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Role of Animal Husbandry Nutrition Science on Feed, Food and Environment Safety

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ABSTRACT

Animal protein is an important part of the human diet to support physical activities. The role of livestock as a source of animal protein requires adequate nutrition from feed to be able to produce optimally. The feed must be given in adequate amount of quality and quantity, safe feed (not toxic) is a must, and this cannot be separated from the contribution of animal husbandry nutrition science. Formulation of feed ingredients based on local feed and agro-industrial by-products into complete feeds in ruminant production is a strategy to meet the nutritional needs of ruminants so that they can produce optimally, efficiently, and environmentally friendly which ultimately produces products that are safe for human consumption. The success of this strategy has a greater opportunity through a corporate-based livestock approach, and through this approach, it is expected that the concepts of safe feed, safe food, and safe environment can be realized. Based on this phenomenon, animal husbandry nutrition science has proven its capability to contribute significantly to 1) produce livestock (ruminants) with efficient nutrition; 2) improve food safety and quality of food products originating from livestock for human consumption; 3) improve health status and welfare of livestock; and 4) reduce greenhouse gas emissions and the impact of livestock on environmental security.

Keywords: Nutrient, livestock, safe, feed, animal food, environment

INTRODUCTION

The rapid growth of the human population along with the increasing urbanization, income, and lifestyle are expected to increase the consumption of animal products by 70% in 2050[1]. In 2022, Indonesia will raise 54.793 thousand heads of livestock from ruminant commodities (cattle, buffalo, goats, sheep) (Figure 1)[2]. Raising livestock is intended to ensure that people have easy access to animal food products, especially meat, considering that food derived from livestock is an important part of the human dietary menu to meet daily nutritional needs (protein). The increasing livestock population certainly requires additional amounts of feed to be produced. The feed produced must pay attention to the adequacy of nutritional value according to livestock needs. In this case, animal husbandry nutrition science has a vital role in determining the success of livestock production. The urgency of animal husbandry nutrition science in the production of quality feed for livestock includes: 1) determining nutritional value indicators based on livestock nutritional needs, 2) identifying anti-nutritional factors and determining strategies to neutralize them, and 3) identifying the influence of certain micro-ingredients and processes to the performance of livestock, health, welfare, quality of products produced and their impact to the environment.

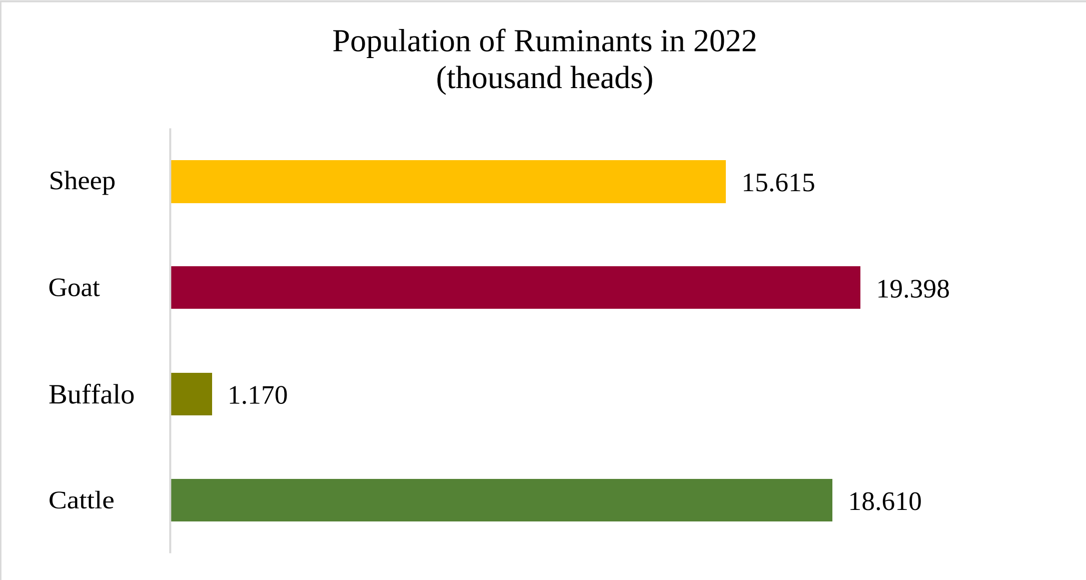
In the global food industry, feed is the largest and the most important component to ensure the sustainability of livestock production in producing safe and affordable animal protein. The current challenge is not only to meet the increasing demand for quality feed, but to ensure its safety because feed safety is a necessity for the health and welfare of livestock and is a prerequisite for food safety and the health of humans who consume it as well as its impact on the environment or known as Safe Feed, Safe Food, and Safe Environment. Food and environmental safety are crucial because they relate to the quality and survival of human life, considering that food is the third most basic human need after air and water. Food safety is part of "one health", namely an integrated approach to prevent and mitigate health threats to animals, humans, plants, and the environment [3]. The role of livestock as a producer of high-quality protein sources requires adequate nutrition from the feed in order to produce optimally, so ensuring that the feed provided is safe and does not have a negative impact on the environment is a must.

Domba: sheep

Kambing: goat

Kerbau: buffalo

Sapi potong; cattle



Source: [2] Figure 1. The population of Ruminants in 2022

DISCUSSION

Characteristic of Ruminants

Livestock commodities in Indonesia are very diverse and have their own uniqueness, one of which is ruminant. The word ruminant etymologically comes from the Latin word "ruminae" which means chewing over again, and in animal husbandry, ruminants are herbivorous animals that chew the cud with a complex digestive system (polygastric or multi-chambered stomach). Ruminants can convert low-quality feed ingredients (containing high crude fiber) into quality food products with high nutritional value (meat and milk)[4]. The ability of ruminants to convert feed is related to their complex digestive systems and mechanisms (mechanical, fermentative, enzymatic, and chemical digestion)[5]. The ruminant's stomach is divided into four compartments (rumen, reticulum, omasum, abomasum)[4] and in the rumen section, there are microorganisms (bacteria, protozoa, fungi) so that ruminants are able to utilize feed with high crude fiber, and produce vitamin B complex (related to fermentation process in the rumen) as well as animal protein (bacterial protein and protozoa protein) for their needs[6]. Each of the diverse microorganisms in the rumen has a specific function in degrading carbohydrates, proteins, and fats originating from feed. Adequacy of feeding (in terms of quality and quantity) must be continuously achieved so that ruminants can produce optimally.

Feed of Ruminants

The development of ruminants in Indonesia has big opportunities, considering the ability of ruminants to convert feed and supported by the abundance of available feed resources. However, the availability fluctuates so livestock development is directed by optimizing the utilization of local feed sources. The diversity of local feed sources offers high flexibility for breeders and complexity for nutritionists so that they can be utilized efficiently but "there is no fixed feed formulation considering that in every region the nutrient content of feed source varies even with the same type". Based on research[7-10], local feed sources such as *Neptunia plena* L. Benth and *Leersia hexandra* Swartz have good digestibility so those are expected to be able to support optimum ruminant production (Table 1).

Table 1. Digestibility of Local Feed Source *Neptunia plena* L. Benth and *Leersia hexandra* Swartz

Livestock Commodity	***Neptunia plena* L. Benth**		***Leersia hexandra* Swartz**	
	DMD	**OMD**	**DMD**	**OMD**
	--------------------%	--------------------		
Cattle	42,94	49,31	41,30	52,89
Buffalo	36,96	45,36	37,81	45,36
Goat	30,93	38,07	21,14	31,42
Sheep	42,71	49,13	41,93	52,72

Remarks: DMD: Dry Matter Digestibility; OMD: Organic Matter Digestibility
Source: [7-9][11]

Based on research[12] [13], other green forage sources which have potential for ruminants feed is *Coix lacryma-jobi* L. or Jelai. *Coix lacryma-jobi* L. has a relatively good nutrient amount and good digestibility (Table 2), thus it has potential for feed ration ingredients. The variance nutrient content of *Coix lacryma-jobi* L. provides high flexibility for breeders and provides complexity for nutritionist to utilize the biomass efficiently[11].

Table 2. Nutrient Composition of *Coix lacryma-jobi* L. Based on Plant Part

Nutrient	Part of the Plant			
	Seed*	Leaf	Stem	Husk (bran)
Moisture Content (%)	11,04	13,27	12,95	11,53
Dry Matter (%)	88,96	86,73	87,05	88,47
Crude Protein (%)	16,20	8,10	7,94	12,55
Crude Fat (%)	5,18	0,89	0,96	6,40
Ash (%)	1,38	12,08	11,26	8,74
Crude Fiber (%)	71,81	21,29	24,11	60,78

Source: Proximate analysis result in Laboratory of Animal Husbandry Nutrition Science, Faculty of Animal Husbandry and Agriculture, Diponegoro University, Semarang (2020); *[14][15]

Table 3. Digestibility of Leaves and Stem of *Coix lacryma-jobi* L.

Plant Part	**Digestibility**	
	Dry Matter	**Organic Matter**
	------------%	------------
Leaves	59,56	38,22
Stem	51,77	34,41

Source: [12]

Digestibility is the percentage of nutrients that can be absorbed by the digestive tract. The nutritional quality of feed ingredients is determined from the nutritional composition and the level of utilization by livestock (digestibility)[16]. High digestibility values indicate that more nutrients are absorbed by livestock[11]. Based on the nutritional content and digestibility value, the biomass which produced by the *Coix lacryma-jobi* L. is potential for rations ingredients in combination with other feed ingredients and supported by the application of processing technology (hay, silage, amofer, complete feed). Effective use of biomass can provide continuous and sustainable feed ingredients, especially forages, so that ruminant feed needs can be met and can provide additional economic benefits[11].

Abundance and nutrition of forages is often influenced by the season, namely: 1) during the rainy season, the production is abundant and contains lots of carbohydrates, protein, fat and vitamins, but mineral deficiency, while 2) during the dry season, the growth of forages is not optimal (due to reduced groundwater) so that the content of carbohydrates, proteins, fats, vitamins and minerals tends to decrease[5][6].

The continuity of local feed sources as forages for ruminants, especially cattle, can be supplied from agricultural by-products (straw) and plantations (oil palm)[17]. The potential of agricultural and plantation by-products as feed sources for cattle can meet the scarcity of feed, especially during the dry season when forages are difficult to obtain. Rice straw is used because the amount is abundant (5-8 tons/ha/harvest) and tends to be wasted, affordable by farmers at low prices, and has the potential as an energy source, but the use of rice straw is often limited by its nutritional quality which not meet the needs of cattle and probability on the presence of anti-nutritional substances[18][19]. Rice straw has a high lignocellulose content (composed of 35-50% cellulose; 25-30% hemicellulose; and 25-30% lignin) which is directly proportional to the high crude fiber content, thus the digestibility value is low and the crude protein content is relatively low, thus the productivity of cattle could not be achieved if the provision is uncontrolled[4]. Efforts that can be made to increase the nutritional value, digestibility, and palatability of rice straw while at the same time providing feed cost efficiency are by utilizing processing technologies such as Ammonia Fermentation (Amofer).

Ammonia fermentation is a combination of two feed processing techniques/processes, namely ammoniation and fermentation [4]. Ammoniation is a form of chemical treatment (for example using urea) that is applied to fibrous feed sources (such as rice straw) to increase their nutritional value and digestibility[18] [20]. Urea added in the ammoniation process plays a role in hydrolyzing lignocellulose bonds destroying lignohemicellulose bonds and expanding cellulose, making it easier for cellulase enzymes to penetrate. Ammoniation causes the fiber in the rice straw to become soft (swollen process) so that it is easier to be degraded by rumen microbes[4]. The fermentation process is carried out anaerobically by adding a starter (a mixture of several bacteria such as proteolytic, cellulolytic, lipolytic, and ligninolytic) to the rice straw. In addition to the increment of nutritional value and digestibility of the rice straw, the combination of these two processes (amofer) can increase the non-protein nitrogen (NPN) content so that the availability of nitrogen for amino acid synthesis by rumen microbes increases which ultimately has an impact on increasing crude protein levels in the rice straw[4].

Table 4. Nutritional Content and Digestibility of the Rice Straw Resulted from Amofer

Parameter	Amount
Nutrient Content	
1. Dry Matter (%)	84,61-87,28
2. Crude Protein (%)	21,04-24,48
3. Crude Fiber (%)	31,30-31,39
4. *Total Digestible Nutrient*	56,19-56,89
5. Nitrogen-Free Extract (%)	23,49-28,08
Digestibility	
1. Dry Matter (%)	50,73
2. Organic Matter (%)	57,08

Source: [21] [18]

The research results indicate that the use of amofer as an applicable technology can improve the quality of rice straw by increasing the digestibility, and crude protein content and reducing crude fiber content (Table 4). Based on the results, the provision of amofer rice straw to cattle as the main feed results in a daily body weight gain of 1,0-1,5 kg/head/day, however, basal administration of amofer rice straw is not enough to meet the maximum needs of beef cattle, hence concentrate is needed to meet their needs so that the productivity is more optimum. An increase in body weight is a manifestation of adequate consumption of dry matter, especially energy and protein. If consumption exceeds basic living needs, then the excess will be used for body weight as a manifestation of production results[4].

The introduction of amofer technology is not limited to rice straw but can be applied to other feed resources based on by-products of palm oil plantation agroecosystems such as fronds, leaves, empty fruit bunches (EFB), mesocarp fiber (MF), palm kernel cake (PKC) and sludge. Optimizing the quality of palm oil plantation by-products aims to increase digestibility, reduce crude fiber content, and increase crude protein content. Based on the research results[22], it was found that complete feed produced from the processing of by-product's palm oil plantation and mill had a DMD of 65,79%, OMD of 70,30%, and crude protein digestibility of 84,34%[22]. Application of amofer doesn't only improve quality but increases quantity such as dry matter content which increases from 14,82 to 15,89 tons/ha/year; crude protein from 0,79 to 2,87 tonnes/ha/yr; and TDN from 7,63 to 8,51 tons/ha/year. This increase was related to an increase in weight due to urea and microbial starter supplementation, although the amount was not significant[23]. The research results show that the by-products of the palm oil plantation agroecosystem have good nutrition and potential carrying capacity to become feed ingredients for complete feed for ruminants.

Complete feed is a method or technique to produce feed by mixing forage and concentrate homogeneously through physical treatment and supplementation which is packaged in a certain form for more effective feeding to livestock and for easier storage[4]. Complete feed contains quite complete nutrition (essential nutrients) for livestock at a certain physiological level and complete feed can be given as the only feed that is able to meet basic living needs or production (or both) without additional feed except water[24]. Making complete feed can reduce the risk of wasted feed because livestock only choose certain feed ingredients so feeding is more effective and efficient[18]. The combination of forages and concentrates in complete feed provides the opportunity to fulfill the nutrition needed by livestock at relatively affordable feed costs followed by increasing livestock productivity[4].

Relevant of Ruminants to the Environment

In addition to feed adequacy, ruminant production needs to pay attention to the impact and/or effect on the environment. The ability of ruminants to convert forage by-products of agro-industry has the potential to reduce waste and environmental pollution, however, this activity produces feces containing CH_4 (coming from plant enteric fermentation[25]. Production of enteric CH_4 in ruminants is a normal phenomenon and plays a role in eliminating secondary gas H_2 which is formed in the rumen as a result of anaerobic fermentation[26]. Elimination of H_2 as a result of fermentation is very important for the optimum function of the digestive system[27]. Hydrogen is produced from the synthesis of acetate and butyrate via the Embden-Meyerhofe pathway (glycolysis), but the anaerobic fermentation capacity of lignocellulosic components relates to the elimination of H_2 in the rumen[28]. Hydrogen in the normal digestive process is released by microbes during the fermentation process and will be used by methanogenic bacteria to convert CO_2 into CH_4 and water[29][30] or known as methanogenesis. The rate of methanogenesis is influenced by chewing activity (mastication), saliva production, and digesta kinetics.

Methane production by the rumen ecosystem is estimated to be around 15% of total atmospheric CH_4 emissions[27]. The production and elimination of CH_4 causes ruminants to lose 2-12% of gross digestible energy[28]. Enteric methane emitted by ruminants causes a much higher amount of feed energy wasted as CH_4 (10-12%), so if the released of H_2 gas can be utilized for propionate production or for some useful end products, rumen fermentation efficiency can be increased with lower enteric CH_4 production[26]. The contribution of ruminant enteric fermentation to world anthropogenic CH_4 emissions reaches 44% and global emissions range from 87-94 Tg CH_4 per year[28][31]. The total contribution of global enteric fermentation produced by ruminants through mixed rearing patterns (plant-livestock) reaches 64%, grazing patterns as much as 35%, and industry-based rearing patterns 1%[31]. Cattle raised on pasture contribute 41% of direct CH_4 emissions, so it is considered the largest contributor from the ruminants group, while sheep and goats contribute around 6,5% of world emissions[29]. The intensity of methane produced by cattle in an extensive pattern reaches a value of 7,1-11,4 kg $CO_{2\text{-equivalents(eq)}}$ kg live weight[32]. Cattle produce between 7 and 9 times more CH_4 than sheep and goats. The meat-producing group of small ruminants has a lower emission potential than large ruminants (cattle) when evaluated in kg $CO_{2\text{-eq}}$, while the emissions from milk production from small ruminants are greater than meat production, especially in Asia[33]. This is probably due to the majority of production and management systems that are extensive and subsistence[28].

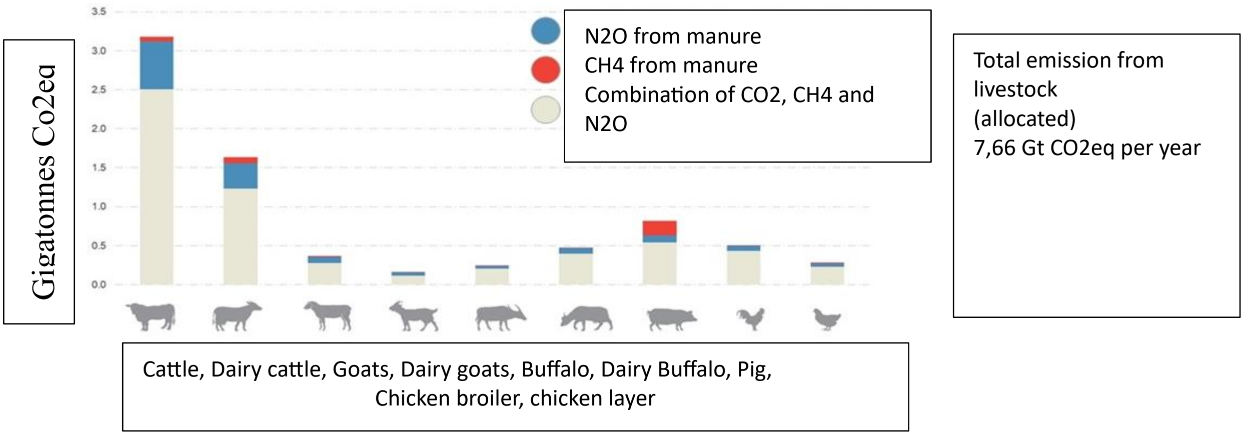


Figure 2. Emission from Manure based on Livestock Commodities[34]

Enteric methane produced in the rumen reaches 87-90% and at a smaller level in the large intestine reaches 13-10%[29]. Enteric fermentation in the rumen is greatly influenced by the quantity, quality, composition, and consumption of feed[29]. Selection of carbohydrates (related to the content of structural and non-fiber carbohydrates) in the diet can reduce the formation of CO_2 and H_2 which are the main precursors of CH_4 production in the rumen. Nitrate and sulfate supplementation in rations is considered as an effective way to reduce enteric CH_4 emissions[27], but this strategy is not the only one. There are many strategies to reduce enteric CH_4 emissions, including 1) inducing changes in metabolic pathways; 2) changing the rumen microbial population; 3) improving the nutrition; 4) improving the potency of feed digestibility[35]; 5) selection of ruminants based on breed or genetics; 6) modification of the rumen environment; 7) intensification of production systems including grassland management; and 8) biotechnology applications[28], [35].

Corporations of Livestock Enterprises

The paradigm of breeders in adopting technology that leads to production efficiency and its impact on the environment is related to their understanding of business orientation, namely running a business with a business orientation, starting to consider inputs, processes, and outputs[17]. The pattern of livestock business from upstream to downstream, which is business-oriented is increasingly optimally run through corporations. Corporations will facilitate collaboration between breeders, large companies, small and medium enterprises, home industries, and other supporting institutions in production, processing, trading, and integration with a wider market[33].

The livestock corporations' concept will create new strengths in the fields of human resources, capital, and banking, thereby expanding the potential for success and growth of livestock businesses. The development of corporate-based livestock businesses is expected to be able to: 1) increase regional competitiveness in developing livestock, especially ruminants, in supporting sustainable national food security; 2) strengthen the livestock business system in one holistic management; and 3) strengthen livestock institutions in accessing information, technology, public facilities and infrastructure, capital, processing and marketing[33].

CONCLUSION

The function of livestock as a source of animal protein requires adequate nutrition from feed to be able to produce optimally, so ensuring that the feed is sufficient (quality and quantity) and safe (not toxic) is a must and this cannot be separated from the contribution of animal husbandry nutrition science. Formulation of feed ingredients based on local feed and agro-industrial by-products into complete feeds in ruminant production is a strategy to meet the nutritional needs of ruminants so that they can produce optimally, efficiently, and environmentally friendly which ultimately produce products that are safe for human consumption. The success of this strategy has a greater opportunity through a corporate-based livestock approach, and through this approach, it is expected that the concepts of safe feed, safe food, and safe environment can be realized. Based on this phenomenon, animal husbandry nutrition science has proven its capability to contribute significantly to 1) produce livestock (ruminants) with efficient nutrition; 2) improve food safety and quality of food products originating from livestock for human consumption; 3) improve health status and welfare of livestock; and 4) reduce greenhouse gas emissions and impact of livestock on environmental security.

REFERENCES

[1] Food and Agriculture (FAO). 2023. Global feed safety platform. https://www.fao.org/feed-safety/background/why-feed-safety/en/

[2] Directorate General of Animal Husbandry and Animal Health of Ministry of Agriculture of the Republic of Indonesia. 2022. Statistics of Livestock and Animal Health. Directorate General of Animal Husbandry and Animal Health of Ministry of Agriculture of the Republic of Indonesia. https://ditjenpkh.pertanian.go.id/berita/1609-buku-statistik-peternakan-dan-kesehatan-hewan-tahun-2022

[3] Food and Agriculture (FAO). 2023. Food safety and quality. https://www.fao.org/food-safety/background/qa-on-food-safety/en/

[4] Mayulu, H. 2019. Teknologi Pakan Ruminansia (*Ruminants Feed Technology*). Rajawali Pres. PT RajaGrafindo Persada, Depok. ISBN 978-623-231-146-6. https://www.scribd.com/document/508393397/18hamdi-Mayulu-Buku-Teknologi-Pakan

[5] Mayulu, H. 2020. Karakteristik pakan ruminansia (*Ruminants Feed Characteristic*). Rajawali Pres. PT RajaGrafindo Persada, Depok. ISBN: 978-623-231-392-7. https://books.google.co.id/books?hl=id&lr=&id=qrjTEAAAQBAJ&oi=fnd&pg=PA15&dq=%3Dhamdi+mayulu&ots=iYANy7hzds&sig=V1cWyZ4-yXYPLHtM9spE34n6Qk4&redir_esc=y#v=onepage&q=%3Dhamdi%20mayulu&f=false

[6] Rasjid, S. 2011. The Great Ruminant: Nutrisi, Pakan, dan Manajemen Produksi (*The Great Ruminants: Nutrient, Feed, and Production Management*). Brilian Internasional. ISBN 978-602-19546-1-4. https://books.google.co.id/books/about/THE_GREAT_RUMINANT.html?id=ZGCiDwAAQBAJ&redir_esc=y

[7] Mayulu, H., N. Fauziah, M. I. Haris, M. Christiyanto and Sunarso. 2018. Digestibility value and fermentation level of local feed-based ration for sheep. Animal Production, 20 (2):95-102. DOI: http://dx.doi.org/10.20884/1.jap.2018.20.2.706

[8] Mayulu, H., F. Rahayu, M. Christiyanto, M. I. Haris, T. P. Daru, and S. N. Rahmatullah. 2020. Evaluation of digestibility value and rumen fermentation kinetic of goat's local feed-based ration. European Journal of Molecular & Clinical Medicine, 7 (8): 3703-3711. https://www.researchgate.net/publication/359364860_European_Journal_of_Molecular_Clinical_Medicine_Evaluation_Of_Digestibility_Value_And_Rumen_Fermentation_Kinetic_Of_Goat's_Local_Feed-_Based_Ration

[9] Mayulu, H., Suyadi, M. Christiyanto, Sunarso, T. P. Daru, and M. I. Haris. 2020. In vitro digestibility and fermentation ruminant pf buffalo ration based on *Neptunia plena* L. Benth dan *Leersia hexandra* Swartz as local resources. Jurnal Ilmu-Ilmu Peternakan, 30 (2): 148-157. DOI: https://doi.org/10.21776/ub.jiip.2020.030.02.07

[10] Mayulu, H. 2022. Lingkungan dan produktivitas ruminansia (*Environment and ruminants productivity*). Rajawali Pres. PT RajaGrafindo Persada, Depok. ISBN: 978-623-372-585-9. https://books.google.co.id/books?hl=id&lr=&id=TLnTEAAAQBAJ&oi=fnd&pg=PA1&dq=%3Dhamdi+mayulu&ots=RBQVy8ErfI&sig=_xvc_HaspwsU5Mcfv1sqo7iDxCM&redir_esc=y#v=onepage&q=%3Dhamdi%20mayulu&f=false

[11] Mayulu, H., T. P. Daru, I. Tricahyadinata. 2023. In vitro evaluation of ruminal digestibilty and fermentation characteristics of local feeds. F1000Research 11: 1-14. DOI: https://doi.org/10.12688/f1000research.123177.3

[12] Mayulu, H., T. P. Daru, Suyadi, and M. Christiyanto. 2020. Nutrient potential of *Coix lacryma-jobi* L. as ruminants feed source in East Kalimantan. International Journal of Psychosocial Rehabilitation, 24 (10): 1460-1470. https://www.researchgate.net/publication/359364774_NUTRIENT_POTENTIAL_OF_Coix_Lachryma-Jobi_L_AS_RUMINANT_FEED_SOURCE_IN_EAST_KALIMANTAN

[13] Daru, T. P., M. Sari and H. Mayulu. 2023. *Coix lacryma-jobi* L. nutritional value concerning nitrogen fertilizer doses. American Journal of Animal and Veterinary Science, 18 (2): 117-124. DOI: https://doi.org/10.3844/ajavsp.2023.117.124

[14] Kim, S. O., S. J. Yun, B. Jung, E. H. Lee, D. H. Hahm, I. Shim, and H. J. Lee. 2004. Hypolipidemic effects of crude extract of adlay seed (*Coix lachrymajobi* var. mayuen) in obesity rat fed high fat diet : Relations of TNF-α and leptin mRNA expressions and serum lipid levels. Life Sciences 75 1391-1404. DOI: https://doi.org/10.1016/j.lfs.2004.03.006

[15] Nurmala, T. 2010. Potency and prospect on the development of Hanjeli *Coix Lacryma-jobi* L. as a fat-rich nutritious food to support food diversification towards independent food security. Pangan 20 (1): 41-48. DOI: https://doi.org/10.33964/jp.v20i1.10

[16] Wild, K. J., H. Steinga, and M. Rodehutscord. 2019. Variability of in vitro ruminal fermentation and nutritional value of cell-disrupted and nondisrupted microalgae for ruminants. GCB Bioenergy 11: 345-359. DOI: http://dx.doi.org/10.1111/gcbb.12539

[17] Mayulu, H., Sunarso , C. I. Sutrisno, and Sumarsono. 2010. Kebijakan Pengembangan Peternakan Sapi Potong di Indonesia (*Policy on the Development of Cattle in Indonesia*). Jurnal Litbang Pertanian 29 (1): 34-41. DOI: https://dx.doi.org/10.21082/jp3.v29n1.2010.p%p

[18] Mayulu, H. 2015. Pakan sapi potong dan efisiensi usaha penggemukan (*Cattle feed and fattening business efficiency*). Unnes Press. Semarang. ISBN: 978 602 285 045 8. https://opac.perpusnas.go.id/DetailOpac.aspx?id=955026

[19] Mayulu, H. T. P. Daru, A. Supriyadi, and M. Ghazali. 2020. The potential of rice straw as a source of feed ingredients for beef cattle in East Kalimantan. European Journal of Molecular & Clinical Medicine, 7 (20): 3712-3724. https://www.researchgate.net/publication/358046710_European_Journal_of_Molecular_Clinical_Medicine_The_Potential_Of_Rice_Straw_As_A_Source_Of_Feed_Ingredients_For_Beef_Cattle_In_East_Kalimantan

[20] Lalman, D., G. Horn, R. Huhnke, and D. Sparks. 2017. Ammoniation of low quality roughages. Oklahoma Cooperative Extention Service. https://shareok.org/rest/bitstreams/2b333eaf-7ec2-434f-be16-a0eef210546a/retrieve

[21] Mayulu, H and Suhardi. 2015. Nutrient Potency of Rice Straw Processed with Amofer as Cattle Feed Stuff in East Kalimantan. International Journal of Science and Engineering, 9 (2):101-105. DOI: https://doi.org/10.12777/ijse.9.2.101-105

[22] Mayulu, H. 2014. The nutrient digestibility of locally sheep fed with amofer palm oil byproduct-based complete feed. International Journal of Science and Engineering, 7(2): 106-111. DOI: https://doi.org/10.12777/ijse.7.2.106-111

[23] Mayulu, H. 2014. The nutrient potency of palm oil plantation and mill's by-product processed with amofer technology as ruminant feed. International Journal of Science and Engineering, 6 (2): 112-116. DOI: https://doi.org/10.12777/ijse.6.2.112-116

[24] Mayulu, H., Sunarso, M. Christiyanto and F. I. Ballo. 2013. Intake and digestibility of cattle's ration on complete feed based-on fermented ammonization rice straw with different protein level. International Journal of Science and Engineering, 4 (2): 86-91. DOI: https://doi.org/10.12777/ijse.4.2.2013.86-91

[25] Adesogan, A. T., A. H. Havelaar, S. L. M. Kune, M. Eilittä, and G. E. Dahl. 2020. Animal source foods: Sustainability problem or malnutrition and sustainability solution? Perspective matters. Global Food Security, 25: 1-7. DOI: https://doi.org/10.1016/j.gfs.2019.100325

[26] Soren, N. M., V. Sejian, M. Terhuja and G. Dominic. 2017. Enteric methane emission in sheep: process description and factors influencing production. Adaptive mechanisms of sheep to climate change. Sejian, V., R. Bhatta, J. Gaughan, P. K. Malik, S. M. K. Naqvi, and R. Lal (Ed). In *"Sheep Production Adapting to Climate Change"*. (pp:209-233). Springer Nature Singapore. DOI: https://doi.org/10.1007/978-981-10-4714-5_10

[27] Hyder, I., P. R. K. Reddy, J. Raju, P. Manjari, C. S. Prasad, K. A. Kumar, and V. Sejian. 2017. Alteration in rumen functions and diet digestibility during heat stress in sheep. Sejian, V., R. Bhatta, J. Gaughan, P. K. Malik, S. M. K. Naqvi, and R. Lal (Ed). In *"Sheep Production Adapting to Climate Change"*. (pp:235-265). Springer Nature Singapore. DOI: https://doi.org/10.1007/978-981-10-4714-5_11

[28] Monteiro, A, L. G., A. M. C. F. Faro, M. T. P. Peres, R. Batista, C. H. E. C. Poli, and J. J.Villalba. 2018. The role of small ruminants on global climate change. Acta Scientiarum. Animal Sciences, 40 (e43124): 1-11. DOI: https://doi.org/10.4025/actascianimsci.v40i1.43124

[29] Chika, E., A. Martins, and A. Augustine. 2015. The contribution of ruminant animals to climate change and its mitigation strategies. P. Kumar 'Bharti' and K. Gajananda (Ed). In *Natural Ecosystem and Climate Change* (71-86). Discovery Publishing House PVT. Ltd. 4383/4B, Ansari Road, Darya Ganj New Delhi–110002 (India). https://www.researchgate.net/publication/283721857_The_Contribution_of_Ruminant_Animals_to_Climate_Change_and_its_Mitigation_Strategies

[30] Aluwong, T., P. A. Wuyep and L. Allam. 2011. Livestock-environment interactions: Methane emissions from ruminants. African Journal of Biotechnology, 10(8): 1265-1269. DOI: https://doi.org/10.5897/AJB10.1117

[31] Downing, M. M. R., A. P. Nejadhashemi, T. Harrigan and S. A. Woznicki. 2017. Climate change and livestock: impact, adaptation, and mitigation. Climate Risk Management, 16: 145-163. DOI: http://dx.doi.org/10.1016/j.crm.2017.02.001

[32] Thomas, D.T., Y.G. Beletse, S. Dominik, and S.A. Lehnert. 2021. Net protein contribution and enteric methane production of pasture and grain-finished beef cattle supply chains. Animal The international journal of animal biosciences, 15: 1-9. DOI: https://doi.org/10.1016/j.animal.2021.100392

[33] Mayulu, H., I. Tricahyadinata, and A. Soepriyadi. 2023. The development of corporate-based cattle breeding areas. Transaction of the Chinese Society of Agricultural Machinery, 54 (6): 168-181. http://nyjxxb.net/index.php/journal/article/view/1630/0

[34] Steinfeld, H. 2019. Improved manure management towards sustainable agri-food systems. Food and Agriculture Organization of the United Nations. Broadening Horizons. Feedipedia. https://unfccc.int/sites/default/files/resource/Keynote_20191202%20COP25_FAO_Koronivia-version3.pdf

[35] Bhatta, R., P. K. Malik, and V. Sejian. 2017. Enteric methane emission and reduction strategies in sheep. Sejian, V., R. Bhatta, J. Gaughan, P. K. Malik, S. M. K. Naqvi, and R. Lal (Ed). In *"Sheep Production Adapting to Climate Change"*. (pp: 291-305). Springer Nature Singapore. DOI: https://doi.org/10.1007/978-981-10-4714-5_13