Feeding Strategies on Farms to Improve Livestock Productivity and Reduce Methane Production

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ABSTRACT

Feed resources, feed processing and feeding technology are essentially key factors to the efficient and successful ruminant production especially in the tropics. Diversity and distribution of roughage resources both quantity and quality will impact on the performance of livestock. Numerous agricultural crop-residues such as rice straw can be treated with urea (U) and lime (L) (1.5+1.5% U-lime) to enrich its nutritive value. Furthermore, fodder trees and shrubs including *Leucaena leucocephala* and *Flemingia macrophylla*, as well as whole cassava crop can be ensilaged (cassava top silage) to produce high quality protein roughages for ruminant feeding. Feeding of these roughage can result in efficient rumen fermentation and improve meat, milk yield, and milk quality, whilst rumen methane was reduced. These feeding interventions can be employed on farms for establishment (E), development (D), utilization (U), and sustainability (S) (EDU-S) of livestock production.

Agricultural production system including animal production has been shown to impact on global warming especially from methane enteric fermentation of ruminants. Many approaches have been reported to mitigate rumen methane production, however, dietary plants containing plant secondary compounds (condensed tannins, saponins) have impacted on rumen microorganisms, hence can reduce rumen methane production. Nevertheless practical feeding implementations on-farms need to be employed and expanded among farmers/producers, not only to reduce global warming but for the economical advantage of the animal production and improvement of livelihoods.

Under this presentation, details of rumen ecology and fermentation, feed preparation and processing and onwards to utilization by ruminants will be fully illustrated and recommended for possible on-farm implementations.

Keyword: Livestock, Sustainable production, Feed resources, on-farm intervention.

INTRODUCTION

Thornton (2010) started the needs to develop breeds, nutrition and animal health to increase potential animal production efficiency especially in the developing countries. Rapid population growth will continue to be an important impediment to achieving improvements in food security. While urbanization and income growth rate (2.1% per capita) will further impact on the need of livestock products consumption. As Steinfeld et al. (2006) indicated that in the year 2050 the annual consumption per capita of meat and milk will be 44, 78 kg with total consumption of meat and milk 326, 585 Mt., for developing countries, while 94, 216 kg with total consumption of 126, 295 Mt., for developed countries, remarkable increase in developing countries. Smith et al. (2013) have reiterated the importance the role livestock production beyond the supply of milk, meat and eggs. Livestock can enhance food and nutrition security and providing income to support the livelihood and well-being of the household formers. The challenges are those how to manage the trade-offs to enable livestock's positive impacts to be achievable while minimizing the negative issues and to maintain environmentally-friendly. Godber and Wall (2014) additionally reiterated the importance of livestock production as an important contributor to sustainable food security, as the animal products account for one-third of global human protein consumption. Livestock-based food security will be more vulnerable to impacts of climate change in addition to prevailing lacks of technical support and economic, as well as other supporting infra-structure and available markets.

FAO (2014) has illustrated action plans to ensure livestock sustainability into practices encompassing the broad areas (Figure I).

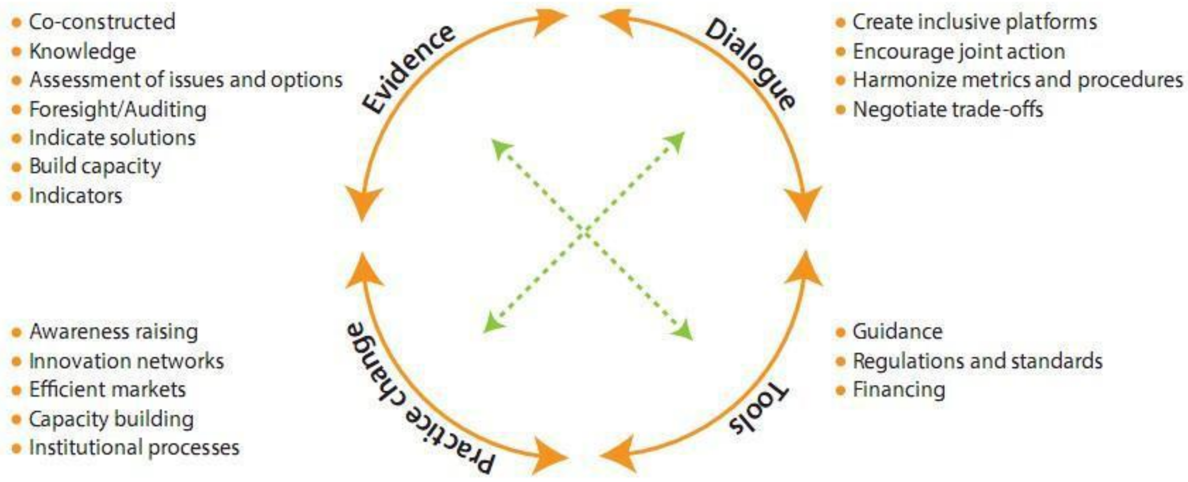

Figure I: Operating Sustainability: Four broad areas of action (FAO, 2014)

Wanapat et al. (2015) reported that animal agriculture has been an important component in the integrated farming systems in developing countries. It serves in a paramount diversified role in producing animal protein food, draft power, farm manure as well as ensuring social status-quo and enriching livelihood. Ruminants are importantly contributable to the well-being and the livelihood of the global population. Ruminant production systems can vary from subsistence to intensive type of farming depending on locality, resource availability, infrastructure accessibility, food demand and market potentials. The growing demand for sustainable animal production is compelling to researchers exploring the potential approaches to reduce greenhouse gases (GHG) emissions from livestock. Global warming has been an issue of concern and importance for all especially those engaged in animal agriculture. Methane (CH4) is one of the major GHG accounted for at least 14% of the total GHG with a global warming potential 25-fold of carbon dioxide and a 12-year atmospheric lifetime. Agricultural sector has a contribution of 50 to 60% methane emission and ruminants are the major source of methane contribution (15 to 33%). Methane emission by enteric fermentation of ruminants represents a loss of energy intake (5 to 15% of total) and is produced by methanogens (archae) as a result of fermentation end-products.

Ruminants' digestive fermentation results in fermentation end-products of volatile fatty acids (VFA), microbial protein and methane production in the rumen. While, Wanapat et al. (2013) reported that the availability of local feed resources in various seasons can contribute as essential sources of carbohydrate and protein which significantly impact rumen fermentation and the subsequent productivity of the ruminant. The use of fodder trees and shrubs has been developed through the process of pelleting; *Leucaena leucocephala* leaf pellets (LLP), mulberry leaf pellets (MUP) and mangosteen peel and/or garlic pellets, can be used as good sources of protein to supplement ruminant feeding. Apart from producing volatile fatty acids and microbial proteins, greenhouse gases such as methane are also produced in the rumen. Several methods have been used to reduce rumen methane. However, among many approaches, nutritional manipulation using feed formulation and feeding management, especially the use of plant extracts or plants containing secondary compounds (condensed tannins and saponins) and plant oils, has been reported. This approach could help to decrease rumen protozoa and methanogens and thus mitigate the production of methane. At present, more research concerning this burning issue the role of livestock in global warming - warrants undertaking further research with regard to economic viability and practical feasibility.

To achieve productive, profitable, sustainable and environmentally friendly in the tropics the following recommendations are highly recommended;

- E = Establishment of feed resources
- D = Development of feeding system
- U = Utilization of feeds including feeding method and processing
- S = Sustainability of the livestock production system

The proposed feeding system for ruminants, food-feed system (FFS) to produce a year round feeding calendar, as well as to enrich the environment on-farm is illustrated in Figure II. Under this system, both grass types (climbing and erecting) can be used to maximize the biomass by grazing and/or cut-and-carry. Root from cassava can be used as carbohydrate source while feed and whole top can be dried as hay as protein (Wanapat et al. 2013). Additionally, fodder trees/shrubs can be harvested intervally to use freshly as supplements and/or hay/silage making.

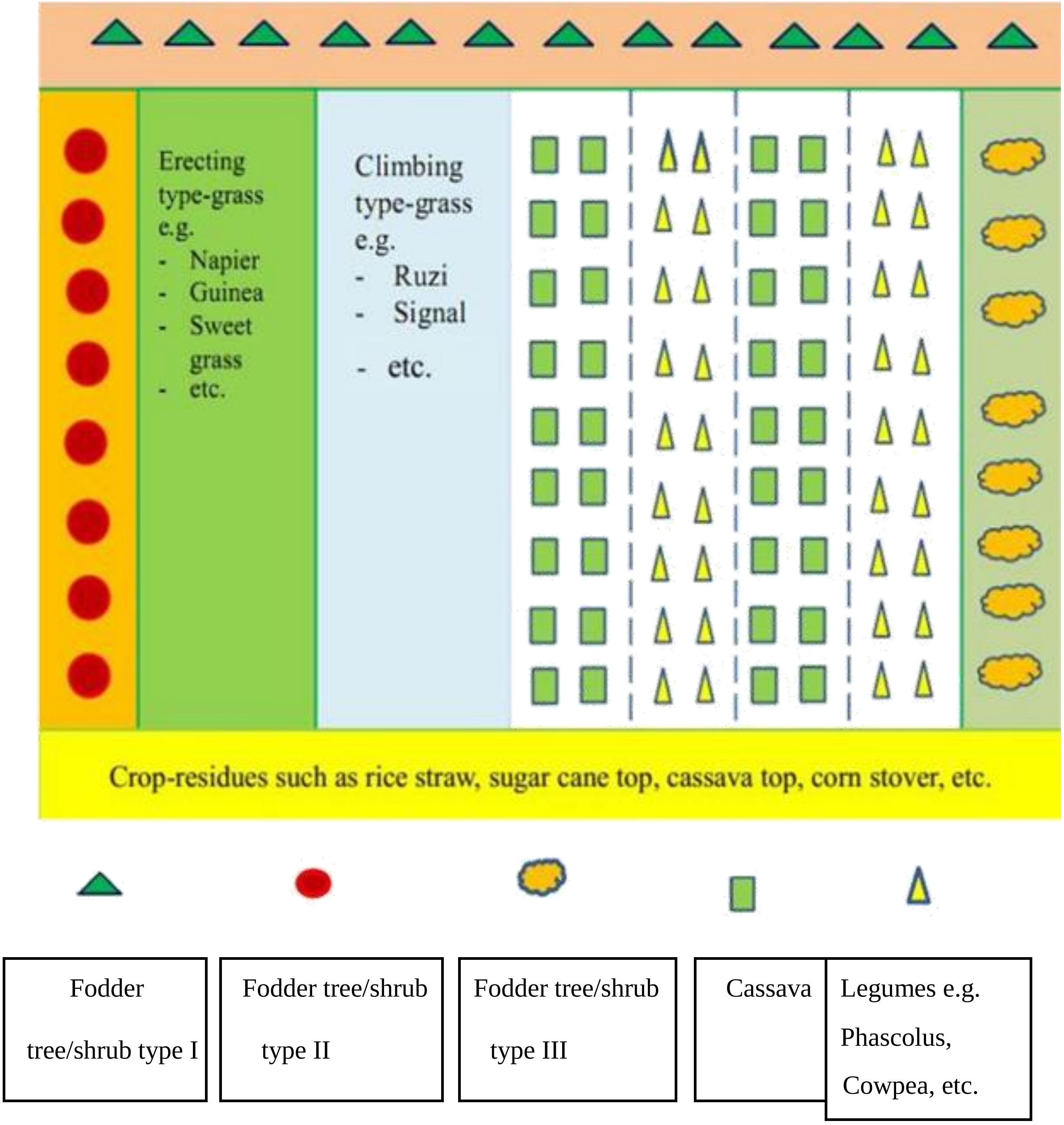

Figure II. The proposed feeding system for ruminants, food-feed system (FFS) for the sustainable ruminant feeding system for smallholder farmers in the tropics.

Current research findings on using local feed resources such as Ipil ipil (*Leucaena leucocephala*), cassava hay and cassava top silage have revealed promising results in ruminant feeding improvements on rumen fermentation end products, nutrient digestibilities, microbial protein synthesis and methane reduction have been obtained. (Ampapon and Wanapat, 2016; Nyuyen et al.,2017; Wanapat et al, 2013) (Tables 1,2,3,4,5,6).

Table 1. Effect of various treated rice straw on milk production and milk composition of lactating dairy cows.

Items	Rice straw			
	Untreated	5.5% U	2 % U+ 2% $Ca(OH)_2$	SEM
Milk yield, kg/day	10.8	11.1	12.1	2.83
3.5% FCM, kg/day	11.3	12. 3	12.9	3.64
Milk composition,%				
Protein	2.8^a	3.3^b	3.4^b	0.34
Fat	$3. 8^a$	4.1^b	4.3^c	0.02
Lactose	4.8	5.0	5.1	0.88
Solids-not-fat	8.3	8.7	8.5	0.98
Total solids	12.1	12.5	12.4	0.86

^{a,b,c} Means in the same row with different superscripts differ *(P*<0.05). (Wanapat *et al.*, 2009)

Table 2. Effects of *Leucaena* silage levels feeding on rumen ecology and fermentation end products in dairy steers

Items	RST	RLS30	RLS60	LS	SEM	Significant level
Temperature (°C)	38.9	39.3	39.1	38.6	0.93	ns
NH_3-N (mg/dl)	7.4^a	16.2^b	22.4^c	27.9^d	0.27	**
BUN (mg/dl)	5.75^a	15.02^b	17.9^c	21.75^d	0.86	**
Ruminal pH	6.7	6.7	6.7	6.6	0.3	ns
Total VFA (mmol/l)	79.5^a	97.1^b	101.3^c	88.2^d	1.2	*
VFA (mol/100 mol)						
Acetate (C_2)	74.6^a	70.6^b	66.5c	66.2^c	0.76	*
Propionate (C_3)	15.9^a	19.6^b	24.9^c	25.2^c	0.5	*
Butyrate (C_4)	9.8	9.7	8.6	8.5	0.92	ns
C_2/C_3	4.8^a	3.6^b	2.7^c	2.6^c	0.28	*
CH_4 production (mol/ 100 mol)	33.2^a	30.3^b	26.5^c	26.3^c	0.39	*

Means in the same row with different letters differ (*$P < 0.05$, **$P < 0.01$)

ns nonsignificantly different, SEM standard error of the means, NH_3-N ammonia nitrogen, BUN blood urea nitrogen, VFA volatile fatty acid, CH_4 methane, RST rice straw, RLS30 70 % rice straw + 30 % Leucaena silage, RLS60 40 % rice straw + 60 % Leucaena silage, LS Leucaena silage. (Giang *et al.*, (2016)

Table 3. Effect of cassava top silage (CTS) on rumen ecology and fermentation in dairy steers

Item	% CTS				SEM	*P*-value
	0	30	60	100		
Temperature, °C	38.5	38.7	38.5	38.6	0.10	0.44
pH	6.6	6.6	6.7	6.6	0.07	0.69
Roll-tube technique, CFU/ml						
Total viable bacteria, $\times 10^{11}$	12.5	16.2	18.9	17.1	1.9	0.22
Cellulolytic, $\times 10^{9}$	3.8	4.2	6.3	6.4	2.1	0.75
Amylolytic, $\times 10^{7}$	1.1	2.1	2.9	2.4	0.5	0.22
Proteolytic, $\times 10^{7}$	3.3	3.5	5.9	6.5	1.2	0.21
Total direct count, cell/ml						
Protozoa $\times 10^{5}$	5.0^{c}	4.2^{b}	3.8^{bc}	3.6^{a}	0.07	0.01
Total VFA, mmol/l	116.8	117.6	115.6	116.9	0.59	0.35
VFA (mol/100mol)						
Acetate (C_2)	68.1^{c}	63.7^{b}	62.4^{a}	62.3^{a}	0.36	0.01
Propionate (C_3)	21.3^{a}	26.8^{b}	28.6^{c}	28.8^{c}	0.39	0.01
Butyrate (C_4)	10.7^{b}	9.5^{a}	8.9^{a}	8.8^{a}	0.31	0.01
C_2/C_3	3.1^{b}	3.2^{a}	2.2^{a}	2.1^{a}	0.14	0.01
CH_4 production^{A}, mol/100mol	29.1^{c}	25.2^{b}	23.8^{a}	23.7^{a}	0.67	0.01
NH_3-N, mg/dl	9.2^{a}	19.6^{ab}	24.1^{c}	29.8^{c}	3.00	0.01
BUN, mg/dl	5.0^{a}	12.8^{ab}	19.3^{bc}	26.0^{c}	3.14	0.01

SEM = standard error of the mean, *CFU* = colony-forming unit.

[a, b, c,] Means in the same row with different superscripts differ ($P<0.05$) and ($P<0.01$) [A] Calculated according to Moss et al. (2000); CH_4 production=0.45(C_2)–0.27(C_3)+0.4(C_4). (Viennasay *et al.*, 2017.)

Table 4. Effeect of cassava top silage on milk yield and composition in lactating dairy cows

Item	Cassava top silage (kg/day of DM)				SEM	*P*-value
	0	0.75	1.5	2.25		
Production						
Milk yield, kg/day	12.7^{a}	13.2^{a}	13.3^{a}	14.0^{b}	0.93	0.04
3.5% FCM, kg/day[1]	14.6^{a}	14.9^{a}	16.1^{b}	17.2^{c}	1.01	0.03
Milk composition, %						
Fat	4.4	4.3	4.8	5	0.35	0.58
Protein	3.2	3.5	3.6	3.8	0.39	0.34
Lactose	4.4	4.4	4.3	4.5	0.14	0.75
Solids-not-fat	9.3	9.3	9.2	9	0.55	0.97
Total solids	14.1	14	14.2	13.9	0.58	0.45

[a,b,c] Means in the same row with different superscripts differ (P<0.05). [1] 3.5% FCM (fat collected milk) =0.432 (kg of milk/d)+16.23 (kg of fat). (Wanapat *et al.*, 2017)

Table 5. Effect of legume foliage supplementation on fermentation characteristics, blood urea nitrogen, and methane production in dairy steers

Items	Control	CH	FMH	CH+ FMH	SEM	*P*-value
Temperature (°C)	38.8	38.9	38.6	38.9	0.05	0.26
NH_3-N (mg/dl)	8.51^{a}	9.06^{b}	9.28^{b}	9.12^{b}	0.20	0.04
BUN (mg/dl)	10.2	9.5	10.8	10.4	0.42	0.86
Ruminal pH	6.8	6.8	6.5	6.6	0.16	0.10
Total VFA (mmol/l)	121.4	124.3	120.5	126.7	2.35	0.49
VFA (mol/100 mol)						
Acetate (C_2)	68.7^{a}	65.1^{b}	64.8^{ab}	62.2^{b}	1.35	0.04
Propionate (C_3)	20.1^{a}	25.4^{b}	24.3^{b}	27.6^{b}	1.03	0.03
Butyrate (C_4)	8.7	8.1	8.9	8.4	0.79	0.87
C_2/C_3	3.4^{a}	2.6^{b}	2.7b	2.3^{b}	0.12	0.05
CH_4 production[d] (mol/ 100 mol)	22.0^{a}	19.1^{b}	18.8^{b}	17.0^{b}	0.29	0.02

[a, b, c] Means in the same row with different superscripts differed ($P < 0.05$) [d]Calculated according to Moss et al. (2000): Methane = 0.45 (C2) − 0.275 (C3) + 0.4 (C4) *CH* cassava hay meal, *FMH* Flemingia hay meal, *SEM* standard error of the means. (Phesatcha *et al.*, 2016)

Table 6. Effect of legume foliage supplementation on urinary purine derivatives and microbial nitrogen supply in dairy steers

Items	Control	CH	FMH	CH+FMH	SEM	*P*-value
Purine derivatives, mmol/day						
Allantoin excretion	24.5	27.4	26.5	31.3	0.63	0.24
Allantoin absorption	75.6	88.1	87.4	98.7	0.16	0.91
MCP, g/day	325^{a}	387^{a}	452^{b}	482^{b}	1.14	0.02
EMNS, g/kg OMDR	23.1^{a}	25.4^{a}	28.7^{b}	30.2^{b}	2.56	0.04

[a, b] Means in the same row with different superscripts differ ($P < 0.05$) *CH* cassava hay meal, *FMH* Flemingia hay meal, *SEM* standard error of the means, *MCP* microbial crude protein, *EMNS* efficiency of microbial N supply, *OMRD* organic matter digested in the rumen. **(**Phesatcha *et al.*, 2016)

CONCLUSIONS

Ruminant production will play a more important role to promote and support the livelihood and well-being of the rural population. EDU-S of local resources especially the feed resources with innovations will enhance the production efficiency, the profitability and sustainability of the systems. More efforts in linkages, sharing experiences among researchers are highly encouraged. Furthermore, on-farm feeding interventions are recommended for implementations.

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