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. 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.

![Population of Ruminants in 2022](image)

**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). The ability of ruminants to convert feed is related to their complex digestive systems and mechanisms (mechanical, fermentative, enzymatic, and chemical digestion). The ruminant's stomach is divided into four compartments (rumen, reticulum, omasum, abomasum) 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. 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

<table>
<thead>
<tr>
<th>Livestock Commodity</th>
<th>Neptunia plena L. Benth</th>
<th>Leersia hexandra Swartz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DMD</td>
<td>OMD</td>
</tr>
<tr>
<td>Cattle</td>
<td>42,94</td>
<td>49,31</td>
</tr>
<tr>
<td>Buffalo</td>
<td>36,96</td>
<td>45,36</td>
</tr>
<tr>
<td>Goat</td>
<td>30,93</td>
<td>38,07</td>
</tr>
<tr>
<td>Sheep</td>
<td>42,71</td>
<td>49,13</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Part of the Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Seed*</td>
</tr>
<tr>
<td>Moisture Content (%)</td>
<td>11,04</td>
</tr>
<tr>
<td>Dry Matter (%)</td>
<td>88,96</td>
</tr>
<tr>
<td>Crude Protein (%)</td>
<td>16,20</td>
</tr>
<tr>
<td>Crude Fat (%)</td>
<td>5,18</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>1,38</td>
</tr>
<tr>
<td>Crude Fiber (%)</td>
<td>71,81</td>
</tr>
</tbody>
</table>

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.

<table>
<thead>
<tr>
<th>Plant Part</th>
<th>Digestibility</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dry Matter</td>
</tr>
<tr>
<td>Leaks</td>
<td>59,56</td>
</tr>
<tr>
<td>Stem</td>
<td>51,77</td>
</tr>
</tbody>
</table>

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 ligno-hemicellulose 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>
<thead>
<tr>
<th>Nutrient Content</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Dry Matter (%)</td>
<td>84,61-87,28</td>
</tr>
<tr>
<td>2. Crude Protein (%)</td>
<td>21,04-24,48</td>
</tr>
<tr>
<td>3. Crude Fiber (%)</td>
<td>31,30-31,39</td>
</tr>
<tr>
<td>4. Total Digestible Nutrient</td>
<td>56,19-56,89</td>
</tr>
<tr>
<td>5. Nitrogen-Free Extract (%)</td>
<td>23,49-28,08</td>
</tr>
</tbody>
</table>

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

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\textsuperscript{[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\textsuperscript{[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\%\textsuperscript{[23]}. 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\textsuperscript{[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\textsuperscript{[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\textsuperscript{[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\textsuperscript{[19]}. 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\textsuperscript{[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\textsubscript{4} (coming from plant enteric fermentation\textsuperscript{[25]}). Production of enteric CH\textsubscript{4} in ruminants is a normal phenomenon and plays a role in eliminating secondary gas H\textsubscript{2} which is formed in the rumen as a result of anaerobic fermentation\textsuperscript{[26]}. Elimination of H\textsubscript{2} as a result of fermentation is very important for the optimum function of the digestive system\textsuperscript{[27]}. Hydrogen is produced from the synthesis of acetate and butyrate via the Embden-Meyerhof pathway (glycolysis), but the anaerobic fermentation capacity of lignocellulosic components relates to the elimination of H\textsubscript{2} in the rumen\textsuperscript{[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\textsubscript{2} into CH\textsubscript{4} and water\textsuperscript{[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\textsubscript{4} emissions\textsuperscript{[27]}. The production and elimination of CH\textsubscript{4} causes ruminants to lose 2-12\% of gross digestible energy\textsuperscript{[28]}. Enteric methane emitted by ruminants causes a much higher amount of feed energy wasted as CH\textsubscript{4} (10-12\%), so if the released of H\textsubscript{2} gas can be utilized for propionate production or for some useful end products, rumen fermentation efficiency can be increased with lower enteric CH\textsubscript{4} production\textsuperscript{[26]}. The contribution of ruminant enteric fermentation to world anthropogenic CH\textsubscript{4} emissions reaches 44\% and global emissions range from 87-94 Tg CH\textsubscript{4} per year\textsuperscript{[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\%\textsuperscript{[31]}. Cattle raised on pasture contribute 41\% of direct CH\textsubscript{4} emissions, so it is considered the largest contributor from the
ruminants group, while sheep and goats contribute around 6.5% of world emissions\textsuperscript{[29]}. The intensity of methane produced by cattle in an extensive pattern reaches a value of 7.1-11.4 kg CO\textsubscript{2}-equivalents(eq) kg live weight\textsuperscript{[32]}. Cattle produce between 7 and 9 times more CH\textsubscript{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\textsubscript{2}-eq, while the emissions from milk production from small ruminants are greater than meat production, especially in Asia\textsuperscript{[33]}. This is probably due to the majority of production and management systems that are extensive and subsistence\textsuperscript{[28]}.

**Figure 2. Emission from Manure based on Livestock Commodities\textsuperscript{[34]}**

Enteric methane produced in the rumen reaches 87-90% and at a smaller level in the large intestine reaches 13-10%\textsuperscript{[29]}. Enteric fermentation in the rumen is greatly influenced by the quantity, quality, composition, and consumption of feed\textsuperscript{[29]}. Selection of carbohydrates (related to the content of structural and non-fiber carbohydrates) in the diet can reduce the formation of CO\textsubscript{2} and H\textsubscript{2} which are the main precursors of CH\textsubscript{4} production in the rumen. Nitrate and sulfate supplementation in rations is considered as an effective way to reduce enteric CH\textsubscript{4} emissions\textsuperscript{[27]}, but this strategy is not the only one. There are many strategies to reduce enteric CH\textsubscript{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\textsuperscript{[33]}; 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\textsuperscript{[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\textsuperscript{[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\textsuperscript{[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\textsuperscript{[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


