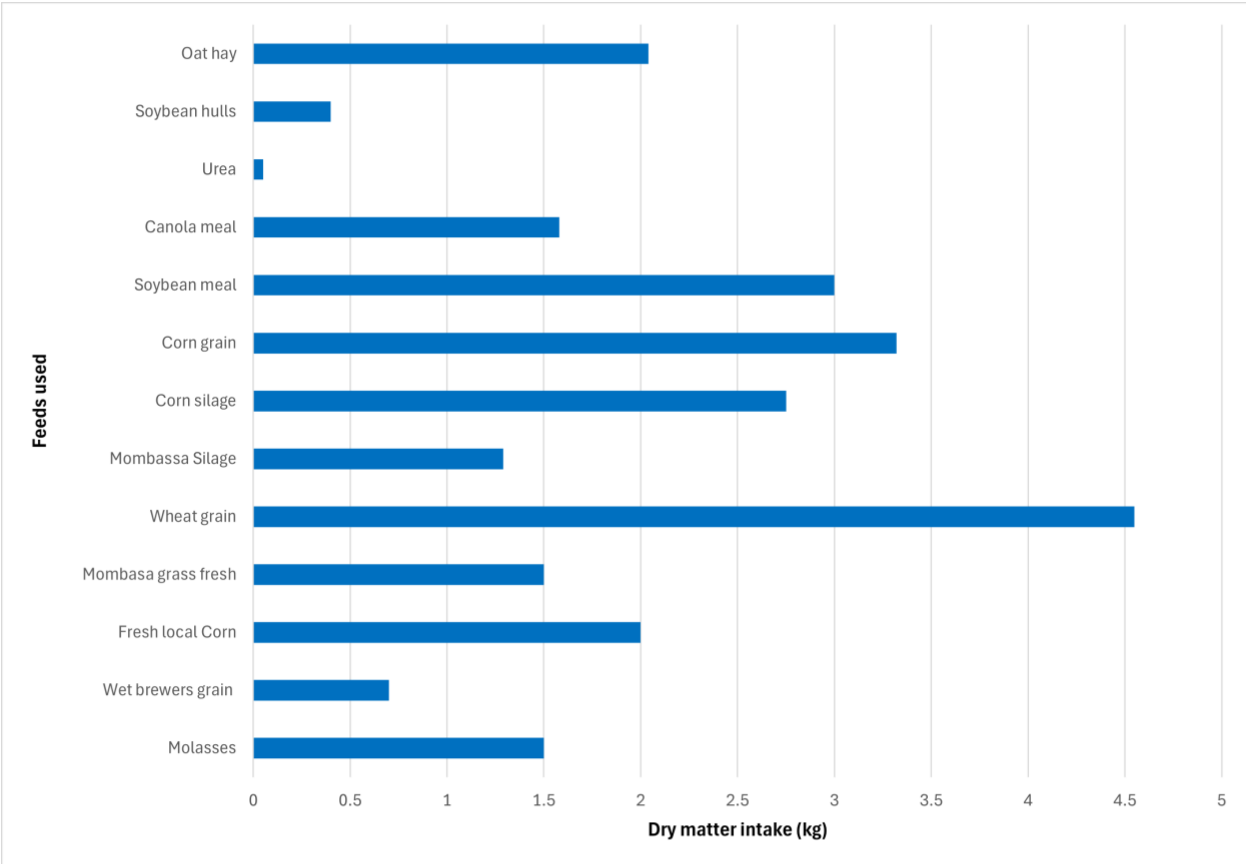
Appendix Figure 1. Graph showing the feeds included kg of DM per day for the Indonesian high cow diet.

Vietnamese high cow early lactation diet

The Vietnamese diet had many tight constraints on commodity use. The main changes in the diet were relatively subtle and to the forages and protein meal inclusions when oat hay was not available.

Appendix Table 2. Feed ingredients and amounts included in Vietnamese high cow early lactation diet

Ingredients	Cost normalised	DM (%)	As fed (kg/d)	DM (kg/d)
Molasses 75%	27.5	75.0	2.00	1.50
Wet Brewers Grain 26%	8.9	26.0	2.69	0.70
Fresh Local Corn	9.5	27.0	7.41	2.00
Mombasa grass fresh	2.9	20.0	7.50	1.50
Wheat grain FC	132.5	89.3	5.05	4.55
Mold inhibitor	224.8	95.0	0.02	0.02
Mombassa Silage	7.0	34.3	3.75	1.29
Corn silage	12.4	30.5	9.00	2.75
Corn grain	119.5	87.0	3.82	3.32
Soybean meal	103.5	89.9	3.34	3.00
Canola meal	181.8	90.6	1.74	1.58
Urea	233.8	99.0	0.05	0.05
Dicalcium phosphate	97.4	99.5	0.03	0.03
Potassium Carbonate	136.0	98.5	0.12	0.12
Limestone	2.9	98.5	0.16	0.16
NaHCO3	72.1	95.6	0.05	0.05
Lysine	904.6	95.0	0.01	0.01
Salt	5.8	98.0	0.10	0.10
Soybean hulls	41.6	88.2	0.45	0.40
Oat hay	100.0	91.1	2.34	2.04
Vitamins, minerals and additives	Not applicable	95.0	1.47	1.40



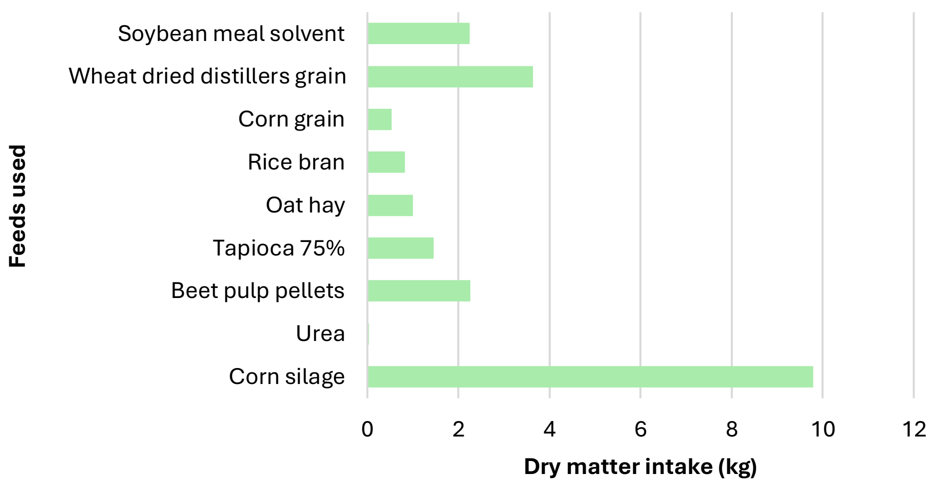
Appendix Figure 2. Graph of the feeds included in the Vietnamese high cow early lactation diet.

Philippines high cow early lactation diet

The diet without oat hay slightly increased use of corn silage to the maximum of 10 kg and used palm kernal meal.

Appendix Table 3. Feed ingredients and amounts included in the Philippines high cow early lactation diet

Ingredients	Cost normalised	DM (%)	As fed (kg/d)	DM (kg/d)
Corn silage	14.5	31.2	31.38	9.79
Urea	277.8	99.0	0.03	0.03
Sodium bicarbonate	74.0	99.0	0.20	0.20
Magnesium oxide	280.3	98.0	0.00	0.00
Limestone	3.8	99.5	0.25	0.25
Salt	31.7	99.5	0.08	0.08
Beet pulp pellets	197.2	91.5	2.48	2.26
Tapioca 75%	59.0	88.7	1.63	1.45
Oat hay	100.0	91.6	1.09	1.00
Rice bran	114.8	91.1	0.90	0.82
Corn grain	77.0	87.6	0.60	0.53
Wheat dried distillers grain	129.6	91.0	4.00	3.64
Soybean meal solvent	81.5	90.0	2.50	2.25



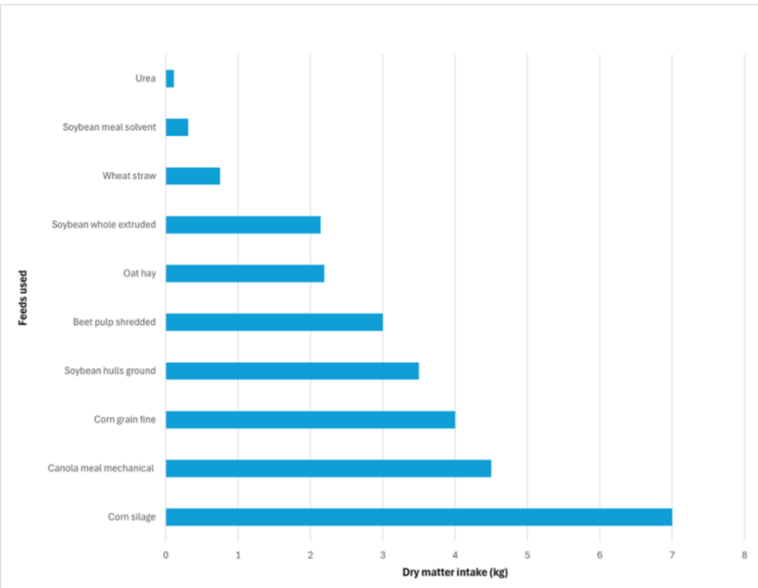
Appendix Figure 3. Graph of the feeds included in the Philippines high cow early lactation diet.

Taiwan high cow early lactation diet

For this diet, pangola silage entered the diet if there was no oat hay. This resulted in substantial differences in the diet structure including changes in grain and protein meal use. For all other Taiwanese diets, the pangola silage displaced oat hay use.

Appendix Table 4. Feed ingredients and amounts included in the Taiwanese high cow early lactation diet

Ingredient	Cost normalized	DM (%)	As fed (kg/d)	DM (kg/d)
Corn silage	33.0	35.0	20.00	7.00
Canola meal mechanical	143.3	90.0	5.00	4.50
Corn grain fine	136.0	88.0	4.55	4.00
Soybean hulls ground	78.3	91.0	3.85	3.50
Beet pulp shredded	76.8	91.0	3.30	3.00
Oat hay	100.0	90.6	2.42	2.19
Soybean whole extruded	204.9	93.6	2.29	2.14
Wheat straw	26.1	92.0	0.82	0.75
Soybean meal solvent	185.2	90.0	0.35	0.31
Urea	197.0	99.0	0.11	0.11
Limestone	1.0	99.5	0.10	0.10



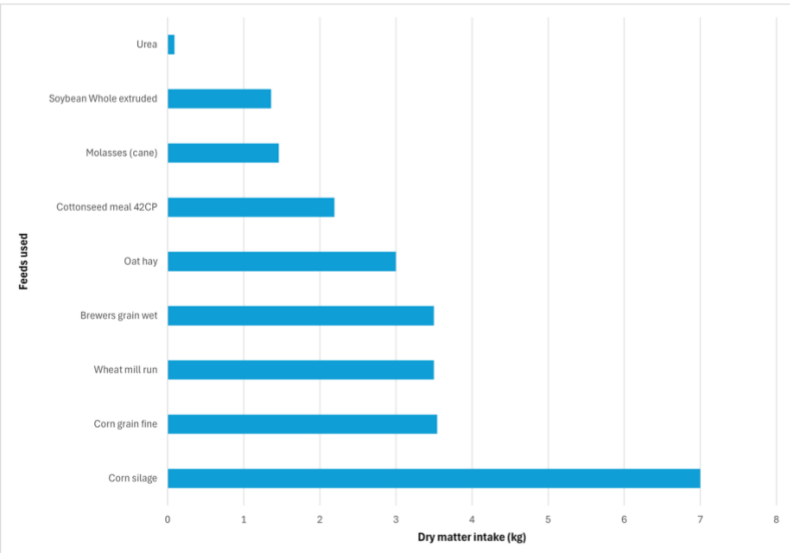
Appendix Figure 4. Graph of the feeds included in the Taiwanese high cow early lactation diet.

Chinese high cow early lactation diet.

The diet without oat hay brought in wheat hay and soya hulls and altered the amounts of protein meal inclusions. This was the feed base for the Chinese diets.

Appendix Table 5. Feed ingredients and amounts included in Chinese high cow early lactation diet

Ingredient	Cost normalized	DM (%)	As fed (kg/d)	DM (kg/d)
Corn silage	20.3	35.0	19.99	7.00
Corn grain fine	78.3	88.0	4.02	3.54
Wheat mill run	62.3	95.0	3.68	3.50
Brewers grain wet	19.0	26.0	13.46	3.50
Oat hay	100.0	91.0	3.30	3.00
Cottonseed meal 42CP	131.4	92.0	2.38	2.19
Molasses (cane)	57.3	73.0	2.00	1.46
Soybean Whole extruded	143.5	93.6	1.45	1.36
Limestone	21.1	99.5	0.20	0.20
Urea	21.1	99.0	0.09	0.09
Sodium bicarbonate	168.0	99.5	0.08	0.08
Salt	21.1	99.5	0.05	0.05



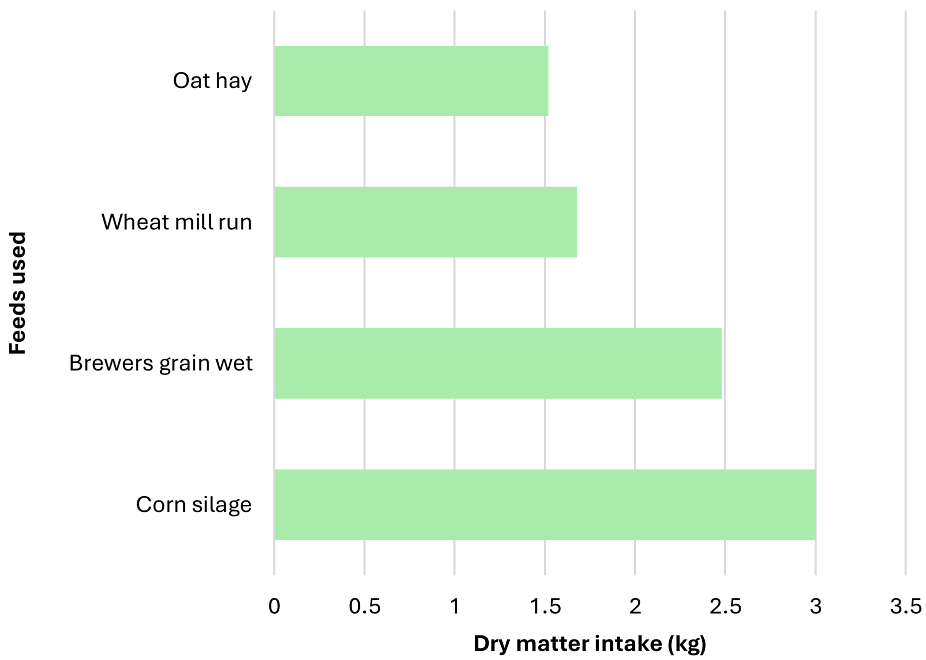
Appendix Figure 5. Graph of the feeds included in the Chinese high cow early lactation diet.

Diet for Chinese 13-month-old heifers. Model for a second Chinese dairy

The diet without oat hay included a Timothy hay of similar costs fed in a greater amount and a reduction in mill run use.

Appendix Table 6. Feed ingredients and amounts included in the Chinese 13-month-old heifer diet

Ingredient	Cost normalized	DM (%)	As fed (kg/d)	DM (kg/d)
Corn silage	22.1	35.0	8.57	3.00
Brewers grain wet	20.6	26.0	9.54	2.48
Wheat mill run	67.6	95.0	1.77	1.68
Oat hay	100.0	90.6	1.68	1.52
Limestone	5.9	99.5	0.06	0.06



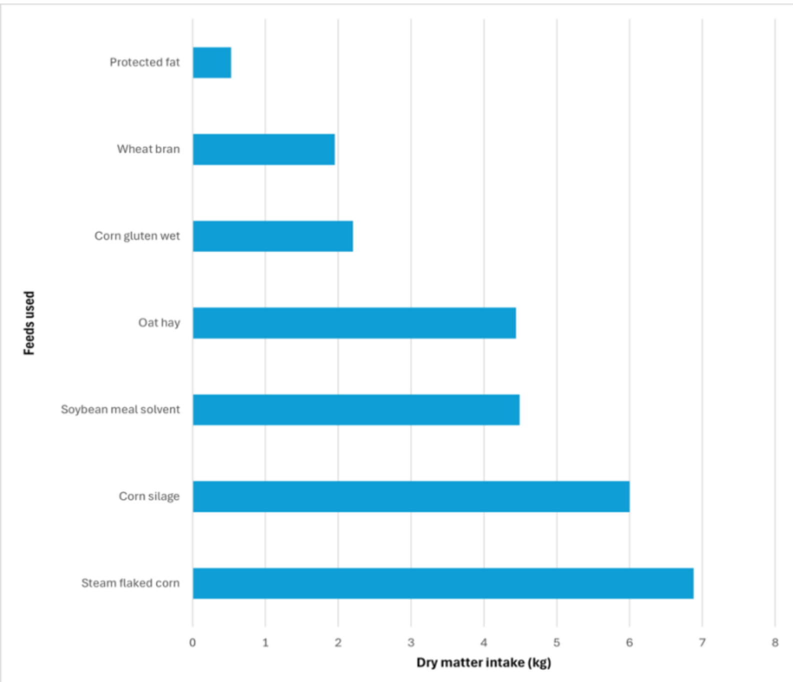
Appendix Figure 6. Feeds used in the diet of a 13-month-old heifer for the second Chinese dairy

Diet for high producing early lactation cows in Saudi Arabia

The diet without oat hay included less corn silage, Rhodes grass hay and a protected soyabean meal. These were the highest producing cows modelled with early lactation production of 55L per day.

Appendix Table 7. Feed ingredients and amounts included in the Saudi Arabian high cow early lactation diet

Ingredient	Cost normalized	DM (%)	As fed (kg/d)	DM (kg/d)
Steam flaked corn	61.3	86.0	8.00	6.88
Corn silage	9.4	30.0	20.00	6.00
Soybean meal solvent	139.2	90.0	4.98	4.49
Oat hay	100.0	91.0	4.88	4.44
Corn gluten wet	125.0	40.0	5.50	2.20
Wheat bran	250.0	88.8	2.20	1.95
Mineral supplement	162.5	96.4	0.80	0.77
Protected fat	228.1	98.0	0.54	0.53
Buffer	156.3	99.5	0.22	0.22



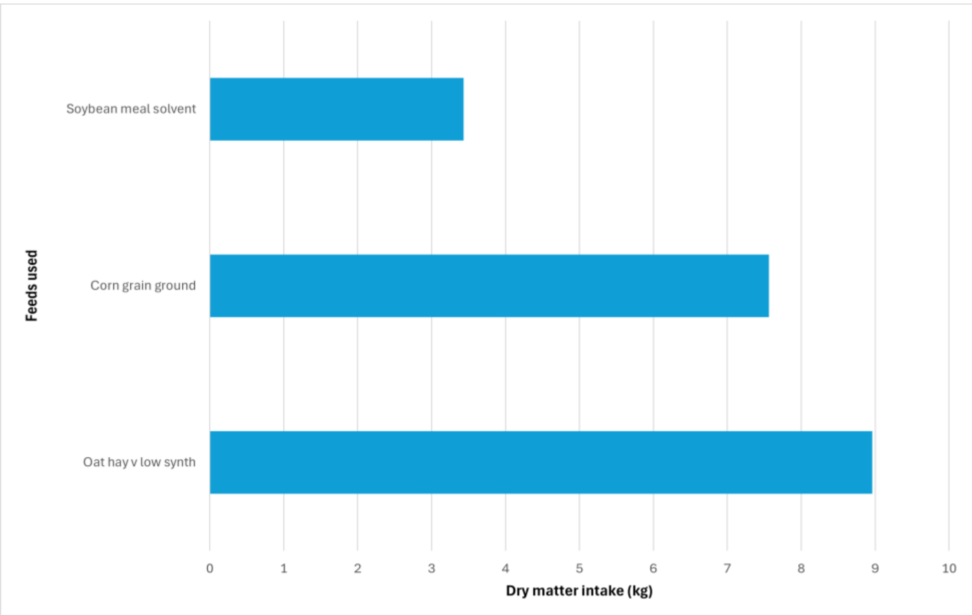
Appendix Figure 7. Graph of the feeds included in the Saudi Arabian high cow early lactation diet.

Korean later lactation cow diet

The diet with no oat hay included Fescue hay with identical cost to the oat hay, but which resulted in changes to other ingredients that increased diet costs. The feed options in this diet were relatively limited.

Appendix Table 8. Feed ingredients and amounts included in the Korean later lactation diet

Ingredient	Cost normalized	DM (%)	As fed (kg/d)	DM (kg/d)
Oat hay lowest quartile	100.0	90.6	9.88	8.96
Corn grain ground	68.3	88.0	8.59	7.56
Soybean meal solvent	136.6	90.0	3.81	3.43
Calcium prill	4.9	99.5	0.30	0.30
Sodium bicarbonate	130.5	99.5	0.20	0.20
Dicalcium phosphate	106.1	99.5	0.10	0.10
Salt	39.0	99.5	0.08	0.08
Magnesium oxide	89.3	99.5	0.04	0.04



Appendix Figure 8. Graph of the feeds included in the Korean late lactation diet.

Appendix Table 9: Example specifications for oat hay (nutritional quality criteria will vary)

Item	Specifications
Moisture	12% maximum
Relative feed value	110
Acid detergent fiber	<33% dry matter
Water soluble carbohydrates	>12% dry matter
Crude protein	>6% dry matter
Aflatoxin	<10 ppb
Mould count	<10,000 CFU/g
Packaging	350 to 750 kg bales double compression Loaded into containers
Packaging	Loaded in 40’ High cube containers