JSAT
Journal of Science and Agricultural Technology
Review Article
https://doi.org/10.14456/jsat.2021.8
e-ISSN 2730-1532, ISSN 2730-1524

Precision feeding management: New approach for better and more sustainable livestock production

M. Marjuki[1*] and S. Wittayakun[2]

[1]Faculty of Animal Science, Brawijaya University, Malang, East Java 65145, Indonesia.
[2]Faculty of Science and Agricultural Technology, Rajamangala University of Technology Lanna, Chiang Mai 50300, Thailand.

***Corresponding author**: marjuki@ub.ac.id*
Received: June 21, 2021. Revised: September 25, 2021. Accepted: September 27, 2021

ABSTRACT

The demand for livestock products increases continuously and cannot be avoided; on the other hand, the total livestock production is still lower than the demand. The problem has recently become more complex, as the demand for livestock production must produce not only enough quantity but also high quality and healthy products for the consumers, create welfare for the livestock, be safe and friendly for the environment, and be highly sustainable for our next generation. All of these demands must be strongly related to the efficiency of feed utilization by the livestock, as feed is the major input for the livestock to maintain its life and production processes. Hence, precision feeding management must become an excellent approach to overcome all of the problems. Precision feeding is an attempt to maximize feed utilization by livestock by supplying the most appropriate nutrients to the livestock. Thus, in this approach, livestock is expected to consume less feed, digests, and metabolizes the feed very much effectively, and then excretes less waste. Those higher efficiencies of feed utilization by livestock must consequently give some advantages, including 1) minimize the amount of feed offered and reduce refusal feed by the livestock; hence the available feeds can be used to rear more the number of livestock to multiply livestock products, 2) increase livestock productivity with less feed cost, hence increase profit for the farmer, 3) reduce livestock waste including feces, urine and also ammonia and methane gas, hence make a better of environment, and finally, all of those advantages must lead more sustainable livestock production systems.

Keywords: precision, feeding, farming, environment, sustainability

INTRODUCTION

The agricultural sector is the most crucial enterprise on this planet. Almost all developed or developing countries and agricultural or industrial countries have the agricultural sector as their enterprises. Each country must have a national agricultural institutional responsible for developing the agricultural sector as there is also one of the Specialized Agencies in the United Nations (UN) called as Food and Agriculture Organization (FAO). This is because almost entirely the requirements of living organisms, most notably for humans, are from the agricultural sector. The agricultural sector is the only and essential source of foods for human beings and other organisms in plant and animal origin foods. In addition, the farm sector also supplies some other important requirements, including the source of income, clothing, housing, medicine, recently for renewable energy (fuel). Hence, agricultural products are the essential commercial commodities in the world. The biggest world trade is for agricultural commodities, especially for food, feed, and fuel. On the other side, the agricultural sector has direct inter-independency with nature, where the agricultural sector must be influenced by the natural conditions and vice versa, the agricultural sector must influence the nature conditions. It means that good agriculture practices will improve or at least keep the natural condition that finally enhances or at least keep the conditions of the agriculture itself. Bad practices of agriculture will degrade land and environmental conditions that finally also degrade the agricultural itself.

Livestock production is one of the sub-sector of the agricultural sector, and this involves livestock as the main agent of producers. In addition to the functions of the agricultural sector for human beings as mentioned above, livestock also has the role as labor for transportation or land cultivation, an organic fertilizer producer, perfect saving, culture, religion or ceremony, symbol of wealth or social status, and souvenir. However, livestock production has been blamed for having a considerable contribution to environmental pollution (land, water, and air), greenhouse gas (GHG) emissions that cause global warming, and environmental degradation, especially land degradation due to land clearing (deforestation), especially for planting feed and fodders. Livestock production has also been blamed

for being the potential to transmit some zoonotic diseases, including food and moot disease (FMD), anthrax, bovine spongiform encephalopathy (BSE) or mad cow disease, verotoxigenic E. coli (VTEC), chronic wasting in cattle, recall of penicillin containing consumption milk, and avian/swine influenza (Thomson, 2003; Noordhuizen and Metz, 2005). Livestock products potentially contain residual antibiotics and growth promoters due to the widespread use of those feed additives in animal production.

Feed and feeding management is also known to have a negative impact on agricultural resources, the environment, and sustainability. This is because most aspects of feed and feeding management are the potential to cause unsustainable conditions. The unsustainable conditions are mostly due to land and environmental degradation and pollutions. The first aspect is the way of feed provision, feed sources, and feed selection to be included in the diet. The second aspect is how feeds are prepared for livestock, including feed processing, feed formulation, mixing, and feeding to livestock. The third aspect is how efficient the feeds are utilized by livestock, including feed consumption and its efficiency of digestion, metabolism, and conversion into livestock products.

Feed is the most abundant input in animal production that must be supplied every day. Intensive production of feeds that are mainly from plants origin has been reported by many authors to cause land and environmental damage, especially caused by land use, land clearing, deforestation, especially for soybean and maize production, and also for pasture or grazing land (Thornton and Herrero, 2010; Macedo et al., 2012; Eshel et al., 2014; Clark, 2012). Depends on quality, palatability, and amount of feed offered, part of feed provided to livestock are wasted as rejected and unconsumed, or refusal feeds. The presence of refusal feed must increase the requirement of feedstuffs in animal production and must increase the need to improve feedstuffs production. In addition, at least 60% of consumed feeds by livestock are wasted and excreted back to nature as feces, urine, gas, heat, and sweat as by-products during feed digestion and metabolism processes. Feed waste production must cause pollution to the environment and global warming. An only a small part of consumed feeds by livestock are utilized, retained, and converted to livestock products. For example, broilers deposit body fat and protein that together represent 35 to 40% of their daily ME intake (Lopez and Leeson, 2005), and less proportion was reported for protein. Cerisuelo and Calvet (2020) reported that the environmental impact of feedstuffs production and feeding management in monogastric animal production is mainly due to the production of feedstuffs and manure or waste management.

Based on the positive and negative aspects of agriculture or livestock production, thus agriculture or livestock production must be managed and operated as well as possible to sustain and maximize its essential functions and minimize its negative impact on life and the environment. For those, this paper discusses the current and future conditions of supply and demand for livestock products and production and strategy to bright the balance between both supply and demand, especially from a feeding management point of view.

SUPPLY AND DEMAND FOR LIVESTOCK PRODUCTION AND IT PRODUCTS

Different kinds of livestock products as food are the second major important foodstuffs after plant origin foodstuffs. Livestock products are considered to have higher quality and price compared to plant-origin food. Livestock products are mostly regarded as good protein sources and have good taste. The protein of animal origin shows high digestibility and contains very good amino acids composition in respect of human amino acids requirement with amino acids score of more than 90%. (Rosegrant et al. (2009) reported that 33% of the total world protein consumption is from livestock products.

The demand for livestock products as food has increased continuously and cannot be avoided. This is because of the continuous increase of the human population, the increase of their income and buying capability, and their awareness of a higher quality of food. The increase has especially happened in the developing countries, which is three times higher than those in the developed countries (Delgado et al., 1999). This is because the consumption of livestock products by people in the developed countries has been very much higher as compared to those in developing countries. However, the total world consumption for livestock products has never been balanced with the total of livestock production (Food and Agriculture Organization, 2011).

With regards to the deficit of the world livestock products in respect of the requirement, there are at least three general causes for these conditions. Those are due to the low world livestock population and productivity. In addition, the world livestock population and their productivity are not well distributed all over the world. The bigger scale of livestock production, higher population, higher application of technology, and higher production rate or productivity of livestock are mostly concentrated

in developed countries and to a lesser extent in developing countries. Moreover, the accessibility of people to livestock products is also higher in developed countries than in developing countries. Consumption of livestock products in some developing countries is still below the requirement due to the lack of livestock products supply and less accessibility of the people in those countries to the livestock products.

The above problem of demand for livestock products has recently become more complex in the last few years. The need for livestock production is not only to produce a sufficient quantity of products as food but also requires high quality, safe and healthy products for the consumers, welfare conditions for the livestock, safety and friendly for the environment, and highly sustainable for our next generation.

It is recently the trend in lifestyle and food consumption by people. The consumers increase not only their quantity consumption of livestock products, but they also need healthy and high-quality livestock products. Especially for meat, the consumers need tender meat with low-fat content and better fatty acids components, mainly for red meat. Meat with such characteristics is considered to be better for health especially to prevent coronary artery disease or heart attack, and good for children's intelligence. Milk protein and fat content are used as milk price determinants. Milk with higher protein and/or fat content has a higher price bonus (Da Cunha et al., 2010; Edwards et al., 2019). Jayakumar and Loganathan (2015) reported that out of 50 respondents at Edamalaippattipudur in Tiruchirappalli District, 48 percent and 44 percent of the respondents purchased milk because of the quality and the taste of milk, respectively. Consumers were reported to prefer purchasing broiler with dark yellow to light orange color and egg with orange to dark orange egg yolk color. Omega-3 fatty acids containing egg and also organic livestock products have been preferred by consumers in the last few years due to their several advantages for health and intelligence. With regard to safely livestock food origin, the use of antibiotics and other additives or implants to improve livestock performance and the use of mycotoxins contaminated feeds have been given serious attention and investigation by vets to minimize or avoid the presence of their residues in livestock products which dangers not only to the livestock especially in case of the use of contaminated feeds but also to the consumers.

For the same reason of safely livestock food origin for consumers, some countries banned animal origin feedstuffs from suspected countries for endemic animal diseases, especially for anthrax and bovine somatotropic encephalomalacia (BSE) and feedstuffs containing genetically modified organisms (GMO). For those, a kind of government institution like the Food and Drugs Agency presents in almost all countries. The agency is responsible for investigating and controlling the distribution of foods and drugs containing any dangerous element for the consumers.

Like other agriculture sectors, livestock production is an enterprise that relates directly to land and water resources, so that livestock production has a high potential to affect land and water environmental conditions and vice versa. Iqubal (2013) reported that livestock production utilizes + 29 % of the total world land surface, mostly for grazing land and for growing crops as fodder or feed, and only a small part is for a farm. While Meek (2019) reported little bit higher data where livestock operations occupy 45 % of the global surface area, and an additional 10 percent is dedicated to growing feed crops for that livestock. Livestock production has been blamed for contributing to environmental degradation and pollutions. Land degradation caused by livestock is due mainly to deforestation or clearing forest trees and vegetation, and the land is then used as grazing land and for growing crops as fodder or feed. It is reported by Food and Agriculture Organization (2006) and Jarvis et al. (2010) that annual deforestation rates of world tropical forest increased between 2005 and 2010 by 8.5% and resulted in an average loss of 10.4 million hectares of forest per year. The effects of deforestation, including loss of biodiversity, cause climate change, increase greenhouse gas emissions, and reduce soil capacity in holding and saving water that causes flooding, soil erosion, and land sliding. Deforestation for livestock productions takes place mainly for growing feed or fodder crops and also for grassland.

Livestock production was reported to contribute to greenhouse gas (GHG) emissions that is the main element causing global warming or glasshouse effect with the estimate ranges from 14.5 percent of annual worldwide GHG emissions to 51 percent (Food and Agriculture Organization, 2006; Goodland et al., 2009). The contribution of GHG emission from livestock production is mostly due to deforestation for growing feed or fodder crops and grassland, and the production by microbial rumen fermentation of ruminant animal which then excreted directly to the air via eructation. Some part of methane gas is also excreted via feces or excreta of all livestock. In addition to methane gas, other pollutants from livestock waste are in the form of microorganism, nitrates (N_2O), phosphor and sulphur. A part of these pollutants especially the last three components are absorbed by the soil and

utilized by vegetations in the different rate of utilization depend on type of land or soil and type and intensity of vegetation. Another part of the pollutants continues to seep into the underground and polluting groundwater or leaks into the river, polluting river, dam, lake, stream water and other wider area. Ground water is common source of drinking water for human being. Some of nitrates are also released to the air as ammonia and cause acid rain in some area of densely livestock populated area (Das et al., 2007; Dopelt et al., 2019)

Based on the above conditions, environmentalists stated that livestock production is still far from sustainable. Many widely used livestock production methods do not satisfy consumer requirements for a sustainable system (Broom et al., 2013). Distribution of world large-scale livestock production is also concentrated mostly in the developed countries, and people accessibility to livestock products is also higher in developed countries than in the developing countries.

FEED UTILIZATION PROCESS BY LIVESTOCK AND SOME LOSSES (WASTES)

Based on the problems of demand for livestock products as mentioned in the above chapter, the conditions must be strongly related to the feeding method to livestock and how efficiently the livestock utilize the feed. Feed utilization processes by livestock and their efficiency are described below and diagrammatically in Figure 1.

Livestock need to consume enough feed that contains all nutrients with the good proportion as they are required for better production. The feed nutrients are then digested in the digestive tract into simple nutrient compounds ready for absorption from the digestive tracts by the bloodstream via the wall of digestive tracts. By the bloodstream, the absorbed nutrients are distributed to all body tissues for metabolism processes. The metabolized nutrients are then utilized for maintenance to maintain life and body condition as the priority. Any excess metabolized nutrients for maintenance are then utilized to perform livestock production.

In fact, only a small portion of feed provided to livestock is really utilized by the livestock for their body condition and live maintenance as well as production. A major part of the feed is wasted by livestock in the form of refusal or not consumed feed, undigested feed, which is then excreted in the feces, and metabolic by-products, which are excreted as urine, heat, sweat, and expiration. In addition, especially in ruminant animals, a part of the feed is also wasted during feed digestion and fermentation in the rumen as heat and gas, mainly CO_2 and methane. The last three wastes are also produced during feed digestion and fermentation in the large intestine of all animals. All the wastes are only potentially causing feed nutrients and economic losses but also environmental pollution and degradation.

So that, with regards to the problems of demand for livestock products as mentioned in the previous chapter, there must be two aspects related to feed utilization processes by livestock that must be optimized. The first is to maximize the proportion of feeds that are really utilized by the livestock for maintenance and especially for the production. Then this must increase the productivity of livestock. The second is to minimize the proportion of wasted feed by livestock, including refusal or not-consumed feed, undigested and unabsorbed feed (feces), digestion, and metabolite by-products (gas, heat, urine, and sweat). Those feed losses do cause not only nutrients losses but also cause economic losses, environmental pollution, and degradation, leading to unsustainable livestock production to provide livestock products.

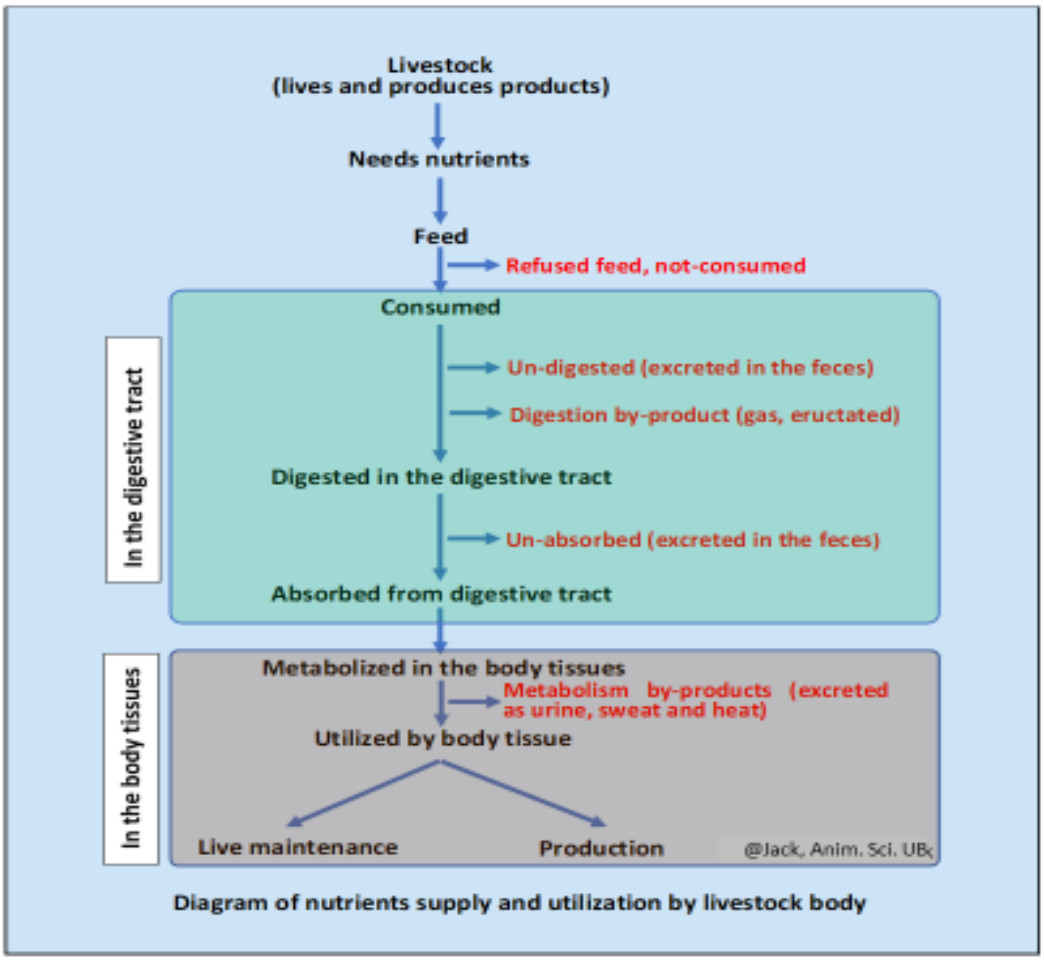

Figure 1. Diagram of feed and nutrients supply and utilization by livestock body

PRECISION FEEDING AS A GOOD APPROACH TO OVERCOME THE PROBLEM OF DEMAND FOR LIVESTOCK PRODUCTS

Feed is the major input in livestock production from which the livestock get their daily supply of nutrients for their life and production. In addition, feed is also the major cost in livestock production that determines mostly the profit in livestock production. On the other side, feed is always the most constraint and is the most challenging for developing livestock production due to its lack of availability and quality, because of the limited availability and the conditions of land and natural resources as feed sources, ongoing climatic changes. Almost entirely feedstuffs for livestock production are from plants origin either as whole plant organs (as forages in ruminant animal production), main plant products (grains and tubers as main feedstuffs in non-ruminant animal production or as a feed supplement in ruminant animal production), or industrial by-products of plant main products processing (SBM, DDGS, CGM, CGF, brewer meal, cottonseed meal, oil palm meal, copra meal, oil seeds meal, etc. as a feed supplement in both non and ruminant animal production). The second major of feedstuffs is from animal origin, especially as industrial by-products of animal products processing (fish meat, MBM, meat meal, blood meal, animal fat, etc.) as a feed supplement in both non and ruminant animal production. The third as minor feedstuffs are natural origin especially mineral as a feed supplement in both non and ruminant animal production. All feed resources are subjected to availability and the conditions of land and natural resources as feed sources, ongoing climatic changes. The costs of all conventional feed resources such as soybean meal and fishmeal are very high, and their availability in the future will be limited. In addition, the increase of food-feed-fuel competition also contributes to the reduction of feed availability for livestock production. Hence, better and most efficient utilization of feed resources for livestock production must be one of the strategies to overcome the

problem. Higher efficiency of feed utilization by livestock must consequently give some advantages, including 1) minimize the amount of feed offered and reduce refusal feed by the livestock, 2) increase livestock productivity with less feed cost, hence increase profit for the farmer, 3) reduce livestock waste including feces, urine and also ammonia and methane gas, hence make a better of environment, and finally, all of those advantages must lead more sustainable livestock production systems.

Precision feeding management is an attempt to maximize as much as possible the efficiency of feed utilization by livestock by supplying the most appropriate and precise feeds and nutrients to the individual or group of animals in a farm (Pomar et al., 2019). For those in precision feeding, all genetic and environmental factors that affect the utilization of feed and nutrients by livestock must be considered based on real-time monitoring. Also, in precision feeding, all related science (including biology, physiology, microbiology, genetic, breeding, reproduction, chemistry, biochemistry, physic, math, health/medicine/immunology), technology and equipment including tools to monitor genetic and environmental factors, sensors, information, and communication technology (ICT) must be incorporated in system construction and application of precision feeding. Many papers discussing all of those factors, science, technology, and equipment and their use in precision feeding were published (Banhazi et al., 2012; Berckmans, 2014; Pomar et al., 2019; Andretta et al., 2018; Halas and Dukhta, 2020; Piccioli-Cappelli et al., 2019; Pomar Cândido et al., 2009; Zuidhof, 2020). Babinszky and Halas (2009); Banhazi et al. (2012) described in the diagram the relations of related science and technology in precision feeding as described in Figure 2.

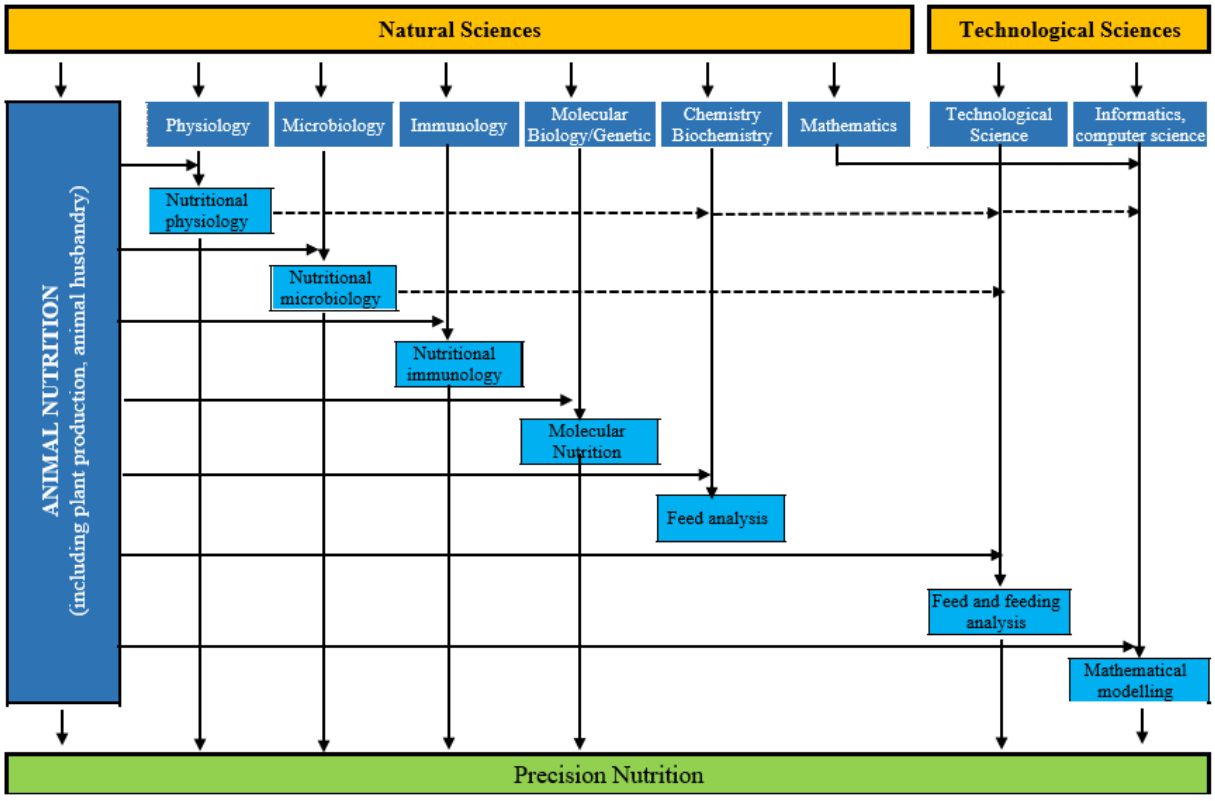

Figure 2. Relationship between natural, nutritional sciences and other related disciplines (Rewritten from Babinszky and Halas (2009); Banhazi et al. (2012))

Precision feeding is a part of precision livestock farming (PLF) that aims to offer a real-time monitoring and management system that focuses on improving the lives of the animals by warning when problems arise so that the farmer may take immediate action to overcome the difficulties. In the PLF, continuous and fully automatic monitoring on the whole farm is practiced to collect real-time information and data about essential aspects of the running farm (Berckmans, 2014; Pomar et al., 2019). The collected information and data are then analyzed, and conclusions are withdrawn to be used to improve

animal health, welfare, and production and reduce the impacts on the environment at the right time. Pomar et al. (2019) defined precision feeding as a feeding technique that allows the proper amount of feed with the suitable composition to be supplied in a timely manner to a group of animals or to individual animals in a group. By precision feeding management, livestock is expected to require and consume less amount of feed, then digests and metabolizes the feed very much effectively, utilizes as efficiently as possible for maintenance and production, and excretes less amount of waste.

Precision feeding management must take an essential role in overcoming the deficit of livestock products by increasing the production and supply of livestock products. Precision feeding management that accurately considers the feed requirement of individual livestock in real-time must supply the most appropriate nutrients for higher productivity with lower feed cost and higher feed efficiency. With high efficiency of feed utilization; hence, the available feed resources can be used to rear a larger population of livestock or increase livestock population. Both livestock productivity and population are two main factors that determine the total production of livestock products. The entire production of livestock products results from the multiplication of the total livestock population by livestock productivity. Increasing livestock productivity has been the main concern in every livestock production system since livestock domestication has been done. All of the efforts, researches, and technologies in all aspects of livestock production, including livestock breeding, feeding, management, reproduction, and health, are continuously designed, tested, and some implemented in livestock production systems with the final target to increase livestock productivity. In addition to the efforts of maximizing livestock productivity, expanding the world production of livestock products through increasing livestock population must have a bigger impact on the increase of the world production of livestock products. Increasing productivity of livestock gives effect on the increase of production of livestock products by the additional scheme, but increasing livestock number or population must give effect on the increase of production of livestock products multiplier scheme. Thus, to increase the total production of livestock products, both livestock productivity, and livestock population has to be increased in a simultaneous way.// However, as a consequence of the increase in livestock population, it must also cause multiple increases in the requirement of feed and other resources for livestock production. For those, better distribution of world livestock production systems all over the world, mainly into countries with low livestock population, has to be done. The distribution includes distribution of livestock population, resources, management, productivity, and the market as well as application of technology in livestock production systems. The distribution must increase the chance of increasing the number of livestock populations all over the world by maximizing the utilization of locally available resources in each area. Finally, the distribution will increase not only the total production of livestock products but also lead to the distribution of better utilization of available resources (land, labor, and feed) for livestock production, distribution of income and wealth for most people, distribution of the supply of livestock products and access. In addition, the distribution will also avoid the overutilization of natural resources for livestock production systems and its impact on land degradation and environmental pollution in certain areas or countries.

To satisfy the demand for livestock products, it is recently not only focused on its quantity but also on its utility and accessibility, where the three focuses are called as three pillars of food security. The quantity means the total production of livestock products that are ready for the consumers. Utility pillars include quality or nutrient content, safety, and healthy of the livestock products. Accessibility pillars include well distribution, availability and stability of livestock products, and consumer access to the products. Due to the increase of consumer's need for a better quality of livestock products, then some attempts have been made to produce such high quality, safety and healthy of livestock products. Several researches have reported accurately feed modification to improve quality or modify the composition of livestock products, e.g., fat, protein, and fatty acids, especially polyunsaturated fatty acids, including omega-3 fatty acids content.

It was reported by many authors that in addition to the livestock wastes as excreted by livestock during utilization processes of feed by their body, the major causes of environmental pollution and degradation from livestock production is due to deforestation and land utilization for providing sufficient feed. Then the use of non-conventional feed resources to feed livestock by precision feeding management must reduce the negative impact of livestock production on further environmental and land degradation. Such non-conventional feed resources are agricultural and industrial by-products, insect and larvae as the feed protein source. The feed resources represent an important human-inedible feed resource for livestock production (Chenost, 1990; Devendra and Sevilla, 2002; Vasta et al., 2008;

Makkar et al., 2014; Amata, 2014; Ncobela and Chimonyo, 2015; Salami et al., 2019).

Another advantage of precision feeding to livestock is the improvement of livestock welfare. Livestock is reared not only to attempt to produce useful products for human beings, but their welfare must also be another concern by farmers. Livestock welfare has become word concerned in the last few years, as stated in Animal Welfare Act 2006 (Dawkins, 2006; Broom, 2011; Cook et al., 2015). According to the Act, livestock must be reared in as comfortably as possible to support the livestock in producing useful products in most welfare conditions. As stated in Section 3 point 1 of the Act, animals shall be given sufficient feed and water and adequate care. Feeding stuff and water must be of good quality and appropriate for the species of animal that is being fed. Thus, precision feeding, where livestock is fed a sufficient amount of feed with a good composition of nutrients required, must comply with livestock welfare as stated in the Act. At least the livestock will not suffer from hunger, nutrient deficiency, and feed-borne diseases. // Precision feeding, with its main focus on maximizing as much as possible the efficiency of feed utilization by livestock, has been reported by many authors to support more sustainable livestock production. With maximum feed utilization efficiency, livestock will convert and deposit the feed as maximum as possible into products with minimum cost and minimize as much as possible the excretion of wastes. With those three advantages of precision feeding focus, all three pillars of sustainability, i.e., sustainable environment, social and economy or planet, people and profit must be achieved (Banhazi et al., 2012; di Virgilio et al., 2018; Lovarelli et al., 2020). For social and economic sustainability, precision feeding must increase livestock production and supply livestock products more efficiently. Increasing livestock production must also serve more people for job creation and income distribution to reduce poverty. This is because livestock production has a long and complex supply and utilization chain. Anonymous (2020); Molina-Flores et al. (2020) stated that the livestock sector is a pillar of the global food system and contributes to poverty reduction, food security, and agricultural development. According to the FAO, livestock contributes 40% of the global value of agricultural output and supports the livelihoods and food and nutrition security of almost 1.3 billion people. Livestock is an important asset for vulnerable communities. Globally, around 500 million pastoralists rely on livestock herding for food, income, and as a store of wealth, collateral, or safety net in times of need. Thus, sustainable livestock production must potentially serve for a better life for most world human population as the source of food, income, and other functions and advantages of livestock production for a human being. For environmental sustainability, precision feeding management must take an important role towards a sustainable environment at least in two ways, i.e., decreasing land and environment due to feedstuffs provision for livestock and maximizing feed utilization or reducing feed waste by livestock. Pomar and Remus (2019) reported that precision feeding management reduced significantly costs of production (>8%), protein and phosphorous intake (25%) and excretion (40%), and greenhouse gases emissions (6%) by increasing individual nutrient efficiency in growing pig operations and it finally increased production, profit, and environmental conditions. In addition, Anonymous (2020) stated that locally, livestock production systems also contribute to preserving biodiversity and carbon sequestration in soils and biomass. In harsh environments, such as mountains and drylands, livestock is often the only way to sustainably convert natural resources into food, fiber, and work power for local communities.

IMPLEMENTATION OF PRECISION FEEDING IN FARM LIVESTOCK PRODUCTION

As the principle of precision feeding and its objectives to maximize as much as possible the efficiency of feed utilization by livestock, by supplying the most appropriate and precisely feeds and nutrients to the individual or group of livestock in a farm in real-time manner (Pomar et al., 2019), by involving all genetical and environmental factors that affect the utilization of feed and nutrients by livestock based on a real-time monitoring and incorporating all related sciences (including biology, physiology, microbiology, genetic, breeding, reproduction, chemistry, biochemistry, physic, math, health/medicine/immunology), technologies and equipment including tools to monitor genetic and environment factors, sensors, information and communication technology (ICT) in system construction and application of precision feeding, then implementation of precision feeding systems in commercial farms requires the integration of three types of activities: 1) automatic collection of data, 2) data processing according to the established control strategy, and 3) actions concerning control of the system (Pomar and Remus, 2019; Pomar et al., 2019). Thus, implementation of precision feeding must involve complex science and high technology that are appropriate mostly only in big commercial farms, but not in small farms where the majority of world farms

or livestock are reared on this farm category. Thus, there must be a big variation of the implementation of precision feeding by farmers, starting from the very much simplest way of better feeding, e.g., selection of better-quality feed by smallholder farmers for their livestock to get higher livestock productivity until the actual precision feeding as described above by commercial farms to get as much as possible of advantages of precision feeding implementation.

CONCLUSIONS

Implementation of precision feeding is very promising for better, most productive, most efficient, and more sustainable livestock production. But there must be a considerable variation in its implementation rate and advantages due to the big variation of world livestock farms.

REFERENCES

Amata, I. A. 2014. The use of non-conventional feed resources (NCFR) for livestock feeding in the tropics: A review. Journal of Global Biosciences. 3 (2): 604-613.

Andretta, I., Hauschild, L., Kipper, M., Pires, P. G. S., and Pomar, C. 2018. Environmental impacts of precision feeding programs applied in pig production. Animal. 12(9):1990-1998. https://doi.org/10.1017/S1751731117003159

Anonymous. 2020. Moving towards sustainability: The Livestock Sector and the World Bank. The World Bank Group. https://www.worldbank.org/en/topic/agriculture/brief/moving-towards-sustainability-the-livestock-sector-and-the-world-bank.

Babinszky, L., and Halas, V. 2009. Innovative swine nutrition: Some present and potential applications of latest scientific findings for safe pork production. Italian Journal of Animal Science. 8. (Suppl. 3): 7-20. https://doi.org/10.4081/ijas.2009.s3.7

Banhazi, T. M., Babinszky, L., Halas, V., and Tscharke, M. 2012. Precision livestock farming: Precision feeding technologies and sustainable livestock production. International Journal of Agricultural and Biological Engineering. 5(4): 54-61. https://doi.org/10.3965/j.ijabe.20120504.006

Berckmans, D. 2014. Precision livestock farming technologies for welfare management in intensive livestock systems. OIE Revue Scientifique et Technique. 33(1):189-196. https://doi.org/10.20506/rst.33.1.2273

Broom, D. M., Galindo, F. A., and Murgueitio, E. 2013. Sustainable, efficient livestock production with high biodiversity and good welfare for animals. In Proceedings of the Royal Society B: Biological Sciences. 25: 280(1771): 20132025 https://doi.org/10.1098/rspb.2013.2025

Broom, D. M. 2011. A History of Animal Welfare Science. In Acta Biotheoretica. 59(2):121-37. https://doi.org/10.1007/s10441-011-9123-3

Cerisuelo, A., and Calvet, S. 2020. Feeding in monogastric animals: A key element to reduce its environmental impact. ITEA Informacion Tecnica Economica Agraria. 116(5): 483-506. https://doi.org/10.12706/itea.2020.039

Chenost, M. 1990. Non-conventional feed resources and fibrous agricultural residues. Strategies for expanded utilization. Animal Feed Science and Technology. 30 (3-4): 192. https://doi.org/10.1016/0377-8401(90)90024-3

Clark, M. 2012. Deforestation in Madagascar: Consequences of Population Growth and Unsustainable Agricultural Processes. 3 (1): 61-71. Global Majority E-Journal.

Cook, K., James, M., Lee, R., Cook, K., James, M., and Lee, R. 2015. Animal Welfare Act 2006. In Core Statutes on Criminal Law. 2-5. https://doi.org/10.1007/978-1-137-54431-5_3

Da Cunha, D. de N. F. V., Pereira, J. C., de Campos, O. F., Gomes, S. T., Braga, J. L., and Martuscello, J. A. 2010. Simulation of Holstein and Jersey profitability by varying milk price payment system. Revista Brasileira de Zootecnia. 39 (4) https://doi.org/10.1590/s1516-35982010000400028

Das, P., Sa, J.-H., Kim, D. S., Kim, K. H., and Jeon, E. C. 2007. A Review on the emission sources of ammonia and the factors affecting its loss. Journal of Korean Society for Atmospheric Environment. 23(E2): 47–56.

Dawkins, M. S. 2006. A user's guide to animal welfare science. Trends in Ecology and Evolution. 21(2):77-82. https://doi.org/10.1016/j.tree.2005.10.017.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S., and Courbois, C. 1999. Livestock to 2020: The Next Food Revolution, Food, Agriculture, and the Environment Discussion Paper 28. IFPRI FAO and ILRI Publication.

Devendra, C., and Sevilla, C. C. 2002. Availability and use of feed resources in crop-animal systems in Asia. Agricultural Systems. 71 (1-2): 59-73. https://doi.org/10.1016/S0308-521X(01)00036-1

di Virgilio, A., Morales, J. M., Lambertucci, S. A., Shepard, E. L. C., and Wilson, R. P. 2018. Multi-dimensional Precision Livestock Farming: A potential toolbox for sustainable rangeland management. Peer J. 6:e4867. https://doi.org/10.7717/peerj.4867

Dopelt, K., Radon, P., and Davidovitch, N. 2019. Environmental effects of the livestock industry: the relationship between knowledge, attitudes, and behavior among students in Israel. International Journal of Environmental Research and Public Health. 16(8), 1359.

Edwards, J. P., Spaans, O. K., Neal, M., and Macdonald, K. A. 2019. Short communication: Milk fat payment affects the relative profitability of Jersey and Holstein-Friesian cows at optimal comparative stocking rate. Journal of Dairy Science. 102(10):9463-9467. https://doi.org/10.3168/jds.2018-16152

Eshel, G., Shepon, A., Makov, T., and Milo, R. 2014. Land, irrigation water, greenhouse gas, and reactive nitrogen burdens of meat, eggs, and dairy production in the United States. Proceedings of the National Academy of Sciences of the United States of America. 111 (33) 11996-12001. https://doi.org/10.1073/pnas.1402183111

Food and Agriculture Organization. 2006. Global Forest Resources Assessment 2005: Progress towards sustainable forest management. In FAO Forestry Paper 147.

Food and Agriculture Organization. 2011. Mapping supply and demand for animal-source foods to 2030. In Animal Production and Health Working Paper. No. 2.

Goodland, R., Anhang, J., and others. 2009. Livestock and climate change: what if the key actors in climate change are... cows, pigs, and chickens? World Watch, November/December.

Halas, V., and Dukhta, G. 2020. Growth models and their application in precision feeding of monogastric farm animals. In Acta Fytotechnica et Zootechnica. 23: 258-264. https://doi.org/10.15414/afz.2020.23.mi-fpap.258-264

Iqubal, M. A. 2013. Livestock husbandry and environmental problem. International Journal of Scientific and Research Publication. 3(5): 1–4.

Jarvis, A., Touval, J. L., Schmitz, M. C., Sotomayor, L., and Hyman, G. G. 2010. Assessment of threats to ecosystems in South America. Journal for Nature Conservation. 18(3): 180-188. https://doi.org/10.1016/j.jnc.2009.08.003

Jayakumar, P., and Loganathan, S. 2015. A Study on Consumer Preference of Milk at Edamalaippattipudur in Tiruchirappalli District. Intercontinental Journal of Marketing Research Review. 3(7): 33–39.

Lopez, G., and Leeson, S. 2005. Utilization of metabolizable energy by young broilers and birds of intermediate growth rate. Poultry Science. 84(7):1069-76. https://doi.org/10.1093/ps/84.7.1069

Lovarelli, D., Bacenetti, J., and Guarino, M. 2020. A review on dairy cattle farming: Is precision livestock farming the compromise for an environmental, economic and social sustainable production?. Journal of Cleaner Production. 262(2):121409https://doi.org/10.1016/j.jclepro.2020.121409

Macedo, M. N., DeFries, R. S., Morton, D. C., Stickler, C. M., Galford, G. L., and Shimabukuro, Y. E. 2012. Decoupling of deforestation and soy production in the southern Amazon during the late 2000s. Proceedings of the National Academy of Sciences of the United States of America. 109 (4) 1341-1346. https://doi.org/10.1073/pnas.1111374109

Makkar, H. P. S., Tran, G., Heuzé, V., and Ankers, P. 2014. State-of-the-art on use of insects as animal feed. In Animal Feed Science and Technology. 197 (Nov.): 1-33. https://doi.org/10.1016/j.anifeedsci.2014.07.008

Meek, T. 2019. How does agriculture cause deforestation, and how can we prevent it?. Environment. Sentient Media. https://sentientmedia.org/how-does-agriculture-cause-deforestation/

Molina-Flores, B., Manzano-Baena, P., and Coulibaly, M. D. 2020. The role of livestock in food security, poverty reduction and wealth creation in West Africa. FAO.

Ncobela, C. N., and Chimonyo, M. 2015. Potential of using non-conventional animal protein sources for sustainable intensification of scavenging village chickens: A review. In Animal Feed Science and Technology. 208 (Oct.): 1-11. https://doi.org/10.1016/j.anifeedsci.2015.07.005

Noordhuizen, J. P. T. M., and Metz, J. H. M. 2005. Quality control on dairy farms with emphasis on public health, food safety, animal health and welfare. Livestock Production Science. 94 (1-2): 51-59. https://doi.org/10.1016/j.livprodsci.2004.11.031

Piccioli-Cappelli, F., Calegari, F., Calamari, L., Bani, P., and Minuti, A. 2019. Application of a NIR device for precision feeding in dairy farms: effect on metabolic conditions and milk production. Italian Journal of Animal Science. 18(1): 754-765 https://doi.org/10.1080/1828051X.2019.1570829

Pomar, C., van Milgen, J., and Remus, A. 2019. 18: Precision livestock feeding, principle and practice. In Poultry and pig nutrition. p. 397 - 418. https://doi.org/10.3920/978-90-8686-884-1_18

Pomar, Cândido, Hauschild, L., Zhang, G.-H., Pomar, J., and Lovatto, P. A. 2009. Applying precision feeding techniques in growing-finishing pig operations. Revista Brasileira de Zootecnia. 38: 226-237. https://doi.org/10.1590/s1516-35982009001300023

Pomar, C., and Remus, A. 2019. Precision pig feeding: a breakthrough toward sustainability. Animal Frontiers. 9(2): 52–59. https://doi.org/10.1093/af/vfz006

Rosegrant, M. W., Fernandez, M., Sinha, A., Alder, J., Ahammad, H., de Fraiture, Charlotte, Eickhour, B., Fonseca, J., Huang, J., Koyama, O., Omezzine, A. M., Pingali, P., Ramirez, R., Ringler, C., Robinson, S., Thornton, P., van Vuuren, D., Yana-Shapiro, H. 2009. Looking into the future for agriculture and AKST. In: McIntyre, B. D.; Herren, H. R.; Wakhungu, J., Watson, R. T. (eds.). International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD): Agriculture at a Crossroads, global report. Washington, DC, USA: Island Press. p.307-376.

Salami, S. A., Luciano, G., O'Grady, M. N., Biondi, L., Newbold, C. J., Kerry, J. P., and Priolo, A. 2019. Sustainability of feeding plant by-products: A review of the implications for ruminant meat production. In Animal Feed Science and Technology. 251(May): 37-55. https://doi.org/10.1016/j.anifeedsci.2019.02.006

Thomson, K. 2003. World agriculture: towards 2015/2030: an FAO perspective. Land Use Policy. https://doi.org/10.1016/s0264-8377(03)00047-4

Thornton, P. K., and Herrero, M. 2010. The Inter-linkages between Rapid Growth in Livestock Production , Climate Change , and the Impacts on Water Resources , Land Use , and Deforestation. World Development.

Vasta, V., Nudda, A., Cannas, A., Lanza, M., and Priolo, A. 2008. Alternative feed resources and their effects on the quality of meat and milk from small ruminants. In Animal Feed Science and Technology. 147 (1-3): 223-246. https://doi.org/10.1016/j.anifeedsci.2007.09.020

Zuidhof, M. J. 2020. Precision livestock feeding: matching nutrient supply with nutrient requirements of individual animals. Journal of Applied Poultry Research. 29(1): 11-14. https://doi.org/10.1016/j.japr.2019.12.009