FORMULATION AND EVALUATION TOOL OF DAIRY CATTLE RATIONS FOR SMALLHOLDERS

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ABSTRACT. A dairy cattle least-cost ration formulation and evaluation tool for smallholders was developed using Microsoft® Excel. The tool has three modules namely ingredients, least-cost and feed evaluation. The feed database contains nutritive values of feed ingredient samples collected from dairy smallholders in Peninsular Malaysia. The least-cost module formulates a least-cost feed based on animal/milk parameters provided. The information generated by the tool was verified using published data and NRC models for dairy cattle. As the feed ingredients availability and cost vary between locations, the farmer can use this tool to effectively formulate feed at the lowest cost. The tool also enables the evaluation of the ration offered by the smallholder to predict its potential for milk yield. This tool is made with a simple interface which enables smallholder farmers to utilise ICT tools for agriculture in enhancing their enterprise, and thus promoting the next generation of ICT savvy farmers.

Keywords: dairy cattle, ration formulation, smallholder dairy, milk yield, feed formulator

INTRODUCTION

Malaysia is about 60% self-sufficient in fresh dairy milk production (). Dairy farming under hot and humid environment is a very challenging enterprise as heat stress adversely affects both the quantity and quality of milk, especially in high yielding breeds (Prathap *et al*., 2017). As in any enterprise, the major component determining profit and sustenance in the dairy industry is the economics of milk production (Calker *et al*., 2005). Hemme *et al*. (2014) benchmarked cost of milk production in 46 countries which produce 87% of the world's total milk and categorised the cost by sectors. The cost per litre in 2010 in the EU, Middle East and China was USD0.40 to USD0.50 (MYR1.60 to MYR2.00); in the USA, Brazil, CEEC and Oceania USD0.30 to USD0.40 (MYR1.20 to MYR1.60); in Africa, Asia, South America, less than USD0.30 (MYR1.20); while in Austria, Norway, Switzerland and Canada, more than USD0.60 (MYR2.40). On the other hand, the cost of milk production in Vietnam in 2006 was only USD0.12 to USD0.17 (MYR0.48 to MYR0.68) per litre (Garcia *et al*., 2006). In Malaysia, farmers sell their milk between MYR2.45 to MYR2.65 (USD0.61 to USD0.66) per litre (Mohd Suhaimi *et al*., 2017).

The current global milk price was estimated at USD0.31 (MYR1.24) per litre (IFCN, 2018). Despite differences in the cost of production, the major component was feed followed by labour, land and machinery (FAO, IDF and IFCN, 2014; Hemme et al., 2014). Feed costs contributed between 50% to 60% of the total milk production cost (FAO, IDF and IFCN, 2014) and was linked strongly to feed prices and feeding systems. Dairy cattle have been traditionally grazed on pasture to keep production costs low and globally, New Zealand produces milk at the lowest cost as 90% of the animal's diet is forage based (FAO, IDF and IFCN, 2014). Increasing the proportion of supplemental feed was observed to increase feed cost by almost 30% in Australian dairy farms (Clark et al., 2018).

Dairy cattle can be fed solely on grazed herbage but milk production is limited to less than 30 kg/day (Doyle et al. 2001) and therefore a small portion of feed is supplemented in temperate countries where production exceed 30 kg/day. In the tropics however, milk production rarely exceeds 30 kg/day and in principle can be totally forage fed. However, the quality of forages in the humid tropics rarely meet the nutritional value of cool climate forages. For instance, the metabolizable energy (ME) and crude protein (CP) of kikuyu grass (Pennisetum clandestinum), a tropical pasture species exceeded 10 MJ/kg and 20%CP respectively and was comparable to the ryegrass (Lolium multiflorum L.), a temperate pasture species in Australia (Fulkerson et al., 2006). However, the same cannot be assumed for the humid tropics. Suhaimi et al. (2017) evaluated 900 samples of Brachiaria decumbens over a period of 5 years from the southern region of Peninsular Malaysia and obtained a mean value of 12.26% crude protein, 33.8% crude fibre and 8.69 MJ/kg metabolizable energy. Due to the poor quality of forages coupled with the lack of land for forage production, the amount of forage in typical diets of dairy cattle in Malaysia is only about 47.5% (Moran and Brouwer, 2014). Therefore, more than 50% of the dairy cattle rations comprise of concentrates, either utilising cereals or agro-industrial by-products. Furthermore, the availability, price and quality of supplemental feed varies between different regions in Malaysia (Hazwan et al., 2016).

Dairy farming in most parts of Asia, including Malaysia is still dominated by smallholders with minimal inputs and low milk yield. As more that 50% of the feed comprises of concentrates, with a highly volatile prices, formulating at the lowest cost possible while meeting animal requirements is a challenge under smallholder conditions. In fact, Moran and Brouwer (2014) observed that only 27% of 30 dairy farms surveyed in Peninsular Malaysia had positive gross profits. Therefore, cost effective feed formulation, which accounts for the biggest portion of the cost of milk production is critical. Although a number of feed formulation tools are available, smallholders seldom use them due to their complexity and lack of local ingredient database. This paper describes a simple least-cost ration formulation tool developed for the smallholder dairy cattle farmer incorporating nutritive values of commonly used local feed ingredients.

MATERIALS AND METHODS

Feed and forage samples were collected from smallholder dairy farms in Peninsular Malaysia and subject to chemical analysis based on established methods (AOAC, 2012). Nutrient requirements of dairy cattle were reviewed for various sources (NRC, 2001; Leonard, 1982; Moran, 2005). After review and evaluation, requirement values published by Moran (2005) for small holder dairy farmers in the humid tropics was adopted. Similar data was also adopted by the FAO Ration Tool for dairy cows (FAO, 2016). Multiple linear regression equations were fitted to dairy cattle requirement data published by Moran (2005) to develop the model. The equations adopted by the current model are as follows:

Metabolizable energy (ME, MJ/d) requirements:

Maintenance $= 8.6 + 0.091 *$ body weight (kg)

Pregnancy $= 26.12 \div (1 + \text{Exp}$
$(-3.84 - 0.55 * \text{pregnancy (month)})^{(1//0.00053)}$

Milk yield (ME/kg milk) $= 1.56 + 0.36 *$ (% milk protein) $+ 0.66 *$ (milk fat %)

Dry matter intake (DMI)
$= 0.03 *$ Body weight (kg)

Neutral detergent fibre (NDF) intake
$= 30\%$ of DMI

Protein requirements:
Dry cow $= 12\%$
Lactating (1 to 3 months) $= 16\%$

Lactating (4 to 6 months) $= 14\%$
Lactating (7 to 10 months) $= 12\%$

Calcium requirements:
Dry cow $= 0.4\%$
Lactating (1 to 3 months) $= 0.8\%$
Lactating (4 to 6 months) $= 0.7\%$
Lactating (7 to 10 months) $= 0.4\%$

Phosphorus Requirements:
Dry cow $= 0.2\%$
Lactating (1 to 3 months) $= 0.4\%$
Lactating (4 to 6 months) $= 0.35\%$
Lactating (7 to 10 months) $= 0.2\%$

A Microsoft® Excel for Windows based tool utilizing Visual Basic for Application (VBA), was developed comprising of three simple modules namely i) an ingredient database, ii) a least-cost ration formulation module and iii) a ration evaluation tool. The least-cost module utilised the solver linear optimisation module inbuilt in Microsoft® Excel. The derived values were verified using data published by NRC (2001), Moran (2005) and DVS (2005).

RESULTS AND DISCUSSION

The program flow is shown in Figure 1. There are five worksheets in the workbook namely Main, Instructions, Ingredients, Least-Cost and Feed Evaluation Tool.

Main worksheet

The Main page (Figure 2) worksheet is the overview of the tool with quick access to various components of the tool. Once the user is familiar with tool, the core least-cost
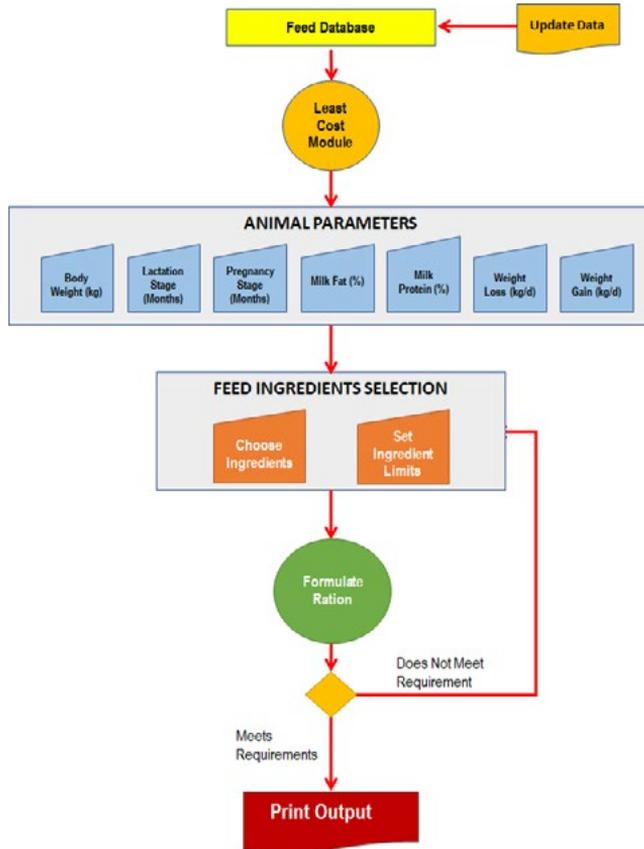
Figure 1. Overall Program Flow of the Ration Formulation Tool
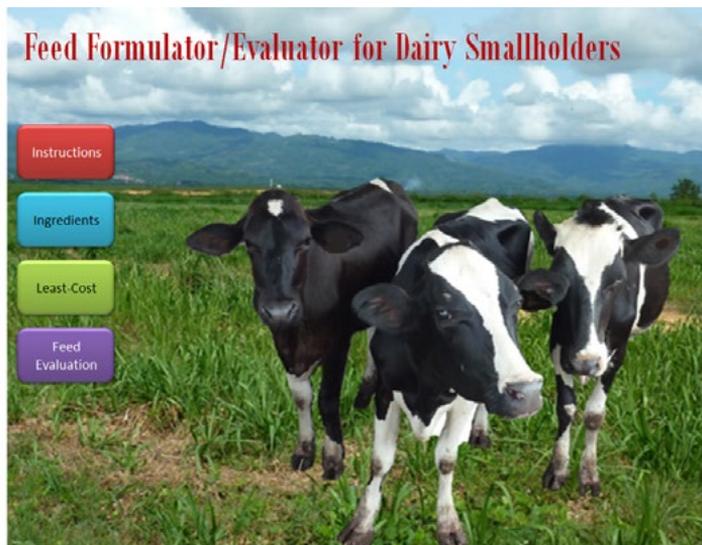
Figure 2. Main page of the Ration Formulation Tool

tool can be accessed directly for the Main page.

Instructions worksheet

The Instructions worksheet (Figure 3) provides brief instructions for the use of the tool. It also describes the type of data required and data entry restrictions. The user should read this to become familiar with the tool and its capability before using the tool.

Ingredients worksheet

The current version of the Ingredients worksheet (Figure 4) has nutrient composition data of feed and forage samples collected from several smallholder farms in Peninsular Malaysia. The user has to update the prices of ingredients in the worksheet before attempting to run the tool as price of ingredients influences its selection for least-cost formulation. Once prices have been updated, the user can run the least-cost tool directly for subsequent analyses, unless ingredient prices change. The user also has the option to enter self-analysed feed sample data by inserting new rows within the limits of the worksheet. However, it is important to ensure all nutrient values are filled in the relevant cells, otherwise the

Figure 3. Brief Instruction to use the Ration Formulation Tool

system will select the ingredient with a value of zero for the particular nutrient.

Least-cost worksheet

The Least-cost worksheet or module (Figure 5) is the core of this tool. All data required to run the tool are entered here. There are components in this worksheet namely animal parameters, ingredient selection,

nutrient balance table and calculated feeding regime (amount/cow). The user only has access to certain cells in all these components of the worksheet to avoid data corruption. The first requirement is for the user to enter animal parameters which include body weight (kg), lactation stage (months), pregnancy stage (months), anticipated milk output (kg/day), milk fat content (%), milk protein content (%), animal

Active Ingredient Box (Dry Matter Basis) — Main | Instructions | Least-Cost | Feed Evaluation

Ingredient	Dry matter (%) 2	ME MJ/kg 3	Crude protein % 5	Ca % 6	Phos % 7	EE/Crude Fat (%) 8	ADF % 9	NDF % 10	Cost RM/kg 12	Ingredient Type 13	Inclusion (%) Min 14	Inclusion (%) Max 15
Conc EMPTY										Empty	None	None
Brewers grain	95.00	10.78	23.10	0.30	0.60	6.70	21.90	56.30	0.73	Conc	0	20
Broken Rice	89.10	13.45	7.40	0.05	0.28	1.90	0.65	9.28	1.59	Conc	0	30
CaCO3 (Limestone)	99.60	0.00	0.00	39.40	0.09				0.17	Conc	0	5
Cassava (dry chip)	86.20	13.00	4.40	0.40	0.50	0.50	37.40	51.40	0.78	Conc	0	40
Copra meal	91.50	12.80	22.40	1.20	5.80	9.80	28.70	54.70	0.55	Conc	0	40
Corn Grain	87.70	13.60	9.40	0.50	3.00	4.30	3.00	12.20	0.90	Conc	0	30
CPO (Crude Palm Oil)	99.00	29.45	0.00	0.00	0.00	99.00			4.45	Conc	0	10
Dairy Cattle Pellet	92.98	12.51	17.15	0.72	0.63			56.84	1.06	Conc	0	30
DCP	97.00		0.00	22.00	19.30				1.40	Conc	0	5
Fish Meal	92.50	3.10	54.60	7.90	2.10	5.90			2.80	Conc	0	40
Groundnut Cake	90.00								0.85	Conc	0	30
Limestone	98.00			34.00	0.02				0.35	Conc	0	30
Molasses	75.00	10.87	5.80	1.00	0.11	0.10	0.00	0.00	1.00	Conc	0	20
Oat polard	93.00	7.10	4.80	0.12	0.13			69.40	0.60	Conc	0	30
Palm kernel expeller	90.90	10.10	16.60	0.58	0.62			67.00	0.66	Conc	0	30
PKE	90.00	11.27	14.50	0.20	0.50			73.00	0.60	Conc	0	30
PKE/PKC	90.00	11.27	14.50	0.20	0.50	15.00		73.00	0.60	Conc	0	80
POME (dry)	91.10	6.50	11.10	0.70	0.50	12.10	44.00	49.00	0.36	Conc	0	40
Rice Bran	89.00	7.78	14.10	0.08	1.70	15.10	18.00	23.00	0.75	Conc	0	40
Rice Hulls	90.00	1.81	3.30	0.10	0.08	0.08	70.00	81.00	0.50	Conc	0	40
Salt	93.00								0.35	Conc	0	0.06
Skim Milk	96.00								3.25	Conc	0	10
Soybean hull	90.00	8.60	19.70	0.49	0.28			51.34	0.95	Conc	0	30
Soybean meal (Imported)	90.00	12.69	48.90	0.15	0.81	1.50	10.00	15.00	1.81	Conc	0	40
Urea	99.00	0.00	288.00	0.00	0.00				2.10	Conc	0	3
Wheat pollard	90.00	10.61	18.30	0.05	0.67			51.34	0.93	Conc	0	30
Vit Min	95.00								2.80	Conc	0.5	0.5
Megalac	95.00	33.30	0.00	9.00		84.00			5.20	Conc	0	3
Forage EMPTY	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		None	None
Bracharia decumbens	17.30	8.50	11.90	0.30	0.60	3.70		60.00	0.10	Forage	0	100
Bracharia ruziziansis	18.40	8.00	14.00	0.60	0.20		41.00	67.00	0.10	Forage	0	100
Corn Silage (without cob)	23.30	5.90	8.20	0.50	0.20	3.10		63.00		Forage	0	100
Glyricidia maculata (young)	18.70	6.70	21.00	1.20	3.00	4.10			0.10	Forage	0	100
Lablab purpureus (lablab) - silage	24.15	9.00	18.00	0.30	0.20	3.20	35.00	43.00	0.10	Forage	0	60
Leucaena leucocephala (young)	19.10	4.60	40.40	4.00	0.50	1.70		41.00	0.10	Forage	0	100
Maize Stover (fresh)	28.90	9.30	6.90	0.37	0.20	1.20	35.90	65.50		Forage	0	60
Morus sp (Mulberry leaves)	28.70	11.93	21.40	2.71	0.27	2.90	16.00	18.00	0.10	Forage	0	100
Napier (Red)	19.34	7.40	7.12	0.40	0.15			72.14	0.10	Forage	0	60
Napier Pak Chong	14.30	9.45	16.30	0.40	0.17	3.71	40.48	61.25	0.10	Forage	0	60
OPF dry	86.00	5.65	4.70	0.40	0.90	2.40	54.00	79.00	0.35	Forage	0	30
Panicum maximum (Guinea)	23.10	7.10	12.40	0.40	0.30	1.80		69.00	0.10	Forage	0	100
Pennisetum purpureum (Napier)	20.00	6.50	9.00	0.40	0.20	1.90		76.00	0.10	Forage	0	100
Rice straw	98.90	7.51	6.70	0.10	0.10	2.90			0.14	Forage	0	80
Sweet Corn Residue	29.50	7.00	9.70	0.30	0.20	1.50	36.00	64.70		Forage	0	60

Figure 4. Ingredient Database of the Ration Formulation Tool
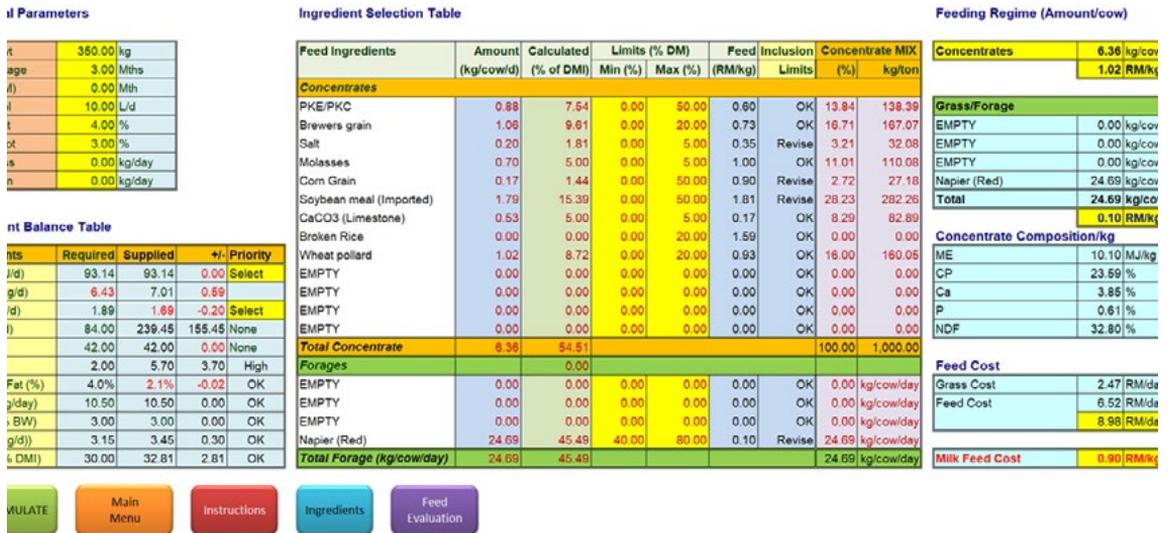
Figure 5. Ration Formulation worksheet of the Ration Formulation Tool

Figure 6. Ration Evaluation Tool

body weight loss (early lactation) and weight gain (mid- to late lactation) in kg/day. If the user does not have sufficient data, the default initial values can be used and only body weight and milk output changed. The nutrient balance table displays the nutrients required based on animal parameters entered as well as the nutrient content of the formulated ration. In the nutrient balance table, the priority section can be altered. The priority can be set as 'select' or 'none' using a pull-down menu. When the particular nutrient is set as 'select', the tool would attempt to equate the supplied nutrient with the required. If it is set to 'none', the tool can provide a ration below or above the requirements of the animals. Although several nutrients priority can be set in the tool, it is suggested that the user prioritise energy and protein in the first instance. The other nutrient can be used as a learning or experimental tool to test different ration formulations. The final procedure is to select the ingredients used in the ration. The ingredient selection component is divided into two sections namely concentrate and forage. The user can select up to 13 types of concentrates and 4 types of forages using the pull-down menu which acquires data from the feed ingredients worksheet. Once the ingredients have been selected, the user has to set constrains. Constrains are set as maximum and minimum percentage of dry matter intake and a minimal default limit of 30% should be set for total forage intake, especially for lactating animals to ensure sufficient fibre intake. Besides fibre, the concentration of some ingredients also requires limitations (Stallings, 2009). A good example is the use of urea in dairy diets which should not exceed 1% in the concentrate or a total of 135 g/cow/day (Kertz, 2010). The content of urea-NPN feed sources should also not exceed 20% of total dietary crude protein (CP) intake. Similarly, the inclusion of molasses in dairy diets should also be limited as feeding more than 6% total sugar was observed to depress milk production (Broderick and Radloff, 2004). The recommended limits are set in the Ingredients worksheet and picked up in the Least-cost worksheet to indicate if revision is required.

Feed evaluation tool

This tool (Figure 6) enables the smallholder to test the nutritive value of the current feed regime. In this tool, all animal parameters are entered in the Animal Parameter Table and normal farm milk yield/animal. The user then selects the concentrates used in the current ration fed as quantity per animal (kg) per animal as well as the amount (kg) of fresh forage offered daily. The Nutrient Balance Table displays the amount of nutrients required based on animal parameters provided and the nutrients supplied by the current farm feeding regime. The Summary of Feed Evaluated Table displays the properties of the feed currently used in the farm and the predicted milk yield based on the nutrients supplied. The Economics of Feed Table shows the daily cost of concentrates, forage and the feed cost per kg of milk produced using the current feeding regime. The smallholder can then evaluate if the present feed regime is producing the amount of milk based on the estimation and if it is not, the ingredients

can be readjusted. The ingredients can also be manually manipulated to derive the anticipated milk yield. The example in Table 6 displays concentrate feed at 7.83 kg costing MYR8.80 and 40 kg of grass at MYR4.00. The predicted milk yield is 13.61 L/day. If the farmer is getting milk yields lower that this, then the animals are probably overfed and ration needs readjustments.

Model validation

The present tool was validated using nutrient requirement data published by Moran (2005), NRC (2001) and DVS (2005). DVS (2005) based on body weight and lactation. Validation was done for metabolizable energy (ME) requirements which is the main limiting component in dairy diets. Figure 7 shows the data for metabolizable energy requirements of a 350 kg, non-pregnant cow producing 0 to 20 litres of milk at 4% fat and 3% protein. The mean ME data provided by DVS (2005) for 0 to 20 litres was 11.54%, 8.79% and 3.87% higher than that predicted by the current tool for lactation 1, 2 and 3 respectively. On the other hand, data from Moran (2005) and NRC (2001) was only 0.23% higher and 1.8% lower respectively (Figure 7). It appears that the requirements of NRC (2001) are similar to those of Moran (2005) although the latter was developed for tropical breeds. The higher margin of error when compared with DVS (2005) could have been due to their use of older NRC (1989) recommendations. However, differences in model predictions can be expected as Oliveira (2015) observed that the *Bos taurus × Bos indicus* crossbred dairy cows had a 26% lower metabolizable energy requirement for

maintenance and variations could be due to differences in animal genetics, environment and especially, feed resources. It is for these reasons that local specific feed formulation tools continue to be developed (Angadi, 2016; FAO, 2016). Therefore, the present tool developed meets the extensively tested National Research Council model for nutrient requirement of dairy cattle. This tool can be used by local smallholder dairy farmers to manage their feed regime as the feed database is based on locally available ingredients. It can also be used by extension agents to assist dairy farmers formulate dairy cattle rations and by universities as a ruminant nutrition teaching tool.

Software assessment

There are several computer based dairy ration formulation models and tools such as the Feed Assist (Angadi *et al.*, 2016) from India, Dairy Ration Tool v1.1.9 by NRC (2001) and the recent FAO Ration Tool (2016), to name a few. Each of these programs have their own advantages and limitations as assessed by Jensen (2015). The NRC Dairy Ration is the most comprehensive and accompanies the Nutrient Requirements of Dairy Cattle textbook which is used as a standard reference worldwide. However, most values are for temperate feedstuffs and cattle. Similarly, the Feed Assist is targeted for local Indian breeds and feedstuffs. The FAO Ration Tool, developed recently by Feedipaedia (2019) attempts to address requirements for a larger target group but also has some limitations such as the lack of fixing exact ingredient values. The tool in this study attempts to address some of the
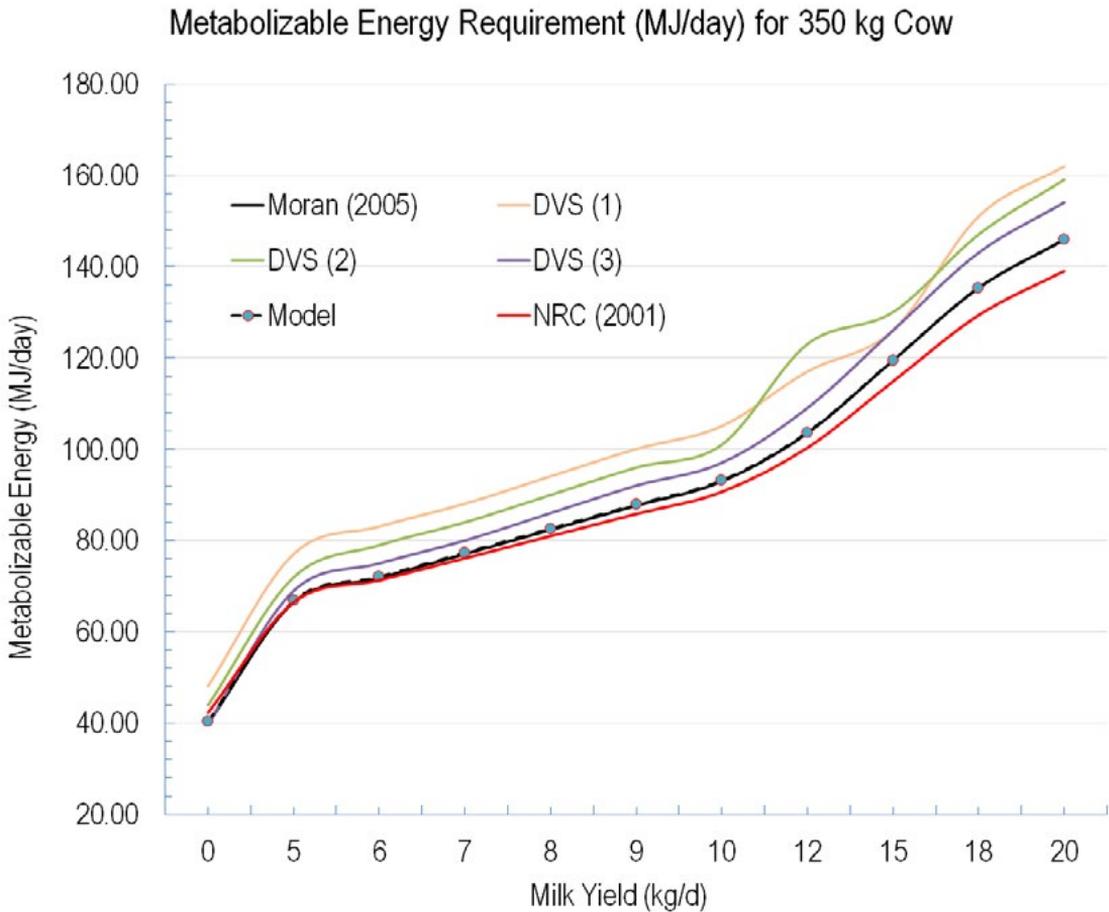
DVS (1, 2 & 3) = Lactation No. 1 to 3 (DVS, 2005); Moran (2005) data; NRC (2001); Model = data predicted by model.

Figure 7. Model validation for energy requirement

limitations of these available tools and to cater for the local dairy sector requirements. It also incorporates a ration evaluation tool whereby the farmers can evaluate their current feed regime, not available in some of the other models. In general, the model is comparable to the other tools published as shown by the validation of the model for the main energy component.

CONCLUSION

A formulation tool of dairy cattle rations was developed using Microsoft® Excel to assist farmers formulate cost effective dairy cattle feeds using locally available feed resources. The tool predicted requirements within the ranges recommended by the National Research Council for dairy cattle. The tool utilises nutritive values of local

feed ingredients and the farmer can update the ingredients database with new feed resources within their access. It can also be used by extension agents as an advisory tool and universities as a teaching aid.

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