Technological Innovation and Education Training in Animal Production with a Focus on Feeding and Feed Production

(The Workshop was organized under the Belt and Road framework)

May 10-13, 2018

Nanjing, China

Organizer

Nanjing Agricultural University
National Center for International Research on Animal Gut Nutrition

Organizing Committee

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P. van der Aar

Conference Agenda

May 10 (Thursday)	
08:30-18:00	Registration at Han-yuan Hotel (Lobby)
18:00-19:00	Dinner at Han-yuan Hotel (3rd floor)
19:00-20:30	Reception at Han-yuan Hotel (1rd floor)

May 11 (Friday) 6th floor	
Opening Ceremony	**Chairperson: D. Jiang**
08:30-09:00	**Welcome Speeches** - Xianglin Yan, Deputy President of Nanjing Agricultural University - Representative, Science and Technology Department, Jiangsu Province - Defa Li, Academician of Chinese Academy of Engineering, China Agricultural University
09:00-09:30	**Group photo** (1st floor)
09:30-09:45	**Tea Break**
Invited Speeches	**Chairperson: H. Makkar**
09:45-10:15	Objective of the Workshop: What we would like to achieve W. Zhu (China)
10:15-10:45	The Belt & Road Initiative and International Cooperation in National Natural Science Foundation of China (NSFC) X. Liu (Director of Division of American and Oceanian Programs, Bureau International Cooperation, NSFC)
10:45-11:30	Investing in generation of feed numbers and innovative feeding strategies for dry areas H. Makkar (Germany)
11:30-12:00	General Discussion: Comments and Questions

Lunch (Han-yuan Hotel)	
Invited Speeches	**Chairperson: S.Y. Mao**
14:00-14:45	Livestock production in Malaysia: current status and sustainable development through enlarging feed resource base and enhancing feed efficiency J.B. Liang (Malaysia)
14:45-15:30	Thailand country report: Livestock production systems, status on national feed resource availability and future developments, and challenges and opportunities to efficiently utilize locally available feed resources and to enhance feed use efficiency K. Sommart (Thailand)
15:30-16:15	Livestock production systems, status on national feed resource availability and future developments, and challenges and opportunities to efficiently utilize locally available feed resources and to enhance feed use efficiency in Myanmar A. Aung (Myanmar)
16:15-16:30	**Tea Break**
Invited Speeches	**Chairperson: K. Sommart**
16:30-17:15	Livestock feeding strategy and feed availability in Mongolia O. Ayushjav (Mongolia)
17:15-18:00	Status quo, challenges and opportunities of livestock production in China J.X. Liu (China)
18:00-18:15	Chairperson: J.X. Liu General Discussion: Comments and Questions
Dinner (Han-yuan Hotel)	

May 12 (Saturday) 6th floor	
Invited Speeches	**Chairperson: A. Aung**
08:30-9:15	Status on animal husbandry and feed resources in Xinjiang: challenges and opportunity X.L. Gu (Xinjiang, China)
09:15-10:00	Status on national feed resource availability and developments in Tibet

	Y. Qiangba (Tibet, China)
10:00-10:45	Sustainable development of livestock production systems through enlarging feed resource base and enhancing feed efficiency: The Kenyan case C.K. Gachuiri (Kenya)
10:45-11:00	**Tea Break**
Invited Speeches	**Chairperson: J.B. Liang**
11:00-11:45	Country Report Pakistan: Feeding systems, status of national feed resources, their availability and future developments, challenges and opportunities to efficiently utilize locally available feed resources and to enhance feed use efficiency S.A. Bhatti (Pakistan)
11:45-12:30	Livestock feedings systems, available feed resources and the challenges and opportunities for enhancing utilization of the available feed resources in Ethiopia A. Tolera (Ethiopia)
12:30-13:15	A review on livestock production systems, and feed production and feeding systems in Iran: Challenges and Opportunity F. Fatehi (Iran)
13:15-13:30	Chairperson: W.Y. Zhu General Discussion: Comments and Questions
Lunch (Han-yuan Hotel)	
Invited Speeches	**Chairperson: A. Tolera**
14:00-14:45	Livestock production systems and feed resources in Greece I. Giannenas (Greece)
14:45-15:30	Livestock production systems and feed resources in The Netherlands P. van der Aar (The Netherlands)
15:30-15:45	China feed and animal industry: current situation and the future challenge L.Z. Jin (China)
15:45-16:15	Chairperson: H. Makkar General Discussion: Comments and Questions

16:15-16:45	**Closing Ceremony**
16:45-17:00	**Tea Break**
Discussion on Network Activities Chairperson: H. Makkar	
17:00-18:30	Ten min presentation per country, stating: a) Based on strengths of your organization what you can contribute to the Network; and b) your expectation from the Network Presentations to be made alphabetically, country-wise
Dinner (Han-yuan Hotel)	

May 13 (Sunday) 7th floor	
Discussion on Network Activities Chairperson: H. Makkar	
08:30-11:30	Ten min presentation per country, stating: a) Based on strengths of your organization what you can contribute to the Network; and b) your expectation from the Network Presentations to be made alphabetically, country-wise
11:30-12:00	**Way Forward by Wei-Yun Zhu and H. Makkar**
Lunch (Han-yuan Hotel)	
14:00-18:00	Scientific Tour
Dinner (Han-yuan Hotel)	

Preface

‘The Belt and Road Initiative’ (BRI) has received positive and enthusiastic response from the international community since this policy was put forward in 2013. This initiative has significant contribution in improving the regional policies and promoting the regional development in a coordinated, cooperative and mutual manner. It also provides opportunities not only for the national development but also for the development of the livestock sector in China and other countries. It is crucial for domestic livestock industry and academia to take advantage of this unique opportunity to initiate work with the industry and academia of other countries and advance it in a collaborative manner. Strengthening the cooperation with the livestock industry in countries along the ‘Belt and Road’ is of great significance in promoting the implementation of the ‘Belt and Road’ national strategy and maintaining the ‘Belt and Road’ regional food safety, prosperity and social stability.

As the globalization of scientific and technological innovations moves forward, the development mode of China's livestock industry has shifted from ‘resource-use driven’ to ‘innovation driven’. We believe that efficient, safe, resource-saving and environment-friendly animal production is the future of the modern livestock industry in China. Scientific and technological innovations and collaboration, as an important part of the ‘Belt and Road’ cultural and scientific exchange, offers an effective way to facilitate the communication between different nations, improve living conditions and wellbeing of people, and bridge different cultures. The awareness and trust from international community will be improved not only through consolidating the innovative research and collaboration but also through sharing and extending the innovative technologies, ideas and concepts related to livestock sector among China and other countries. Our state leaders proposed the ‘Belt and Road’ Science and Technological Innovation Initiative at the ‘Belt and Road’ International Cooperation Summit on May 14, 2017. Under the framework of this initiative, Nanjing Agricultural University and National Center for International Research on Animal Gut Nutrition have initiated and co-sponsored this ‘Belt and Road Workshop on Technological Innovation and Education Training in Animal Production’.

The workshop will be held in Nanjing from May 10 - 13 and is being supported by Ministry of Science and Technology of China, Ministry of Education of China and the Department of Science and Technology of Jiangsu Province. The objectives of the workshop include facilitation of the communication of policy, technology, education and culture among the countries along the ‘Belt and Road’ route, development of innovative ideas for the livestock sector development, building of a cooperation and exchange platform for livestock science and technology innovation, facilitation of the exchange of green livestock science and technology, promotion of mutual understanding and trust, advocate of the transformation and upgradation of livestock industry, and acceleration of the pace of livestock industry modernization.

We have invited domestic and oversea experts, scholars, and industrial partners from livestock and related fields to present their work and participate in the discussions. This workshop proceeding includes reports on status of livestock feed and feeding systems, and challenges and opportunities for enhancing efficiency of feed-use and sustainability of livestock sector by the experts from 11 Asian, African and European countries along the ‘Belt and

Road' route. These reports and the presentations based on these reports will also set a scene for the way forward to strengthen future work and collaboration. We are looking forward to the workshop presentations, discussions and proceedings and wish the workshop to be a grand success.

Organizing Committee

'Belt and Road' Workshop on Technological Innovation and Education Training in Animal Production

May 10, 2018

Invited Talks

Investing in generation of feed numbers and innovative feeding strategies for developing countries

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Abstract

The feed is the main driver of livestock production. It accounts for up to 70% of the total cost of livestock operation. The poor or unbalanced feeding adversely affects the productivity, health, behaviour and welfare of animals, in addition to adversely affecting the environment. Population growth, urbanisation and income growth are generating enormous increases in demand for foods of animal origin, which is resulting in huge feed demands. Factors such as scarcity of land, soil and water; food-fuel-feed competition; ongoing global climate change; increased competition for arable land and increased cost; and use of non-renewable resources such as fossil fuel and minerals are challenging the sustainability of feed-production systems. Efficient use of available feed resources is key to efficient animal production and food and nutrition security. 'If you cannot measure it, you cannot manage it' is a famous management quote. To efficiently utilize feed resources, it is imperative to know where, what and how much of them are available. Generation of feed-related data such as feed inventory, feed balance and in-depth knowledge of feeding systems, especially what and how much of feed resources and when they are fed to livestock, are imperative for development of the livestock sector on firm foundation and for efficiently addressing livestock emergencies. The importance of investing in generation of data on the above-mentioned feed related parameters, and on sound chemical composition and nutritional value including safety parameters of feed resources has been outlined in this paper. The feeding strategies based on human-inedible components are of special importance for developing countries due to shortages of foods in these countries. Appropriate technologies for application in developing countries are the use of densified straw- or hay-based feed blocks or pellets, conventional urea molasses blocks and their variants, forages after chopping, appropriate feeding troughs, alkali treatment of straws and stovers, spineless cactus, enzymes and second-generation biofuel-led treatments, among others are highly relevant. Their use provides 'win-win' situation in terms of increase in livestock productivity and thus income of farmers and decrease in greenhouse gases (GHG) from the livestock production systems. Novel feeding options using insect meals, by-products of the biofuel industry, seaweed, leaf meal and protein isolates, vegetable and fruit wastes, agro-industrial by-products, single cell protein produced using waste streams, algae when adopted at a large scale would not only decrease food-feed competition but also broaden the feed resource base, and increase both economic and environmental efficiency of livestock rearing operations. The use of any feed and feeding related innovations through adopting business approaches will make them main stream feeds and feeding technologies.

Introduction

Livestock are vital for the food and nutrition security of millions of people. Livestock contribute around 12.9% of global calories and 27.9% of protein directly through provision of meat, milk, eggs and offal. The biological value of animal-source protein is approx. 1.4 times higher than that of plant foods[1]. Furthermore, the bioavailability of essential amino acids and micronutrients from animal products is higher than from plant foods. Moreover, in livestock systems that primarily consume roughages and agro-industrial by-products, livestock add to the food supply beyond what can be provided by crops. They also help to alleviate seasonal food variability and make a very important contribution to food access and stability through the income and products they provide to small-scale mixed farmers and pastoralists. Livestock generate employment and income that contributes to food security, and they are a supplier of production inputs for example manure as fertiliser and soil conditioner, weed control, draught power, recycling and use of secondary and waste products, utilisation of marginal lands and crop residues for sustainable agricultural development. There is a need to adequately consider the contribution of the livestock sector in policies, investment programs and legal frameworks addressing food security and nutrition.

Population growth, urbanisation and income growth are generating enormous increases in demand for foods of animal origin, which is resulting in huge feed demands. Several biophysical factors such as scarcity of land, soil and water; food-fuel-feed competition; ongoing global climate change; and increased competition for arable land and increased cost and use of non-renewable resources such as fossil fuel and minerals are challenging the sustainability of feed-production systems[1]. Efficient use of available feed resources is key to efficient animal production and food security. There is global recognition that insufficient attention has been paid to the generation of livestock-related data, including on feeds, at the level of detail required for elucidating the future role of livestock in attaining key global sustainability goals. Generation of such data is vital for sustainable development of the livestock sector especially in developing countries due to scanty data available on feed related aspects in these countries[2]. The main feed and feeding-related areas that require urgent attention with regard to generation of sound quantitative data are:

- National feed assessments
- Reliable chemical composition and nutritional value data
- Characterization of feeding systems

To increase livestock productivity equally important is to develop efficient feeding strategies based on locally available feed resources. This becomes even more important for the dry areas due to dearth of conventional feed resources. This article will also address efficient feeding strategies as well as options for broadening of feed resource base using novel approaches.

National feed assessments

Most developing countries do not have feed inventories i.e. quantitative information on availability of animal feed resources. The feed inventory should contain information on what, how much, where and when the feed resources are available. A pre-requisite for making the best use of available resources is to accurately assess availability of feed resources at national and/or regional level along with their nutritive value. The assessments of current and future supplies and demands for livestock feed are also needed for national food security policy and planning, as well as for setting of environmentally sustainable stocking rate. Feed resources must be assessed and monitored to provide information for the development and implementation of policies that will contribute to the sustainable growth of national livestock sectors. Information provided by livestock feed inventories would be of immense utility for policy makers, government agencies, non-government organisation, intergovernmental agencies and development agencies in formulating and implementing sustainable livestock-development activities and for preparing and coping with climatic variations, such as droughts, floods, severe winter weather events and global climatic change. Spatial and temporal assessments of current and forecasted feed resources, including forages, will assist in situations such as floods and droughts. Feed assessments will also inform decisions related to the nature and quantities of commodities, the feed resources that could be traded locally, potential areas for feed markets, and feed resources involved in imports and exports. In addition, information on availability of feed ingredients at a country level will enhance efficiency and profitability of the animal-feed industry and assist researchers to formulate sustainable feeding strategies. The estimation of feed resources at national level will also improve the accuracy of estimates of the environmental impacts of livestock, not only through land-use transformations, but also in the estimation of GHG emissions associated with livestock production. It would also be of use for determining potential for carbon sequestration. Although, livestock-feed shortages have clearly constrained productivity in many countries, the impacts of feed shortages at national levels have been poorly characterised due to the lack of national-scale feed assessments. Generation of feed balance at country level will be possible with the feed-inventory information, which will assist in proper planning of the livestock industry; for example, the number of animal heads that can be raised with the existing feed resources and determining what feed resources should be made available to achieve the set targets. Such efforts will, in turn, translate into enhanced food security. Herd-structure information is also required for calculation of animal requirements in terms of, for example metabolizable energy and crude protein, without which feed balance cannot be calculated. Reliable and harmonised herd-structure data are also lacking for many developing countries.

FAO[3] has developed methodologies and guidelines to generate feed inventory and feed balance. Using these tools, feed inventory and feed balance have recently been created for Ethiopia and a programme has been launched to generate similar data for Kenya. The categories under which feed inventory can be created are:

- Cereal straws/stovers
- Cereal brans
- Cereal stubble feeding
- Pulse straws/aerial parts
- Pulse bran and husk mix
- Oilseed straws and other parts
- Oilseed cakes
- Roots of root crops
- Roots crop aerial and other parts
- Horticulture - vegetable plant aerial parts
- Horticulture - fruit peel and kernels
- Industrial crops
- Pods and cladodes
- Cultivated fodders
- Grazing biomass

In East African countries, livestock feed and feeding systems are constrained by a host of interconnected factors including recurrent droughts, grassland degradation, overgrazing, land tenure and land use changes, resource use conflicts, encroachment of invasive plant species, soil infertility and lack of inputs and planting material, among others. The seasonal feed shortage and the inefficient feed utilization by pastoralist and agro pastoralist are the major challenges affecting livestock productivity in Eastern Africa. In addition, poor conservation practices, and a lack of knowledge on appropriate feed and feeding practices are among the critical constraints for efficient utilization of available feed resources.

Available evidence in the Horn of Africa indicates that pastoral destitution is largely driven by feed and water scarcity, as the natural resource base in the rangelands in most countries are shrinking fast due to prolonged and often frequent drought events. The drought of 2017 affected Ethiopia, Kenya, Somalia and Djibouti with significant livestock losses which result into migration of people and livestock in search of pasture and water. A systematic approach for feed assessment is required in these countries for making the efficient use of feed resources and developing feed reserves so that livestock morbidity and mortality during emergency periods could be reduced.

Reliable chemical composition and nutritional value data

The next major step that needs fulfilling to make the best use of feed resources is their evaluation for chemical composition and nutritional value so that guidelines could be developed for their safe, sustained and productive use. Equally important is the accurate determination of these parameters. In most developing countries, basic facilities for determination of chemical composition are available, though facilities for evaluation of nutritional quality may be lacking, but unfortunately most feed-analysis laboratories in developing countries do not integrate quality-control systems in routine analysis of feed ingredients and, as a result, the quality of data emanating from laboratories is not robust. So there is a need to integrate the quality-control approaches in feed-analysis laboratories. Once reliable data are generated, a national database on feed resource availability, chemical composition and nutritional value must be developed for effective and efficient use at national and international levels. FAO has coordinated proficiency testing of feed-analysis laboratories and online courses on strengthening quality control in animal feed-analysis laboratories, contributing to generation of sound quantitative data on feed composition and nutritional value of feed ingredients.

Such efforts, besides making the efficient use of feed resources, also enhance research capabilities, make the feed industry competitive, reduce costs, boost profitability and strengthen local economies. Additionally, good laboratory data can help promote the use of locally available feed resources and create employment, giving a boost to local economies. Accurate feed-analysis data also helps researchers develop more cost-effective and sustainable feeding strategies that can then be commercialised or directly used by farmers. At regional and international levels, the reliable and accurate analysis of feed promotes trade and economic growth, involving both livestock and the feed.

The safety and quality of the food chain can be affected because of the close link between feed and foodborne pathogens such as *Escherichia coli* O157, *Salmonella* and *Campylobacter*. The presence of mycotoxins, heavy metals and pesticides in feed can also adversely affect animal and human health and product quality and safety. Furthermore, for reducing wastages, enhancing food safety through enhancing feed safety and for promoting international trade, data on the presence of microbial contaminants including mycotoxins, heavy metals, antibiotic and pesticide residues must also be strengthened and made transparent at the national level. Efforts have been made recently for assessing the prevalence of various mycotoxins at a global level[4,5].

Feed-analysis laboratories play an important role in ensuring animal product quality via the accurate and regular measurement of contaminants and toxins. The feeding of balanced diets decreases the level of excretion of feed nutrients as well as increases feed-use efficiency by increasing incorporation of nutrients into animal food chain[6]. Feed-analysis laboratories, therefore, assist in reducing the environmental pollution caused by animal production by more reliably determining the chemical constituents of feed ingredients and ensuring they are not excessive or unnecessary in the diets. It is vital that science managers and feed industries must ensure that quality-control systems and good laboratory practices are used on routine basis in feed-analysis laboratories.

Characterisation of feeding systems

A Feeding System is characterised by: which feedstuffs, in what proportion, which period of the year, in which region and in which livestock production system are fed. Equally important is the information on the feeding systems. It provides information on how feed resources are being used in different livestock sectors and production systems. Assessment of environmental impact of livestock[7], development of optimal feeding strategies for reducing carbon footprint, increasing animal productivity, health and welfare, and increasing the quality and safety of animal products rely on information on feeding systems, quality of feedstuffs used and data on feed inventories.

The strategies for characterisation of feeding systems could be based on livestock production systems, agro-climatic/agroecologic zones and seasons. Feeding systems can also be characterised based on other criteria (such as topography – highland/mountain and plans). The final layer in the process of feeding system characterisation (i.e. naming of feeding systems) may be based on approximate proportion of feedstuffs used or the main components used in the region. Much more heterogeneity in ruminant feeding systems is expected, while in the intensive monogastric systems, there is much more uniformity and the effect of season is not drastic. Recently, through FAO efforts, feeding systems in the dry areas of Ethiopia have been characterized[8].

Other vital data requirements

Generation of data on wasted feeds is vital. Equally important is to assess the reasons for these wastes and the steps in the feed-food production chain at which these take place. This information helps to put in place practices for waste reduction. The following information, aggregated at the national level, will help to generate indicators that could be used for measuring progress on feed related aspects of the livestock sector at the national level.

- Feed manufacturing industries and the type and amount of feed being produced.
- Directory of feed distributors, feed retailers and feed ingredient suppliers.
- Agroindustry by-product production and use data.

- Amount of (a) concentrate feed prepared on-farm per year, (b) amount of grains, cereals and beans, and c) oilseed meals/cakes used in this concentrate per year for each animal species.
- Amount of crop residues fed per year on-farm, which ones and for large and small ruminants separately.
- Area (ha) under cultivated forages using improved/certified/ truthfully labeled seeds, and average forage dry matter yields.
- Extent of regular use of mineral and vitamin mixture in animal diet; for large and small ruminants separately.
- Source of drinking water (feed use is impacted by amount and quality of water consumption) provided to animals.
- Data on number of animals under grazing: months in a year animals graze the whole day or graze partially; and during this period what and how much supplementary feed, if any is given per animals.
- Information on system of grazing used: continuous, rotation, silvopastoral.
- What proportion of feed resources are farm grown, purchased or from communal land.
- Extent of use of balanced feeding (i.e. feed provision corresponding to animal product yield).
- Extent of feed ingredients analysed for chemical constituent before making on-farm feed.
- Extent of feed ingredients analysed for mycotoxins before making on-farm feed.

The policy makers and science managers should ensure that mechanisms to generate the above data and information are in place at the national level. To sustain efforts to generate feed related data, it is imperative that the process for collating and managing such data is institutionalised. Ministries such as Agriculture or Agriculture Statistics and government departments such as animal husbandry and national research institutions should integrate work on generating and updating, on regular basis, the national feed assessments.

Efficient feeding strategies

The feed is the main driver of livestock production. It accounts for up to 70% of the total cost of livestock operation. The poor or unbalanced feeding adversely affects the productivity, health, behaviour and welfare of animals. In addition, this also diverts a substantial portion of feed carbon and nitrogen to wasteful products in the form of GHG. Globally, the production, processing and transport of feed account for 45% of the GHG emission from the livestock sector. Enteric methane contribution is 39%[9], which also depends on the type of feed fed to livestock. The area dedicated to feed-crop production represents 33% of total arable land and the grazing land constitutes 30% of the terrestrial land. Feed production is highly resource demanding. Approximately 33% and 6% of the grains produced are used for livestock feeding and bioethanol production respectively[10]. The food-feed-fuel competition is one of the complex challenges, and so are the ongoing climate change, land degradation and water shortages that need addressing for sustainable intensification of livestock production and for realization of sustainable food production and consumption systems. By 2050 the world population is expected to be 9.6 billion, which will require 60–70% more meat and milk than consumed today. Most of this increase will be from developing countries, which already face many food security challenges[11]. Most developing countries have extreme shortages of feed resources. Additional feed required for the projected increased demand of animal products, if met through food grains, will further exacerbate the food insecurity in these countries. Livestock use about 60% of the biomass used for food production. Ruminant livestock consume 78% of this biomass used and convert crop residues and by-products into edible products. Furthermore, in marginal areas, where agro-ecological conditions and weak infrastructures do not offer much alternative, it is the main source of livelihoods and food. Most of the dry matter consumed by livestock is composed of grass (39%) and other non-humanly edible materials such as crop residues (26%) and agricultural by-products (bran, oilseed cakes etc., 8%) (http://www.fao.org/gleam/en/). Technologies are available that enhance digestibility of crop residues and by-products and also increase nutrient availability from them to animals i.e. increase feed conversion efficiency. Given that feed is by far the dominating physical flow, in energy terms, increase in feed conversion efficiency enhances overall resource use efficiency. Feed related technologies that illustrate 'win-win' situations: increase livestock productivity and income of farmers, decrease environmental pollutants and better social outcomes including empowerment of women and decrease in food-feed competition are highly relevant for developing countries. Some of these are presented below.

Densified straw based total mixed rations

Crop residues such as straws and stovers are valued feed resources in developing countries and they form 50–60% of the ruminant diets. The efficient technologies are now available for collection of straws from the crop fields. The collected straws can be used to form total mixed ration (TMR) by mixing with, for example, locally available oil seed cakes, urea, molasses, vitamin and mineral mixtures; followed by compacting to form blocks or pellets using hydraulic press. The TMR based on densified straw based blocks or pellets supply balanced feeds to animals and increase their productivity, resulting in profitability increase for farmers[12]. These blocks or pellets containing no or very little human edible components can maintain a cow giving up to 15 litres of milk per day. Farmers find this technology attractive because use of a complete ration in the form of blocks/pellets decreases the feeding time. This is of particular importance for women because they are the main care takers of animals in developing countries. Time saved in feeding empowers women because they can use this time in other productive purposes. This technology can also be effective in disaster management and emergency situations that arise due to natural calamities, for example floods, droughts and man-made conflicts. Feed banks could be set up to overcome the problem of feeding animals during these natural calamities, which are common in the tropics. These blocks are easier and safer to transport and store - being denser than the original bulky straw. Also this technology provides an opportunity for the feed manufacturers and entrepreneurs to remove regional disparities in feed availability and to supply balanced feeds to dairy and other livestock farmers on a large scale. In addition to providing a balanced diet in terms of chemical composition, physical factors such as the particle size of the fibre or feeding of ingredients as individual components or as a TMR also influence the nutrient use efficiency in the animal. Over feeding ingredients separately, feeding of TMR has been shown to have several advantages, such as lower feed loss, higher nutrient availability, lower enteric methane production and higher animal performance[12].

Chopping of roughages and use of feeding troughs

Simple technologies, such as chopping forages, increase animal productivity and reduce forage waste. Both intake and rumen digestion of chopped forages are higher than the un-chopped forages[13]. Animals use a considerable amount of energy in chewing forages and chaffing saves this energy and diverts it for productive purposes. Continuous mixing of rumen contents improves the intimacy between ingested feed particles and the microbial population, which is essential for optimal fibre digestion. In addition, use of feeding troughs by farmers decreases feed wastage and indirectly increases feed use efficiency. Use of these technologies must be widely propagated.

Urea molasses multi-nutrient blocks

The crop residues and grazing pastures during dry periods are deficient in nitrogen, energy and minerals. Urea molasses block supplementation enhances the supply of nitrogen, minerals and vitamins to rumen microbes which increases the nutrient supply to the ruminants from fibrous feed stuffs, thus enhancing their efficiency of utilization. Further, feeding crop residue with urea molasses blocks has resulted in the increased cost: benefit ratio ranging from 1:2 to 1:5 depending on the cost of feed and sale price of milk. The blocks also provide supplements to animal in ranches. These supplements are vital during the dry season when the quality of the forage in rangelands decreases. In extensive grazing situation the blocks are generally kept near watering points. Use of the blocks for both confined and grazing situations in the tropics, especially dry season has been shown to increase profitability[14]. In the recent years, use of urea molasses or multi-nutrient blocks during prolong winter period or severe drought has gained much attention. These blocks could also be used as a carrier for anthelminthic and tannin-neutralizing agents such as polyethylene glycol[14].

Urea-ammoniation or CaO treatment of straw

Treatment of straws with 4-5% urea at 50-60% moisture level, followed by anaerobic fermentation for 15-20 days (depending on ambient temperature) increases digestibility by 10-15% units. This leads to higher productivity[13]. Instead of urea, calcium oxide treatment can also be used to treat straws and stovers. Feedlot research done at Iowa state university showed $28.04 higher profit per steer when fed corn stover based diet treated with $Ca(OH)_2$. Performance of the steer was similar but the treated stover used less corn. This strategy has been effective in replacing substantial portion of grain in cattle diet thus reducing the food-feed competition and also enhancing the profit compared with the untreated corn based ration[15]. Similarly, in another experiment by Shreck *et al.* [16] crop residues (corn stover, corn cobs and wheat straw) were treated with 5% calcium oxide. Compared to the control finishing diet, the treatment groups were given 10% more roughage and less corn; however, they gained as effectively as the control animals. Economic analysis revealed $6.46, $21.42 and $36.30 average profit per head from the treated diets as compared with the control when the price of the corn was $3.0, $4.50 and $6.00 respectively.

Ensiling and converting waste to resources

Silage-making, especially using locally available resources as done in Bangladesh[13], is also an attractive approach for reducing wastage of forages whose availability is high in rainy seasons. In some months of the year availability of vegetable and fruit wastes is also high which can also be converted into valuable resources through silage making. An FAO document, targeting extension workers, covers conversion of vegetable and fruit wastes into animal feeds in the form of silage or blocks[17]. These resources can be used for feeding during the dry season when availability of feed is low. Approximately 1.3 Gtonnes of food is lost or wasted globally every year, which is estimated to have enormous environmental, social and economic costs. Also the food loss and waste has an impact on food security, natural resource availability, and local and national economies. A part of these losses can be converted to animal feed, without compromising animal product safety and animal and human welfare. This conversion, through technologies such as ensiling, block making, and raising insects, is possible. This would also decrease food-feed-fuel competition and enlarge the feed resource base, contributing to feed and food security. Valuable nutrients in food wastes can be brought back to food chain through their use as animal feed[18, 19]. Recently, a study conducted by Bangladesh Livestock Research Institute, jointly with FAO, explored the possibility of using vegetable waste from whole sale vegetable market in Bangladesh. These wastes had 14-15% crude protein and 85% dry matter digestibility, suggesting it to be a good feed for ruminant livestock. The levels of various hazards such as pesticide, heavy metals and aflatoxin were below the permissible levels[20, 21]. A number of value-added products can also be produced from fruit and vegetable wastes[22].

Spineless cactus

Cultivation of spineless cactus (*Opuntia ficus-indica*) in degraded and marginal lands produces feed in water deficient conditions and also offers possibilities for carbon sequestration and land reclamation. It does not like saline and water logging conditions, but thrives in dry conditions, uneven rainfall and poor soils. It has the potential of not only decreasing the carbon dioxide levels in the atmosphere through the gas exchange pattern, termed as, Crassulacean Acid Metabolism (CAM) but also controlling of soil erosion by providing cover and enhancing afforestation. A biomass yield of 180 tonnes per hectare per year has been recorded in Brazil, and under mixed cropping systems with barley a yield varying from 25 to 100 tonnes has been obtained in Tunisia. The cactus cladodes are low in nitrogen but high in energy and water. A diet containing 60% cactus pods, 20% chopped hay and 20% protein rich concentrate mixture can support a cow yielding 25 litres milk per day[23]. In Tunisia, a study shows that lambs that were fed on straw supplemented with cactus and saltbush grew at the rate of 80 g/day[24]. In South Africa efforts are being made to produce silage from cactus for feeding to animals. For further reading on use of spine-less cattle as livestock feed and human food, refer to FAO[25].

Broadening of feed resource base through use of novel feed resources

Industrial swine and poultry production account for 55% and 71% of global pork and poultry production, respectively. These systems will account for over 70% of the increases in meat production to 2030, especially in Latin America and Asia. The demand for maize and coarse grains is projected to increase by 553 million tonnes by 2050 as a result of this monogastric expansion, and will account for nearly half of the grain produced in the period 2000–2050[26]. Also almost 78% of the grain use for feeding is in the monogastric sector. Novel human-inedible resources such as insect meals, leaf meals, protein isolates from agro-industrial by-products, single cell protein produced using waste streams, algae, co-products of the biofuel industry, etc. have potential to reduce the use of human edible components including soybean in the feed industry, decrease food-feed competition and make the livestock sector more sustainable, especially in developing countries, which require the foods most.

Insect meals

Food waste can also be used as a substrate for rearing insects such as black soldier fly larvae, maggot meal, mealworm larvae, which contain approximately 50% crude protein with good amino acid composition and can replace 50% of the conventional feed resources such as soymeal and fishmeal in the diets of poultry and fish[27, 28]. These approaches convert ‘disposal problems into opportunities for development’.

Distillers grains

These are co-products of the bioethanol industry. Cereals such as maize, wheat, sorghum and barley are fermented to bioethanol. The mass of the dried distillers grains recovered after distillation of bioethanol are approximately one-third of the cereal mass taken for bioethanol production. Global yearly production of distillers grains is approximately 48 million tonnes. It is extensively used as livestock feed. For example, in the United Stated of America the beef industry uses 66% of the available distillers grains, the dairy industry 14%, swine industry 12% and poultry industry 8%. The use of dried distillers grains with soluble (DDGS) as a substitute for the higher priced corn and soya bean in the diets of cattle, pigs, poultry and fish has been recorded, although the optimum levels of inclusion are still being determined. Distillers grains with solubles or with added protein (HP-DDGS) can be fed to pigs at all stages of the production chain. The energy of DDGS is similar to corn, unless the oil has been removed, but the energy of HP-DDGS is higher. The digestibility of P in DDGS is high. Growing pigs, from two to three weeks after weaning can be fed diets containing 30% DDGS, while gestating sows can be fed a diet containing 50% DDGS as long as all amino acid requirements are met. With finishers it may be necessary to withdraw DDGS three to four weeks before slaughter because the higher iodine content could reduce fat quality. Diets for lactating sows can contain 30% DDGS, thus replacing all the soya bean in the diet. It has been observed that DDGS up to 20% in the pig diet did not affect growth, fattening and carcass composition. With laying hens, inclusion levels between 15 and 30% DDGS had no effect on laying intensity, egg quality and hen health, but with broilers there was a suggestion that levels above 10% may reduce performance unless non-polysaccharide degrading enzymes are added to the diet. Wheat DDGS are seen as sources of energy, protein and P for poultry and pigs. Crude protein of DDGS can be as high as 30%, but lysine levels are low and variable, with ileal digestibility lower than with whole wheat especially if the DDGS has any heat damage; the energy value of wheat DDGS is also lower than whole wheat, the difference being dependent on the fibre content of the DDGS; however, wheat DDGS can be included at up to 30% in poultry and pig diets as long as the diet meets the criteria for the desired output[29].

Leaf meals and protein isolate

Moringa oleifera is a very fast growing plant. Moringa if grown as a fodder plant, contains on an average 16-17% crude protein while the leaf meal (without twigs and stems) contains 25-26% crude protein. The quality of moringa protein, in terms of essential amino acid composition and protein digestibility is very high - as good as soymeal. Under intensive cultivation conditions, moringa protein yield per hectare could be almost 5-times higher than that of soybean. Moringa leaf meal is also good source of sugars, vitamins and antioxidants. Moringa leaf meal could be a good replacer of soymeal in monogastric diets, while the twigs and soft stems could be fed to ruminants[30]. Protein isolates prepared using the principle of isoelectric precipitation from protein rich resources such as white clover, rapeseed meal/cake and sunflower meal/cake could also be good substitutes for soymeal in monogastric diets. The process of protein isolate preparation reduces the content of fibre and antinutrients, if any, in the original materials, making them suitable for incorporation into the diets of poultry and swine.

The use of green chemistry is in vogue and the aqueous extraction of oil from oil seeds is an attractive process because it does not use organic solvents. The enzyme cocktails (mix of cellulases, pectinases, proteases, etc.) in the presence of water help extracting oil[31]. In addition, these enzymes convert proteins to protein hydrolysate which have higher biological value than the original proteins. These hydrolysates form a good source of amino acids in the diets of monogastric animals[32].

Enzymes and treatments for second generation biofuel

An extensive research is undergoing on development of enzymes and treatments to enhance the economic viability of the second-generation biofuels production. These could possibly be used for enhancing nutritional value of straws and stovers for feeding to livestock.

Other novel feed resources

Fatty acid distillate and glycerine are co-products of biodiesel industry, produced at first and last step respectively in the transesterification process of converting oil into biodiesel. These are good source of energy and can replace cereals in livestock diets. Further research is required on use of these feed resources in the diets of aquaculture species[29].

Algae co-products[29] and seaweeds could be good sources of protein and minerals. Brown seaweeds have been more studied and are more exploited than other algae types for their use in animal feeding because of their large size and ease of harvesting. Brown algae are of lesser nutritional value than red and green algae, due to their lower protein content (up to approx. 14%) however brown algae contain a number of bioactive compounds. Red seaweeds are rich in crude protein (up to 50%) and green seaweeds also contain good protein content (up to 30%). Seaweeds contain a number of complex carbohydrates and polysaccharides. Brown algae contain alginates, sulphated fucose-containing polymers and laminarin; red algae contain agars, carrageenans, xylans, sulphated galactans and porphyrans; and green algae contain xylans and sulphated galactans. These could be used as prebiotic for enhancing production and health status of both monogastric and ruminant livestock[33].

Cassava residues or sweet sorghum residues obtained after conversion of starch and sugars present in cassava and the sorghum to bioethanol are also good animal feeds[2]. In addition, single cell proteins obtained on growing bacteria and yeasts especially on waste streams could also be exploited as feeds. Agro-industrial by-products rich in starch and sugars such as cassava peal, pineapple waste, culled tomatoes, among others, after their enrichment with a low-cost non-protein nitrogen sources such as urea could be transformed into protein rich products using bacteria, fungi or yeasts, for use in the diets of monogastric animals.

A main principle for successful technology adoption

Development of a business model around a feeding technology

Some of the technologies such as urea molasses block, silage making, urea-ammoniation of straws have been widely demonstrated by a number of organizations since 1980s. However, these have not been widely adopted. In 2011, through an e-conference, we investigated the reasons for their (non) adoption despite great efforts of the development organizations in training the farmers on these technologies. Almost all development organizations trained the farmers in preparing the feeds themselves in the form of urea-molasses multinutrient blocks, silage and ammoniated straw. The farmers used these practices only till the project provided inputs and technical backup services; however, the use of the technology was abandoned soon after the project concluded. Although farmers are convinced of the benefits of the technology, the reasons for not using the technologies after conclusion of the projects were identified as: unavailability of the inputs or their availability at high costs, preparation of feeds not fitting into the farmers’ routine, and preparation of feeds at home taking a lot of time. However, at places where a private organization was involved in the feed preparation, for example in preparing the blocks, straw-ammoniation or silage making, the technologies were being used even after the project had terminated. The private organization was making money and so were the farmers. The private organizations were buying the inputs in bulk which provided them price negotiating power, to purchase them at a low cost. In addition, the private organizations had better skills and equipment to produce the feeds in large amounts and of better quality at a lower cost[13].

Lessons learnt from the above are that for wider and successful adoption of a feed technology, there is a need to develop a business model around the technology and bring on board a private company, preferably run by a young entrepreneur. Technical support must be provided to the private company by a local technical/research institution. A three-tier approach in which technology know-how available with a public technical/research institute could be transferred to a private company[34]. Initial teething problems experienced by a private company in introducing a technology could be addressed by the public institution through technical backstopping. The private company works towards upscaling of the feed technology, make available ready-to-use feed at the farmers doorsteps and disseminate the technology widely, leading to their successful adoption. Policies that facilitate provision of loans to young entrepreneurs, or establishment of a revolving fund by donors to give a push-start to the business will help establish such smallscale businesses. This will create jobs, promote businesses, enhance farmers' profit and bring social benefits.

References

1. Makkar HPS. Feed demand landscape and implications of food-not feed strategy for food security and climate change. Animal, 2017: 1-11.
2. Makkar HPS, Ankers P. A need for generating sound quantitative data at national levels for feed-efficient animal production1. Animal Production Science, 2014, 54(10): 1569-1574.
3. Coughenour MB, Makkar HPS. Conducting national feed assessments. FAO, 2012.
4. Streit E, Naehrer K, Rodrigues I, *et al*. Mycotoxin occurrence in feed and feed raw materials worldwide: long-term analysis with special focus on Europe and Asia. Journal of the Science of Food and Agriculture, 2013, 93(12): 2892-2899.
5. Naehrer K, Kovalsky P. Global state of mycotoxins. AllAboutFeed, 2014, 2(2):10–13.
6. Garg MR, Makkar HPS. Balanced feeding for improving livestock productivity. 2012.
7. Golub AA, Henderson BB, Hertel T W, *et al.* Global climate policy impacts on livestock, land use, livelihoods, and food security. Proceedings of the National Academy of Sciences, 2013, 110(52): 20894-20899.
8. Makkar HPS, Addonizio E, Gizachew L. Characterization of feeding systems in Ethiopia with a focus on dry areas. Broadening Horizons N°51, 2018, 3(51): 1-9.
9. Gerber PJ, Steinfeld H, Henderson B, *et al.* Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities. Food and Agriculture Organization of the United Nations (FAO), 2013.
10. Makkar HPS. Biofuel co-products as livestock feed-opportunities and challenges. Food and Agriculture Organization of the United Nations (FAO), 2012.
11. Makkar HPS. Smart livestock feeding strategies for harvesting triple gain–the desired outcomes in planet, people and profit dimensions: a developing country perspective. Animal Production Science, 2016, 56(3): 519-534.
12. Walli TK, Garg MR, Makkar HPS. Crop residue based densified total mixed ration. Food and Agriculture Organization of the United Nations, 2012.
13. Owen E, Smith T, Makkar H. Successes and failures with animal nutrition practices and technologies in developing countries: A synthesis of an FAO e-conference. Animal Feed Science and Technology, 2012, 174(3-4): 211-226.
14. Feed supplementation blocks: urea-molasses multinutrient blocks: simple and effective feed supplement technology for ruminant agriculture. Food & Agriculture Org., 2007, pp 1-12.
15. Russell JR, Loy DD, Anderson J, *et al.* Potential of chemically treated corn stover and modified distiller grains as a partial replacement for corn grain in feedlot diets. Animal Industry Report, 2011, 657(1): 10.
16. Shreck AL, Nuttelman BL, Griffin WA, *et al.* Chemical treatment of low-quality forages to replace corn in cattle finishing diets. 2012.
17. Wadhwa M, Bakshi MPS. Utilization of fruit and vegetable wastes as livestock feed and as substrates for generation of other value-added products. Rap Publication, 2013, 4: 30.
18. Wadhwa M, Bakshi MPS, Makkar HPS. Waste to worth: fruit wastes and by-products as animal feed. CAB Reviews, 2015, 10(031): 1-26.
19. Bakshi MPS, Wadhwa M, Makkar HPS. Waste to worth: vegetable wastes as animal feed. CAB Reviews, 2016, 11(012): 1-26.
20. Das NG, Huque KS, Amanullah SM, *et al.* Study of chemical composition and nutritional values of vegetable wastes in Bangladesh. Veterinary and Animal Science, 2018, 5: 31-37.
21. Das NG, Huque KS, Amanullah SM, *et al.* Feeding of processed vegetable wastes to bulls and its potential environmental benefit. Animal Nutrition, 2018.
22. Wadhwa M, Bakshi M P S, Makkar HPS. Wastes to worth: value added products from fruit and vegetable wastes. CAB International, 2015: 1-25.
23. Dubeux Jr JCB, Dos Santos MVF, de Mello ACL, *et al.* Forage potential of cacti on drylands. VIII International Congress on Cactus Pear and Cochineal 1067. 2013: 181-186.
24. Isaac AA. Overview of Cactus Opuntia ficus-indica (L): A myriad of alternatives. Studies on Ethno-Medicine, 2016, 10(2): 195-205.
25. FAO. Crop ecology, cultivation and uses of cactus pear. Food and Agriculture Organization of the United Nations (FAO), Rome, Italy, 2017.
26. Herrero M, Thornton PK, Gerber P, *et al.* Livestock, livelihoods and the environment: understanding the trade-offs. Current Opinion in Environmental Sustainability, 2009, 1(2): 111-120.
27. Makkar HPS, Tran G, Heuzé V, *et al.* State-of-the-art on use of insects as animal feed. Animal Feed Science and Technology, 2014, 197: 1-33.
28. Tran G, Heuzé V, Makkar HPS. Insects in fish diets. Animal frontiers, 2015, 5(2): 37-44.
29. Makkar HPS. Biofuel co-products as livestock feed-opportunities and challenges. Food and Agriculture Organization of the United Nations (FAO), 2012.
30. Foidl N, Makkar HPS, Becker K. The potential of Moringa oleifera for agricultural and industrial uses. In: (Ed) Fuglie LF. The Miracle Tree: The Multiple Attributes of Moringa, CTA, Wageningen, The Netherlands., 2001, 45-76.

31. Yusoff MM, Gordon MH, Niranjan K. Aqueous enzyme assisted oil extraction from oilseeds and emulsion de-emulsifying methods: a review. Trends in Food Science & Technology, 2015, 41(1): 60-82.
32. Latif S, Kumar V, Stadtlander T, *et al.* Nutritional and biochemical studies on feeding of hydrolysed and unhydrolysed detoxified Jatropha curcas protein isolate in common carp fingerlings. Aquaculture Research, 2016, 47(12): 3873-3887.
33. Makkar HPS, Tran G, Heuzé V, *et al.* Seaweeds for livestock diets: a review. Animal Feed Science and Technology, 2016, 212: 1-17.
34. Makkar HPS. Towards zero waste and sustainable food production using human-inedible agroproducts and food loss and waste as animal feed. Sustainable value chains for sustainable food systems, 2016, 29-38.

Livestock production in Malaysia: current status and sustainable development through enlarging feed resource base and enhancing feed efficiency

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Abstract

Malaysia is self-sufficient in poultry meat, eggs and pork; however, beef, mutton and milk productions are far below the demand. The low self-sufficiency level (SSL) for products from the ruminant sector is primarily due to the lack of high genetic potential breeding stock adapted to the hot and humid environment and affordable quality feed for efficient production. The productions of poultry, eggs and pork are heavily depending on imported feed. The production of feed-corn and soybean locally for the poultry and pig industries is not viable because of high costs. Good quality feed including forage are also lacking for efficient production of ruminant livestock. Thus, sustainable development through enlarging feed resource base and enhancing feed efficiency provide an opportunity to enhance livestock production in Malaysia.

Introduction

Malaysia is self-sufficient in poultry meat, eggs and pork (Table 1). The achievement of both poultry and pig industries in meeting the domestic demand is driven primarily by the availability of breeding stock and feed at competitive prices. On the other hand, the ruminant industry lacks the important inputs, especially good quality feeds for efficient production of beef, mutton and milk.

In general, livestock sector accounts for about 12% of the total agricultural gross domestic product (GDP) with the poultry sub-sector contributing 63% of the livestock GDP while the ruminant sub-sector contributes only 12.1%. However, the poultry and the pig industries depend heavily on the importation of feed ingredients to sustain their production. The livestock industry also provides around 20% of national labour force and thus is important for the livelihood of the rural populations. The Malaysian National Agro-food Policy 2011-2020 (NAP) forecasted that the annual demand and production of meat are expected to increase at 2.4% and 2.7%, respectively. Thus, although the overall livestock industry in Malaysia looks promising over the near future, there are a number of challenges, particularly the over-dependence of imported feed ingredients for the monogastric (poultry and pigs) animals and lack of affordable good quality feed to expend the ruminant industry which Malaysia needs to overcome in order to enhance long-term sustainable development of the livestock industry to ensure national food security. This paper focuses on stainable development of livestock industry in Malaysia through enlarging feed resource base and their efficient utilisation.

Table 1 Percent self-sufficiency levels of animal products in Malaysia (2011-2017)

Commodity	2011	2013	2015	2017
Beef	29.2	25.7	23.1	23.4
Mutton	15.3	15.5	11.5	11.4
Pork	94.6	96.9	93.6	90.3
Poultry meat	105.6	104.9	104.2	103.3
Eggs	115.4	119.4	114.0	119.1
Milk	134.1	76.6	64.4	58.7

Source: Department of Veterinary Services, Malaysia, 2017

The feeding systems

Ruminants

Feeding systems for ruminants in Malaysia can be categorized into the following three systems:

Grazing. The bulk of the cattle, buffaloes, sheep and goats are owned by the small-holder farmers having between 1 to 10 heads per household. These animals are left to search for their own food, mainly grazing on native grass naturally available on vacant lands around the villages and mostly without any supplemental feeds. In some villages, communal grazing lands are provided by the Department of Livestock Services (DVS) for the animals. Productivity of animals under this feeding system is very low. To enhance the productivity of the animals, the so-called "high yielding" exotic pastures and legumes, particularly from Australia, were introduced in the early 70s to improve the local feed resources for ruminant animals. The introduction of these exotic pastures also led to the establishment of large-scale cattle farms based on open grazing system. Unfortunately, this open grazing system was not sustainable because it required high input cost and management skill. Currently only a handful of these large-scale grazing farms, belonging to or partly owned by the government have remained.

Feedlot. Concurrently with the introduction of exotic pastures, some commercial cattle feedlots were also established in the same period to take advantage of the abundant agro-byproducts available locally. Young feeder cattle, mainly from Australia, were imported to feed on the agro-byproducts such as palm kernel cake (PKC), cocoa pots, fruit-wastes from the pineapple canneries and other food industries. However, large-scale cattle feedlots did not last long as costs of some of these byproducts, such as PKC, increased many folds due to export demand. In addition, because of shortage of land, managing the waste from feedlots was almost impossible for many farms and thus they were forced to close their operation. Currently feedlot is still a popular feeding system for both cattle, sheep and goats by some small-holder farmers and also in temporary transit-farms owned by trading companies which import breeding and feeder stocks from overseas.

Integrating ruminants under oil palm plantations. Malaysia is the second largest palm oil producing country, after Indonesia. Malaysia has a total of 5.8 million ha of oil palm plantation (http://bepi.mpob.gov.my/images /area/2017/Area_summary.pdf) covered with a wide variety of native forages[1]. A systematic management system to rotationally graze the naturally available forages under the oil palm plantation has been developed in Malaysia. Depending on the age of palm which in turn determines the availability of the forage, the averaged carry capacity currently practiced is 3 to 4 ha per cattle (ESPEK Livestock Sdn. Bhd. Malaysia, personal communication). It thus suggests that the forage resource available in the 5.8 million ha of oil palm plantation in Malaysia is sufficient to feed more than a million cattle, equivalent to all the large ruminants (800,000 cattle, 120,000 buffaloes) in the country.

Monogastric animals

i *-Poultry.* Poultry continued to be the major livestock sub-sector since 1990s with ex-farm value of US $4.4 billion in 2017, contributing 78% of total livestock value. Malaysia exports 7% of the broiler chickens and 15% of eggs on annual basis. Poultry meat and egg registered the highest rate of increase in consumption, average 6% per year (Table 2) and are expected to increase with the same rate till 2020. In the broiler industry, the number of farm is gradually getting smaller but with higher production capacity due to severe market competition. Currently the broiler industry has 10 integrators with 2403 contact farmers, producing the bulk of the national poultry meat with the remaining from individual medium and smaller farms. A typical integrated poultry operation consists of breeder and hatchery to supply the day-old chicks, and feed mill to produce the feed for the grow-out farms to produce the broiler chickens. Most integrators also have their own market channels to sell their products (Figure 1).

Table 2 Per capita consumption of livestock products in Malaysia (2011-2017)

Commodity	2011	2013	2015	2017
Beef (kg)	5.8	6.6	7	6.5
Mutton (kg)	0.7	1	1.2	1.3
Pork (kg) only non-Muslim	19.5	18.5	18.9	16.6
Poultry meat (kg)	42.1	45.8	49.9	51.5
Chicken eggs	309	314.5	370.4	337.7
Milk (L)	0.7	1.3	1.8	2

Source: Department of Veterinary Services, Malaysia

ii-*Poultry eggs.* Poultry egg industry in Malaysia has grown rapidly over the decades and turned into one of the modern industries. There are approximately 370 layer farms producing 40 million eggs daily with about 6 large companies producing more than 1 million table eggs per day each. Thus, the bulk of the eggs are still produced by intermediate and small scale farmers. The most preferred eggs are brown eggs but variety of designer-eggs claimed to be enriched with micro-nutrients, vitamins and low cholesterol are also produced (http://www.flfam.org.my/ index.php/industry-info/the-poultry-industry/table-egg-production). The five most popular layer breeds in Malaysia are Hisex, Lohmann Brown, H & N Brown, ISA Brown and Novogen.

iii-*Swine.* In 2017, there were 509 swine farms carrying a total population of about 1.4 million heads. Many small farms have closed down due to economic viability and environmental factors but the bigger farms are expanding their production capacity (http://flfam.org.my/index.php/ industry-info/the-swine-industry). Except for a few large commercial farms, majority of the swine farms in Malaysia evolved from traditionally family-owned farms keeping between 50-1,000 sows per farm. These farms are mainly located in peri-urban areas next to the larger cities along the west coast of Peninsula Malaysia which have larger number of non-Muslim population. The biggest concern of these family-own farms is shortage of land space to manage the waste resulting in environmental pollution. Similar to the poultry industry, swine are fed with compound feed produced by commercial feed mills or self-mixed compound feed prepared through years of self-experience by the farmers or on the advice of feed ingredient and feed supplement suppliers. The use of local feed ingredients is also limited to small quantity of rice bran, PKC ad CPO. The feed conversion ratio of swine in Malaysia averaged 3.08, achieving an average daily gain of 681g from weaning to market (https://www.angrin.tlri.gov.tw/English/2014Swine/p153-166.pdf).

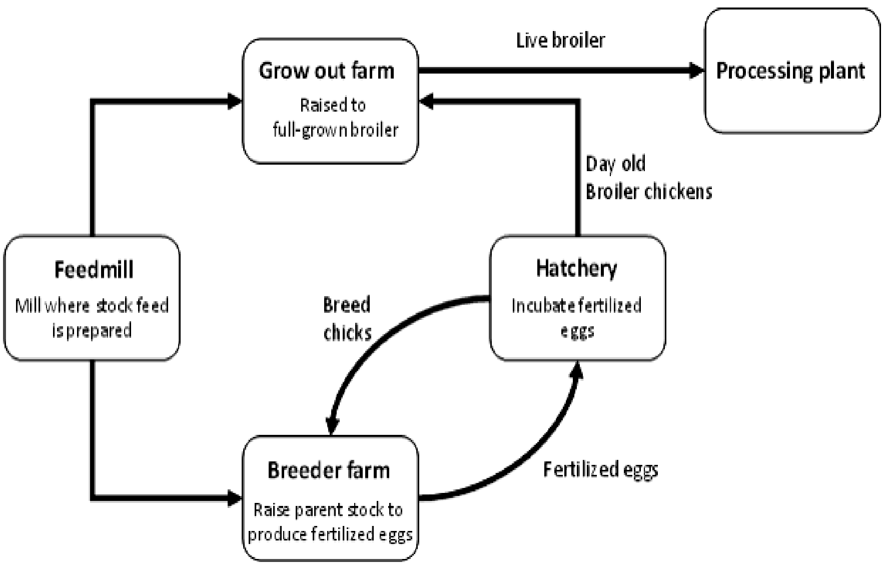

Figure 1 Typical operation of an integrated poultry farm

Available feed resources

Malaysian agriculture is primarily based on plantation crops production, including oil palm, rubber and cocoa with oil palm being the major crop. Currently, Malaysia is the second largest producer of palm oil, after Indonesia, and the palm oil industry is the fourth largest contributor to the national economy (http://theoilpalm.org/economic-contribution). Production of the traditional feedstock (corn and soybean) for livestock, especially for the monogastric animals, is almost non-existing because of the unfavourable climatic conditions and high cost of production. Thus, nearly 85% of the feedstock for poultry and pig industries in Malaysia are imported, making the two livestock sub-sectors unsustainable in the long term. Nevertheless, there are numerous agro-byproducts from the crop industries which can be used to support both, the monogastric and ruminant livestock production. Availability of the major agro-byproducts in Malaysia and their use for the livestock industry are presented in Table 3.

The most important local byproduct use as animal feed is palm kernel cake, commonly called PKC. However, majority of the PKC produced in Malaysia is exported primarily to China, New Zealand, Korea and EU as feedstock for cattle. The export demand has created an increase in price (US $ 100-250 per metric ton depending on seasonal demands) for this byproduct making it difficult for local small-holder farmers to use it. Being a byproduct from the extraction of the palm kernel oil, the quality of PKC is not regulated and thus the nutrient content, particularly oil and shell contents, varied greatly from mill to mill and season to season. And together with the high fiber content, PKC is used in very small quantity (~5%) in poultry and pig diets. Although research has shown that oil palm fronds (OPF), oil palm trunk (OPT) and palm oil sludge can be used as a feed ingredient for ruminants, the actual quantity of these materials used as feed is limited. Similarly, the feeding of rice straw to ruminant animals in Malaysia is also limited. Fruit-wastes, particularly pineapple peels from the canneries and cocoa peels are used to some extents in areas where these byproducts are produced. However, there are great opportunities to expand the use of these byproducts for ruminant feedings.

Status of feed industry and regulatory authority

As mentioned earlier, feed ingredients used for poultry and swine industries are not produced locally and thus they are mainly imported. The imported ingredients range from cereal grains, vegetable and animal proteins (soybean meal, corn gluten meal, fish meal and meat and bone meal), minerals and micro-ingredients and other additives used to enhance feed efficiency and growth. Some local feed ingredients such as rice bran, PKC, palm oil, molasses, broken rice, tapioca, sago, rice husk, rubber seed meal etc are also used.

Table 3 Availability and use of agro-byproducts in different livestock industries in Malaysia

Crop	Byproducts	Availability	Use by
Oil palm	Palm kernel cake	++	Ruminant, limitedly for monogastric
	Oil palm fronds	+++	Ruminant
	Oil palm trunk	++	Ruminant
	Palm oil sludge	++	Ruminant
	Forage under palm	++	Ruminant
Rice	Rice straw	+++	Ruminant
	Rice Husk	++	Ruminant
	Rice bran	+	Ruminant and monogastric
Fruit waste	Pineapple peels	+	Ruminant
Cocoa	Cocoa peels	++	Ruminant
Rubber	Rubber seed meal	+	Monogastric
Brewery	Brewery grains	+	Ruminant

Note: +available in low quantity, ++ in intermediate quantity, +++ in large quantity

Malaysia imports feedstuffs to the value of US $2 billion annually. Currently, there are 53 feed mills in the country that produce approximately 6 million metric tonnes of commercial compound feed yearly (2.7, 1.6, 1.5 and 0.2 million metric tonnes for broiler, layer, swine and others, respectively) with total revenue of US $2.4 billion. More than 90% of the compound feed is consumed in the monogastric animals and the rest in aquaculture and ruminant industry. In addition, there are 250 on-farm feed producers especially in the swine industry. The major feed ingredients for the poultry are corn (50-55%) and soybean meal (25-30%) which are imported. The local feedstuffs accounted approximately 15% of ingredients and are mainly including rice bran, PKC and crude palm oil (CPO) (http://www.doa.gov.my/index/resources/aktiviti_sumber/sumber_awam/penerbitan/kertas_pembentangan/ kertas_kerja11.pdf).

Although Malaysia is self-sufficient in poultry meat and eggs since early eighties, the industry is not sustainable in the long term due to heavy dependence on imported feed which continued to increase. Cultivation of corn and soybean is not viable due to the climatic conditions and high cost of production. However, utilization of local agro-byproducts such as PKC offers a possible solution to the over dependence on importation of feedstuffs. For the poultry and swine industries to remain competitive in the free trade economy system, efficient utilization of local feedstuffs needed to be developed.

Department of Veterinary Services (DVS), Malaysia is the regulatory authority for the feed industry in Malaysia. An updated version (1 July 2014) of the Feed Act 2009 (Act 698) is available on line at the home page of the Ministry of Agriculture and Agro-based Industry, Malaysia (http://www.agc.gov.my/agcportal/uploads/ files/Publications). In brief, the Act is "to establish the Feed Board, to regulate feed quality by controlling the importation, manufacture, sale and use of feed and feed additive, to ensure that feed satisfies nutritional requirement of animals, is not harmful to animals and is not contaminated so that animal products are safe for human consumption and other usage, and for other matters incidental thereto". Because of the large numbers of small-holder farms, regulating and monitoring to ensure adoption of the Feed Act is challenging.

Challenges and opportunities in enhancing utilization of locally available feed resources and enhancing feed use efficiency

In Malaysia, although there are a number of agro-byproducts which can be used as feed ingredients, many of them are only available seasonally or in small quantity, and thus they are rarely used by the farmers. On the other hand, byproducts which are available in larger quantity are mainly fibrous agro-byproducts, such as PKC, oil palm fronds and rice straw, suitable only for feeding to ruminants. Although utilization of these unconventional feed resources faces numerous challenges, such as high cost of collection and transportation due to their bulky nature and difficulty in meeting the nutrient requirements of the animals because of their poor quality, nevertheless opportunities to use these resources remain viable. The use of physical, chemical and biological treatments to breakdown the fiber component of rice straw, oil palm fronds and other similar materials have been extensively researched[2-3] and some of these technologies are been adopted by farmers. We have recently developed a technology to treat rice straw with *Aspergillus terreus* (fungus), which hydrolyses the fiber component leading to enhanced digestibility and also produces lovastatin, capable of reducing enteric methane emission (Table 4)[4]. This environmentally-friendly technology has been extended to use PKC in place of rice straw as the substrate to obtain higher concentration of lovastatin and also allow easy delivery of the targeted naturally produced lovastatin to the animals[5]. It is anticipated that this and other technologies can open new opportunities to enlarge the use of local feed resource and enhance feed efficiency for ruminant production in Malaysia and beyond.

Table 4 Effect of feeding Aspergillus terreus treated rice straw on CH4 production and dry matter (DM) digestibility in goats[6]

	Control*	**Treated**	**% change**
CH4 production (L/day)	20.1 ± 3.19^{a}	13.3 ± 1.57 ^{b}	- 34.1
CH4 production (L/day/kg DM intake)	42.3± 6.71 ^{a}	27.9 ± 3.30 ^{b}	- 34.1
DM digestibility (%)	69.9 ± 4.47 ^{b}	80.0 ± 5.27 ^{a}	+ 12.6
CH4/kg DMD intake	60.5 ± 9.60 ^{a}	34.9 ± 4.12 ^{b}	- 42.4

Note: *untreated rice straw^{a,b}: indicating means within rows with different letters differed significantly (P<0.05).

The most economically important agro-byproduct in Malaysia is PKC. Malaysia produced 2.1 million metric tons of PKC annually (http://bepi.mpob.gov.my/index.php/en/statistics/production/177-production-2017/795-

production-of-palm-kernel-cake-2017.html) and majority of the PKC is exported to New Zealand, China, Korea and EU countries as feed ingredients for ruminants, particularly dairy cows. Although the export of PKC contributes to the national income, the Malaysian government is promoting the use of PKC as feed ingredient for local poultry and pig productions which now almost totally depend on importation of their feedstock. The Institute of Tropical Agriculture and Food Security, UPM has recently spearheaded a holistic research program to achieve the above objective. Among the outputs from the programme include: i) Enzymatic[7] and removal of shell enhanced nutritive value of PKC, ii) treated PKC can be included up to 25% in finishing poultry, which reduced feed cost by US $0.07 per bird produced (unpublished data) and iii) Oligosaccharides mainly in the form of mannan-oligosaccharides in PKC is a good source of prebiotics[4-8]. However, feed formulation based on local feedstuffs such as PKC needs thorough investigation before it can be commercialized.

One of the key priorities in the Malaysia agriculture policy is to increase ruminant production to raise the SSL for beef, mutton and milk which are lagging far behind the demands. Ruminant production in Malaysia faces numerous challenges, such as (i) limited number of good animal to increase the breeding stocks, (ii) heat stress imposed on the animals, particularly the high producing breeds, due to high ambient temperature and humidity, (iii) limited local availability and poor quality of feedstock and (iv) the importation of cheaper low-quality beef and mutton from the neighboring countries. Thus, ruminant production in Malaysia must adopt systems which can produce beef, mutton and milk at competitive prices. One potential production system is the integration of ruminants under oil palm plantations. Integrating cattle (and sheep) under oil palm plantation has been practiced in various scales by farmers in Malaysia decades ago. However, adaptation of a more systematic rotational grazing of the available forages under plantations, initiated by some commercial-scale oil palm (and to lesser extents, rubber) plantations, started in the early 70s. Forage availability at various ages of oil palm and rubber (Figure 2) and their quality, with crude protein averaged between 12 to 25%, respectively for grass and legume[1] indicate a carrying capacity of one cattle per 3 ha land.

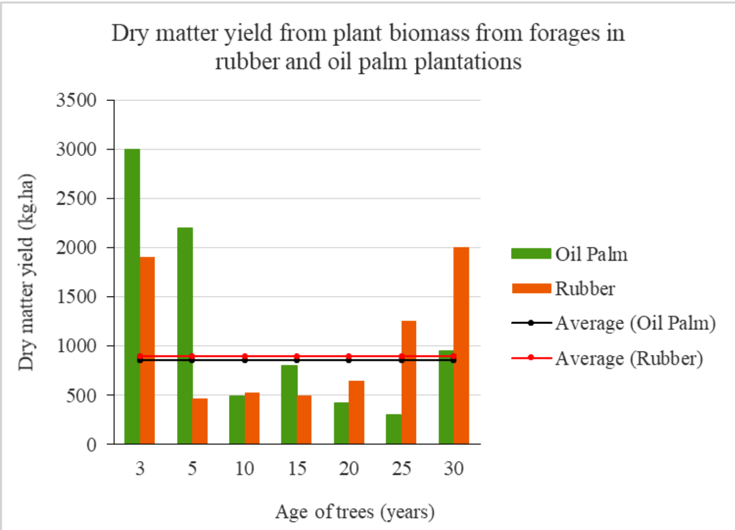

Figure 2 Dry matter yield of forages in oil palm and rubber plantation in Malaysia[9]

Thus with the current 5.8 million ha of oil palm plantation in Malaysia, it can carried approximately a million cattle, which is equivalent to the current total cattle population in the country. However, the adoption of grazing cattle under oil palm plantations has not been very encouraging in the last decade, partly because of lack of determination to implement the system it at the plantation management level. However, ESPEK Livestock Sdn. Bhd., a subsidiary of the RISDA Plantation had been producing live cattle under oil palm plantation for the last 4 decades. The company has now also process and market their own beef and beef related products produced from their farms.

Conclusion

The Malaysian livestock industry contributes significantly to the national economic, food security and provides employments and livelihoods to millions of its population. Although the nation is self sufficient in poultry meat and eggs and pork, the overdependence on importing the raw feed ingredients to support the above two sub-sectors is unsustainable in term of long term national food security. On the other hand, the productions of beef, mutton and milk are lagging far behind the continuous increasing demand for these animal products. Although the above scenarios are affected by a range of constraints, feedstock is identified as a major issue which needs to overcome to ensure a more sustainable livestock production environment in Malaysia. R&D to further knowledge and innovation to enlarge feed resource base, particularly of the locally available unconventional feed resources, and to enhance feed efficiency offer an important avenue in developing long-term sustainability of livestock industry in Malaysia.

References

1. Chin FY. Some aspects of management and utilization of ground vegetation under rubber and oil palm for animal production. 1991, 121-128

2. Bengaly K, Liang JB, Jelan ZA. Optimization of steam treatment as a method to increase in situ degradability of oil palm (Elaeis guineensis) frond in Malaysia. Livestock Research for Rural Development, 2004, 16:45-53.

3. El-Razik IMA, Abd E-RGA, Ayyat MS. Effect of biological and chemical treatments of rice straw on lamb performance. Zagazig Journal of Agricultural Research, 2012, 39:655-664.

4. Jahromi MF, Liang JB, Abdullah N. Extraction and Characterization of Oligosaccharides from Palm Kernel Cake as Prebiotic. Bioresources, 2015, 11:674-695.

5. Liang JB, Mahadzir MF, Garba S. Effect of Feeding Increasing Levels of Aspergillus terreus Fermented Palm Kernel Cake on Methane Emission in Goats. 2017

6. Azlan PM, Jahromi MF, Ariff MO. Aspergillus terreus treated rice straw suppresses methane production and enhances feed digestibility in goats. Tropical Animal Health & Production, 2017, 21:1-7.

7. Alshelmani MI, Loh TC, Foo HL. Biodegradation of Palm Kernel Cake by Cellulolytic and Hemicellulolytic Bacterial Cultures through Solid State Fermentation. The Scientific World Journal, 2014, 21:729852.

8. Faseleh JM, Shokryazdan P, Idrus Z. Modulation of Immune Function in Rats Using Oligosaccharides Extracted from Palm Kernel Cake. BioMed Research International, 2017, 6:2576921.

9. Chen CP, Shamsudin AB. Limitation of forage availability on cattle productivity under oil palm. 1991, 139-147.

Livestock production systems, status on national feed resource availability and future developments, and challenges and opportunities to efficiently utilize locally available feed resources and to enhance feed use efficiency

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Abstract

Domestic demand for livestock products will continue to grow in Thailand, while exports will be accelerated due to increase in world's population and income growth in developing countries. Growing food and feed demand, investments in the livestock and export of livestock products have influenced land use changes, livestock production systems and feed resources utilization. Thailand is one of the leading Asia Pacific Hub for animal feed industry, increasing approximately 50% over the past decade, with increasing use of corn, cassava and oilseed cake as inputs into the compound feed production. The country produces surplus food for humans and is relatively sufficient in major feed ingredients for livestock feed and nutrient requirement except for protein feed sources for non-ruminant. Poultry and pig intensive production system are likely to be key factors influencing protein source feed imports, which is expected to continue to increase in the future. Insufficient feed intake, digestibility and energetic efficiency utilization, and thus low ruminant production efficiency have been identified the major constraints, and to overcome these constraints has been identified as the future research issue. Furthermore, research is needed on efficient use of locally available quality feed resources and development of feeding innovation that combine the use of concentrate supplements with forages, crop residues and/or agro-industrial co-products.

Introduction

In Thailand, livestock industry is an integral part of farming and rural life, providing food, family income and employment. Within the context of world population growth and economic development, consumption of animal products has been increasing, alongside increasing regulatory pressures related to food safety concerns, and concerns about environmentally sustainability. Growing food and feed demand (influenced by rice, and cassava availabilities and export of livestock products e.g. chicken industry) and investments in the bio-energy sector have influenced prices of feed grains and induced land use changes (e.g. shift from corn, cassava, and sugarcane to rubber tree and palm oil production). It is clear that there is a growing need of current and future food-feed supplies as well as of livestock products, and information and data about all of these are needed for planning national food security policy. This paper analyses the changing patterns of livestock production systems, available feed resources and requirement for feed production and utilization for livestock in Thailand.

Livestock production systems

The major livestock species are chicken, swine, dairy cattle and beef cattle, while goat and sheep form only a very minor composition of national stocks (Table 1). The two main livestock production systems, extensive and intensive are classified as follows.

Intensive system or commercial farming operations are characterized by larger herds per farm. The introduction of intensified modern livestock operations (dominated by contract farming system/companies) over the past 30 years has resulted in a decline in the number of back-yard growers and a structural change from extensive to intensive production system especially in dairy cattle, swine, broiler, layer and duck. Broiler products (commercial chicken cuts) are the main commodity for export while other non-ruminant species and ruminant are produced for domestic consumption and small scale trading. The average boiler farm size is now 6,000 birds per farm with corporate farms holding over 100,000 broilers per farm, which are characterized by closed semi-automatic housing systems and use large fans and water to cool houses to 28 degree Celsius, thus saving housing and labor costs and reduce mortality rates. The farm size of swine is up to 300 sows (for contract farms) or 2400 sows (for corporate farm)[1]. The shift to large scale operations is driven by benefits associated with economies of scale in both production and marketing, input procurements and risk management when compared to smaller operations. Thailand expects to continue as an exporter of chicken cuts at least till 2030. However, Thai exporters, recognizing the importance of adding value to export products while being a large net importer of animal feedstuffs (corn, soy bean meal and fish meals), did not attempt to export fresh whole chicken from the beginning, capitalizing on higher value cuts. The rapid intensification of poultry and pig production has; however, increasingly raised issues related to environmentally friendly production practices, animal welfare, diseases and bio-security (e.g. Highly Pathogenic Avian Influenza). The growth of the dairy cattle population (Table 1) and production has increased in the past decade. The largest population of dairy cattle is in the central region (average 30 cattle per farm on 3.2 hectare land holding) with total milk production totaling approximately 967,844 tonne per year. The number of dairy cattle has increased approximately 50% over the last decades.

Table 1 The livestock number (million heads) in Thailand

Year	Beef Cattle	Dairy Cattle	Buffalo	Swine	Broiler	Hen	Native Chicken	Duck
2008	6.7	0.4	1.7	7.8	123.5	36.7	58.8	15.8
2009	6.6	0.4	1.6	7.4	129.6	38.7	59.8	15.9
2010	6.4	0.5	1.6	7.6	131.3	39.4	61.1	15.9
2011	5.8	0.5	1.5	7.7	137.6	40.4	62.6	15.8
2012	5.3	0.5	1.5	7.8	221.5	41.9	63.8	15.1
2013	4.9	0.5	1.2	7.6	236.8	45.4	58.5	21.7
2014	4.5	0.5	1.0	7.5	235.9	46.2	59.3	21.6
2015	4.4	0.6	0.9	7.1	248.9	48.5	60.4	20.9
2016	4.5	0.6	0.9	6.8	259.1	48.8	59.8	20.8
2017	4.6	0.6	0.8	7.5	283.9	50.1	60.1	21.3
Change (%)	-29.8	+50.0	-52.9	-3.8	+129.8	+36.5	+2.2	+34.8

Source: OAE (2018) (http://www.oae.go.th/download/download_journal/yearbook61.pdf)

The rearing of livestock species: beef cattle, buffaloes, native chicken, goats and pigs, kept in low input or integrated crop-livestock farming systems form the extensive production system. A large proportion of good arable land has been used for main crop production which includes rice in the low lands, cassava, sugar cane, pineapple, corn and other crops on uplands as are oil palm and rubber trees while the remaining low fertile land is used for ruminant grazing. The major ruminant population is the cattle beef production, which serves the local beef and premium beef markets (growing at 15% per yearly. The beef cattle and buffaloes numbers continue to decrease (Table 1), reflecting land use change which is intensifying food-feed-bio energy crop production that has limited the growth of extensive production system that depending on crop-by product and/or natural forage grazing area and household labor availability.

Status on national feed resource availability and future developments

Thailand is located in tropical and monsoon region and supported by a number of plantations, producing human food and animal feed. It is one of the world's major rice, palm oil and cassava exporter. Major crops produced include rice, maize/corn grain, cassava, sugar cane, oil palm, soybeans, coconuts and rubber tree which are for human consumption/use with crop by-products and wastes used for livestock production. For non-ruminants, including broilers, layer hens, meat ducks and pigs, feed availability is linked to commercial compound feed manufactured by feed factories. Main commercial compound feed ingredients for non-ruminants include corn, soybean and other oils seed cake, cassava, broken rice and rice bran. The country produces surplus food for humans and is relatively sufficient in major feed ingredients for livestock except for protein feed requirements for non-ruminant.

Thailand is one of the leading Asia pacific Hub for animal feed production [2], increasing approximately 50% over the past decade, with increasing use of corn, cassava and oilseed cake as inputs into the compound feed industry. As a major producer and exporter of meat from non-ruminants, particularly pig and poultry, the compound feed industry in Thailand has witnessed very fast growth. The Thailand Feed Mill Association has 51 members that commercially produced compound/concentrate feeds. The Thailand Feed Mill Association (2018) publishes data on national compound feed production with the compound feed estimated annually shown total quantity of compound feeds produced in Thailand increased approximately 22% over the past 5 years to 20,080,934 tons, and it is distributed among the major livestock species, mainly broilers (33%), layer hens (12%), finishing pigs (28%) and other species included fish and shrimp (Table 2).

Results of the estimated available feed resources and composition are presented in Table 3. The annual feed availability in Thailand totaled 51,519,301 tons, derived mainly from crop residues (32%), grain by-products (8%), roots (29%) and by-products (4%) and grains (6%). Crop residues are the major sources of dry matter (DM) and metabolizable energy (ME), accounting for 32% and 36% of total supplies, respectively, while cassava is the largest source (41%) of energy feed sources.

Table 2 Estimate livestock compound feed productions (tonnes) in Thailand, from 2014 to 2018

Species/Year	2014	2015	2016	2017	2018	Change (%)
1. Broiler	5,328,037	6,095,520	6,195,480	6,345,394	6,535,797	+22.6
2. Broiler parent stock	733,824	854,784	868,896	912,240	939,456	+28.1
3. Layer pullets and chicks	812,283	977,383	1,010,244	1,010,244	921,801	+13.4
4. Layer hens	1,880,000	2,149,600	2,216,000	2,335,767	2,377,747	+26.4
5. Layer parent stock	27,200	30,400	31,200	31,200	28,800	+5.8
6. Finishing pigs	4,720,000	4,867,500	5,256,900	5,448,600	5,659,200	+19.8
7. Breeder pigs	883,500	920,700	957,900	995,100	993,240	+12.4
8. Meat ducks	264,600	264,600	264,600	264,600	310,800	+17.4
9. Layer ducks	22,995	22,995	22,995	22,995	23,360	+1.5
10. Breeder duck	169,000	195,000	214,500	379,600	391,280	+131.5
11. Beef and dairy cattle	620,865	620,865	620,865	850,275	875,453	+41.1
12. Shrimp	450,000	390,000	450,000	450,000	480,000	+6.6
13. Fish	600,453	544,000	533,120	533,120	544,000	-9.3
Total	16,512,757	17,933,347	18,642,700	19,579,135	20,080,934	+21.6

Source: Thailand Feed Mill Association (2018) (http: //www.thaifeedmill.com)

The estimate of national feed balances using the Department of Livestock Development feed assessment model is presented in Tables 4 and 5 which indicated a surplus of feed availability in terms of dry matter (DM) (+27%), digestible crude protein (DP) (+9%) and ME (36%). Crops, crop by-products and co-products (crop residues, grain by-products, roots, roots by-products, grains, crop by products) were major sources of feed DM (75%), DP (51%) and ME (82%). Imported feeds (soybean meals and protein supplements) are supplies a significant quantity of DP (32%).

Challenges and opportunities to efficiently utilize locally available feed resources and to enhance feed use efficiency

Besides producing a large quantity of food and feed, Thailand is importing and will continue to import large quantities of raw materials especially protein source (e.g. soybean meal) for pig and poultry feed production. Therefore, increased consolidation of the poultry and pig industries is likely to be a key factor influencing protein source feed imports, which is expected to continue to increase in the future.

However, ruminant production systems, currently challenged by periodic feed shortages, need to develop an increased linkage between quality feed production and specialized large farm size (e.g. beef fattening, milking cows system) to manage operational risk in a low return business. Ruminant feeding systems are based largely on local agro-industrial by-product based feed and on natural grasses fed in the traditional crop-rice-livestock based mixed farming system. The majority (95%) of extensive beef production system has use no cereal grain or concentrate feed supplements[3]. Ogino *et al.*[3] also demonstrated that the environmental impacts of the extensive and intensive finishing zebu beef production (per kg of live weight) were 14.0 and 10.6 kg CO_2 equivalents for climate change, 3.5 and 11.3 MJ for energy consumption, and 47.4 and 61.8 g SO_2 equivalents for acidification, respectively. In case of beef-dairy cattle, a shortage of feed, both in terms of quantity and quality, is a major constraint and is expected to pose larger obstacles as farm sizes increase. Shortage of good quality roughage force farmers to use rice straw and/or other crop residues, resulting in limited voluntary intake, digestibility, nutrient and energy balance, which consequently impacts productivity and environmental sustainability. This has become a particular challenge for the livestock sector given that stocks of zebu cattle in developing countries in tropical regions now account for more than half of the global beef cattle population. Chaokaur *et al.* reported that increasing feeding level caused an increase in the daily weight gain of Brahman cattle and that the observed increase in energy efficiency was attributed to reduced energy losses in urine, methane and heat production. Enteric methane energy losses decreased (from 11.5 to 7.3% of gross energy intake, GEI) with increasing feeding level[4]. Tangjitwattanachai *et al.* confirmed that greater dietary intakes in Thai native beef cattle resulted in improved efficiency of energy utilization, and thus enhanced energy retention because of the reduction in enteric methane energy emission and heat production dilution. Enteric methane energy and heat energy production losses also linearly decreased with increasing ME intake levels. Enteric methane energy losses ranged from 8.4 to 10.0%, although these values are much higher than the IPCC recommended value (6.5% of GEI) for calculation of national inventory of enteric methane emissions. The relationship between the carbon footprint and the daily weight gain or feed per gain (Figure 1) suggested that increasing productivity reduced greenhouse gas emissions, thus improved environmental sustainability[5].

Table 3 Estimated available feed resource supply and composition in Thailand (year 2012)[6]

	Feed resources	Composition of available feeds		
		DM (tonne)	**DP (tonne)**	**ME (million MJ)**
1	Crop residues			
	Rice straw	8,696,151	313,061	57,916
	Corn stem and aerial parts	651,608	54,083	6,321
	Cassava leaf	133,228	29,577	1,549
	Molasses	1,813,029	81,586	27,087
	Sugar cane top	275,521	19,838	2,254
	Bagasse	900,364	34,214	7,635
	Palm kernel cake & meal with coat	1,970,839	193,142	19,708
	Palm kernel cake & meal without coat	1,938,983	321,871	23,210
	Palm fruit press	370,807	22,619	2,529
	Subtotal- Crop residues	16,750,529	1,069,992	148,209
	%	32.51	35.87	26.01
2	Grain by products			
	Broken rice	1,408,620	191,572	16,002
	Rice bran	2,779,478	216,799	34,104
	Corn husk	109,842	13,181	982
	Subtotal- Grain by product	4,297,940	421,553	51,088
	%	8.34	14.13	8.96
3	Roots by products			
	Cassava residue	1,288,163	36,069	13,848
	Cassava pulp ethanol residue	661,728	26,469	7,219
	Subtotal- Roots by products	1,949,891	62,538	21,067
	%	3.78	2.10	3.70
4	Grains			
	Corn grain	3,254,316	270,108	48,619
	%	6.32	9.05	8.53
5	Roots			
	Cassava chip	14,855,787	341,683	233,236
	%	28.84	11.45	40.92
6	Fodders			
	Cultivated pasture	249,630	18,435	2,326
	%	0.48	0.62	0.41
7	Grazing			
	Communal pasture	9,855,432	630,748	61,596
	%	19.13	21.14	10.81
8	Animal by product	305,776	168,177	3,772
	%	0.59	5.64	0.66
	Grand Total	51,519,301	2,983,232	569,913
	%	100.00	100.00	100.00

Note: DM = dry mater; DP = digestible protein; ME = metabolizable energy

Table 4 Estimated feed demand and nutrient requirements of livestock by using Department of Livestock Development feed assessment model in Thailand (year 2012)[6]

Livestock category	Requirement Per Year		
	DM (tonnes/year)	**ME (million MJ)**	**CP (tonnes/year)**
Goats and sheep	114,710	1,162	7,364
Pigs	6,236,293	86,371	913,115
Dairy cattle	1,925,871	11,545	162,914
Buffalo	3,708,817	20,626	157,384
Cattle	17,625,400	121,855	836,989
Chicken	9,250,509	135,098	1,551,994
Ducks	1,668,506	19,292	280,298
Total	40,530,105	395,950	3,910,058

Therefore, research focus should be on using locally available feeds and on development of feeding innovation that use concentrate supplements along with rice straw and other crop residues, agro-industrial co-products and/or low quality roughages[6]. Also, as results of low feed intake, digestibility and energy utilization, and thus low ruminant production efficiency coupled with air and water environmental stress in the topics have been identified as the future research issues[3-4, 7-8].

Table 5 Feed balances using feed assessment model for Thailand (year 2012)[6]

			Feed and Nutrient availability		
Feed resources	**Production (tonne)**	**Available for feed (tonne)**	**DM (tonne)**	**CP (tonne)**	**ME (million MJ)**
Crop and by-products	186,839,635	52,249,035	41,543,668	2,216,749	507,108
%			74.9	51.4	82.3
Animal by product	443,153	332,365	305,776	168,177	3,772
%			0.5	3.9	0.6
Forage and roughage	35,805,025	10,105,063	10,105,063	649,182	63,922
%			18.2	15.0	10.3
Import feed and raw materials	6,097,100	5,295,681	4,197,944	1,371,872	51,296
%			7.5	31.8	8.3
Export feed and raw materials	3,581,281	3,580,957	721,198	93,394	10,037
%			1.3	2.1	1.6
Total Availability	232,766,194	71,563,101	55,431,253	4,312,586	616,061
%			100.00	100.00	100.00
Total Requirement			40,530,105	3,910,058	395,950
Balance			+14,901,148	+402,528	+220,111

%	+26.88	+9.33	+35.73

Conclusion

In Thailand, domestic demand for livestock products will continue to grow, while exports will be accelerated by world's population and income growth. Our study indicated that feed production in the country produces surplus food for humans and is relatively sufficient in major feed ingredients for livestock except for protein feed requirements for non-ruminant. More research work on feed and nutrients requirement by using local available supplements combined with rice straw, crop residue, agro-industrial co-products and/or low quality roughage to develop a practical and economical ruminant farming system to improve productivity and environmental sustainability are suggested.

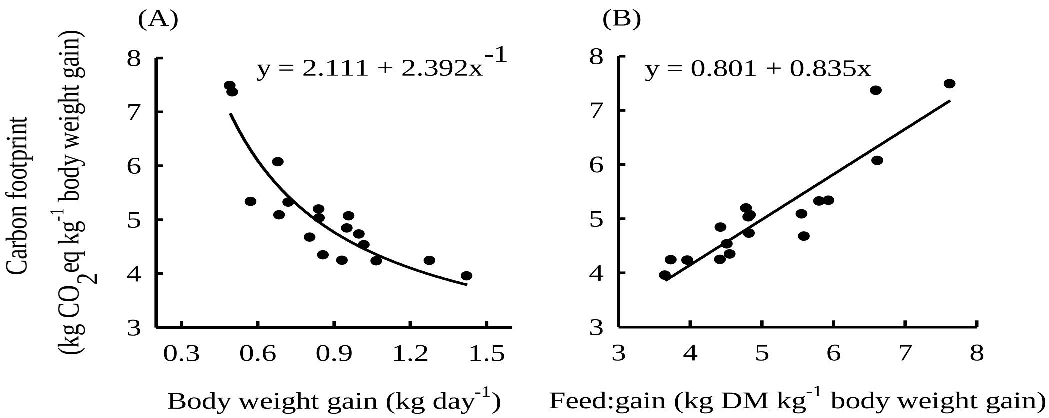

Figure 1. The relationship between (A) daily body weight gain and carbon footprint (*n* = 18, coefficient of determination = 0.820, *P*<0.001, residual SD = 0.226), and (B) feed per gain and carbon footprint (*n* = 18, coefficient of determination = 0.823, *P*<0.001, residual SD = 0.246) of native Thai beef crossbred cattle fed fermented total mixed ration diets. CO_2eq, carbon dioxide equivalent; DM, dry matter[7].

References

1. Poapongsakorn N, Thailand. Livestock industrialization in Thailand: Success, concerns and outlook for smallholders. 2012.
2. Alltech. Alltech global feed survey results. <https://www.aquaculturealliance.org/wp-content/uploads/2014/01/alltechglobalfeedsummary2014.pdf>. Accessed 2014.
3. Ogino A, Sommart K, Subepang S, *et al.* Environmental impacts of extensive and intensive beef production systems in Thailand evaluated by life cycle assessment. Journal of Cleaner Production, 2016, 112: 22-31.
4. Chaokaur A, Nishida T, Phaowphaisal I, *et al.* Effects of feeding level on methane emissions and energy utilization of Brahman cattle in the tropics. Agriculture, Ecosystems & Environment, 2015, 199: 225-230.
5. Kaewpila C. Metabolizable energy requirement for maintenance in native Thai-European crossbred beef cattle. Khon Kaen University, 2017.
6. Sommart K, Nakavisut S, Subepang S, *et al.* Food-feed estimation: Data, methodologies and gaps. The Food and Agriculture organization of the United Nations consultant report, 2012.
7. Kaewpila C, Sommart K, Mitsumori M. Dietary fat sources affect feed intake, digestibility, rumen microbial populations, energy partition and methane emissions in different beef cattle genotypes. Animal, 2018: 1-10.
8. Kongphitee K, Sommart K, Phonbumrung T, *et al.* Feed intake, digestibility and energy partitioning in beef cattle fed diets with cassava pulp instead of rice straw. Asian-Australasian Journal of Animal Sciences, 2018.

Livestock production systems, status on national feed resource availability and future developments, and challenges and opportunities to efficiently utilize locally available feed resources and to enhance feed use efficiency in Myanmar

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Abstract

The economy of Myanmar is based on agriculture. Livestock is also important for nation's economy and contribute 9% of total Gross Domestic Product (GDP) together with fisheries. Farmers raise cattle for draught. Some commercial dairy farms have been established in Yangon, Meikhitla, Mandalay and Pyin Oo Lwin. Poultry production is most prominent in many places of Myanmar. In Myanmar, agricultural by-products are used as animal feed. Rice straw and sorghum stover are mainly used as a basal diet. Forages from pulses are also mixed with the basal diet to feed the ruminants. Feed resources and feed types vary from region to region and with seasons. The farmers feed about 40 g of concentrate per head per day for cattle and it is much below the amount of concentrates required by them. Seven feed mills produce feed for animals. Farmers have poor knowledge in feeding system for the ruminants. Very few Myanmar people are interested in the investment for the feed manufacturing. It is needed to have collaboration between farmers and technicians to improve the utilization of feeds locally available in Myanmar. The regulations for feed manufacturing will be set in Myanmar soon.

Introduction

Myanmar economy is based on agriculture. Livestock is also one of the main sectors for the nation's economy. Livestock and fisheries contribute about 9% of total GDP. Private sector contributes 99% of the livestock production. Only a little amount of meat is imported for consumption in some hotels. Myanmar imports grandparents, parent stocks, day old chicks, hatching egg, beef/dairy semen, and milk powder and breeding pigs (http://www.asiabeefnetwork.com/wp-content/uploads/2017/08/Myanmar-Livestock-Industry-overview-Dr-Hla-Hla-Thein-Dr-Thet-Myanmar.pdf).

In Myanmar, 70% of population are residing in the rural area and 64% of population are farmers. Livestock along with crop production provide the main source income for the farmers. Some farmers also have pig, and village chicken, and pig are raised as in the back yard system, at a small scale (Table 1). The small-scale livestock farmers get draught power, transport in the rural areas, and manure as fertilizer from the draught animals. The small-scale livestock system also provides egg, milk and meat, and is a source of a part of house hold income. There is a need to shift livestock production system from small scale to commercial livestock production in Myanmar. Small-scale farmers also use local cows as a breeding stock and also sometimes for milk production. Some commercial dairy farmers have been established in Yangon, Meikhtila, Mandalay and Pyin Oo Lwin. However, the commercial production also exists in other parts of Myanmar. Beef cattle production is still in early stages of development. Nowadays, the cattle from Myanmar are allowed to export legally. Most of the cattle are exported to China and Thailand.

Myanmar people prefer chicken meat and fish. Dried fish and fish paste are also produced in Myanmar. Goat meat is expensive, and the live goats are exported. Meat and fish are sufficient for our country and no importation of these take place. Till now, most Myanmar people do not eat beef and the beef cattle industry is not well developed[2].

Table 1 Animal population in Myanmar in 2016[1]

Sr. No	Type of animal	Population (Millions)
1	Cattle	16.50
2	Buffaloes	3.63
3	Pigs	16.34
4	Goats	7.09
5	Sheep	1.45
6	Chicken	293.60
7	Duck	23.57

Feed resources for ruminants available in Myanmar

It is important to understand the feed and feeding system for ruminants. In Myanmar, the farmers use the agricultural fibrous residues as a basal diet. Those basal diets are low in nutritive, digestibility high in fibre content. To meet the nutrient requirement, concentrates are needed to improve the nutritive value of fibrous agricultural residues. Feeding balanced ration is the most effective feeding system. Feeding balanced ration can reduce the feed cost per unit production, because the energy and protein content of the diet can be properly used by the microbes in the rumen which favour the digestion and are energy and protein sources for the host animals. As the energy and protein content in the balanced diet is synchronizes, there can be no ammonia over flow and excessive amount of energy release in the rumen. Therefore, the methane emission from the ruminant digestion can be decreased by feeding balanced diets. In addition, milk and meat production can be increased. Therefore, feeding balanced diet is beneficial for the farmers. However, use of the ration balancing approach is very limited and further work is required. Moreover, the more work on the usage of forages and some drought tolerant bushes is also needed. Knowledge on the correct feeding strategy and balanced ration should be transferred to the farmers. The information on the feed resources, feed availability and feeding strategies is important for preparing the balanced ration.

As Myanmar is one of the agri-based country, there are many types of agricultural fibrous residues and agroindustrial by-products that can be used as animal feed. Some of these are used as animal feed in Myanmar. The case studies for the feed resources in different areas have been conducted in Myanmar. Tin Ngwe and coworkers conducted a survey on the dairy production in Tapei Village in Kyaut Sei District[3]. They found that fresh maize stover is fed mixed with Euphobia longana, peacock’s tail, Bermuda grass and rice bran. Sesame cake and rice bran were used as concentrate for the dairy cattle. It was also reported that dried sorghum stover is used as a basal diet in Myingyan District[4]. Dried groundnut forage is also fed to cattle, because it contained about 12% of crude protein. In the report of Min Aung, the farmers from Tada U Township used rice straw and sorghum as basal diets[5]. In the rainy season, they also used fresh grass as a basal diet. In Nay Pyi Taw area, Rice straw is used as basal diet[6]. Groundnut cake, sesame cake and dried forages of pulses grown in this are mixed with basal diet to feed the cattle. In Yangon area, fresh grass is used as a basal diet in rainy season and rice straw in winter and summer seasons. It was also found that leucaena is one of the potential tree forages to be utilized as dry season feed for ruminants. Soe Min Thein reported that the farmers from Central Dry Zone of Myanmar used dried sorghum stover as a basal diet and mixed it with residues of pigeon pea[7]. The commercial dairy farmers buy the commercial concentrates from the feed companies.

Ruminant feeding system

The dry matter intake of cattle in most areas of Myanmar ranged from 2 to 2.5 % of body weight. The farmers used very little concentrate for the cattle. It was found that about 40 g per day per head was fed to the cattle and it is much below the amount of concentrates required by them. However, as protein source, the farmers used the dried forages from pulses such as black gram, green gram, pigeon pea and groundnut. In Nay Pyi Taw area, farmers used rice straw, approximately 91% of total diet in winter, 41% in summer and 40% in rainy. In rainy season, the farmers used fresh grass, approximately 77% of total diet. They mixed dried forages of pulses as other component of the diet. The farmers let their draught cattle graze during the rainy season. The same is the case with farmers from central dry zone of Myanmar. Traditionally, in doors cattle are fed by soaking the feeds in feed trough. The feeding system of cattle in two villages of central dry zone is presented in Table 2.

Table 2 Occurrence (%) of feeding practices in the study area[7]

	Number of farmers		**Percent (%)**		
	KyaukAoe	**YaThar**	**KyaukAoe**	**YaThar**	***P*-Value**
Stall feeding	27	29	54[a]	32[b]	0.038
Semi-intensive	15	56	30[b]	63[a]	0.001
Grazing	8	4	16[a]	5[b]	0.001
Total	50	89	100	100	

Status of feed industry and regulatory authority

Currently, the number of feed industries is increasing. Till now very little investment is being made by local companies. The feed industries produce feeds for poultry, pig and cattle (Table 3). Livestock Breeding and Veterinary Department has the responsibility for the regulation of feed and feed industry. Currently feed is regulated under the Animal Health and Livestock Development Law enacted in 1993. That law was enacted to regulate product and facilitate registration, labeling and monitoring of products for compliance. It also aims to govern the distribution of all animal feeds, both medicated and non-medicated. It primarily focuses on establishing rules governing the use of animal drugs and other feed additives in feeds. That law covers among others registration of feed manufacturer. Government Directives No. 16 empowers the Regional Veterinary Officer to inspect and issue license to feed mill. It also has labeling guidelines. The environment, contaminated raw materials, storage, transportation and distribution of feed can be checked by the inspection team. The Assay Lab from Livestock Breeding and Veterinary Department (LBVD) can conduct the laboratory analysis of imported or exported feeds against a fee. The feeds manufactured by the feed industries can also be checked at the lab, to assess if they meet the quality requirements.

Table 3 Feed manufacturing companies in Myanmar

Sr. No.	**Name of company**	**Country of origin**
1	Myanmar CP livestock	Thailand
2	May Kha	Malaysia
3	Deheus	The Netherlands
4	Sun Jin	Korea
5	CJ feed	Korea
6	Green Feed	Vietnam
7	Kaung Htet	Myanmar

Challenges and opportunities in enhancing utilization of locally available feed resources and enhancing feed use efficiency

For development of livestock production, it is necessary to have good quality feed. However, a big challenge is that there is no pasture or grass land in Myanmar. In central dry zone area, feed scarcity is also limiting the livestock production. Thus, improvement of feed resources for small farmers is one of the options to increase the livestock production. According to a case study conducted under an FAO project, most of the farmers in central dry zone of Myanmar have at least one acre for plantation of sorghum as forage for ruminants. Good quality forage varieties should be provided to the farmers to establish small pasture plots on their land. Sometimes there can be rain in April or May. Some forage varieties can be green because of the rain and reduce the feed shortage during the dry period.

Another challenge is the poor knowledge for feeding ruminants. Most farmers feeding the animals on diets with insufficient nutrients. Therefore, training of extension workers and farmers is needed to improve the feeding practices. It is also desired to store and preserve the feed systematically to reduce their waste. Hitherto, there is little investment in livestock and feed production by local companies. Another challenge is limited collaboration between scientist and livestock farmers, which must be strengthened.

It is suggested to establish a national feed database in Myanmar. Although the analyses of feed ingredients and feeds are done by many laboratories, but these data are not collated in a database. A national feed database would be very helpful in enhancing the utilization of locally available feeds in Myanmar.

Conclusion

It is concluded that Myanmar should set suitable rules and regulations for the livestock production system, export and import of animals, animal product and animal feeds. The market assessment is also desirable for the livestock system. Because of lack of assessment on the market chain, the farmers cannot get the suitable price for selling animals and decrease the interests on the livestock production. Therefore, the technicians for livestock farm economics should be produced from the University of Veterinary Science to study on the market assessment and help the farmers for the improvement of livestock production. By increasing the lands for pasture, it can improve the feed resources and reduces the feed scarcity. Moreover, the extension works for the motivation of farmers on the development of pasture is also one of the recommendations for livestock system in Myanmar. To solve the problem of labor shortage for the livestock production system, the skillful labors for the livestock production should be trained. Till now, the collaboration and cooperation between scientists and farmers are very weak. If the relationship between them can be improved, technical support on feeding system and management can be provided to the farmers. It is needed to raise the interests of farmers and investors to invest in the feed manufacturing and livestock production. To increase the interest on the utilization of locally available feed resources in Myanmar, it is suggested to have web based feed data base for Myanmar.

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References

1. LBVD. Myanmar Livestock statistical year book. 2016.
2. Ngwe Tin, Win YH, Mu KS. Preliminary survey on the dairy production in Ta Pei Village, Kyak Sei Distric, with special reference to the nutritional requirement. Myanmar Veterinary Journal, 2006, 31-37.
3. Ngwe T, Soe TM, Mu KS. Preliminary report of chemical compositions of feedstuff commonly fed to draught cattle in Myingyan district. Myanmar Veterinary Journal, 2007, 88-95.
4. Aung M, Khaing M, Ngwe T, *et al.* Preliminary survey on the dairy cattle production system and conventional feed resources in the central dry zone of Myanmar. Global Journal of Animal Scientific Research, 2015, 3(2): 383-387.
5. San H. Study on the feed and feeding practices of draught cattle in Dakhina District, Nay Pyi Taw. University of Veterinary Science, Myanmar, 2016.

6. Thein SM, Aung A, Oo KN. Proccedings of the 16th AAAP Animal Science Congress. Yogyakarta. 2014, 915-918.

7. Thein SM. Comparison on performances between cattle fed on locally available forages and introduced forage in dry zone area. University of Veterinary Science, Myanmar, 2016.

Appendix: Feedstuffs utilized in ten townships of Myanmar

Mandalay Region

Pyawbwe	Patheingyi	Tada U	Meikhtila	Myingyan
Rice straw	Rice straw	Rice straw	Sorghum straw	Sorghum stover
Maize stover	Maize stover	Sorghum stover	Rice straw	Groundnut stover
Pigeon pea residues	Sorghum stover	Chickpea husk	Sorghum stover	Groundnut cake
Groundnut cake	Pigeon pea residues	Butter bean forage	Garden pea residues	Sesame cake
Sesame cake	Groundnut forage	Butter bean husk	Pigeon pea residues	Pigeon pea residue
Chickpea husk	Soybean straw	Rice bran		
Mixed ration (CP)	Rice bean straw			
Rice bran	Chickpea dregs			
Green grass	Green gram dregs			
	Common wheat bran			
	Black gram dregs			
	Chickpea bran			
	Green grass			

Nay Pyi Taw

Laewai	Pyinmana
Rice straw	Rice straw
Maize stover	Rice bran
Sorghum stover	Sesame cake
Rice bran	Groundnut cake
Black gram reside	Fresh grasses
Fresh grassed	
Groundnut cake	

Yangon Region

Mingaladon	Hlegu	Taik Kyi
Dried grass	Rice straw	Rice straw
Fresh grass	Rice bran	Rice bran
Chickpea husk	Groundnut cake	Sesame cake
Brewers spent grain dregs (Wet and dry)	Brewers spent grain dregs	Commercial concentrates
Common wheat bran	Commercial concentrates	Fresh grasses
Rice bran	Green grass	
Mixed ration CP 006		
Mixed ration CP 005		
Mixed ration CP 972		
Mixed ration CP 974		

Livestock feeding strategy and feed availability in Mongolia

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Abstract

Mongolia is a country known as one third of the total population herd livestock at natural pasture which is the most important feed source for their animals. The pasture feeds over 66 million heads of animal for all year. Therefore the livestock feeding strategy is closely related to pasture productivity that is very dependent from the environment. The most common supplement feed for livestock is hay grass harvested from the pasture. Across the country cultivates only 55 thousand tonnes of fodder in over 30 thousands hectares of area which accounts approximately 2% of total arable land. In every year about 100 thousand tonnes of feed is produced domestically and imports roughly 30 thousand tonnes of feedstuff mostly from neighbouring countries. All of these feed available in the country are not enough to feed not even to supplement livestock population in Mongolia. Consequently, scientists have been and still testing different methods that enhances palatability of non-forage plants in order to increase feed availability in the country. Simultaneously national government taking initiatives for filling the feed gap but these actions seem to be not strong enough to achieve its aim since livestock number is continuously increasing year by year. Thus comprehensive scientific studies needs to be conducted which can bring opportunities to use locally available non forage plants into livestock feed.

Introduction

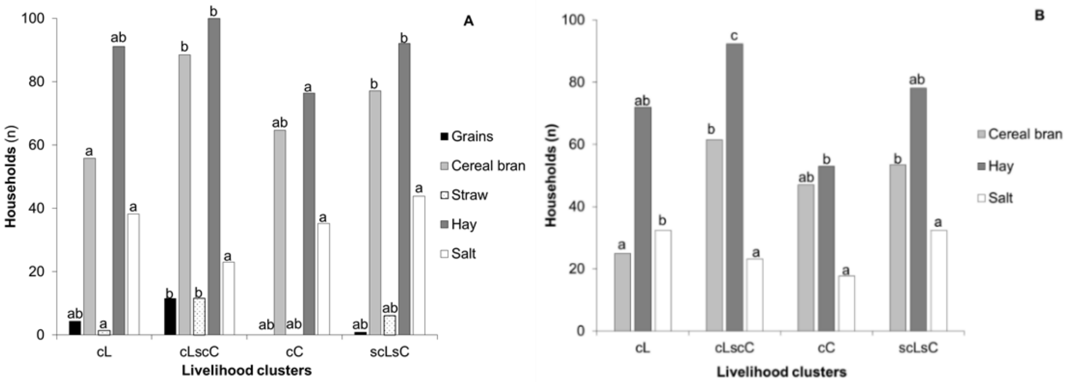
Mongolia is one of the few truly pastoral countries in the world[1] with a 2000 to 3000 years old nomadic tradition[2]. Although nowadays, mining contributes considerably to the country's economic growth, livestock husbandry has been, and still is, an important sector for Mongolia's economy and employment[3]. The National Statistical Office of Mongolia reported that at the end of 2013 the agricultural sector contributed 15% to the national gross domestic product, which is equivalent to 7% of the country's total export income[4]. Of this fifteen percent, 80% are derived from the livestock sector[5]. In addition, the livelihoods of approximately 1.5 million rural dwellers directly and indirectly depend on animal husbandry[6], which is almost half of Mongolia's population. By the end of 2012, 160,000 out of 208,000 livestock keeping households in Mongolia were characterized as true herder households whose livelihoods directly depended on animal husbandry; each herder household has on average four family members[5].

Mongolia has the largest area of common pasture land in the world[7], which is divided into four different zones based on ecological conditions and herding practices, namely: Altai mountain, Khangai-Khentii mountain, steppe and desert[8]. Fernandez-Gimenez reported that Mongolia's pastures were grazed sustainably for most of the last century (socialist era) during which animal numbers remained relatively constant. However, nowadays the pastures are exposed to a considerably higher grazing pressure, whereby sharp increases in animal numbers as a result of the introduction of market economy in the 1990s[9] and climatic influence (warming and lesser precipitation[3] are two important drivers). Impacts of those two major challenges together with other socio-economic and environmental constraints (pasture regulation, herding management and lack of feed) are mostly limiting pasture production, animal reproductive performances and livestock herding practices across the country[9-11]. Under these challenging conditions, the main strategy to use the native pasture in an environmentally friendly way was, and still is, the seasonal mobility of Mongolian herders and their flocks. Yet, herding practices of livestock keepers changed substantially under the newly established socio-economic conditions, due to loss of pasture utilization regulation, dismantling of subsidies and services for transportation, lack of labour for livestock mobility and rural poverty[12]. In the recent past, herders reduced the frequency of herd movement per year, shortened distances between seasonal pastures[9], and changed herd structure in favour of goats and to the detriment of camels and yak. The loss of traditional herding knowledge increased the herds' vulnerability to extreme weather events such as dzud and drought[13-14]. This report aimed to explain how livestock are fed, how much feed is needed for supplementation to livestock and how much feed is produce domestically. Two main reference study were used in this report; one of them was conducted in high mountainous region in western Mongolia by German-Mongolian scientists and another one was conducted by Erdenebolor *et al.* in collaboration with a German project team[24-25].

The feeding strategy

Across country and seasons, the vegetation of natural pastures is the most important feeding resource for all livestock species in Mongolia[15-16]. The pasture grass development and their availability is dependent on climatic conditions[3, 10] and the growing season in Mongolia determines feed availability[17-18]. Therefore, herders' feeding strategies can be differentiated between two main seasons namely rainy-warm season and dry-cold season[19]. Herders classify pasture areas into summer, autumn, winter and spring pastures using different types of criteria, such as aboveground net primary production and suitability of the vegetation for different livestock species, topography and elevation, and drinking water availability[9, 20] as well as distance from the homestead[6]. Summer and autumn seasons can be referred as rainy-warm season while spring and winter considered as dry-cold season. During the rainy-warm season, animals can ingest enough good quality fodder from the native pastures, freely to build up body fat reserves (especially fat rump sheep, camels, and yak) for coping with the harsh dry and cold season. Within this season livestock receives only very small amount of mineral supplements such as salt or other equivalent locally available materials[21].

During the dry and cold season, the pastures were still important resources for livestock feeding, particularly for animals in good physical condition and non-lactating animals. Camels and horses fed autonomously on large pasture areas throughout the year; only less than 10% of all herder households offered salt to those animals. A case study conducted by Munkhnasan *et al.* in Mongolian Altai mountainous region shows that dairy cows, yaks, weak small ruminants and working horses were offered supplemental feed at the homestead during the winter time[21] (Figure 1A). The supplement for cattle was mostly based on grass hay, cereal bran and salt. Grass hay and cereal bran were also the most common supplemental feeds for weak and small ruminants (Figure 1B). All these



supplements except cereal bran can be considered as home-made feedstuffs.

Figure 1 Number of households per cluster offering different types of supplemental feeds to their large animals (A) and small ruminants (B) during the dry and cold season in western Mongolia. *cL - commercial livestock keeping; cLscC - commercial livestock keeping plus semi-commercial field cropping; scLsC - semi-commercial livestock keeping plus subsistence field cropping; cC - commercial field cropping*[21].

([a, b] Superscripts on bars indicate significant differences between the clusters tested by Mann-Witney U-test)

Availability of feed resources

Cultivated Fodders

The contribution of cultivate fodder in the crop sector is quite insignificant as it only accounts for 6% of total sown areas and 7% of the total crop yield in 2016. This relationship emerges from the dominance of wheat cropping, which results from the comparative advantage due to the government subsidy on wheat. Wheat is subsidized by the government in order to maintain self-sufficiency in flour and keep it affordable because flour is widely consumed in Mongolia, thus declared a strategic product.

Nevertheless, fodder cropping increased by 117% during the last 5 years and reached nearly 30 thousand hectares in 2016. The total yield of fodder crops was 53.4 thousand tonnes in 2016 (Table 1).

Pelleting, grain crushing and fodder mixing at small scale (usually by farmers and herders themselves) and green fodder production hardly qualify as industrial fodder production. Hence, including mills, the number of industrial fodder producers in Mongolia is 41 and their combined fodder production capacity is approx. 263 thousand tonnes (Table 2).

Annual bran production is estimated by Tugs-Erdene, The ministry of Food, Agriculture and Light Industry at 70 to 80 thousand tonnes. Annual production of concentrates except bran (pellets and compound feeds) is estimated at approximately 21.7 thousand tonnes in year 2016. In summary, industrial fodder production in Mongolia, is approximately 100 thousand tonnes in 2016.

Table 1 Overview of fodder cropping in the period from 2012 to 2016

Fodder crops	**2012**	**2013**	**2014**	**2015**	**2016**
Sown area, ha					
Annual green fodder crops	9,424	10,500	9,023	11,244	19,311
Perennial crops	2,860	2,364	3,789	4,377	3,986
Silage crops	1,196	1,348	2,965	4,648	256
Other crops	303	144	1,200	3,572	6,341
Total area	13,784	14,390	16,976	23,841	29,893
Fodder yield, tonnes					
Annual green fodder crops	30,077	29,697	24,547	38,468	34,393
Perennial crops	9,964	8,038	7,963	8,850	11,263
Silage crops	6,178	3,879	9,236	1,344	2,222
Other crops	0.5	1,024	2,533	519	5,546
Total area	46,219	42,638	44,278	49,181	53,424

Source: National Statistical Office, 2017[22]

Table 2 Overview of fodder production facilities that are in operation in 2017

Type of facility	**Number of facilities**	**Products**	**Approximate combined production capacity, tons per year**

Fodder factories	11	Bran, mixed concentrates (compound feed), incl. pellets, protein concentrates	172 thousand tonnes
Mills with fodder mixers	4	Bran, mixed fodder	3.7 thousand tonnes
Cereal Mills	26	Bran	87 thousand tonnes
Small mills with pelleting equipment	2	Bran, pellets	1.5 thousand tonnes
Pelleting equipment	2	Pellets	2.9 thousand tonnes
Grain crushers	5	Crushed grain	11.5 thousand tonnes
Fodder mixers	16	Mixed fodder	60 thousand tonnes
Other	3	Green fodder, unknown	N/A

Source: The ministry of Food, Agriculture and Light Industry, 2017[23]

Livestock feed and feedstuff import

Imports of feed and feed ingredients totalled 69 thousand tonnes in 2015 and 43 thousand tonnes in 2016. Ingredients for industrial fodder production included maize, barley, soy, bone meal, starch and brewery wastes, wastes of soy oil production and other non-specified wastes used in animal feeding. In addition, approx. 50% of waste grain was used in industrial feed production. The estimated amount of imported feed directly used in animal feeding was 30 thousand tonnes in 2015 and 32.0 thousand tonnes in 2017 (Table 3). This substantial increase can be explained by Government's low interest on loans that aimed to import more feed in order to prevent livestock loss due to lack of feed during winter season 2017-2018.

Table 3 Feed imports in last three years, tonnes（dry matter basis）

Feed	2015	2016	2017
Hay	-	20.0	96.0
Oat	9,288.8	10,913.1	11,448.9
Waste grain (wheat grain)	18,316.3	5,892.6	20,461.9
Compound feed	2,438.5	1,814.8	-
Total amount	30,043.7	18,640.5	32,006.8

Source: Mongolian custom's statistic 2017 (http://customs.gov.mn/statistics/index.php?module=users&cmd=info_st)

Current feed balance

The overall rate of feed sufficiency (i.e. rate of supply in relation to requirements) of dairy, beef, pig and poultry farms in 2016, measured in metabolizable energy (ME) values, was 68%. Highest feed sufficiency rates of 71 and 68% were attained by dairy and beef farms and poultry farms, respectively. In contrast to dairy and beef farms, however, poultry farms only achieved a relatively high feed sufficiency through consumption of a substantial amount of imported feed. This is indicated by the domestic sufficiency rate of 55% for poultry farms in contrast to 70% for dairy and beef farms. Pig farms only reached a 53% overall f sufficiency (Table 4).

Table 4 Total feed balance of dairy, beef, pig and poultry farms in 2016, expressed in MJ ME

Key figures	Dairy and beef farms	Pig farms	Poultry farms	Total
Metabolizable Energy supply, MJ				
Supply from domestic feeds	876,069,350	148,463,097	215,635,679	1,240,168,126
Supply from imported feeds	21,971,071	8,162,749	50,570,502	80,704,321
Total supply	898,040,420	156,625,846	266,206,181	1,320,872,447
Total energy requirements by livestock, MJ ME	1,259,154,699	293,102,032	390,847,355	1,943,104,087
Energy balance in relation to total feed supply, MJ ME	-361,114,279	-136,476,187	-124,641,174	-622,231,640
Total sufficiency rate	71%	53%	68%	68%
Energy balance in relation to consumption of domestically supplied feeds, MJ ME	-383,085,349	-144,638,935	-175,211,677	-702,935,961
Domestic sufficiency rate	70%	51%	55%	64%

Source: Erdenebolor (2017) [24]

In contrast to the relatively high rate of roughage sufficiency, the rate of concentrate sufficiency was only 56% in 2016. Poultry farms reached the highest concentrate sufficiency of 68%, in comparison to 50% for dairy and beef farms and 51% for pig farms. The relatively high concentrate sufficiency of poultry farms is explained by their use of a considerable amount of imported concentrates. If poultry farms had only consumed domestic concentrates, their concentrate sufficiency would have been 55%. For dairy and beef farms, on the other hand, consumption of imported concentrates only made a difference of 1% in the total concentrate sufficiency. Pig farms covered 48% of their concentrate requirements from domestic supply and another 3% from imported concentrates (Table 5).

Table 5 Roughage balance of dairy, beef, pig and poultry farms in 2016, expressed in MJ ME

Key figures	Dairy and beef farms	Pig farms	Total
Energy supply from roughage consumption, MJ ME			
Total supply	605,209,398	31,008,000	636,217,398
Domestic supply	585,915,935	31,008,000	616,923,935
Energy requirements on roughage consumption, MJ ME	670,456,708	47,723,919	718,180,627
Energy balance in relation to total supply of roughages, MJ ME	-65,247,311	-16,715,919	-81,963,229
Total sufficiency rate, %	90%	65%	89%
Energy balance to in relation to domestic supply of roughages, MJ ME	-84,540,774	-16,715,919	-101,256,692
Domestic sufficiency rate, %	87%	65%	86%

Source: Erdenebolor (2017) [24]

In summary, feed consumption is most balanced for dairy and beef farms. This is mainly due to the fact that approx. 60% of their feed requirements are covered through grazing, hence deducted from the total feed requirements. The 71% fodder sufficiency itself is essentially constituted by the consumption of hay as a low cost roughage and bran as a low cost concentrate, both available in relatively sufficient amounts.

Scientific efforts to fill feed gap via degrading fiber content in the hay grass and straws

Mongolian animal nutritionists started researching optimum methods to enhance digestibility of hay grass prepared from the native pasture and of other locally available materials since late 20th century. Firstly, they introduced mineral block made from locally available minerals, and multinutrient blocks containing wheat bran, minerals and urea[25] then they used different types of fibre degrading enzymes t in the newly developed feed rations that use crop by-products and other local plants[26-28]. However, application of enzymes to treat feed resources still remains an area of research.

Conclusion

The current feeding strategy and feed availability in the country seems not likely to supplement all livestock during the dry-cold season adequately and there is no evidence for enhancing feed availability in the near future. Therefore the country should have livestock number declining policy unless scientists and feed producers bring comprehensive newly developed technologies that improves digestibility of locally available forages those do not used as common feedstuff.

References

1. Suttie, JM. Grazing management in Mongolia. In: Reynolds, S.G., Batello, C. (eds.). Grasslands of the World. FAO Plant Production and Protection Series No. 34, Rome, Italy, pp. 2005, 265-304.
2. Rudaya NA, Tarasov PE, Dorofeyuk NI, *et al.* Environmental changes in the Mongolian Altai during the Holocene. Archaeology, Ethnology and Anthropology of Eurasia, 2008, 36(4): 2-14.
3. Batima P, Natsagdorj L, Gombluudev P, *et al.* Observed climate change in Mongolia. Assessments of Impacts and Adaptations to Climate Change (AIACC) Working Paper 12. 2005, 12: 1-26.
4. Komiyama, H., Chantsaldulam, R., Du, F. The present situation and the future direction of animal husbandry in Mongolia. Japan International Research Center for Agricultural Sciences Working Report, 2013, 73:1–26.
5. NSOM (National Statistical Office of Mongolia). Statistical Yearbook of Mongolia. 2013.
6. Fernandez-Gimenez, ME. The role of Mongolian nomadic pastoralists' ecological knowledge in rangeland management. Ecological Applications, 2002, 10(5):1318-1326.
7. Upton C. Living off the land: Nature and nomadism in Mongolia. Geoforum, 2010, 41(6): 865-874.
8. Bazargür D, Shiirevadja C, Chinbat B. Territorial organization of Mongolian pastoral livestock husbandry in the transition to a market economy. 1993.
9. Lkhagvadorj D, Hauck M, Dulamsuren C, *et al.* Pastoral nomadism in the forest-steppe of the Mongolian Altai under a changing economy and a warming climate. Journal of arid environments, 2013, 88: 82-89.
10. Munkhtsetseg E, Kimura R, Wang J, *et al.* Pasture yield response to precipitation and high temperature in Mongolia. Journal of arid environments, 2007, 70(1): 94-110.
11. Miao L, Fraser R, Sun Z, *et al.* Climate impact on vegetation and animal husbandry on the Mongolian plateau: a comparative analysis. Natural Hazards, 2016, 80(2): 727-739.
12. Fernandez-Gimenez ME, Le Febre S. Mobility in pastoral systems: Dynamic flux or downward trend? The International Journal of Sustainable Development and World Ecology, 2006, 13(5): 341-362.
13. Fernández-Giménez ME. Sustaining the steppes: a geographical history of pastoral land use in Mongolia. Geographical Review, 1999, 89(3): 315-342.
14. Fernandez-Gimenez ME, Batkhishig B, Batbuyan B. Cross-boundary and cross-level dynamics increase vulnerability to severe winter disasters (dzud) in Mongolia. Global Environmental Change, 2012, 22(4): 836-851.
15. Jordan G, Goenster S, Munkhnasan T, *et al.* Spatio-temporal patterns of herbage availability and livestock movements: A cross-

border analysis in the Chinese-Mongolian Altay. Pastoralism, 2016, 6(1): 12-18.

16. Bat-oyun T, Shinoda M, Tsubo M. Estimation of pasture productivity in Mongolian grasslands: field survey and model simulation. Journal of Agricultural Meteorology, 2010, 66(1): 31-39.

17. Li S G, Romero-Saltos H, Tsujimura M, *et al.* Plant water sources in the cold semiarid ecosystem of the upper Kherlen River catchment in Mongolia: A stable isotope approach. Journal of Hydrology, 2007, 333(1): 109-117.

18. Nergui, D., Jigjidpurev, S., Otgoo, T., *et al.* Animal feed and feeding research. Review for the 50th anniversary of the Mongolian Institute of Animal Husbandry. Munkhiin Useg Group LLC, Ulaanbaatar, Mongolia, 2011: 664.

19. Gendaram, H. Animal feed and feeding. Munkhiin useg group Ltd, Ulaanbaatar, Mongolia, 2009: 247.

20. Tomorjav, M. Mongolian grazing animal husbandry; Tradition, reconstruction and intensification. Munkhiin Useg Group Ltd, Ulaanbaatar, Mongolia, 2004:350.

21. Munkhnasan, Ts. Herding management and livestock productivity in the Altai region of western Mongolia. University of Kassel, Witzenhausen Germany. 2016:153.

22. NSOM (National Statistical Office of Mongolia). Statistical Yearbook of Mongolia. 2017.

23. Ministry of Food, Agriculture and Light Industry. Current situation of the food, agriculture and light industry sector. Unpublished Power point presentation, 2017.

24. Erdenebolor B. Market Study on Livestock Fodder Production and Demand in Mongolia. 2017.

25. Togtokhbayar N. Evaluation of pasture forages as livestock feed. Improving Animal Productivity by Supplementary Feeding of Multinutrient Blocks, Controlling Internal Parasites and Enhancing Utilization of Alternate Feed Resources, 2006: 211-218.

26. Otgonjargal, A. Nutritive value, methane and carbon dioxide production from pastures of mountainous steppe. Mongolian State University of Agriculture, Ulaanbaatar, Mongolia, 2012: 124.

27. Togtokhbayar N, Cerrillo MA, Rodríguez GB, *et al.* Effect of exogenous xylanase on rumen in vitro gas production and degradability of wheat straw. Animal Science Journal, 2015, 86(8): 765-771.

28. Togtokhbayar N, Urankhaich C, Ayushjav O, *et al.* Effects of exogenous cellulase and xylanase enzyme preparations on feed intake, nutrient digestibility, growth, and economics of rearing Mongolian lambs. Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), 2017, 118(1): 81-89.

Status quo, challenges and opportunities of livestock production in China

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Abstract

The livestock industry in China, accounting for about 30% of total agricultural output, is an important industry with various feeding systems. After the development of feed industry for nearly 40 years, the total output of industrial feeds exceeded 200 million tonnes in 2016, giving China the status of biggest industrial feed producer in the world. In terms of animal population, China ranks the first place in the world for swine, poultry, sheep and goats, and the third for cattle and buffaloes. China has proposed a feeding strategy aiming for a “high product quality, high production efficiency, and healthy, safe, and environment friendly and grain-saving” production system. Well-established institutions and organizations plan, develop and supervise the feed industry under the Ministry of Agriculture and Rural Affairs of China. The livestock industry in China also faces a number of challenges. Because of huge population and limited arable land, the competition for grains and other resources between people and livestock is getting intense. A large amounts of grains (sorghum, barley, etc.) and protein-rich feeds such as soybean (more than 80 million tonnes of soybean were imported per year) and alfalfa hay are imported per year. Lack of feed grains substantially limits the sustainable livestock production in China. However, nearly 1 billion tonnes of unconventional resources including 700 million tonnes of crop byproducts can be exploited and utilized as animal feed. In addition to the traditional pretreatments, supplementary strategies based on nutritional metabolism are of great potential, which warrant further studies and exploration.

Introduction

China has fed 22% of the world total population with only 7% of global arable land. With economic development and improvement of peoples’ living standard, the demand for the food of animal origin is steadily increasing in China. How to feed over 1.3 billion people is the central issue. The intense competition for grains between people and livestock and the lack of feed grains have significantly limited livestock production. It is essential to assess the current situation of livestock production so that appropriate strategies can be developed to promote sustainable development of the livestock sector in China.

The ruminant and monogastric feeding systems

Total production

China's animal husbandry shows a steady and healthy development in recent years. The production structure is being further optimized, and in addition to meeting the quantitative requirement of feeds, the attention is being focused on the use of feeds that are of high quality, have high feed-use efficiency, are environment friendly and do not compromise health and welfare of animals. Animal products currently account for about 30% of total agricultural output in China[1]. According to the Food and Agriculture Organization of the United Nations (http://www.fao.org/faostat/en/#data), China had 457 million pigs, 6.3 billion poultry and 311 million of sheep and goats in 2016, accounting for 46.5, 25.4 and 14.3% of the world's total stock, respectively (Tables 1 and 2). The population of cattle and buffaloes in China (108 million) accounts for 6.5% of the total stock, ranking 3rd in the world.

China produced a total of 87.6, 32.4 and 42.0 million tonnes of meat, eggs and dairy products in 2016, accounting for 26.5, 40.1 and 5.3% of the world's total output, respectively (Table 3). The per capita output of meat is higher than the world average, and per capita output of eggs is twice the world average. In contrast, the production of milk is only 1/3 of the world average, indicating great potential for dairy production.

Co-existence of various feeding systems

China's animal husbandry, like other agricultural production in China, has been dominated by the small-scale production in rural area for a long time. China is currently transiting from traditional smallholder to intensive feeding system. However, the smallholder farming is still predominant in the country.

Table 1 Number of primary monogastric animals in China and the world [1]

Year	Pigs ($\times 10^6$ head)				Poultry ($\times 10^9$ head)			
	Live		Output		Live		Output	
	World	China	World	China	World	China	World	China
1978	737.5	296.0	664.9	171.1	7.21	1.06	17.05	1.26
1988	829.5	331.9	884.3	287.7	11.00	2.25	26.90	2.43
1998	870.4	408.5	1055.7	439.6	14.65	3.82	40.00	7.45
2008	940.4	446.7	1299.8	602.2	20.95	6.08	57.46	10.62
2010	974.5	476.3	1383.8	677.2	22.31	6.43	60.66	11.39
2012	972.3	475.1	1428.3	708.6	22.47	5.92	63.80	12.46
2014	987.9	480.1	1470.0	744.9	23.03	5.58	65.97	11.96
2016	981.8	456.8	1478.2	715.4	24.82	6.30	70.29	12.48

Note: [1] Data adapted from FAO (http://www.fao.org/faostat/en/#data)

For monogastric animals, smallholder pig farming has played, and is still playing a prominent role in China. Pork from smallholder farms that each produces less than 50 pigs annually accounted for 56.2% of the China's total port production in 2016, whereas only 13.2% of total pork was produced from large-scale enterprises, each farm producing more than 3000 pigs annually. Similarly, small-scale farming still dominates the poultry broiler sector. A total of 67.2% of annual broiler chicken were from smallholder farms that produce less than 2000 broilers annually per farm, and only 12.6% were from large scale enterprises, each of which produces more than 100 thousand broilers annually.

Table 2 Number of primary ruminants in China and the world [1]

Year	Cattles & Buffalo (×10^6 head)				Sheep & Goats (×10^6 head)			
	Live		Output		Live		Output	
	World	China	World	China	World	China	World	China
1978	1322.9	70.2	256.7	2.9	1489.6	161.6	515.0	30.4
1988	1415.8	94.1	265.7	7.9	1707.9	178.8	648.2	68.0
1998	1469.2	122.0	288.7	32.7	1761.2	256.1	773.0	173.0
2008	1591.0	106.1	317.3	44.5	1982.8	285.9	933.3	261.9
2010	1603.9	107.4	320.7	47.3	1985.6	284.7	948.2	277.9
2012	1622.6	103.8	323.5	47.7	2048.5	282.6	955.6	271.0
2014	1636.4	104.0	327.3	49.4	2103.2	290.5	992.4	287.5
2016	1674.2	108.3	328.2	52.8	2176.2	311.2	1011.3	307.3

Note: [1] Data adapted from FAO (http://www.fao.org/faostat/en/#data)

For ruminants, 47.6% of sheep and goat meat were from smallholders that produce less than 30 sheep or goats per farm, whereas only 13.4% were from large scale enterprises, each of which produces more than 500 sheep or goats annually. Additionally, 62.5% of beef was from smallholders that produce less than 10 beef each farm, whereas only 14.1% was from scaled farms which produce more than 100 beef cattle per farm. The proportion of intensive feeding of dairy cows was much higher. Only 24.8% of cows were from smallholders with less than 10 dairy cows per farm, whereas 53.5% were from farms with more than 100 dairy cows[2]. Because intensive feeding needs skilled workers and better infrastructure, efforts are still needed to develop China's intensive feeding system.

Development of sustainable feeding system

As mentioned above, China has proposed a new feeding strategy, wherein feed quality and feed-food safety nexus are of paramount importance. In 2017, the proportion of animal feed resources that met the quality standard was 97.4%, and this proportion for animal source foods including meat, raw milk and dairy product was 99.8, 99.8, and 99.5%, respectively (http://www.jgj.moa.gov.cn/tpxw/201804/t20180402_6139486.htm, http://www.jgj.moa.gov.cn/kptd/201801/t20180103_6133765.htm)[3]. The animal feeding is also turning from extensive to natural resource saving system, in which use of agricultural and industrial by-products and other unconventional resources is aimed to reduce the cost and alleviate the competition for grains between human and livestock. For example, the amount of straw and stovers from crops used as animal feed reached 220 million tonnes in 2015, accounting for 25% of the annual production of these materials, which is equivalent to the nutritional value of 60 million tonnes of conventional grain feed (http://www.miit.gov.cn/n1146290/n4388791/c5458461/content.html)[2]. The feeding strategies are now increasingly based on precise feeding. The use of complete formula feeds has reached more than 90 and 75% for poultry and swine, respectively. Total mixed ration is used in 70% of intensive dairy farm[4].

Many farms in China have adopted intelligent feeding and managing systems, including automatic feeders and water dispensers, automatic dropping scraper, milking machine, among others. According to China Dairy Quality Report in 2017, 100% of large-scale dairy farms now use the mechanized milking system, and 80% of intensive dairy farms are equipped with mixers for making total mixed ration (http://www.jgj.moa.gov.cn/tpxw/201804/ t20180402 _6139486.htm).

Table 3 Production (×10^6 tonnes) of meat, eggs and milk in the world and China [1]

Year	Meat			Eggs			Milk		
	World	China		World	China		World	China	
		Amount	%[2]		Amount	%		Amount	%
1978	127.5	11.1	8.7	25.8	2.6	10.2	452.7	2.8	0.62
1988	171.1	26.5	15.5	36.0	7.2	19.9	529.9	6.4	1.20
1998	224.4	58.9	26.2	51.6	20.6	39.9	560.3	10.5	1.88
2008	281.2	74.5	26.5	66.8	27.4	41.0	701.6	40.2	5.73
2010	294.6	81.1	27.5	69.5	28.0	40.3	724.5	41.2	5.68
2012	307.4	85.5	27.8	72.6	29.0	39.9	760.4	42.4	5.57
2014	320.5	88.7	27.7	75.8	29.3	38.7	794.4	42.3	5.32
2016	329.9	87.6	26.5	80.8	32.4	40.1	798.5	42.0	5.25

Note: [1] Data adapted from FAO (http://www.fao.org/faostat/en/#data); [2] Indicate the percentage of world total

Status quo of feed industry and regulatory authority

The growth in the Chinese feed industry has been very high since China started the reform and opening-up policy. Currently, the feed industry has become much mature and efficient than it was in the pre-reform period.

Production value and output

The rapid development of feed industry has led to 11,627 feed and feed additive manufacturers in China by the end of 2016. Both total output and value of feed production have increased steadily over the last 15 years. Gross value of feed industry was 801.4 billion Chinese Yuan (RMB) (equivalent to 630 billion USD) with an annual average growth rate of 2.6%, and the output of industrial feed exceeded 200 million tonnes in 2016 (Figure 1) (http://www.feedtrade.com.cn/)[5-7]. It is clear that China has become the largest feed producer in the world.

The structure of feed products continues to optimise. Feed products include compound feed, concentrated feed and feed additive premix. The output of compound feed increased remarkably during 2007 to 2012, with a year-to-year growth rate of 12.48%; and then rose slightly since 2013 and reached to about 184 million tonnes[5-6]. The production of concentrated feed increased to about 25 million tonnes in 2005, after which it remained the same for many years and then decreased to 18 million tonnes in 2016 (http://www.feedtrade.com.cn/)[5]. The rising trend was also seen in the output of feed additive premix which reached to 7 million tonnes in 2016.

In terms of the feed share for different animals, the pig feed always accounted for the biggest proportion of total feed, increasing from about 37% in 2006 to 42% in 2016 (Figure 2). The broiler feed proportion increased from 26% in 2006 to 29% in 2016. The proportion of aquatic feed and layer feed slightly decreased from 2006 to 2016 (http://www.feedtrade.com.cn/)[5]. The Ruminant feed production is stable, but only accounts for about 4%.

Regulatory authority

Well-established institutions and organizations plan, develop and supervise the feed industry (http://www.moa.gov.cn/) in China. Under the China Ministry of Agriculture and Rural Affairs, the Department of Livestock Production (also National Feed Industry Office) is responsible for the registration, importation-review and approval of feed and feed additives, and organization and development of the feed sector's development strategies and policies. The Veterinary Bureau is responsible for supervision and administration of veterinary drugs, veterinary medical appliances and their importation and exportation. China General Station of Animal Agriculture advises and helps the Government to develop legislation rules to improve animal agriculture industry. National Committee of Feed and Feed Additives Evaluation, and Nation Feed Industry Association under the General Station also give guidance for the development of feed industry and evaluate feed and feed additive products.

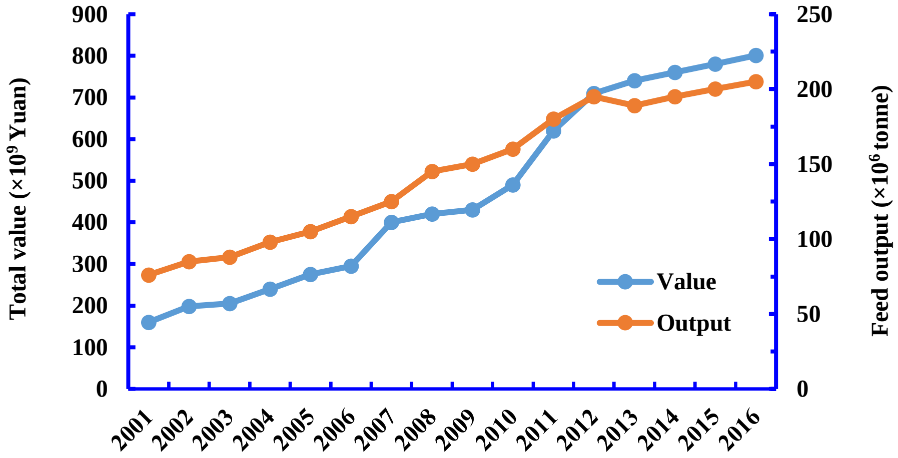

Figure 1 Total output and value of feed production in China

Available feed resources

Since China supports her huge population with very limited arable land, the competition for grain between people and livestock, and the dearth of feed grain are the bottle necks in livestock production in China. The shortage of feed ingredients will be a long-term structural challenge. Addressing this issue is the key to promoting the development of the livestock industry.

Energy feed supply

Wheat and rice are the major staple food of Chinese people and are rarely used as feed for livestock. The output of barley is unstable. Therefore, corn is the main energy feed in China. Although China's corn production is huge, it relies on its imports to meet the need of the feed industry. China's corn production has increased steadily in recent years, reaching 225 million tonnes in 2015. It increased by 8.93 million tonnes in 2014. In 2015, China’s imported corn increased significantly to 4.73 million tonnes (Table 4) with an increase of 2.13 million tonnes (increase rate of 81.9%) in 2014. China's fodder corn consumption was about 106 million tonnes in 2015. Raw material substitution has reduced the demand for corn feed, as the imports of low-priced cereals such as barley and sorghum have increased substantially. Due to the low price of imported sorghum and the lack of import quotas, imported sorghum has become an important alternative to feed corn since 2014. In 2015, China's imported sorghum reached 10.7 million tonnes with an increase of 4.92 million tons (increase rate of 85.2%) compared with 2014.

As a traditional raw material for wine production, the amount of barley used in feed has also increased since 2014. In 2015, China’s imported barley increased to 10.73 million tonnes with the increase of 5.32 million tonnes (increase rate of 98.3%) compared with 2014. Consumption of wheat decreased in 2015 due to the narrowing price between corn and wheat, as well as increased consumption of imported sorghum and barley forage. Because of quota restrictions on corn import, and no-quota on importation of sorghum and barley, imported grain will continue to replace domestic corn[4].

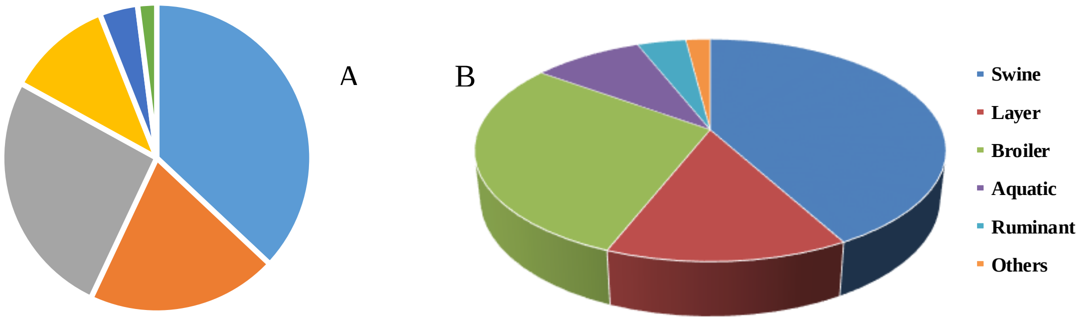

Figure 2 The proportion of different animal feeds in 2006 (A) and 2016 (B)

Table 4 Main feed ingredient consumption and import in China in 2014 and 2015

Items	Consumption (x10^6 tonnes)		Import (x10^6 tonnes)	
	2014	2015	2014	2015
Corn	132	106	2.6	4.73
Soybean	-	-	71	82
Soybean meal	56	61	-	-
DDGS	-	-	5.41	6.82
Rapeseed meal	11	11	0.26	0.12
Cotton seed meal	4.45	3.17	0.002	-
Fish meal	1.45	1.35	1.01	1.03

Source: China Feed Industry Yearbook. 2015-2016/2016-2017.

Protein feed supply

The main protein feed ingredients in China still rely on imports. In particular, fish meal and soybeans (bean pods) are highly dependent on foreign markets.

From 2001 to 2015, China's soybean imports increased from 13.94 million tonnes to 81.74 million tonnes (Table 4), especially with an increase of 10.35 million tonnes (increase rate of 14.5%) in 2014. Fishmeal production in China was about 420,000 tonnes, whereas the import amount was 1.03 million tonnes. China is a net importer of meat and bone meal. China imported 190,000 tonnes of meat and bone meal in 2015 with an increase of 59,000 tonnes (increase rate of 4.5%) compared with 2014. The production of cottonseed meal is the largest in the world, with 34.9 million tonnes in 2015[4].

Potential unconventional feed resources

The unconventional feed generated in China is about 4 billion tonnes annually, but less than 1 billion tonnes is used for livestock production[8].

Crop byproducts such as straw and stovers are the most abundant and widespread unconventional feed resources. Currently, only about 31% of the crop residues are used as feedstuff in China. Besides, 45% of crop residues are used for fuel energy, 3% for paper industry, and other 21% are directly returned to farmland[9]. There is enormous potential to improve the feeding value and increase the use of crop byproducts in animal feeding. Forest-industrial by-products that can be used as animal feed are mainly foliage, twig and tailings of wood. There are about 500 million tonnes of foliage resources in China; 100 million tonnes of twigs, and 100 million tonnes of tailings of wood are produced annually in China[10]. Currently, only about 1% of available forest-industrial by-products are used as feedstuff in

China. In addition to above resources, bagasse and residues from beet, fruit and tea are widely used as roughage sources in China[11-13]. Bamboo shoot shell and mulberry leaves are also widely used in southern provinces[14-16]. In addition, China has abundant feed resources of tubers such as potatoes and sweet potatoes, and the annual output of agricultural and by-products such as distillers grains, vinegar residue, sauce residue, fruit residue, soybean residue, and corn syrup (industrial by-products) reaches 100 million tonnes. However, the utilization of these resources in the feed industry is less than 10%, which is mainly due to the use of traditional processing technologies, lack of competitiveness, low in input-output ratio, and low energy conversion efficiency of products.

Challenges and opportunities in enhancing utilization of locally available feed resources and enhancing feed use efficiency

With huge population and limited arable lands, China is not able to provide the needed food grains as animal feeds. Animal production is hardly sustainable if it relies on the imported feeds. Therefore, the main challenges are to enhance the utilization of feed resources available locally and improve the efficiency of their utilization. There are 700 million tonnes of crop by-products such as straw and stovers available[17], but only less than one-third of these resources are used as animal feeds. High fiber content, low intake, and poor digestion are the constraints for utilization of these resources.

Upgrading of local resources

Numerous studies have been conducted to upgrade the unconventional feed resources. For the upgradation, physical, chemical and biological pretreatments have been used. The physical methods usually include smashing, shortening, making granules, cooking, soaking, straw milling, green forage modulation, among others. Chemical methods commonly used include urea-ammoniation and alkalization using hydroxides. Using these techniques, the digestibility of organic matter straw can be increased by 10 to 20%, which also increases the feed intake of animals.

Biological methods mainly include microbial pretreatment and ensilage. The materials used for silage-making in China include the fresh pasture, all kinds of vines and corn stalks after harvesting seeds, among others. After 1980s, with the continuous increase in the degree of mechanization, silage making has become a conventional technology in the cattle industry throughout the country. With the continuous development of animal husbandry, the demand for silage is also rising. In 2015, the demand for silage was 161 million tonnes in China.

Challenges and opportunities

Low content of nutrients and poor digestibility of most unconventional feed resources including crop by-products limit their efficient use in the feed. There is enormous potential to improve the feeding value and increase the use of straw and stovers in animal feeding. Since 1990s Chinese animal scientists have attempted to effectively use non-grain resources as animal feed. Several studies have focused on improvement of the utilization of straw by pretreating straw.

Some studies have focused on the reasons of the low efficiency of straw used as animal feed. The deficiency of amino acids and low content of non-fibrous carbohydrate may be the important factors limiting the use of corn stover compared to alfalfa hay[18]. Supplementation of corn stover-based diet with starch and amino acids can improve milk performance of lactating dairy cows. When alfalfa hay and Chinese wild ryegrass hay was replaced by corn stover (up to 30% of dietary dry matter), the rumen fermentation parameters including volatile fatty acids and microbial protein production in the rumen, the flow of amino acid through small intestines, and the uptake of amino acid and glucose into mammary gland decreased[19]. The metabolic pathways of many amino acids were significantly different between the cows fed corn-stover and alfalfa hay-based diets[20]. On feeding a modified corn stover diet, in which non-fibrous constituents were added and amino acids were balanced, milk yield and serum metabolomics profiles were similar to those fed with high quality forage. Importantly, this modified corn stover diet provides more economic and environmental benefits[20]. These results provide important guidance to improve the efficiency of straw as feedstuff.

Conclusion

As a result of increased livestock number, the growth of the feed sector has been very high in the last two decades. China has become the largest feed producer in the world. The well-organized government institutions ensure the quality and safety of feed and food. The development of grain-saving strategies for the animal agriculture is a way to secure the sustainable supply of animal products in China.

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References

1. National Bureau of Statistics of China. Statistical yearbook of China 2017. China Statistics Press, Beijing, 2017.
2. China animal husbandry yearbook editorial department. China animal husbandry yearbook 2016. China Agriculture Press, Beijing, 2016.
3. China dairy editorial department. Quality report of Chinese dairy industry 2017. China Dairy, 2017, 7:16-16.
4. China Feed Industry Association. China Feed Industry Yearbook 2016. China Business Press, Beijing, 2016.
5. China Feed Industry Yearbook. China Statistical Publishing House. Beijing, 2000-2012.
6. China Feed Industry Information Center. The situation of the national feed industry in 2013. China Feed. 2014, 10:2-2.
7. China feed industry information center. The situation of the national feed industry in 2015. China Feed. 2016, 10:1-2.
8. Feng DY. Optimization and application of unconventional feed for pigs. Feed and Animal Husbandry, 2012, 2: 8-12.
9. Han LJ, Teng GH, Liu XY, et al. Straw resources and their utilization in China. Transactions of the Chinese Society of Agricultural Engineering 2002, 18:87-91.
10. Liang YS, Liu YL, Zhou XY. Exploit and utilization of non-traditional feed resources. Beijing Agricultural Press, Beijing, 1996.
11. Wang JQ, Guo NP. Exploitation and utilization of beet as feedstuff. Animal Science Abroad. 1944a, 21: 2-6.
12. Wang JQ, Guo NP. Exploitation and utilization of sugarcane as feedstuff. Animal Science Abroad. 1944b, 21: 6-11.
13. Wang JQ, Guo NP. Exploitation and utilization of banana as feedstuff. Animal Science Abroad. 1944c, 21: 12-14.
14. Liu JX, Wang XQ, Shi ZQ, et al. Nutritional evaluation of bamboo shoot shell and its effect as supplementary feed on performance of heifers offered ammoniated rice straw diets. Asian-Australasian Journal of Animal Sciences, 2000, 13(10): 1388-1393.
15. Liu JX, Yao J, Yan B, et al. Effects of mulberry leaves to replace rapeseed meal on performance of sheep feeding on ammoniated rice straw diet. Small Ruminant Research, 2001, 39(2): 131-136.
16. China Agricultural Yearbook Editorial Committee. Chinese Agricultural Yearbook 2016. China Agriculture Press, Beijing, 2016.
17. Zhu W, Fu Y, Wang B, et al. Effects of dietary forage sources on rumen microbial protein synthesis and milk performance in early lactating dairy cows. Journal of Dairy Science, 2013, 96(3): 1727-1734.
18. Wang B, Mao SY, Yang HJ, et al. Effects of alfalfa and cereal straw as a forage source on nutrient digestibility and lactation performance in lactating dairy cows. Journal of Dairy Science, 2014, 97(12): 7706-7715.
19. Sun H, Wang B, Wang J, et al. Biomarker and pathway analyses of urine metabolomics in dairy cows when corn stover replaces alfalfa hay. Journal of Animal Science and Biotechnology, 2016, 7(1): 49.
20. Sun HZ. System-biology based approaches to explore the physiological and metabolic mechanisms for regulation of lactation performance in dairy cows receiving different quality of forages. Zhejiang University, China. 2017.

Sustainable development of livestock production systems through enlarging feed resource base and enhancing feed efficiency: The Kenyan case

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Abstract

The livestock industry in Kenya plays a major role in the country's economy contributing about 12% of the country's gross domestic product (GDP) and 42% of agricultural GDP. This contribution is through mainly dairy and meat production, eggs, hides, skins and wool from cows, sheep and goats. The most recent official livestock population estimates (Table 1) are: cattle 17.5 million, sheep 17.1 million, goats 27.7 million, camels 2.9 million, donkeys 1.8 million, pigs 0.3 million, indigenous chicken 25 million and commercial chicken 6.1 million. Despite the vibrancy of this livestock sector, it is faced with a myriad of constraints. Availability, both quantity and quality, of feed is a major constraint for the dairy, poultry and pig industry while in the Arid and Semi-Arid Lands (ASALs), the main constraints to production are prolonged droughts, which are getting more frequent due to climate change leading to scarcity of water and pasture. Dairy production is mainly through the stall feeding system where animals are fed on fodder with some supplementation. Beef production is mainly through extensive system (pastoralism) and ranching where animals are grazed with minimal supplementation. Both dairy and beef production are based on fodder and pasture and the main constraint is unavailability of both in terms of quantity and quality. This is attributed to reliance on rain fed feed production. Poultry production is mainly through traditional system where chicken scavenge for feed resulting in low production. In the commercial poultry sector, feed costs account for about 70% of production due to reliance on cereals grains in competition with humans and high cost of importation of protein concentrates. Pig production sector is also constrained by the high cost of feeds. To alleviate the feed constraints, there is a need to increase available fodder and pasture through irrigation, use of high yielding and good quality fodder seeds, drought resistant pasture varieties, efficient use of crop residues and increased feed conservation during times of plenty. There is a need to reduce reliance on cereals which are in direct competition with humans through research on alternatives. Enforcement of quality standards of commercial concentrates will go a long way in improving productivity.

Introduction

Agricultural is a strategic sector in the economic development of Kenya. It contributes 35% of the GDP and constitutes 40% of the export earnings. Of this, the contribution by livestock is often given as as 12% of the country's GDP and 42% of agricultural GDP[1]. The actual contribution has at times been contested. In a recent study by IGAD (Intergovernmental Authority on Development) and the Kenyan National Bureau of Statistics (KNBS), it was demonstrated that the contribution could be 2.5 times more than the official estimates meaning that livestock contribution was just below that of crops and horticulture (https://www.igad.int/index.php/programs/95-icpald/714-icpald-policy-briefs) . This contribution is through mainly dairy, meat, eggs, hides, skins and wool from cows, sheep and goats. Apart from primary producers, some urban households are also dependent on income earned through sale of livestock products or employment in livestock-related agro-processing industries such as dairy, meat, and leather. Apart from the monetary contribution, livestock play important roles in socio-economic development and contribute towards household food and nutritional security.

The distribution of different types of livestock, especially ruminants, is dependent on the ecological zone which determines the availability of resources especially feed and water. The country can be divided into three regions according to land productivity potential: high potential areas (>750mm), medium potential areas with an annual rainfall of > 625 mm < 750 mm and low potential areas with annual rainfall of less than 625 mm (http://www.fao.org/Wairdocs/ILRI/ x5485E/x5485e0o.html).

The most recent official livestock population estimates (Table 1) cattle 17.5 million, sheep 17.1 million, goats 27.7 million, camels 2.9 million, donkeys 1.8 million, pigs 0.3 million, indigenous chicken 25 million and commercial chicken 6.1 million (https://www.igad.int/index.php/programs/95-icpald/714-icpald-policy-briefs). Of the 17 million head of cattle, about 4 million are exotic or exotic crosses kept in the high potential land where dairying is practiced while the rest are mainly indigenous breeds (zebu and boran) kept in the ASALs. Sheep and goats are also concentrated in the ASAls. About 60% of Kenya's livestock herd is found in the arid and semi-arid lands (ASALs), which constitute about 80% of the country. Livestock in the ASALs have been reported to provide 90% of households livelihood and nearly 95% of family income [2].

Despite the vibrancy of this livestock sector, it is faced with a myriad of constraints. In the dairy sector, the major constraint is inadequate feeds both in terms of quantity and quality mostly due to dependence on rain fed forage production and high cost of commercial concentrates to supplement the low quality forage. Other challenges include milk marketing, infrastructure among others[3]. The poultry and swine sector is also constrained by the high cost of concentrate feeds, mostly as a result of competition for grain with humans and high cost of imported protein sources.

In the ASALs, the main constraints to production are prolonged droughts which are getting more frequent due to climate change, leading to scarcity of water and pasture. Poor infrastructure, overstocking leading to soil erosion and environment degradation, diseases and rampant cattle rustling are other constraints[4].

Table 1 Livestock population in Kenya: head in 2009 and proportion of individual animal species number in % of 2009 census figure

	National MLD* 2008 estimates	**National 2009 population census**	**ASAL**	**Arid**	**Semi-arid**	**Highlands**
Cattle	13,522,500	17,467,774	12,155,974	6,281,354	5,874,620	5,311,800
	77%	100%	70%	36%	34%	30%
Sheep	9,907,300	17,129,606	14,954,925	10,246,527	4,708,398	2,174,68
	58%	100%	87%	60%	27%	13%
Goats	14,478,300	27,740,153	25,250,865	18,230,633	7,020,232	2,489,288
	52%	100%	91%	66%	25%	9%
Camels	1,132,500	2,971,111	2,968,670	2,924,742	43,928	2,441
	38%	100%	100%	98%	1%	0%
Donkeys	786,800	1,832,519	1,616,522	1,126,103	490,419	215,997
	43%	100%	88%	61%	27%	12%
Pigs	330,120	334,689	82,500	1,438	81,062	252,189
	98.6%	100%	25%	1%	24%	75%
Chicken indigenous		25,756,487	10,258,066	1,063,276	9,194,790	15,498,421
	29,615,000	81%	32%	32%	29%	49%
Chicken commercial	93%	6,071,042	1,523,983	131,811	1,392,171	4,547,059
		19%	5%	1%	4%	14%

Note: MLD-Ministry of Livestock Development- Division of Animal Production.

The feeding systems

Dairy

The feeding and management system of dairy cattle differ where adoption is mainly based on available feed resources, land size and population density [5]. Within the Kenya highlands, where land size is limiting, the main production system is intensive (zero grazing/stall feeding), while the animals are fed on forages and crop residues in mixed agriculture farms [6]. In areas where land pressure is low due to low population densities, semi intensive system is practiced with animals being grazed and/or stall fed depending on the season [7].

Intensive/ Stall feeding/ Zero grazing system. Dairy production in Kenya is smallholder dominated and the main feeding system is stall-feeding and is based on cut and carry where they are offered improved or preserved fodder with supplementation [8]. This production system has been adopted where land pressure is high due to extensive land subdivision and competition with food crops (http://www.fao.org/Wairdocs/ILRI/x5485E/x5485e0o.html). The system is characterized by owning a few acres of land and 1 to 5 milking cows with a close integration of cattle and crops, mostly maize [9]. In this system of production there is interdependency between crops and animals through use of manure accompanied by minimal wastage of feed through trampling [10]. Njarui *et al.* (2016) [7] concluded that in this system, cows are easier to manage as they are kept in close vicinity, can be fed as per productivity, and parasite and disease control is easier. The exact number of smallholder farmers practicing intensive dairying may not be known but was estimated to be 1.5 million households, accounting for more than 85% of the annual total milk production and 80% of total marketed milk [11]. An increasing number of farmers is taking up commercial dairy farming; a majority of whom are in the urban and peri-urban areas and fully rely on commercial feed/fodder markets due to limited access to land. It is estimated that the smallholder farmers produce only about 70% of their feed requirements resulting in under feeding and that this deficit may run 4 to 6 months during a year [6].

In this system, cattle are fed mainly planted fodder like Napier grass, maize, weeds, grass and crop residues [12] and sometimes supplemented with concentrate feeds such as grain millings or compounded dairy feeds [7]. According to Njarui [12], approximately 95% of dairy farmers stored crop residues for their livestock but the storage methods were inappropriate to maintain the quality, with 93% of the smallholder farmers experiencing seasonal fluctuation of feed availability and therefore milk production. It is important to note that in some cases, a large proportion of fodder is gathered from public or common land or is purchased, so feed resources are by no means limited to those produced on farm.

The feed/forage used by farmers includes maize stovers, poultry waste (dried), hay (usually purchased pure Lucerne, grass or Lucerne/grass mix), silages (by a few farmers), home-made rations of locally available grains and other ingredients, and grazing (the most common feed source) [13]. Commercial dairy feeds include dairy meal, dairy cubes, calf pullets, maize germ, maize bran, molasses, cottonseed cake, wheat pollard and wheat bran. Commercial feed production for 2017 was 25,000 tonnes/month [14]. Energy sources include locally produced maize and its milling by-products, while the sources of other nutrients are mainly imported. Protein sources are imported from the East Africa region, and are mainly sunflower/cottonseed cakes and premixes from countries such as Switzerland, the Republic of Korea, China, South Africa and Israel [3]. Daily milk production in this system averages 15-30 litres [15].

Semi- Intensive. In Kenya, this system is practiced in areas where availability of land is not a constraint mostly in medium to high potential areas. The dairy cattle are often raised together with other animals like chicken, sheep and goats [11]. The system combines grazing and stall feeding or purely paddock grazing. Feeding system varies across regions including use of natural grass, improved pasture and post harvest grazing. Animals are supplemented during milking and farmers keep either pure or crosses of the dairy exotic breeds of cattle [8]. Milk production in this system is lower than stall fed cows averaging 6 litres per day [11].

Extensive. This is a pasture based system where exotic and cross bred dairy cattle are kept in large farms with controlled grazing and in some communal farms with uncontrolled grazing with animal numbers ranging from 10 to 50 per farm. The exact numbers of farms are not known but Omore *et al.* estimated them to be 3% of the dairy farms keeping 35% of the cows [16]. Milk production in this system is low ranging between 4-11 litres per cow per day [17].

Beef

The beef industry is an important contributor to the Kenyan economy especially in the arid and semi-arid areas where beef production from pasture is the main economic activity [18]. Beef production in Kenya is based on about 13 million cattle, which are predominantly reared in pastoral systems (80-90%), ranching (20.30%) and highlands (8-18%) [19].

Most of Kenya (80%) is classified as ASALs where the precipitation does not allow crop agriculture. The bulk of beef consumed in the country is produced in these areas, mostly through 2 main systems: large-scale commercial ranching and traditional pastoral production system. In both these systems, production is pasture-based through indigenous breeds (small East African zebu and Boran) or exotic beef (for example, Hereford, Simmental, Charolais, Angus) mainly kept by the commercial ranchers.

Nomadic pastoralism. This is based on seasonal pattern of movement by the herders on a regular pattern based on low input and low output with low livestock densities. This is an environmentally sustainable system in the ASALs and has been practiced for decades in these areas. Indigenous beef cattle breeds predominate and are kept in mixed herds with other animals [18]. This system supplies about 80-90% of beef consumed in Kenya, both from within the country borders and also from neighbouring countries [19].

This system could lead to the destruction of fragile ecosystems through environmental degradation by overstocking. The transhumance nature of the production system exposes pastoralists to conflicts over pasture and water rights.

Ranching. This is practiced within the confines of a space (a ranch) where optimal stocking rates are maintained. Within the ranch, infrastructure for the cattle are available including fences, dips and watering points. Some level of supplementation may be available. The system is highly commercialized and target prime markets for their products contributing to most of the beef exports. The main input is natural or cultivated pasture with supplementation during the dry season.

This system is constrained by recurrent conflicts with pastoralists especially during the dry season when there is scarcity of pasture. Disease challenges due to interaction with wildlife have been reported.

Agropastoralism. Practiced within mixed crop livestock farms where crop residues and byproducts are used for feeding animals and the manure is used for crops, and at times the animals may provide draught power. These animals are normally found grazing in communal areas.

Feedlot system. A feedlot project was started in Kenya with the aim of obtaining immature animals from the ASALs during the periods of feed shortage and to feed them to market weight. The system was not sustainable due to lack of markets for the high value beef and demand for high energy feed from cereals. As currently practiced, immature animals obtained from the ASALs are put on a feeding regime to attain a certain growth rate and weight within a short period (mostly 3 months). The animals are fed on high amounts of concentrate containing substantial amounts of human edible components, mainly cereals.

Lack of capital and investment capacities have been cited as constraints to expansion of feedlots. The system is re-emerging with the emergence of demand for quality meat by affluent consumers.

Sheep and goat

Small ruminants play an important role in the livelihoods of resource-poor farmers in Kenya, though their contribution is often underestimated. Besides being an important source of protein and immediate cash, they also have a variety socio-cultural values. Small ruminants also provide one of the practical means of using vast areas of natural grassland in regions where crop production is impractical [20]. Sheep types found in Kenya are both meat and wool breeds while goats are of both meat and dairy types. Hair sheep (Red Maasai and Somali breeds) are normally found in the ASALs on natural pastures while wool sheep (Merino and Corriandale) are found in the medium to high potential areas under improved pastures. Meat goats are mostly the Small East African and Galla breed while dairy goats comprise mostly imported breeds (Toggenburg, Saanen,Alpine, Nubian) or their crosses with local breeds.

As a result of diminished land sizes in the high potential areas, the importance of small ruminants in these areas is expected to increase. This is especially so for dairy goats whose population has continued to increase due to their low feed requirements and perceived medicinal properties of its milk.

Constraints to sheep and goat production include prolonged droughts, high occurrence of diseases and poor markets, among others [21].

Feeding systems for monogastric

Poultry. Poultry production in Kenya is either traditional (intensive using local breeds) or commercial intensive (using hybrids). It is one of the major livestock industries producing about 8% of agricultural GDP in 2004 [13]. It is estimated that 65% of Kenya households keep at least one bird [22].

Traditional system. This sector (also referred to as backyard system) comprises indigenous chicken, ducks and turkeys and other poultry types kept in the rural areas and in the urban informal settlements. It is a low input low output system and represents up to 80% of total poultry production in Kenya and revolves around low income households [23]. The numbers vary with region, species and consumption needs.

The birds are either confined in small structures and fed locally available feed resources or left to scavenge whatever they come across including kitchen leftovers (with minimal supplementation) during the day and enclosed at night.

Commercial production system. This sector comprises small and large scale producers that keep between 100-100,000 layers and between 300-30,000 broilers per farm for commercial purposes. Day old broilers chicks are purchased from established hatcheries while some large scale keepers obtain them on a contractual basis from big hatcheries that also market processed poultry products (Kenchic Ltd and Quality Meat Processor Ltd). These contracts guarantee a market for the ready birds.

All commercial chicken are fed on commercial mixed feeds which are supplied by the many feed manufacturers as discussed later.

Pigs: Production systems for pigs in Kenya, include large and small-scale commercial systems in which improved breeds are fed commercial concentrates. Free range (scavenging) system is practiced in a few areas in the country. Housing systems range from simple structures to complex housing with sophisticated equipment.

Commercial pig production. The commercial small-scale system is characterized by improved breeds, high planes of nutrition consisting of concentrates, which results in high performance [24]. The amount of manufactured pig feeds in the country is next to poultry and dairy feeds. The raw materials used for the manufacture and their sources are discussed later under 'Concentrates'.

Free range pig production. In this system (also known as ‘scavenging’) the pigs move freely around the house and the surroundings areas scavenging for feed. They are at times supplemented with organic household waste (mostly kitchen waste). These pigs are rarely sheltered with minimal or no investment, and rarely fed on commercial feeds or provided veterinary services [25]. This type of pig farming is quite popular in Western region of Kenya. In these settings, families keep an average of one to two pigs which are usually tethered or allowed to scavenge on their own [26].

Available feed resources

The available feed resources in Kenya can be classified into roughages and concentrates. Roughages comprise of grasses, fodder crops, crop residues and industrial byproducts. A recent study estimated the fodder requirements in the country for dairy cattle, beef cattle, shoats, camels and donkeys against the supply and concluded that currently the fodder deficit stands at 50% of requirement [27].

Napier grass

Napier Grass (*Pennisetum purpureum*) which is also commonly referred to as elephant grass is the most popular fodder crop for small scale dairy farmers in the high and medium potential dairy production areas of Kenya. The grass is fed fresh under the cut and carry (zero grazing) system of production. The grass is easy to establish either through splits or cuttings. It is a high yielding fodder crop and is highly palatable especially when harvested young at about one metre tall. The grass is not suitable for direct grazing as regeneration is poor. It can be grown in diverse altitudes if there is enough precipitation (best at 1500 mm per year) but beyond an altitude of 2000 m from mean sea level growth is slow and it may die from frost [28]. Bana is the most popular variety, being characterized by short succulent stems with broad leaves and has the least tendency to be stemy at maturity while French Cameroon variety, which grows up to 3 metres is stemy and hairy. Outbreak of diseases such as head smut and stunting disease have reduced dry matter yields [29-30] of the common cultivars, suggesting a need to develop new varieties. One variety, Kakamega 1 is resistant to head smut and has been widely adopted.

In Kenya, the average dry matter yields vary between 10 and 40 tonne dry matter (DM) per ha per year, depending on soil fertility, climate, and management [31]. Napier grass on average contains 20% DM, 7 to 10% crude protein (CP), 70% neutral detergent fibre (NDF), 45% acid detergent fibre (ADF) [32-33]. Due to its low CP content, research has shown that intercropping Napier with legumes (e.g., Desmodium) increases yield due to nitrogen fixation, and enhances milk production when the forages are fed together. Kariuki *et al.* (1998) [34] observed a positive growth response in heifers fed on Napier grass supplemented with protein rich forages and attributed this to additional rumen degradable protein and/or bypass protein from protein rich forages (PRF) that overcame protein deficiency in Napier grass. Supplementation of Napier with high protein and energy concentrates is recommended when feeding high yielding dairy cows due to its low nutrient and high moisture contents.

Due to fast growth rate of Napier grass after the rains, farmers are not able to utilize it fast enough leading to overgrowth and deterioration in quality. It is therefore recommended that the excess should be conserved and due to the high moisture of the stems (difficult to dry) and brittle nature of the leaves (breakage on drying), conservation through silage making should be practiced. Due to low levels of water soluble carbohydrates in Napier grass required for fermentation [35], addition of molasses is recommended during ensiling.

Fodder maize

The use of maize fodder for animal feeding is fast gaining ground in both small and large scale mixed farms in Kenya. In the past, maize fodder for livestock feeding was only obtained from stripping maize plants while allowing the grain to mature [36].

Of late, due to realization that the popular Napier grass would not be enough to sustain the high milk production of improved dairy cows, maize fodder is gaining popularity in the high rainfall areas where most of the dairying is practiced. Maize for forage production has been reported as a quick way of obtaining high DM production and an ideal quality feed for cattle feeding. It can be fed either as fresh forage or as silage [37-38] Estimates show that fodder maize contributes up to 24% of the total cattle feed thus making maize production for grain and fodder equally important [39]. The most common method of feeding maize in the country is as silage which has the following advantages: high energy feed forage to meet the requirement of milking cows and an efficient way to store high quality feed for feeding during the dry season.

Ensiling maize has several advantages over Napier grass, the most common fodder for small scale farmers. Maize has high levels of soluble carbohydrates (thus ferments very well with minimal need for additives). The resultant silage is highly nutritious, especially energy wise, as the crop is harvested at the hard dough stage. The high energy of maize silage helps meet the increased demands of a lactating dairy cow for energy to produce milk.

Maize silage is high in energy, moderate in protein and low in minerals such as calcium, phosphorus and magnesium, relative to other forages such as Napier or Lucerne. Typical good maize silage, with lots of kernels has 8% CP and 70% total digestible nutrients (TDN) (energy) and 0.2% both Calcium and Phosphorus on dry matter basis [40]. Furthermore, maize forage, while fresh, has a 7.2 to 8.5% of CP, from 32.5 to 33.5% of crude fiber, and from 1 to 2.5% of fat, besides containing high quantities of soluble carbohydrates. It has the potential of providing an energy rich material for cattle feeding and of being of use at all levels of production [41].

Sorghum

Due to increased pressure on land in the high rainfall areas of Kenya, competition between food and feed has become more intense resulting in reduced area for animal feed production. The solution to this lies in growing of dual purpose crops or increase in utilization of the marginal areas. Sorghum *(Sorghum bicolor)* has been identified as alternative to some previously grown fodder crops as dual varieties have been developed and it is more drought resistant that both Napier and maize. Sorghum is gaining acceptance for grain and forage production because of early maturity ratooning and tillering abilities [42].

Several of these dual purpose varieties have been tested for their nutritional value [43]. Several improved, grain, forage and dual purpose genotypes suitable for various regions of Kenya such as low altitude zones (Eastern, Coastal regions), medium altitude zones (Western Kenya) and high altitude zones (Rift Valley, Central Kenya) have been developed [44]. Sorghum fodder can be fed fresh or as silage. The silage is high in energy but low in protein and does not meet the requirements of high yielding dairy cow, and therefore supplementation with high protein concentrate is recommended [45].

Sweet potato vines

Sweet potato vines are mainly used as dairy cattle feed in high potential areas in Kenya especially for the cut and carry feeding system [46]. The crop is established through storage roots, sprouts and cuttings and spreads quickly, forming a dense ground cover on the ground when fully established [47] Dual purpose cultivars of sweet potato vines (SPV) provides tubers for human consumption and vines for feeding livestock and thus suitable in areas where land is limiting [46]. Apart from the sweet potato being a fodder crop, it is grown widely as a food crop in Kenya. Sweet potato is an important secondary food crop for many Kenyans whose staple diet is based on cereals, particularly maize[47]. The estimated annual production of sweet potato root in Kenya is 740,000 tonnes a year.

When harvested at an age of 6-8 weeks, Lukuyu *et al.* [48] reported that the fresh vines had CP, NDF, digestibility percentages and metabolizable energy of 16%, 46%, 60% and 8.3 MJ/kg respectively on dry matter basis. When silage was prepared from vines and roots, these values were: 16.2%, 20%, 69% and 13.3 MJ/kg respectively.

Nutritionally, one of the limitations of utilization of SPV is high moisture content which can be as high as 87 and 72% for fresh vines and silage (vines and roots), respectively. Controlling this moisture content when making silage is challenging for farmers but can be achieved through using improved tubes which allow drainage [48]. Yield and quality of forage vary with age of plant, with dry matter yield of vines ranging from 4.3 to 6 tons DM/ha [47]. Manoa (2012) [39] reported average DM yield of vines to be from 0.8 to 7.2 tonnes DM/ha for different varieties (both fodder and non-fodder) of sweet potato recommended in Kenya.

The major challenge facing sweet potato farmers is the current low yields, which are the result of high losses due to pests and diseases and inadequate quantities of clean planting materials. The losses due to viruses can be as high as 80% of harvest [49]. Kenya's average sweet potato root yields are 6 tonne DM/ha, which is less than half the world's average yields of 14 tDM/ha [50].

Calliandra. Calliandra (*Calliandra calothyrsus Meissner)* a multipurpose tree legume. It was introduced to the Central Highlands of Kenya in the 1980s and since then has been widely promoted and adopted as a supplement to ruminants fed on low-quality forages [51-52]. Calliandra has been adopted due to its fast growth and high biomass production of foliage as well as wood for fuel [53]. Despite its high CP content (up to 22%) [54], Calliandra is high in tannins which suppress ruminal degradation of proteins through formation of tannin-protein complexes. These complexes are hardly degraded by ruminal microbes [55]

Due to the high costs of commercial dairy concentrates, Calliandra has been recommended as a supplement to the basal diets, to lower production costs. Patterson *et al.* [31] suggested that one kg of dry Callindra contained about the same amount of digestible CP as one kg of commercial dairy concentrate. Currently, Calliandra is one of the most adopted protein rich forages and is used in either dried leaf (easy to store) or wilted fresh form.

Lucerne

Lucerne is a high yielding perennial forage legume that grows upright to about one metre and is ideal for conservation as hay or silage. In Kenya, large scale production of lucerne is practiced in the medium to high potential areas either as rain fed or through irrigation. This Lucerne is primarily grown for farm use or sale as a high protein hay mostly for feeding high yielding dairy cows. It is not grazed directly due to risk of death through bloat but can be fed after wilting.

Lucerne does well in high rainfall areas but due to its deep rooting system, it can survive in lower rainfall areas once it is well established. Due to Nitrogen fixing ability, it is at times intercropped with other fodder crops like Napier. Annual yield of 16-18 tonnes DM (80-90 tonnes wet weight) at 20-25 % CP have been reported [57].

Other protein rich forages that are in use, albeit in smaller quantities, are Sesbania (*Sesbania sesban*), Mulberry *(Morus alba)* and Leucaena (*Leucaena leucocephala).*

Rhodes grass

Rhodes grass is a perennial grass that once established, spreads quickly forming good ground cover, growing to a height of 0.5 metres tall [58]. Rhodes grass can easily be established using seeds at a rate of 4-6 kg per hectare [59], and performs best in clays to sandy loam soils with annual rainfall of 24–40 inches (600–1000 mm) [58].

The grass is highly palatable with CP content of about 8-11% and in Kenya it is useful in cut and carry feeding systems and open grazing. It is highly suitable for making hay. It is primarily grown for hay making and is the most traded fodder hay in the country.

Kikuyu grass

Kikuyu grass is a creeping sub-tropical grass that forms a dense turf and provides excellent forage for all grazing animals, beef, dairy, sheep, goat, horse and camel [60]. It is tolerant to heavy grazing and popularly used as pasture in dairy production in Kenya highlands. The common kikuyu cultivar does not produce seeds and thus are propagated using runners and usually forms a dense sward after establishment. Under moisture stress, seedlings grow and establish slowly but once established it is very tolerant to heavy grazing [61].

Young kikuyu grass has high CP levels of up to 21% and *in vitro* organic matter digestibility of 64% [62]. Presence of a legume in the sward increases utilization of the grass [61]. It has been estimated that milk production of up to 15 litres per day can be obtained on feeding young Kikuyu grass.

Crop residues

Crop residues are an integral part of livestock feeding in Kenya. Though many types of crop residues are fed to livestock, primarily cattle, sheep and goats, the most common are those obtained from the common cereals staples. Maize is the staple food in Kenya and as such produces the highest amount of crop residues. Other commonly used residues are wheat, rice and barley straws and sorghum stovers. Bean haulms are also gaining popularity.

Crop residues are known to be of low nutritive value. They are high in fibre (including lignin) and are low in CP, resulting in low digestibility. These are considered as dry season feeds. Trade in straws and stovers is very common during the dry season and their value cannot be underestimated in maintaining the animals during this period.

Attempts have been made to improve these residues through mechanical processing (mostly chopping) to increase intake as well as through chemical means by using urea-ammoniation to improve digestibility[63]. The viability of this chemical improvement is dependent on the cost of urea and labour, and level of improvement achieved [64].

Concentrates. Feeding of non-ruminants is fully based on concentrates including energy, protein, mineral and vitamin sources. There are no concentrates grown purposely for animal feed, but the industry is based on cereals grown as human food, byproducts of cereal milling, oilseed cakes as protein source, local or imported mineral sources and imported vitamins and additives. Fish meal is mostly from local fish (*Rastrineobola argentea*) obtained from Lake Victoria or trimmings from the fish filleting industry.

The country is not self sufficient in concentrates and are imported from neighbouring countries (Uganda, Tanzania) and from India, China, South Africa and Brazil.

The most commonly used concentrates fed either singly as mixed feed are (Table 2):

- Energy sources: Maize, maize germ, wheat bran, wheat pollard, sorghum, and rice bran;
- Protein sources: Fish, soya (full fat and meal), cotton seed cake, sunflower seed cake and copra cake;
- Minerals sources: Salt (mined from volcanic Lake Magadi and from the sea) and limestone (mined locally), bone meal. Other mineral sources are imported; and
- Additives and premixes: Imported premixed or mixed locally from imported raw materials.

Of all the raw materials, maize, wheat and their byproducts are the most dominant feed resources for the feed manufacturers.

Status of feed industry and regulatory authority

Currently the commercial feed industry is composed of sale of roughages consisting mainly of hay (mostly Rhodes grass and Lucerne) and limited sale of maize silage, raw materials for commercial concentrate mixing and mixed concentrates. The regulatory authority in the commercial feed industry is the Kenya Bureau of Standards (KeBS) whose mandate is to develop standards (Table 3) pertaining to raw materials for use in feed mixing, mixed feeds for different classes of livestock and standards for good manufacturing practices and to enforce the same. KeBS does not currently regulate the trade in roughages (hays) but there are indications that this will be done soon.

The feed milling industry comprises of a majority (>90%) of small scale manufacturers (1000 tonnes/month), 7% producing 1000-5000tons/month and 2-3% producing >5000 tons/month [14]. The large industries are located around the capital city and environs where the most intensive livestock production is practiced. The high concentration of these manufacturers in one location has contributed to high costs of finished feeds in other locations due to transport costs. This has led a proliferation of small feed millers in these locations, some of them do not conform to standards and are difficult to regulate because they do not register with regulator.

Table 2 Types of concentrate feed ingredients and their sources

Ingredient	Local availability (% of total)	Imported (% of total)	Imported from
Maize grain	80	20	Uganda, Tanzania
Yellow maize	0	100	Source varies year to year (South Africa, USA, Brazil)
Maize germ	78	22	Uganda
Maize germ cake	100	0	
Wheat grain	100	0	
Wheat bran	69	31	
Wheat pollard	75	25	Uganda
Rice polish	60	40	Uganda
Rice bran	40	60	Uganda
Sorghum	100	0	
Mollasses	100	0	
Fish meal	33	73	Uganda, Tanzania, Zambia
Fish (omena)	50	50	Uganda, Tanzania
Soya	25	75	Tanzania
Cotton seed cake	43	57	Uganda, Tanzania
Sunflower meal	67	33	Uganda, Tanzania
Sunflower seed cake	25	75	Uganda, Tanzania
Amino acids, additives, premixes	0	100	USA, Europe, India, China, South Africa

Source: Kenya market trust, 2017 （http://www.kenyamarkets.org/wp-content/uploads/2017/10 Accessed 26th April 2018）

The main driver of the feed manufacturing industry is poultry feeds which comprise of 41%, dairy and pig feeds forms 39% and 13% of the manufactured feeds[65]. In an earlier study, poultry was reported to make up 68% of manufactured feed while dairy constituted 28%[14]. This is expected as uptake of poultry products (meat and eggs) has increased in recent times.

The study by KMT (*http://www.kenyamarkets.org/wp-content/uploads/2017/10 Accessed 26th April 2018*) established that the installed feed manufacturing capacity is only 69% utilized with an estimated current production of 64,000 tonnes/month versus a potential production of 94,000 tonnes [65]. In an earlier study, only 45% of the installed capacity was reported to be utilised.

The KeBS in fulfilling its feed industry regulatory mandate has developed standards to be adhered to by all manufacturers. The standards that have been developed so far include, among others, for poultry, dairy, pigs, ostrich and fish feeds, and for raw materials.

Some government policies and regulations also influence the feed industry. Restriction of importation of maize from some countries (e.g., USA) by the Biosafety Act resulting in denying the industry cheap maize as well as increasing competition with humans for the white maize. The government has however waived taxes on imported raw materials. Currently, a feed policy document is at an advanced stage, and could be passed soon to guide the livestock feed industry.

Challenges and opportunities in enhancing utilization of locally available feed resources and enhancing feed use efficiency

There are a number of challenges and opportunities in enhancing utilization of locally available feed resources and enhancing feed use efficiency.

Challenges

The challenges to enhancing productivity and utilization of locally available feed resources and maximizing efficiency of utilization are diverse and thus can be addressed differently.

Roughages. Forage (pasture and farmed fodder) form the backbone of livestock production in the country. Currently all pasture production (both in high potential and ASALs) and over 90% of farmed fodder are dependent on rain. Most parts of the country experience two rainy seasons (which is becoming less reliable with climate change). Between the two seasons, there is a deficit and animals lose weight in range areas (and sometimes lead to death depending on severity of the drought) while in dairy producing areas, there is recurrent fluctuations in milk production.

Low adoption in feed conservation has led to excess fodder during the rainy season which overgrows and deteriorates resulting in loss of quality. This overgrown material is poorly utilised by livestock resulting in lower stocking densities and hindering increase in growth.

Table 3 Animal feed standards in Kenya

No.	Name	Contents
1	KS 2543: 2014	The animal feed industry - Code of practice
2	KS 2577: 2015	Calcium phosphates feed grade - Specification
3	KS 2599: 2015	Calf milk replacers - Specification
4	KS 2132-1: 2008	Cat foods - Specification - Part 1: Complete meal
5	KS 458: 2010	Common salt and mineral supplements for livestock - Specification
6	KS 2451-1: 2015	Compounded catfish feeds- Specification Part 1: Complete feed
7	KS EAS 55: 2000	Compounded pig feeds - Specification
8	KS 61: 2009	Compounded poultry feeds - Specification (Third Edition)
9	KS 2533: 2014	Compounded quail feeds Specification
10	KS 2289-2: 2015	Compounded tilapia feeds Specification Part 2: Supplementary feed
11	KS 2451-2: 2015	Compounded Catfish Feeds - Specification Part 2: Supplementary Feed
12	KS 2500: 2014	Dairy cattle feed premix- Specification
13	KS 62: 2009	Dairy cattle feed supplements - Specification
14	KS EAS 58: 2000	Dog feeds - Specification
15	KS 1742: 2013	Horse feed supplement - Specification
16	KS 2358: 2012	Maize gluten meal - Specification
17	KS EAS 287: 2002	Oil-seed cakes for compounding livestock feeds - Specification
18	KS EAS 233: 2001	Ostrich feed - Specification
19	KS 2540: 2014	Pig feed premixes Specification
20	KS 2508: 2014	Poultry feed premixes - Specification
21	KS 2289-1: 2015	Specification for compounded tilapia feeds Part 1: Complete feeds diet
22	KS 2243-1: 2010	Specification for Puppy food - Part 1: Complete meal
23	KS 2325: 2012	Specification for rabbit feed supplement
24	KS 2244: 2010	Urea molasses block as ruminant feed supplement - Specification

In the ASALs, overstocking and prolonged droughts have led to overgrazing resulting in soil deterioration and environmental degradation. These result in poor productivity. Reduction in pasture productivity has resulted in conflicts over grazing rights.

Availability of quality (certified) and affordable fodder seeds is also a challenge. Multiplication has been slow resulting in producers using uncertified seeds that give low yields.

Another emerging challenge is shrinking land areas especially in high rainfall areas due to urbanization and land subdivision to cater for expanding family sizes. This has decreased fodder availability for feeding dairy cattle because the number of animals has not reduced. The solution is to use marginal areas for fodder production using drought resistant varieties.

The available pasture and fodder is low in CP and they do not satisfy the protein requirements of medium to high yielding dairy cattle. Increasing protein content using commercial supplements is at times not viable due to the high cost because most of them are imported.

Post-harvest losses of fodder due to poor handling has been reported. These losses occur because of spillage and rotting at farm level especially during the rainy season. Poor on farm storage exposes the feed to vagaries of weather, due to lack of storage infrastructure. This could also lead to mold growth and contamination with Aflatoxins, which raises the issue of feed safety.

Commercial concentrates. The biggest challenge is dependence on cereal grains for commercial feed production thus creating competition with human food needs. The most commonly used energy source for non-ruminants is maize which also happens to be the staple diet in the country. This leads to high cost of the cereal, translating to high costs of the mixed feed. As a result of this the final product (either meat or eggs) becomes too expensive. During times of shortage, it is not available for use in animal feeds resulting in substandard feeds as feed mixers look for alternatives.

Availability of protein rich raw materials has been a challenge to the livestock sector in the country. As discussed earlier, most of the protein rich raw materials are imported from neighbouring countries. There are efforts to increase use of locally available oil seed cakes; and of late, there is increased use of canola and copra cakes.

The quality of commercial concentrates is a challenge especially for the poultry and pig industry. Substandard mixed feeds is a common complaint from most farmers in the country resulting in low productivity (poor growth and low laying percent). The responsibility of enforcing quality of mixed feeds by ensuring adherence with the legal standards is shouldered by KeBS. Enforcement of standards by KeBS is hampered by lack of manpower to police many feed manufactures, most of them do not get their products certified.

Affordable and reliable feed quality testing laboratories have been a bottleneck in the production of quality commercial feeds. Until recently, feed quality testing facilities were only available in government research stations and training institutions whose main mandate is research. Results of quality tests from these laboratories were at times not timely due to bureaucracy.

Knowledge on feed quality and feeding has at times been lacking due to lack or poor extension services. This has at time led to inefficient use of available feed resources, either through poor feed formulations or poor fodder production techniques, resulting in low dry matter yields and poor quality of harvested material.

Disconnect between research priorities by national agricultural research institutions (NARIs) and needs of farmers. This is mainly because research in livestock feeds is donor funded and as such the farmers immediate problems may not be adequately addressed. When the relevant problems have been researched on, the information may not trickle down to end users due to ineffective dissemination channels.

Opportunities

Roughages. Arising from chronic fluctuations in fodder availability due to seasonality of production, opportunities arise from irrigated fodder (viability is low), through conservation at farm level (either hay or silage) or establishment of fodder banks (hay) by local or national government. Technology for feed conservation has been widely disseminated and the local governments and cooperatives are now investing in machinery which can be shared by the farmers.

The fodder seed market has attracted investors due to high demand. It is envisaged that in the future availability of quality seeds will not be a constraint as the trade in fodder has been expanding. A large number of those growing fodder in large scale are not livestock keepers but traders.

Research to improve fodders and use alternative feed resources within the National Agricultural Research Institutes has been intensified. As a result, improved varieties of fodder sorghum, higher yielding sweet potato varieties are now available. Improved grass varieties like Bracharia are also being tested.

Use of protein rich forages (PRFs) offers an opportunity to increase the protein content of pastures and fodders. Research on inclusion of these PRFs in cattle diets and the advantages of intercropping legumes with fodder grasses is being carried out.

Commercial concentrates. Research on efficient use of unconventional raw materials has been intensified. Use of sorghum, which can thrive well in the ASALs, has been used as an alternative to maize. Root crops like cassava have also been used in place of maize in non-ruminant diets with encouraging results. Research on use of insects (e.g., Crickets and Black Soldier fly) as feed is undergoing with promising results.

The Association of Kenya Feed Manufacturers (AKEFEMA), a body encompassing all commercial feed manufacturers, hopes to educate their members on the importance of adhering to the standards. This development, where manufacturers can police themselves, is a step towards improving the quality of manufactured feeds. The main limitation is that AKEFEMA has no legal authority to enforce the standards.

Commercial feed quality laboratories are now available in the country and these have contributed substantially in improving the quality of commercial concentrates. Currently, rapid testing equipment (Near Infra-Red Spectroscopy, NIRS) are available in many laboratories guaranteeing timely results to allow decision making for procuring raw materials for feed production.

The country does not lack qualified personnel in animal feed science and they can be effectively mobilized to train feed producers and livestock keepers. They can also be used to disseminate relevant research findings to the stakeholders. Recently, in an attempt to bring services closer to the farmers, extension has been devolved from the national government to the local government.

Conclusion

The animal feed industry in Kenya is based largely on roughages composed of fodder and both natural and planted pastures for feeding the large numbers of ruminant animals. Due to increased intensification in livestock production, concentrates are playing an increasing role especially in the manufacturing of dairy supplements and poultry and pig feeds. constraints facing the industry include reduced pasture due to climate change and environmental degradation, reduction in land available for fodder due to pressure on land for food production, lack of quality fodder seeds, reliance on cereals for concentrate feeds and low quality of manufactured feeds. Wastage of the available fodder due to low adoption of conservation in small scale farms is common. Different players are playing different roles in ensuring increased availability (quantity) through development of improved varieties and production methods, and reduction in wastage through processing and conservation. Research into use of alternative unconventional feed resources is undergoing and needs further strengthening. Improving quality of commercial feeds through strict regulatory enforcement is required.

References

1. SNV. Process Report on the National Conference on Public Private Partnership in the Development and Management of Livestock Marketing in the ASALs. Nairobi, 2008.

2. Kenya Ministry of Agriculture. Agriculture, Livestock, Fisheries and Rural Development Sector Medium-Term Plan 2008-2012. Republic of Kenya, Ministry of Agriculture, 2008.

3. Muriuki HG. Dairy development in Kenya. Food and Agricultural Organization, Rome, 2011.

4. Onono JO, Wieland B, Rushton J. Constraints to cattle production in a semiarid pastoral system in Kenya. Tropical animal health and production, 2013, 45(6): 1415-1422.

5. Staal S J, Waithaka M M, Njoroge L, et al. Costs of milk production in Kenya: Estimates from Kiambu, Nakuru and Nyandarua districts. 2003.

6. Njarui DMG, Gichangi EM, Gatheru M, et al. A comparative analysis of livestock farming in smallholder mixed crop-livestock

systems in Kenya: 1. Livestock inventory and management. Development, 2016, 28: 4.

7. Mbugua PN, Gachuiri CK, Wahome RG, et al. Performance of dairy cattle under two different feeding systems, as practiced in Kiambu and Nyandarua district of Central Kenya. 1999.

8. Muia JMK, Kariuki JN, Mbugua PN, et al. Smallholder dairy production in high altitude Nyandarua milk-shed in Kenya: Status, challenges and opportunities. Livestock Research for Rural Development, 2011, 23(5): 2011.

9. Muriuki HG. Milk and dairy products, post-harvest losses and food safety in sub-Saharan Africa and the near east, a review of the small scale dairy sector-Kenya. Rome, Italy: Food and Agricultural Organization, 2003.

10. De Haan C, Steinfeld H, Blackburn H. Livestock & the environment: Finding a balance. Rome, Italy: European Commission Directorate-General for Development, Development Policy Sustainable Development and Natural Resources, 1997.

11. Staal SJ, Owango M, Muriuki H, et al. Dairy systems characterisation of the greater Nairobi milk shed. International Livestock Research Institute (ILRI), Nairobi, 2001.

12. Njarui DMG, Gatheru M, Wambua JM, et al. Feeding management for dairy cattle in smallholder farming systems of semi-arid tropical Kenya. Livestock Research for Rural Development, 2011, 23(05).

13. FAO. FAOSTAT. Data for 2014, 2017.

14. KMT. Mapping animal feed manufacturers and ingredient suppliers in Kenya. Kenya, 2017.

15. Rademaker I F, Koech R K, Jansen A, et al. Smallholder Dairy Value Chain Interventions; The Kenya Market-led Dairy Programme (KMDP)–Status Report. Centre for Development Innovation, 2016.

16. Omore AO, Muriuki H, Kenyanjui M, et al. The Kenya dairy sub-sector: a rapid appraisal. 1999.

17. Lanyasunya TP, Wang HR, Mukisira EA, et al. Effect of seasonality on feed availability, quality and herd performance on smallholder farms in Ol-Joro-Orok Location/Nyandarua District, Kenya. Tropical and Subtropical Agroecosystems, 2006, 6(2).

18. Kahi AK, Wasike CB, Rewe TO. Beef production in Arids and semi arid areas of Kenya: Constraints and prospects for development. Outlook on Agriculture, 2006, 35(3), 217-225.

19. Bergevoet RHM, Engelen A. The Kenyan meat sector Opportunities for Dutch agribusiness. LEI Wageningen UR, 2014, 2014-032.

20. Baker RL, Rege JEO. Genetic resistance to diseases and other stresses in improvement of ruminant livestock in the tropics. 7th World Congress on Genetics Applied to Livestock Production, 1994, 405-412.

21. Kipronoh KA, Kiara HK, Binepal YS, et al. Pastoralists' perception of constraints affecting goat production in the Rift Valley region of Kenya. Livestock Research for Rural Development, 2016, 28(3), 5-10.

22. Omiti JM, Okuthe SO. An Overview of the Poultry Sector and Status of Highly Pathogenic Avian Influenza (HPAI) in Kenya: Background Paper. International Food Policy Research Institute (IFPRI), 2009.

23. KNBS. Kenya National Bureau of Statistics, County summaries for livestock products for year 2016, 2016.

24. Wabacha JK, Maribei JM, Mulei CM, et al. Health and production measures for smallholder pig production in Kikuyu Division, central Kenya. Preventive veterinary medicine, 2004, 63(3-4): 197-210.

25. Kagira JM, Kanyari PWN, Maingi N, et al. Characteristics of the smallholder free-range pig production system in western Kenya. Tropical animal health and production, 2010, 42(5): 865-873.

26. Mutua FK, Randolph TF, Arimi SM, et al. Palpable lingual cysts, a possible indicator of porcine cysticercosis, in Teso District, Western Kenya. Journal of Swine Health and Production, 2007, 15(4): 206-212.

27. USAID-KAVES. Kenya fodder value chain analysis report. Kenya Agricultural Value Chain Enterprises Project, 2017.

28. Skerman PJ, Riveros F. Tropical grasses. FAO, Rome, 1990.

29. Farrell G, Simons SA, Hillocks RJ. Aspects of the biology of Ustilago kamerunensis, a smut pathogen of Napier grass (Pennisetum purpureum). Journal of phytopathology, 2001, 149(11 - 12): 739-744.

30. Jones P, Devonshire BJ, Holman TJ, et al. Napier grass stunt: a new disease associated with a 16SrXI group phytoplasma in Kenya. Plant Pathology, 2004, 53(4): 519-519.

31. Schreuder R, Snijders PJM, Wouters AP, et al. Variation in OM digestibility, CP, Yield and ash content of Napier grass (Pennisetum purpureum) and their prediction from chemical and environmental factor. Res. Rept., Natl. Anim. Husb. Res. Station., KARI, Naivasha, Kenya, 1993, 28.

32. Gwayumba W, Christensen DA, McKinnon JJ, et al. Dry matter intake, digestibility and milk yield by Friesian cows fed two Napier grass varieties. Asian Australasian Journal of Animal Sciences, 2002, 15(4): 516-521.

33. Islam MR, Saha CK, Sarker NR, et al. Effect of variety on proportion of botanical fractions and nutritive value of different Napier grass (Pennisetum purpureum) and relationship between botanical fractions and nutritive value. Asian Australasian Journal of Animal Sciences, 2003, 16(6): 837-842.

34. Kariuki JN, Gachuiri CK, Gitau GK, et al. Effect of feeding napier grass, lucerne and sweet potato vines as sole diets to dairy heifers on nutrient intake, weight gain and rumen degradation. Livestock Production Science, 1998, 55(1): 13-20.

35. Mbuthia EW, Gachuiri CK. Effect of inclusion of Mucuna pruriens and Dolichos lablab forage in Napier grass silage on silage quality and on voluntary intake and digestibility in sheep. Tropical and Subtropical Agroecosystems, 2003, 1(2-3).

36. Abate A, Kayongo-Male H, Wanyoike M. Fodder for high potential areas in Kenya: Animal feed resources for small-scale livestock producers. Proceedings of the Second PANESA Workshop held in Nairobi, Kenya. 1985: 11-15.

37. Boschini C, Amador AL. Ruminal degradability of corn in different stages of growth. Mesoamerican Agronomy, 2001, 12(1): 89-93.

38. Iqbal MA, Iqbal A, Ahmad A, et al. Overviewing forage maize yield and quality attributes enhancement with plant nutrition management. World Journal of Agricultural Sciences, 2015, 11(3): 128-134.

39. Manoa LA. Evaluation of dry matter yields and silage quality of six sweet potato varieties. University of Nairobi, Kenya, 2012.

40. Mellish K, Scothorn D, VanLeeuwen J, et al. Feeding Maize Silage to Kenyan Dairy Cattle. Farmers Helping Farmers, 2016.

41. Dahmardeh M. Effect of plant density and nitrogen rate on PAR absorption and maize yield. American Journal of Plant Physiology, 2011, 6(1): 44-49.

42. Cothren JT, Matocha JE, Clark LE. Integrated crop management for sorghum. Sorghum: Origin, History, Technology, and Production, 2000: 409-441.

43. Kitilit JK, Njehia GK, Irungu KRG. Nutrient Composition and Degradability in highland Dual Purpose Brown Mid-Rib Sorghum Genotypes[J]. 1998, 81: 2300–245.

44. Ashiono GB, Kitilit JK, Irungu KRG, et al. Nutrient characteristics of six cold tolerant sorghum (Sorghum bicolour (L) Moench) genotypes across different ecozones. Journal of Agronomy, 2005, 4(4): 273-276.

45. Kokkonen T, Tuori M, Leivonen V, et al. Effect of silage dry matter content and rapeseed meal supplementation on dairy cows. 1. Milk production and feed utilisation. Animal Feed Science and Technology, 2000, 84(3-4): 213-228.

46. James MK. Assessment of sweet potato cultivars as protein and energy feed supplements in the Kenyans highlands. Egerton University,2013.

47. Ondabu N, Kitilit J K, Mwangi J. Evaluation of sweet potato vine cultivars as animal feed in Nakuru district, Kenya. African Crop Science Conference Proceedings. 2005, 7(2-3): 575-577.

48. Lukuyu BA, Muriuki K and Lukuyu M. Growing maize for food and fodder. Kenya, 2008.

49. KARI. Monsanto Virus Resistant Sweet potato Project. For Alleviation of Hunger and Poverty. Nairobi, Kenya, 2000.

50. Mungai N. Transgenic Sweet Potato Could End Famine. Environment News Service, 2000.

51. Wambugu C, Franzel S, Tuwei P, et al. Scaling up the use of fodder shrubs in central Kenya. Development in Practice, 2001, 11(4): 487-494.

52. Franzel S, Wambugu C, Tuwei P, et al. The adoption and scaling up of the use of fodder shrubs in central Kenya. Tropical grasslands, 2003, 37(4): 239-250.

53. Tuwei PK, Kang'Ara JNN, Mueller-Harvey I, et al. Factors affecting biomass production and nutritive value of Calliandra calothyrsus leaf as fodder for ruminants. The Journal of Agricultural Science, 2003, 141(1): 113-127.

54. Wambui CC, Abdulrazak SA, Noordin Q. The effect of supplementing urea treated maize stover with Tithonia, Calliandra and

Sesbania to growing goats. Livestock Research for Rural Development, 2006, 18(5): 64.

55. Broderick GA, Albrecht KA. Ruminal in vitro degradation of protein in tannin-free and tannin-containing forage legume species. Crop Science, 1997, 37(6): 1884-1891.

56. KARI. Lucerne cultivation. KARI e-Mimi Fact Sheet, 2014, 13-201.

57. Lukuyu BA, Kinyua J, Agili S, et al. Evaluation of sweetpotato varieties for the potential of dual-purpose in different agroecological zones of Kenya. Challenges and Opportunities for Agricultural Intensification of the Humid Highland Systems of Sub-Saharan Africa. Springer, Cham, 2014: 217-231.

58. Lukuyu MN, Romney DL, Ouma R, et al. Feeding Dairy Cattle: A manual for smallholder dairy farmers and extension workers in East Africa. Manuals and Guides, 2007.

59. KARI. Kenya Agricultural Research Institute, Kenya Technical information bulletin. 2012.

60. Moore GA, Sanford P, Wiley T. Perennial pastures for Western Australia. 2006.

61. Donaldson CH. A practical guide to planted pasture. Cape Town: Kalbas publishers, 2001.

62. Hennessy DW, Williamson PJ. The nutritive value of kikuyu grass (Pennisetum clandestinum) leaf and the use of pelleted leaf in rations high or low in energy. Australian Journal of Experimental Agriculture, 1976, 16(82): 729-734.

63. Woyengo TA, Gachuiri CK, Wahome RG, et al. Effect of protein supplementation and urea treatment on utilization of maize stover by Red Maasai sheep. South African Journal of Animal Science, 2004, 34(1): 23-30.

64. Woyengo TA, Gachuiri CK, Wahome RG, et al. Economic evaluation of increasing the energy value of Zea mays stover by urea treatment. Proceedings of the 9th Biennial KARI Scientific Conference, 2004.

65. MOLD. Ministry of Livestock Development. Feed milling industry survey. Vincent Githinji, Monica Olala and Wesley Maritim, 2007.

Country Report Pakistan: Feeding systems, status of national feed resources, their availability and future developments, challenges and opportunities to efficiently utilize locally available feed resources and to enhance feed use efficiency

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Abstract

Pakistan is an agricultural country and livestock is a major subsector of agriculture. Pakistan habitats about 191 million ruminant and non-ruminant animals in addition to 1108 million poultry. Large ruminants are mostly stall fed on cut and carry systems and less commonly on preserved fodder. However, in rain-fed areas and sandy deserts of the country, where fodder is not abundant as in irrigated area of the country, large ruminants are also raised on grazing. Major proportion of feed of small ruminants comes from grazing on rangelands, roadsides, post-harvest fields, and fodder fields. Goats also get some of their daily nutrients from browsing trees. Camels mainly depend upon browsing with partial stall feeding depending upon availability of fodder and brows. Hay and silage making has been started and being prepared on commercial scale. A meagre amount of hay is also being exported to neighbouring Middle Eastern countries. There are two main sowing seasons in the country: summer (Kharif) and winter (Rabi). Crop residues, fodder crops and rangelands are providing about 90% of the total feed resources for livestock. Main fodder crops are Egyptian clover, alfalfa, maize, millet, sorghum, mustard, oat, barley, guar and pulses. Grains and agro-industrial by-products of wheat, maize, oilseeds, sugarcane, beet pulp, etc. meet only 8% of the total nutrient requirements of the animals. Rangeland area is about 60 percent of the total geographical area of the country but is unable to support livestock to its potential due to its poor management and overgrazing. Present feed resources are sufficient only to meat 62% of the crude protein and energy requirements of the animals. Pakistan is importing soybean meal and canola, among others, for meeting local demands of poultry feed industry. Poultry and cattle feed industry are more developed in Punjab than other provinces. Punjab state has a feed regulatory body, but other provinces do not have one. Land area for fodder crop is decreasing due to pressure of growing cash crops. Per acre yield of fodder crops is low due to non-availability of good quality seed of high producing fodder varieties, poor agronomic practices and diminishing water resources. Rangelands are eroded and over grazed. Multi-prong approach is required to meet the nutrient requirements of ever growing livestock population. Increasing per acre yield of fodder crops and harvesting maximum nutrients rather than dry matter may narrow the gap of supply and demand of nutrients. Proper management of rangelands is an opportunity to meet nutrient requirements of livestock.

Introduction

Pakistan lies between latitude 23 °N and 37 °N and longitude 60 °E and 76 °E. Total area of Pakistan is 79.61 million ha, out of which cropped area is 22.67 million ha. Forest area is 4.55 million ha and area that is not available for cultivation is 23.04 million ha. Its population is 200 million with an average growth of 1.86%[1]. Agriculture is the backbone of Pakistan. Agriculture accounts for 19.5 percent of its gross domestic product, employing 42.3 percent of the labour force and providing raw material for several value-added sectors. Agriculture thus plays a central role in national development, food security and poverty reduction. Livestock is a sub sector of agriculture; it contributed about 58.3 percent to the agriculture value added and 11.4 percent to the overall GDP Livestock during 2016-17. It has a growth rate of more than 3.0 percent during the last decade. Total estimated livestock population was 191.3 million in 2017 (Table 1). Gross value addition of livestock at constant cost factor of 2005-06 has increased from Rs. 1288 billion (2015-16) to Rs. 1333 billion (2016-17) (1 US$ = Rs.), showing an increase of 3.4 percent over the same period last year. Livestock has an important and crucial role in rural economy and rural socio-economic development.

Nearly 8 million families are involved in livestock rearing, deriving more than 35 percent income from livestock production activities. It is central to the livelihood of the rural poor in the country. It is a source of cash income, providing a vital and often the only source of income for the rural and most marginal people[1]. This country report describes feeding systems for ruminant and monogastric animals in Pakistan, available feed resources, status of animal and poultry feed industry and challenges and opportunities in enhancing utilization of locally available resources and enhancing their feed use efficiency.

Table 1 Estimated livestock population (million)[1]

Species	2014-15	2015-16	2016-17
Cattle	41.2	42.8	44.4
Buffalo	25.6	36.6	37.7
Sheep	29.4	29.8	30.1
Goat	68.4	70.3	72.2
Camels	1.0	1.0	1.1
Horses	0.4	0.4	0.4
Asses	5.0	5.1	5.2
Mules	0.2	0.2	0.2
Total	171.2	186.2	191.3
Poultry (Total)	932	1016	1108

Feeding systems

Following are the ruminant feeding systems

Cut and carry feeding system. Fresh fodder is harvested on daily basis, transported to livestock farms and offered to the animals in stalls and shed (Figure 1). This practice is in vogue in smallholder farming systems. Majority of large ruminants in irrigated areas of the country are stall fed during most part of the year. During abundant supply season, fodder is the only feed offered to the animals. However, during fodder scarcity season, fodder is supplemented with concentrate and or straws (Figure 1).

Figure 1 Fodder after chopping (a) is fed to buffalo (b) and cows (c); animals on wheat straw and concentrate during fodder scarcity season (d)

Total Mixed Ration Feeding system. In this system, concentrate, silage and hay are mixed to constitute a complete feed and offered to animals as it ensures regular supply of nutrients to the animals. This system is generally practiced on high producing dairy and beef farms to provide a balanced ration to meet the animals' requirements (Figure 2). Individual animals kept for sacrificial purposes are also fed total mixed ration; their feed consists of concentrate plus seasonal fodder or concentrate plus wheat straw.

Grazing and browsing system. Sheep and goat herds are generally raised on grazing. Animals are grazed on roadsides (Figure 3), ranges, pastures, harvested fields of wheat, paddy, maize, cotton and other crops and less frequently on sown fodder crops (Figure 3). Large ruminants (cow and buffalo) are generally stalled fed during most part of the year, however, they are also grazed when Egyptian clover is in abundant supply (Figure 4) and cut and carry system become more labour intensive. Large and small ruminants are also grazed in harvested wheat fields (Figure 4); this is a season when fodder is not available in abundant supply. Besides grazing, goat herds also depend upon browsing tree leaves (Figure 5). Camels get major part of their feed from browsing tree leaves (Figure 5) but are also stall fed (Figure 6), when fodder is available in abundant supply. Small ruminants raised for sacrificial purposes are offered small quantities of concentrates, in addition to grazing, a few months before selling them at the time of sacrificial day so that they can be sold at a better price.

Figure 2 Animals at a commercial Dairy Farm being offered total mixed ration (silage plus concentrate)

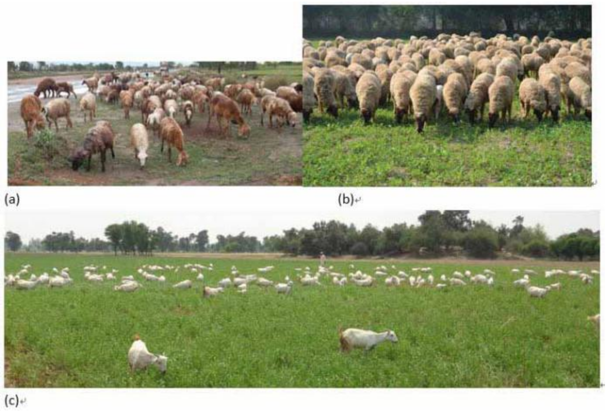

Figure 3 Sheep grazing (a) on roadside and in (b) Berseem field, (c) goats grazing in Berseem field

Figure 4 Buffaloes (a) grazing in a Berseem field and (b) cows grazing in wheat harvested field

Feeding systems for monogastric animals

Monogastric animals include pigs, and herbivores such as horses, asses, mules and rabbits. Pigs are not raised in Pakistan at all. Horses, asses, mules and rabbits are generally stall fed. Seasonal green fodder is offered to all these monogastric animals when available. However, in the absence of green fodder, oat hay (with rains intact) is preferred for horses and rice husk generally offered to asses and mules.

The degree to which the animals are raised on a specific feeding system depends upon the geographical area they are in, and the purpose they are raised for. For example, large commercial dairy farm keeping exotic animals and beef fattening farms offer total mixed ration to the animals round the year. They don't rely on cut and carry system. However, dairy farms raising local breeds of cows and buffalo partially depend upon cut and carry system and partially on total mixed ration. Small ruminants in Balochistan, Khyber Pakhtunkhwa and Sind provinces are grazed most part of the year. Dry large ruminants (neither pregnant nor lactating) in rural areas are generally offered crops residues with little concentrate. Marghazani *et al.*[2] have described feeding systems for Balochistan that are almost similar to that described in the preceding paragraphs.


(a)
(b)

Figure 5 Goats (a) and camels (b) browsing the trees

Figure 6 Camels being stall fed

Available feed resources

Livestock is getting a major share of their nutrients from crops residues and fodders. Fodder supply round the year is not uniform. There are two fodder scarcity periods during the year; one in summer (May-June) and the other during winter (December-January). However, actual availability of fodder to the livestock during other months of the year is not abundant either. The time and duration of scarcity period can shift to either side depending upon rain fall, onset of winter and water availability from canals and tube wells for the fodder crops.

In Pakistan, nutritional requirements of animals are mainly met through fodder crops, shrubs, grasses on ranges, barren lands and post-harvest fields and agro-industrial by-products. Primary data on demand and supply of nutrients to livestock is not maintained by any organization; however, Habib *et al.*[3] has calculated the contribution of nutrients by feed categories (Table 2). Livestock are getting 58.8, 23.8, 9.2 and 8.2% of their dry matter form crop residues, fodders crops, grazing, grains and agro-industrial by-products, respectively. The existing available feed resources can only meet 62% of the total crude protein and energy requirements of the animals[3]. However, earlier it was reported that animals in Pakistan were getting 51, 38, 3, 6, and 2% of their nutrients from fodders and crop residues, rangeland, post-harvest grazing, cereal by-products and oil cakes, respectively[4].

Fodder crops

Pakistan has two crop sowing seasons; one is Rabi season and the other is summer (Kharif) season. The winter (Rabi) crops are sown in winter and harvested in spring. These fodder crops include Egyptian clover, alfalfa, oat, barley, and mustard, (Figure 7). The summer fodder crops are sown from mid-April to mid-October and harvested before winter. These crops include maize, maizenta, sorghum, sadabahar (multi-cut sorghum), millet, multi-cut millet, mott grass, cowpeas (*Vigna unguiculata*), moth bean (*Vigna acotinifolia*), and Jantar (*Sesbania bispinosa*) (Figures 8a and 8b). Maize is generally grown in both summer and winter seasons; recently three crops of maize per year are being harvested. Estimated total area under fodder crop is 2.11 million ha, fodder production is 45.77 million tonnes with an average per ha yield of 21.7 tonnes [Director, Fodder Research Institute, Sargodha: Punjab, Pakistan: personal Communication]. Berseem is the highest cultivated fodder crop in Punjab followed by sorghum. Fodder Research Institute Sargodha has the mandate to develop and introduce new varieties of fodder in the country. This institute has introduced many improved varieties of fodder with higher per hectare yield. In addition to Fodder Research Institute, Sargodha, many international companies are introducing high yielding varieties of fodder with better nutritional value. Production data for some of the cereal grains and other crops in Pakistan is given in Table 3.

Table 2 Contribution of main feed sources to total feed availability

Feed Source	Dry matter (x10^6 tonnes)	Crude protein (x10^6 tonnes)	Metabolizable energy (x10^{10} MJ)
Crop residues	68.99	2.83	45.64
Oilcakes/meals and cereal brans	4.98	0.87	5.57
Grazing	10.74	1.1	9.34
Fodders	27.89	3.3	25.97
Grains	4.71	0.56	6.19
Total	117.31	8.66	92.6

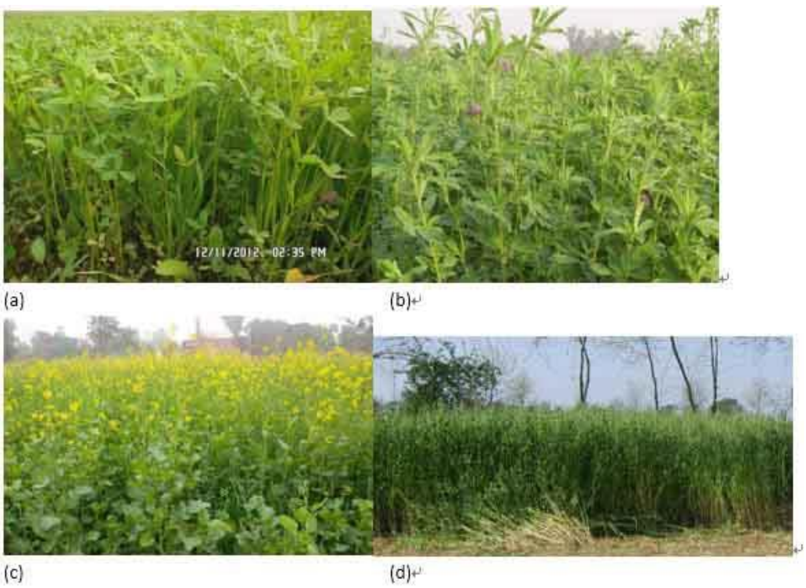

Figure 7 Major Rabi fodder crops: (a) Berseem, (b) Alfalfa, (c) Mustard and (d) Oat

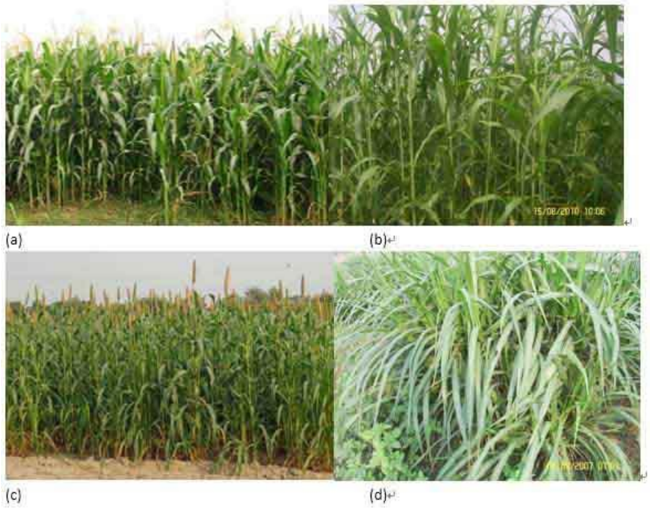

Figure 8a Kharif Fodder Crops: (a) Maize, (b) Sorghum, (c) Millet and (d) Mott grass

Figure 8b Kharif fodder crops: (a) Guar, (b) Soybean,(c) Cowpeas and (d) Moth

Crop residues

Major crop residues of Pakistan are wheat and paddy straw (Figure 9). Sugarcane tops, maize stovers (Figure 10), oat straw, berseem straw, chickpea straws are also available in limited quantity. Cotton plants, after cotton picking, are also offered to livestock in cotton growing areas. Waste dates, apricots, and other waste fruits are also used as livestock in their growing regions.

Wheat straw is the most widely used crop residue for livestock throughout the country and round the year. It is baled (Figure 9) and sold throughout the country. Price of wheat straw fluctuate throughout the year; it is lowest in wheat harvesting season and then rises as the time passes by. Paddy straw is the second largest crop used in the country after wheat straw. However, it is available only in rice growing and adjoining areas and not preferred as much as wheat straw. Stovers are used in the areas where respective crops are grown and are not available for sale as wheat or paddy straw.

Table 3 Production of cereals grains and other crops in the country during 2016-17[1]

Item	Yield (x000 tonnes)
Wheat	25,750
Rice	6,849
Barley	55
Maize	6,130
Millet	305
Sorghum	149
Gram (chick pea)	359
Sugarcane	73,607
Rapeseed and mustard	179
Sesame	341

Fodder preserved as hay

Preservation of fodder in Pakistan has started in the recent decade. Alfalfa is major crop used for hay (Figure 10) and or haylage making. Alfalfa hay has also been exported to neighbouring countries but at a limited scale. Sorghum, when surplus in the season, is also stored as hay (Figure 10) for feeding it in winter season in combination with Egyptian clover. Ryegrass is also being grown for hay and being sold to exotic dairy herds in the country and or being exported to Middle East.

Fodder preserved as silage

Preservation of fodder has started recently with the import of machinery required for silage making. Major silage crop is corn; however, sorghum and millet are also being used in a limited quantity. Silage is prepared in ground bunkers (Figure 11) at the farms. But for commercial purposes, the silage is prepared in bales (Figure 11) and sold to intended buyers in the country. Silage business is now growing up in the country and thus many investors have joined this business.

Figure 9 Crop residues: (a) Fresh paddy straw, (b) baled wheat straw from wheat thresher, (c) baled wheat straw from combined harvester and (d) wheat straw stored in heaps

Figure 10 Crop residues and hay: (a) Maize stovers (b) Berseem hay and (c) Sorghum hay

Range lands

In Pakistan, rangelands cover 52.3 million ha of land (Table 4) and account for 60% of the entire geographical area of the country (87.9 million ha) including Gilgit and Azad Jammu and Kashmir[5]. Excluding the northern areas (Gilgit and Azad Jammu and Kashmir), rangeland area is 49.5 million ha of total 79.61 million ha area of Pakistan accounting for 62% of reported geographical[5]. These rangelands are major feed resources for small ruminants in the country. Current level of average forage production from rangelands is 6.6 tonnes/ha compared to a potential of 20.8 tonnes per ha, which is about 31% of their potential output. Over the last two decades, proportion of palatable species has decreased by up to 30% and foliar cover of grass and forage up to 40%. This deterioration is result of climatic changes, overgrazing and bad management of the rangelands.

The carrying capacity of these rangelands varies from province to province. The estimated dry matter productivity of rangelands in Balochistan varies from 30-280 kg/ha/year and overall carrying capacity varies from 2-3 ha per ewe. Influx of Afghan refugees in 1980s in the province exerted a huge pressure on the productivity of rangelands and thus forest and rangeland vegetation were completely wiped out near the refugee camps. Presently, no grazing management exists in Balochistan except some traditional regulating grazing on rangelands. The condition and productivity of rangelands in Sindh has also been declining over the years due to natural and environmental factors. Overstocking and frequent movement of animals from one region to another resulting from population growth and poverty have deteriorated the rangeland productivity of this province. Rangelands in Khyber Pakhtunkhwa provide forage, water, tourism opportunities, wildlife, medicinal plants, biodiversity and fuel wood. However, non-uniform grazing, accelerated soil erosion, spread of weeds and poisonous plants and conversion of rangelands into agricultural lands have a negative impact on the rangelands. Rangeland productivity and management situation in Punjab is comparatively better than in other provinces, but still faces challenges of overpopulation and overgrazing. Improved rangeland management in the country can narrow the gap between demand and supply of nutrients for livestock.

Figure 11 Silage: (a) silage in ground bunker (b) silage in bales and (c) open baled-silage

Grains and agro-industrial by products

Major grain used for livestock and poultry feed industry in the country is maize. Other grains used include wheat, oat, barley, gram, sorghum, millet, cow pea, moth and rice. Agro-industrial by-products are the major feed ingredients used for preparing concentrate feed for livestock and poultry (Figures 12a to12d). Locally available by-products are wheat bran, by-products of corn wet milling industry that include maize bran, maize gluten 20%, maize gluten 30%, maize gluten 60%, maize oil cake, corn steep liquor and enzose, a byproduct of maize wet milling industry which includes 80% dextrose. Other maize by-products are corn stovers and waste corn flakes. In addition, agro-industrial by-products are cotton seed cake, cotton seed meal, rape seed cake, canola meal, rice bran, rice husk, rice polish, molasses, distillery waste sludge, beet pulp, citrus pulp, guar meal, bone meal, meat meal, feather meal, poultry by-product meal, blood meal, husks of beans and peas (chick pea, mung bean, mash, cow pea, etc.) are also used. Availability of locally available by-products is not uniform and is linked to the harvesting season of the crop they are by-products of.

Table 4 Rangeland area of Pakistan (million ha)[5]

Province	Total area	Rangeland area	Percentage
Balochistan	34.7	27.4	79
Sindh	14.1	7.8	55
Punjab	20.6	8.2	40
Khyber Pakhtunkhwa including FATA*	10.2	6.1	60
Gilgit	7.0	2.1	30
Azad Jammu and Kashmir	1.3	0.6	45
Total	87.9	52.2	60

FATA, Federally administered Tribal Area

Import of feed ingredients

Some of the poultry and livestock feed ingredients are imported (Table 5) from other countries to meet the local demand. These include soybean meal, palm kernel cake, dried distiller grains, different fat sources including oils.

Status of feed industry and regulatory authority

Primary data on actual number of poultry and cattle feed mills in the country and their production potential is not available as there is no public or private organization to record such data. However, information collected at personal level indicates that at present Punjab has the highest number of poultry and cattle feed mills followed by Sindh. Feed industry in Balochistan and Khyber Pakhtunkhwa is not much developed. There are more than 79 poultry feed mills and 61 cattle feed mills registered in Punjab; and a number of other firms have initiated process of registration. Major feed mills in Punjab are clustered around cities of Rawalpindi, Islamabad, Lahore, Sheikhupura, Faisalabad and Multan. Feed industry is expanding in the country as a result of fast growth of poultry industry and establishment of modern livestock farms. These feed mills are run by animal and poultry nutritionists qualified from local and international universities. These feed mills have their own quality control laboratories to assess the quality of feed ingredients used for feed manufacturing. Majority of the feed ingredients used in feed manufacturing are produced locally. These feed ingredients include grains and their milling by-products, cakes and meals and by-products of sugar mills. Feed additives, vitamins and minerals are imported from other countries. Soybean, soybean meal, canola and palm kernel cake are major feed ingredients imported from other countries. Feed is prepared both in mash and pellet forms. Machinery used in the feed mills is produced locally as well as imported from abroad.

Figure 12a Agro-industrial by-products: (a) wheat bran, (b) maize bran (c) corn flakes (d) waste bakery bun and (e) waste bakery bread and (f) waste potato chips

Figure 12b By-products of maize: (a) corn cobs, (b) maize gluten 30%, (c) maize gluten 60% and (d) maize oil cake

Figure 12c (a) Rice polish and (b) urea molasses block

Figure 12d Meals and cakes: (a) rapeseed meal, (b) canola meal, (c) sunflower meal and (d) cotton seed cake

In Pakistan, poultry feed industry is more developed than cattle feed. Volume of poultry feed industry is also bigger than the cattle feed industry. Poultry feed is prepared as complete feed for different physiological stages of layers, broilers and their breeder stock. Whereas cattle feed is generally prepared to offer as supplemental feed in addition to green fodder. Exception to supplemental feed in cattle are large commercial dairy and beef farms where animals are offered total mixed ration (including fodder and concentrate) to fulfill their specific nutrient requirements.

As a result of trained professional in the field of animal nutrition, quality feed is being prepared to meet requirements of the poultry and livestock industry.

Feed regulatory authority

In Punjab, animal feed act was passed in 2016 to regulate the animal feedstuff and compound feed (Annex-I). This act defines the feeds stuffs that can be used for livestock and poultry feed including roughages, micro-ingredients and feed additives. This act also requires having a license for manufacturing poultry or cattle feed from Livestock and Dairy Development Department, Government of Punjab. Adulteration of feed with non-feed items is punishable by law. There is no feed regulatory authority in other provinces of the country as yet.

Challenges and opportunities in enhancing utilization of locally available feed resources and enhancing feed use efficiency

Challenges

Locally available feed resources are insufficient to meet the nutrient requirements of the animals. This emanates because of the following.

- Low priority of fodder crops by the farmers. Fodder is sown on the land that is available in between the harvesting time of one cash crop and sowing time of the other.
- Limited availability or decreasing land for fodder cultivation.
- Cut and carry system is a hurdle in continuous fodder supply to livestock. This is because of many reasons: unexpected or delayed rains, power outage, closure of canals, labour issues, transportation problems, and extreme weather. Under commercial livestock farming operation, daily cut and carry system is not feasible for feeding livestock.
- Low productivity of fodder per unit of land and its low nutrient profile. Poor quality of fodder is attributable to poor agronomic practices and harvesting of over-mature fodder in cut and carry system.
- Non-availability of better quality seed of high yielding fodder varieties is not in access to all farmers at affordable prices.
- Deteriorating rangelands because of unplanned and excessive grazing.
- Adulteration is a major challenge to the agro-industrial by-products used for livestock and poultry in the country. Adulteration of feed ingredients with non-feed materials render them to a poor quality feed ingredient. Recently introduced Feed Act in Punjab may help reduce adulteration of feed ingredients.
- Price fluctuation of feed ingredients that are imported in the country. Devaluation of Pakistani currency against US dollars also influences the prices of feed ingredients in local market.
- Regular data recording on feed and fodder production and their availability, biomass availability from range lands, demand and supply of feed nutrients to livestock in the country is non-existent.

Table 5 Import of feed ingredients to Pakistan [Ministry of Food security and research: personal communication]

Description	2014-2015		2015-2016		2016-2017	
	Quantity	Value	Quantity	Value	Quantity	Value
	x000 Tonnes	Million PKR*	x000 Tonnes	Million PKR*	x000 Tonnes	Million PKR*
Bran sharp and residues of cereals	0.00	0.85	0.00		0.00	
Bran sharp and residues of maize	0.00		0.05	1.22	0.00	
Bran sharp and residues of wheat	0.00	0.01	0.07	2.95	0.04	2.46
Bran sharp residue legume plant	0.00	0.02	3.16	136.29	3.33	108.86
Brewing/distilling dregs/waste	46.19	184.54	24.66	1,350.33	1.47	84.36
Cereal straw and husks and pellet	47.55	781.03	16.70	281.59	0.05	1.26
Flours, meals, pellets, of meat	0.00	0.01	3.07	119.71	2.82	76.68
Lucerne (alfalfa) meal and pellets	0.36	13.48	0.00		0.00	
Oil-cake/solid residue coconut	4.00	84.05	0.00	0.02	0.00	
Oil-cake/solid residue colza seeds	5.66	184.45	0.00		0.00	
Oil-cake/solid residue cotton seeds	0.00		0.00	0.28	0.00	0.12
Oil-cake/solid residue linseeds	0.04	1.26	0.00		0.00	
Oil-cake/solid residue palm nuts	130.50	1,909.34	174.05	2,231.18	96.51	1,049.04
Oil-cake/solid residue rape seeds	2.39	65.45	0.00		0.00	
Oil-cake/solid residue soybean	794.91	44,827.42	644.03	31,822.21	67.09	2,970.77
Oil-cake/solid residue sunflower seeds	0.47	6.38	34.88	2,509.54	0.12	3.90
Oil-cake/solid residue vegetable	0.24	4.35	7.81	178.39	9.01	212.67
Other flour, meal, pellets, of fish	1.07	114.29	1.05	81.94	0.00	0.02
Preparations for animal feed	1.25	562.93	1.61	637.75	0.54	223.26
Preparations for complete animal feed	12.23	5,310.37	10.84	4,356.04	3.36	1,373.50
Residue of starch manufacture	0.03	3.04	0.45	21.99	0.33	16.58
Shrimp meal	0.00	1.69	0.00		0.00	
Swedes, mangolds, fodder, hay	0.01	0.18	0.00		0.00	
Vegetable materials, waste, residue	0.16	5.81	14.31	169.88	4.36	77.84
Total Imports	1,047.06	54,060.94	936.75	43,901.30	189.04	6,201.33

Note: *PKR: Pakistani Rupees

Opportunities

Following opportunities exist for enhancing utilization of locally available feed resources.

- Provision of high quality seed of high-yielding fodder varieties at farmers' doorsteps. This is the most important single issue, if handled, can improve fodder supply and thus improve nutritional status of the animals.

- Availability of machinery for hay and silage should be developed locally. However, in the absence of such machinery, government should encourage import of such machinery by private sector, so that land use efficiency could be increased to grow more fodder.
- Provision of water to water-scarce land areas.
- Creating awareness among farmers by public-run institutions whether these be government departments or educational institutions (universities).
- Preservation of fodder as hay and (or) silage offers a solution for irregular supply of fodder for livestock. Making silage spares land for another crop and increases the nutrient availability from the same piece of land. Hay making from alfalfa crop can give 1-2 extra cuts of quality fodder compared with cut and carry system. With small land holdings, buying machinery for hay and silage making is an issue, however, can be resolved with rented machinery for the purpose, as is done for threshing of wheat and paddy.
- Better agronomic practices can increase per acre fodder yield; these agronomic practices include proper land preparation, sowing at proper time, providing required water, fertilizers and pesticides.
- Chemical/physical/biological treatment of low quality roughages can enhance nutrient availability from the same dry matter. Straws are major feed resources for livestock in the country; they have low nutritional values because of higher fibre and low protein contents. Nutritional values of straws can be increased by chemical treatments. However, this solution is only of an academic importance in the absence of farmer friendly technology for chemical treatment of straws.
- Use of ionophores, prebiotics, buffer salts can improve the efficiency of feed utilization by livestock.
- Range lands are potential feed reservoir for livestock in Pakistan. Proper management of range land can provide fodder to the small ruminants. Range management, conservation and improvement policies are required to utilize range land for nutrient supply to the livestock. Maintenance and development of range lands can be the major intervention. Thus, government needs to focus on how to use these unutilized land resources to provide more nutrients to the livestock.
- Providing a nutritionally balanced ration can enhance the output of animals. Haphazard feeding to livestock can result in wastage of nutrients, which if fed in proper proportion can be better utilized. For example, feeding berseem and (or) maize fodder separately to livestock will result in energy and protein deficiency, respectively. However, if fed in combination, with a proper proportion can provide a balanced ration for livestock. Similar is the situation with other agro-industrial feed ingredients for livestock. Thus, with a judicious feeding management, a lot of feed resources, which otherwise are being utilized inefficiently, can be used very efficiently.

Conclusions

Livestock in Pakistan is underfed as a result of deficient nutrient supply. This situation may aggravate if remedial measures are not taken on time. However, there is potential to improve the supply of nutrients to livestock from available land resources. This includes improvement in management of rangelands of Pakistan. The land for fodder production can't be increased, however, per acre productivity of fodder can be improved by introducing high yielding fodder varieties, improving agronomic practices and preserving fodder as hay and silage.

References

1. Government of Pakistan. Pakistan Economic Survey 2016-17. Islamabad: Finance Division, Government of Pakistan, 2017.
2. Marghazani I, Kakar M, Nasrullah M. Livestock feed resources and feeding practices in Balochistan. Journal of Animal and Plant Science, 2014, 24:87-90.

3. Ghulam H, Muhammad F, Ullah K. Assessment of Feed Supply and Demand for Livestock in Pakistan. Journal of Agricultural Science and Technology, 2016, 6:191-202.

4. Sarwar M, Khan M, Iqbal Z. Feed Resources for Livestock in Pakistan. International Journal of Agricultural Biology, 2002, 4:186-192.

5. FAO. Rangelands of Pakistan: Current status, threats and potential. Islamabad: Food and Agriculture Organization of the United Nation, 2016.

Annex-I

THE PUNJAB ANIMALS FEED STUFF AND COMPOUND FEED ACT 2016 can be downloaded from http://punjablaws.gov.pk/laws/2675.html, which was passed by the Punjab Assembly on 01 December 2016; assented to by the Governor of the Punjab on 05 December 2016; and, was published in the Punjab Gazette (Extraordinary), dated 06 December 2016, pages 2911-17.

Livestock feedings systems, available feed resources and the challenges and opportunities for enhancing utilization of the available feed resources in Ethiopia

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Abstract

Ethiopia has diverse agro-ecologies and livestock production systems**Erreur ! Signet non défini.**. Although livestock resources play very important roles both at household and national levels, the productivity and economic contribution of the livestock sector is much below the potential due to various constraints. Shortage of feed supply, low nutritional quality and inefficient management and utilization of the available feed resources are among the main factors limiting the realization of the full potential of the livestock resources of the country. Low input low output extensive and semi-extensive feeding systems are the predominant livestock feeding and management systems in Ethiopia. The available feed resources are dominated by poor quality natural pastures and crop residues. The availability of improved forages and agro-industrial by-products is limited. Thus, the predominant feed resource base is comprised of natural pastures and crop residues for ruminants, whereas scavenging feed resources make the bulk of feeds used for poultry. The use of supplementary concentrates and improved forages is very much limited and practised only in market oriented feedlots and dairy cattle production as well as in commercial poultry production systems. Thus, the livestock feed supply requires a complete transformation to achieve the desired improvement in livestock production and productivity. Potential options for addressing the problem include engagement in expanding the feed resource base and enhancing the utilization of the available feed resources through various management and technological applications.

Introduction

Ethiopia has diverse agro-ecologies suitable for different livestock production systems. There are three major livestock production systems in the country. These are smallholder mixed crop-livestock, pastoral and agro-pastoral livestock, and the urban and peri-urban livestock production systems. The mixed crop-livestock system is found in the highland and mid altitude areas. The pastoral and agro-pastoral systems exist in the arid and semi-arid lowlands, mostly in the southern and eastern parts of the country. The pastoral areas are the prime sources of animals for conditioning in feedlots for live animal and meat export. The urban and peri-urban production system is an emerging component of the livestock sector, which includes smallholder and commercial dairy, feedlot and poultry operations around the major towns.

In mixed crop-livestock systems, livestock feed supply is mainly dependent on crop residues, other agricultural by-products and natural pastures. Extensive grazing and browsing of range vegetation is the main source of feed for pastoral herds and flocks. However, both the quantity and quality of the available forage shows a drastic decline during the dry season, which is often exacerbated by recurrent drought and shrinkage of traditional grazing areas due to increasing population pressure and other interventions. Almost all the urban and peri-urban livestock producers are entirely dependent on purchased feeds, as they do not have land for feed production or for grazing. Thus, nearly all commercial dairy farms, feedlots, and poultry farms buy-in all their feed needs, be it roughage or concentrate.

Livestock resources have significant economic and social importance at household level and make significant contributions to the national economy and foreign currency earnings of the country. However, the productivity and economic contribution of the livestock sector is much below the potential due to various constraints. Among the constraints, shortage of feed supply, low nutritional quality and inefficient management and utilization of the available feed resources are the main factors limiting the realization of the full potential of the livestock resources of the country.

In general, shortage and escalating price of feeds is adversely affecting the productivity and profitability of the livestock sector. Thus, the livestock feed supply requires a complete transformation to achieve the desired improvement in livestock production and productivity. Potential options for addressing the problem include engagement in expanding the feed resource base and enhancing the utilization of the available feed resources through various management and technological applications.

Livestock feeding systems (ruminants as well as monogastric animals)

Ruminant feeding systems

Extensive grazing on communal and private grazing lands, fallow lands, forest and shrub lands, roadsides and crop aftermath are the most common ruminant livestock feeding system in Ethiopia. Smallholder farmers and pastoralists traditionally use naturally occurring grasses, legumes, herbs, shrubs and tree foliage as the primary feed for ruminants. In mixed crop-livestock production and agro-pastoral production systems, the naturally occurring forages are supplemented with crop residues and by-products from their farms. Animals may be tethered or allowed free access to grazing being herded by children or adults. Zero-gazing is practiced on some intensively cultivated small mixed farms. The availability and quality of natural pastures vary with altitude, rainfall, soil type and cropping intensity. The intensity of cropping determines the area available for grazing. Livestock grazing is the predominant form of land use in pastoral areas. The quantity and quality of available feed declines as the dry season progresses. Fodder conservation to help reduce seasonal feed supply gap is rarely practiced by the smallholders.

The total area of naturally occurring forages is declining as the more favourable areas are converted to crop land triggered by the rapidly increasing human population. The increased expansion of crop production provides a range of residues and agro-industrial by-products that can be utilized by ruminants and non-ruminants. Stubbles are frequently grazed *in situ* after the crop is removed. Thus, crop residues are becoming increasingly important as sources of animal feed in smallholder mixed farming systems. But the actual quantities of crop residues available for livestock feeding is reduced by the costs of collection, transport, storage and processing, seasonal availability, other alternative uses and wastage. Crop residues are usually stacked after threshing and fed to animals during times of feed shortage, mostly during the dry season. However, the crop residues are usually used without any pre-treatment that may improve their feeding value. Depending upon the locality and availability of other feed resources, the crop residues could be supplemented with green forages as well as agricultural and agro-industrial by-products. Brewery and distillery by-products and household wastes constitute important sources of supplementary feed. This is particularly important for farmers residing in the proximity of commercial breweries or for landless farmers maintaining a small number of small ruminants or dairy animals in urban and peri-urban areas. In addition to commercial breweries, small scale home brewing is practiced in most localities and villages. There is a tradition of feeding homemade brewery and distillery by-products to lactating cows or small ruminants in different parts of Ethiopia. Reject fruit and vegetables could also be important sources of feed for small ruminants in areas where horticultural crops are grown and marketed.

Agro-industrial by-products such as oilseed cakes and meals (e.g. cottonseed cake, sunflower cake, oil palm kernel cake), wheat bran and molasses are important sources of feed mostly in urban and peri-urban livestock production or in areas close to the agro-industrial plants. The agro-industrial by-products make up most part of concentrate rations. Oilseed cakes serve as important protein supplements in concentrate mixtures. The various milling by-products such as wheat bran, maize bran and rice bran are also of great interest as livestock feed in commercial or market-oriented peri-urban and urban livestock farms.

The contribution of cultivated forage and pasture crops to the diet of farm animals in smallholder mixed farming systems is relatively very small. However, with decreasing availability of feed from natural pastures and increasing availability of cereal crop residues, the production of supplementary forage crops that are compatible with the existing cropping systems would be one of the most viable options of improving livestock feed supply on smallholder mixed farms. The introduction of improved forage species for ruminants can promote the sustainability of the cropping systems. Improved forages, particularly legumes, have high feeding value and make important contributions to erosion control by providing cover and to increased soil fertility.

Foliage from trees and shrubs contributes a significant proportion of feed to ruminants in many parts of the country. Farmers and pastoralists traditionally lop branches of trees and use them as supplementary feed for their animals during the dry season. Foliage from trees and shrubs is the preferred forage particularly for goats. In harsh and arid conditions, trees provide more edible biomass than pasture and the biomass remains green and high in crude protein (CP) when pastures dry off and senesce. The leaves and pods from fodder trees and shrubs usually have a higher CP and lower fibre content than dry grass forages and cereal crop residues. Thus, proper and strategic use of these feed resources as supplementary feed during the dry season can help to minimize seasonal fluctuation in productivity.

Commercial feedlots, which keep from as few as 20-50 animals to as many as 5000 head of cattle, depend on purchased concentrates and roughage feeds for their operation as they do not have land for feed production. Most feedlots are in an area where they have easy access to agro-industrial by-products such as wheat bran, oilseed cakes and molasses, which form a major portion of the concentrate mix fed to the animals. The major roughage source for these feedlots is either grass hay sourced from Sululta, north of Addis Ababa, or various cereal straws (tef, barley or wheat) purchased from the surrounding farmers. In addition, there are traditional and indigenous systems of cattle and small ruminant fattening practices in different parts of the country. These are typically carried out in the backyard using any feed resources produced on the farm. The main feed resources are crop residues, cut-and-carry grass and various agricultural by-products such as sweet potato vines and tuber, thinning or whole crop maize, inset supplemented with boiled maize and haricot bean and household wastes such as *atella* (homemade brewery and distillery by-product) and coffee residues.

Monogastric animals feeding system

Poultry, particularly chicken, are the main monogastric animals commonly reared in Ethiopia. There are two typical types of poultry production systems in the country. These are the traditional low input and backyard poultry production based on indigenous chicken and scavenging feed resources. The scavenging feed resources may include spilled grain, household wastes, earth worm and other worms and foraging around the homestead. This is a low input low output system characterized by low reproduction as well as low egg and meat production performance. This system accounts for about 95% of the total poultry production in the country.

Commercial poultry production is based on exotic hybrid layer or broiler breeds of chicken and compound concentrated feeds composed largely of grain and agro-industrial by-products. The commercial poultry feeding is affected by unreliable supply and ever-increasing price of locally produced feed ingredients and compound as well as imported premixes and feed additives. The competition between food and feed is expected to further increase the feed price, forcing producers to look for alternative feed resources.

Available feed resources

Different types of feed resources are available in Ethiopia. These are broadly grouped into concentrates and roughage feeds. The main sources of concentrate feeds are agro-industrial by-products, whereas the main sources of roughages are natural pastures, crop residues, and cultivated forage and pasture crops. The description of these major feed resources is given in the following sections.

Natural pastures

Natural pastures are naturally occurring grasses, legumes, herbs, shrubs and tree foliage that are used as animal feed. Traditionally grazing and browsing used to be the main feed resources for livestock feeding in Ethiopia. However, the area and productivity of grazing lands is decreasing with time. The intensity of cropping determines the area of land available for grazing and browsing. In the densely populated areas of the Ethiopian highlands, the better soils are used for cropping, and the steep slopes and the seasonally waterlogged foothills are allocated for grazing. On the other hand, livestock grazing is the predominant form of land use in pastoral areas, which account for over 60% of Ethiopia's land cover and receive less than 600-700 mm annual rainfall[1]. Most of these rangelands are situated in the northeastern, eastern, and southern parts of the country with the remaining rangelands lying in the wetter Gambella and Benshangul-Gumuz regions. Largely, these environments, with the exception of the wetter western lowlands, are arid and semi-arid with characteristic high ambient temperatures, low and erratic rainfall regimes. Recent estimate[2] shows that grazing biomass contributes 57.09 million tonnes of livestock feed supply.

The rangeland vegetation structure is influenced by the utilization pressure, topography and the amount and distribution of rainfall. In the hot and dry north-eastern and eastern arid rangelands, the sparse vegetation constitutes ephemerals, annual grasses, and dwarf shrubs suiting browsing camels and goats. The vegetation composition in the slightly better moisture regimes of the semi-arid areas of southern and eastern Oromia, southern parts of Southern Nations, Nationalities and Peoples Region (SNNPR), and parts of Somali (southern and western) region, is predominantly *Acacia commiphora* bush lands with understory perennial grass cover. In the much wetter Gambella and Benshangul-Gumuz rangelands, woodlands and savannah grasses make up much of the plant communities.

Forage from the rangeland is the principal source of feed for domestic and wild herbivores and availability of range forage shows considerable temporal and spatial variability. Natural pastures are continually decreasing due to rapidly increasing human population and expansion of cropland. Hence, the contribution of natural pastures to the dietary needs of animals is substantially decreasing with time. The quantity and quality of feed obtainable from natural pastures particularly decline during the dry season. The CP content and digestibility of most grass species decline rapidly with advancing physiological maturity. Extensive grazing areas are communally used, which does not encourage individual farmers to invest in pasture productivity improvement.

Natural pasture could be utilized through either direct grazing or zero grazing or the combination of grazing and zero grazing by harvesting and conserving as hay or silage. The application of these practices depends on the level of intensification of the production system, the environmental situation, topography, soil conditions, productivity, and management of the pasture. The most efficient way of using natural pastures could be a combination of grazing during the unproductive dry season and resting and harvesting the pasture during productive months of the year.

The pastoral areas are faced with complex challenges constituting recurrent drought, population pressure, continued loss of prime grazing lands, the weakening of customary institutions and pervasive rangeland degradation threats[1,3,4,5]. Compared to the highlands, the livestock feed insecurity is higher in the lowland parts of the country. The causes of rangeland degradation and the corresponding growing livestock feed insecurity are many and complex including prolonged and excessive rangeland use, recurrent drought, inefficient use of local available resources, invasive species encroachment, land use change and lack of sustained investment in grazing land improvement.

Crop residues

Crop residues are becoming increasingly important as sources of roughage feeds for ruminants. The principal crop residues used for animal feeding are the straws of cereals and pulses. Cereal straws include straws of crops such as tef, wheat, barley straws and stovers of maize and sorghum. Pulse or grain legume straws/haulms include residues of crops such as haricot bean, field pea, chickpea, lentil and groundnut. Sweet potato and cassava tops and vines, sugarcane tops and enset by-products also play important roles in small-scale livestock production systems. Based on crop production data of Central Statistical Agency (CSA), the total annual contribution of crop-based forages were estimated at 52.7 million tones, which include 5.8 million tonnes of stubble biomass[2]. However, the actual quantities of crop residues available for livestock feeding is reduced by the costs of collection, transport, storage and processing, seasonal availability, other alternative uses and wastage.

The nutritive value of crop residues is variable depending upon the species and variety of the crops, time of harvest, handling and storage conditions and other factors. Cereal straws and stovers are generally characterized by relatively low nutrient content, high fibre content, low digestibility, and low voluntary intake (limited consumption) by animals. The nutrient supply of many cereal straws such as tef, barley and oat straws is closer to that of medium quality native grass hay. Thus, good quality straw can be regarded as a good roughage source for ruminants next to native grass hay. Most cereal straws and stovers have lower nutritive value than the haulms from grain legumes and/or vines from root crops such as sweet potato. The haulms of pulse crops represent medium quality roughage with a CP content of 5-12%. Most roughage feeds are bulky and of low nutrient density, which make the transportation cost very expensive relative to the nutritive value of the feeds especially when they are transported over a long distance. Thus, provision of such feeds should be planned based on ease of accessibility of source of supply.

Without supplementation, crop residues cannot satisfy even maintenance requirements of animals primarily because of low nitrogen, high cell wall and slow digestion leading to a negative N balance and loss of body weight and productivity and death of the animal in critical cases. Post-harvest management technologies, such as efficient collection and conservation are crucially important. Though not widely practiced, chopping increases intake and digestibility of straws. Urea and biological treatment of cereal straws hold high potential for increasing CP content, intake, and digestibility of the straws.

Conserved forage

The objectives of forage conservation is to preserve forage resource for the dry season in order to ensure continuous and regular supply of feed for livestock, either to sustain growth, fatten animals or produce milk, or to continue production in difficult periods. The most commonly practiced forage conservation method is hay making while ensiling is rarely practiced.

In general, fodder conservation as hay or silage is not a common practice in many parts of Ethiopia with the exception of the central highlands around Addis Ababa. There is a long established practice of commercial hay production from natural pastures or meadow grass in parts of North and West Shewa zones of Oromia National Regional State. A more efficient system of harvesting grass using a scythe, locally known as *falch*, has been a common practice in these areas although in other parts of the country the sickle is the only tool available for cutting grass. Medium and big private and government run livestock farms do also make silage from a variety of forage sources during wet season. Locally produced native hay and silage can serve as useful source of roughage in commercial livestock operations. However, the nutritive value of the hay and silage could be very variable depending upon botanical composition or species of the forage crop, stage of maturity at the time of harvesting as well as harvesting, drying/ensilage and storage conditions.

Agro-industrial by-products

Agro-industrial by-products are the by-products of the primary processing of crops. They include flour mill by-products, oilseed cakes, brewery by-products, and molasses. These feed ingredients are the main constituents of concentrate feeds.

Milling by-products

Milling by-products include bran and related by-products such as wheat short, wheat middling, rice bran and screening. The annual potential availability of cereal and pulse brans is estimated to be around 2 041 000 and 488 000 tonnes, respectively[2]. For both cereal and pulse brans, the highest production is in Oromia, followed by in Amhara and SNNPR.

Wheat bran is the most common milling by-product used for livestock feeding in Ethiopia. The other minor by-product is wheat middling, which is finer than wheat bran with higher energy and lower fibre contents. Wheat screenings are broken or shrivelled kernels plus some foreign materials such as cheat and weeds. In areas where rice is produced and processed for food, rice bran, rice hulls, and broken rice grains are produced as by-products. Rice bran consists of the fibrous outer layer of the grain, some hulls and chipped grain. In general, rice mill by-products are characterized by high fibre and low energy content.

Oilseed cakes

Oilseed cakes are the residues or cakes that are produced as by-products during extraction of oil from oilseeds. They include noug cake, cottonseed cake, groundnut cake, linseed cake, sesame cake, sunflower cake and others. The potential production of oilseed cakes is estimated to be a total of 567 000 tonnes[2]. The same report showed that, most (about 79%) of the oilseed cakes are produced in Oromia and Amhara Regional States, each contributing about 43.7% and 35.4%, respectively. The production of oilseed cakes in Somali, Harari, Gambela and Afar regions is negligible.

There are two methods of extracting oil from the oilseeds. These are mechanical (press) and solvent extraction methods. Most oil-processing plants in Ethiopia use the expeller (mechanical) method of extraction. The mechanical extraction employs the application of pressure to force out the oil from the oilseed, whereas the solvent extraction uses organic solvent, usually hexane, to dissolve the oil from the oilseed. The mechanical extraction is a less efficient method of extracting oil from oilseeds, which leaves a substantial amount of oil in the residue.

The oilseed cakes are rich in protein, which may vary from 20 to 50% depending upon the type of oilseed and the method of extraction of oil -- mechanical *vs* solvent. However, the CP content of most oilseed cakes such as noug and linseed cake lies within the range of 28-35%. Most oilseed cakes are low in the essential amino acids cystine and methionine and have variable and usually low lysine content. Depending upon the method of processing, some oilseed cakes may have high proportion of fibre bound nitrogen, which could reduce digestibility of the CP. Oilseed cakes can also supply considerable amount of energy, depending upon the method of extraction of oil and the amount of residual oil remaining in the cake. The energy content varies from 2.03 to 3.7 mega calorie of metabolizable energy per kilogram dry matter (Mcal ME/kg DM) depending on processing method. Extraction of oil leaves a residue that may contain from 1 to 12% fat depending upon the process and efficiency of extraction. Solvent extraction removes nearly all the oil from oilseeds leaving only about 1% or less in the residue. Oilseed cakes produced by mechanical extraction contain more fat and fibre and less CP than those produced by solvent extraction. Oilseed cakes have high phosphorus (0.75-1.31%), potassium and magnesium contents and low content of calcium (0.17-0.72%) and sodium[6].

Brewery and winery by-products

There are breweries and wineries in the country (Table 1) that produce by-products of potential feed use, but which have not been fully utilized so far. Brewery, distillery, and winery by-products could be important sources of supplementary feed in commercial livestock operations. This is particularly important for farmers residing in the proximity of commercial breweries, distilleries, and wineries. The by-products have moderately high CP and metabolizable energy contents and digestibility.

Molasses and other by-products of sugar factories

Currently, Ethiopia is expanding its sugar industry. The sugar factories produce significant quantities of by-products such as molasses, bagasse, and cane tops that could potentially be used as animal feed (Table 2). Molasses has high sugar content, which is readily digested. It is also a good source of minerals such as calcium, potassium, sulphur and trace minerals, but deficient in nitrogen and phosphorus. Molasses is a concentrated source of energy that could be stored for a long period. Molasses is often used as a carrier for urea in molasses-urea blocks since it is palatable and provides a wide range of minerals. Some of the molasses is used for ethanol production n addition to its use as animal feed. Because of its bulky nature and difficulty of transport, only small proportion of the cane tops is effectively used as animal feed. As a result, most of the cane tops is either burned or just left in the field.

Table 1 Annual by-products production capacities of breweries* and wineries

Brewery/Winery	Location	By-product produced/year	Source or Remark
St. George Brewery – wet spent grain with yeast	Addis Ababa	18,768 t	St. George Brewery (2012)**
Meta Brewery	Sebeta	4000 t	Varela-Alvarez[7]
Bedele Brewery–Wet spent grain	Bedele	88,000 HL	Bedele Brewery (2007)**
Bedele Brewery–Brewers' yeast	Bedele	20,000 HL	Bedele Brewery (2007)**
Harar Brewery – Spent grain	Harar	5,000 MT	Harar Brewery (2012)**
Harar Brewery – wet brewers' yeast	Harar	6250 HL	Harar Brewery (2012)**
Harar Brewery – dry brewers' yeast	Harar	125 t	Harar Brewery (2012)**
Dashen Brewery–malt grain	Gonder	4,950 t	Tegegne and Assefa[8]
Dashen Brewery – Wet brewer's spent grain	Gonder	5,940 t	
Dashen Brewery – Dry brewer's spent grain	Gonder	1,488 t	Tegegne and Assefa[8]
BGI Brewery-Wet spent grain	Kombolcha	6,559 t	
BGI Brewery-Wet spent grain	Kombolcha	7474 t	Tegegne and Assefa[8]
BGI Brewery-Dry spent grain	Kombolcha	1,868 t	Tegegne and Assefa[8]
BGI Brewery – Wet spent grain	Hawassa	3528 t	Hawasa BGI Brewery (2012)**
Awash Winery	Addis Ababa	100 t	Varela-Alvarez[7]

Note: *This is excluding some of the newly built breweries such as Walia, Habesha, the second Dashen, Rayya etc. Breweries. **Information obtained from the production managers of each factory in the indicated years. t = tonnes; HL = Hectolitre

Grains and grain screenings

Depending upon availability and price, cereal grains and grains damaged during processing could be used as sources of high-energy feeds. Substantial amount of screenings and damaged grains are produced during grain processing and seed cleaning. Grain represents a concentrated feed resource, which can be transported over a long distance at a relatively low cost. Maize, wheat, barley, oats, sorghum and rice are usually highly digestible (80-85%), rich in energy and have a CP content of 8-12% of DM. Maize grain has a high potential in this respect because of its high-energy content, relative abundance and reasonable price most of the time. Cereal grains are low in calcium content and need to be supplemented with limestone to correct the deficiency. Screenings of barley and wheat have potentially high contribution to the diet of farm animals.

Table 2 Status of production and utilization of different by-products of sugar factories

By-product	Factory		
	Fincha'a	Metahara	Wonji-Shewa
Molasses			
• Annual production	• 30,000 tonnes	• 38,500 tonnes	• Mostly sold to alcohol producing factories
• Use for ethanol	• 100%	• 100%	• Remainder sold for use as animal feed
Bagasse			
• Annual production	• 300,000 tonnes	• 375,000 tonnes	• Mostly used for power generation
• Use for power	• 200,000 tonnes	• 337,500 tonnes	• Remainder is sold to furniture producers
• Balance	• 100,000 tonnes*	• 37,500 tonnes**	
Cane tops	All wasted	Used by pastoralists	Used by neighbouring livestock producers
Vinasse	• By-product of ethanol production from molasses (Finchaa and Metahara) • Claimed to be unfit for feeding to animals due to absence of essential nutrients or presence of toxic substances • Used for making compost for use as a fertilizer.		

Note: * So far from this amount about 1/3 of the bagasse produced per annum is being wasted. However, the respondent from the factory indicated that pulp and paper as well as chip wood producers are interested to buy and use it. ** Any remaining bagasse from use for power generation is baled and sold to briquette companies.

Improved forages and pastures

Thousands of forage species and accessions have been tested and a number of them recommended for wider adoption in different agro-ecologies and production systems during the last five decades. Appropriate agronomic practices have also been developed for selected species. Though Ethiopia is the centre of diversity for many forage species, most of the tested forages are of exotic origin.

Various forage development strategies have been developed and recommended for different agro-ecologies and production systems. These strategies address the needs of both smallholder farmers and specialised large-scale forage producers. For smallholder farmers with problems of land shortage, options like integration of food and forage crops are highly suitable. In areas with problems of soil fertility and soil degradation, forage crops can suitably be planted on soil bands, soil conservation structures, as hedge and alley crops. Highly productive and quality forage crops such as alfalfa, elephant grass, cowpea, lablab, vetch and others are suitable and productive in well-organized intensive production systems through better production inputs and irrigation to supply quality feed for highly productive fattening and dairy animals on a large-scale.

The adoption and utilization of improved forage and pasture crops is extremely low due to various factors, which may include low economic incentives under subsistence production system, limitations in seed/planting material supply and support service delivery, competition for land and other resources with crop production as well as policy and institutional issues. Moreover, adequate technical and material resources have not been allocated to the sector[9]. In addition, the insufficient know how and awareness of the farmers has also contributed to the low adoption of forage crops[10]. However, the expansion of market oriented livestock production and increased interest in raising genetically improved (crossbred) animals that respond better to nutrition may provide impetus to enhance forage adoption.

Other feed resources

Thinning, leaf stripping and topping from maize and sorghum: Crops such as maize and sorghum can generate animal feed throughout the cropping cycle as thinning, leaf stripping and topping. Usually farmers plant more than one seed per hill as a security against germination losses. The extra seedlings are thinned at weeding and serve as feed for animals. Leaf stripping involves removing the bottom leaves from the plant sequentially over a period and feeding to animals. Topping is the harvest of maize plant tops at silking stage. Although labour intensive, both leaf stripping and topping can produce better quality feed than harvesting dry stover without significantly affecting grain yield. When maize is harvested in green cob, green maize stover, which is of much better quality than the dry stover, is used for feeding animals. Maize plants that fail to set seed and all male lines from seed multiplication sites and commercial farms are harvested immediately after shedding pollen grains and used as green forage.

Sweet potato vines and tuber: The principal nutritive value of the sweet potato vines is as a source of CP and vitamins. The DM yield of sweet potato vines can be as high as 6 tonnes/ha with a CP content of over 20% and digestibility of 70%. Sweet potato vines have good palatability. In addition to the vines, damaged tubers that are unfit for human consumption can also be fed to farm animals. In general, in densely populated and land scarce areas, sweet potato has a promising potential for use as animal feed because of its relatively short vegetative cycle and high yield potential with minimal horticultural practices. Sweet potato has a vegetative cycle of 4-5 months fitting into tight cropping systems. It also has wide adaptation to diverse altitudes and temperature conditions and competes better with weeds than other root and tuber crops.

Banana and enset plants and by-products: Banana has a considerable potential for use as food and feed crop as it produces starch-rich fruits for human consumption and leaves, pseudo-stems and peelings that could be used as animal feed. The leaves have moderately high CP content (15%) while the pseudo-stem is rich in fermentable energy[11]. Banana leaves and pseudo-stems can be used as supplementary feeds to pasture and crop residue based diets. The banana plant has a high yield of total biomass. Banana leaves and pseudo-stems have relatively high digestibility of 65% and 75%, respectively. However, both are deficient in fermentable nitrogen. Thus, they should be supplemented with a source of nitrogen such as urea and highly digestible forage or sweet potato foliage.

Enset is a large banana like perennial plant native to the highlands of south and southwestern Ethiopia. It is cultivated mainly for a starchy human food as well as livestock feed. Leaf pruning and thinned *enset* plants are used for feeding animals. The very low DM content of the pseudo-stem poses DM intake limitation on animals while it could be an advantage if drinking water is in short supply. The relatively high CP content of the leaf (about 17%) makes it a favourable feed resource in ruminant feeding, as the protein content is comparable to that of many browse species. On the other hand, the corm and pseudo-stem have low CP content, which may depress feed intake when fed to ruminant animals if not properly supplemented with nitrogen sources.

Foliage and pods from naturally growing trees and shrubs: The leaves and pods of trees and shrubs are sources of good quality feed during the dry season when herbaceous forages are in short supply. Foliage of trees such as different *Acacia* species and *Balanites aegyptiaca* as well as the pods and fruits of *Prosopis* and different *Acacia* species can be used as a substitute for concentrate supplement. *Prosopis juliflora* has invaded vast areas the rangelands in Afar, Somali, and SNNPR. One way of controlling its expansion would be through proper utilization of the pods as component of animal feeds. The collection and utilization of the pods (after crushing the seeds) would have a double advantage of providing nutritious feed for livestock and greatly reducing further spread of the plant. Hence, the utilization of the *Prosopis* pods as source of animal feed through collection and crushing of the pods will help prevent further spread of the invasion to new locations[12]. Moreover, mixing the crushed pod with other feed materials like concentrates can be economical and nutritionally rich. In general, the supplements are expected to play a catalytic role in feed utilization and are needed in small quantities relative to the basal roughage. In harsh and arid conditions, trees provide more edible biomass than pasture and the biomass remains green and high in CP when pastures dry off and senesce. The leaves and pods from fodder trees and shrubs usually have higher CP and lower fibre content than dry grass forages and cereal crop residues. Thus, proper and strategic use of these feed resources as supplementary feed during the dry season can help to minimize seasonal fluctuation in animal productivity.

Cactus pear: Cactus (*Opuntia ficus-indica*) pear is a drought tolerant plant adapted to arid and semi-arid areas. It is a very valuable feed resource for feeding animals particularly during drought or prolonged dry season. It is tolerant to poor soil conditions and produces high biomass yield with acceptable palatability to animals. It is generally characterized by low dry mater, CP, phosphorus and cell wall carbohydrate contents, but highly digestible and rich in non-structural carbohydrates and calcium contents[13,14]. It can remain succulent during drought or long dry seasons and produce forages and fruit as well as be a source of ample water for animals. It has much higher efficiency of water use efficiency than any grass species and is estimated to produce at least 10 tonnes DM/ha/year. The low CP content is the main limiting factor of its use in animal feeding, which could be alleviated by small supplementation of high protein feeds such as oilseed cakes.

Status of feed industry and regulatory authority

Status of the feed industry

Early establishment of feed processing plants in Ethiopia dates back to the 1950s. However, the industry is still at an infant stage of development. A recent report[15] depicts that currently there are 81 enterprises under five major categories in the Ethiopian commercial feed sub-sector (Table 3). Of these, there are 32 feed processing plants owned by private companies and 28 feed processing plants owned by farmers' cooperative unions scattered across the four major regions of the country. Most of the private feed processing plants are located in Oromia (37%) and Addis Ababa (31%). There are a total of 15 importers or manufacturers of supplements (premixes, feed additives, etc.), most of which are located in Addis Ababa (66.7%), followed by Oromia (26.7%) and with only 1 enterprise (6.7%) located in the SNNPR. Similarly the existing five importers or suppliers of feed processing machineries are also concentrated in Addis Ababa (80%) with the remaining one enterprise (20%) being in Adama city of Oromia Regional State. There is only one commercial forage seed supplier located in Addis Ababa with field production operations carried out in Oromia and Amhara Regions.

Other than Addis Ababa and the four major regions indicated above, the remaining regions of the country (Afar, Benishangul-Gumuz, Gambella, Somali, Harari and Dire-Dawa city administration) do not have any feed processing plants, be it private or farmers' coop union owned, or other feed industry associated enterprises. Most of the premixes and feed additives are imported from abroad. Domestic supply of feed supplements is currently limited to mineral supplements and effective micro-organisms.

The capacity of feed mills ranges widely from 0.5 to 12.5 tonnes/hour. The output of compound feeds has increased during the recent years. The compound feed produced in private feed mills is dominated by poultry feeds. Most dairy farms and feedlots purchase different feed ingredients and practice home mixing of the ingredients. Most feed mills operate much below their capacity and for much lower than eight hours per day while they can potentially operate for at least two shifts of eight hours each. The main reasons for this could below availability of ingredients, inadequate storage capacity, localized distribution of the plants and various technical limitations.

Table 3 Regional distribution of feed processing plants and other associated enterprises engaged in feed industry in Ethiopia[15]

Type of enterprise	Regions					Total
	Addis Ababa	Oromia	Amhara	SNNPR	Tigray	
Feed processing plants	10	12	4	4	2	32
Farmers Coop Unions	1	6	7	6	8	28
Supplement importers/manufacturers	10	4	0	1	0	15
Feed processing machines/ equipment suppliers	4	1	0	0	0	5
Forage seed supplier	1	0	0	0	0	1
Total	26	23	11	11	10	81

Feed regulatory system and authority

Feed is a major determinant of productivity and welfare of animals. Animals receiving poor quality diets will perform poorly leading to a decrease in the income and overall benefit of the producer. In order to overcome this, safeguards and regulatory mechanisms are necessary. The following three bodies are expected to play positive roles in this respect. These include:

- The Ethiopian Standards Authority (ESA)
- The Veterinary Drug and Feed Administration and Control Authority (VDFACA)
- The Ethiopian Animal Feed Industry Association (EAFIA)

The Ethiopian Standards Agency (ESA): The Agency is the national standards body of Ethiopia that is responsible for developing national standards for local products and services. In general, the objectives for which the Agency has been established include the following.

- Develop Ethiopian standards and establish a system that enable to check whether goods and services follow the required standards,
- Develop national standards for local products and services to make them competitive in the international market.

When it comes to the feed industry, the ESA is responsible for preparation and revision of standards for industrial compound feeds and feed ingredients as well as for methods of sampling and testing feed and feed ingredients. The Agency also serves as custodian of the feed standards.

The Veterinary Drug and Feed Administration and Control Authority (VDFACA): The Authority was established in 2012 by the Council of Ministers Act No. 272/2012 following the enactment of the Veterinary Drug and Feed Administration and Control (Proclamation No. 728/2011) by Parliament in 2011. The Authority is mandated to regulate and control veterinary drug and feed safety and quality to guarantee the safety of animal products. It is responsible to carry out regulatory feed inspection to verify compliance with statutory requirements. VDFACA is responsible for initiating revision of the Feed Safety and Quality Act as necessary and for developing guidelines to be followed by the feed industry actors.

The Ethiopian Animal Feed Industry Association (EAFIA): The Association was established in 2008 by feed producers and processors as a platform to achieve production and marketing efficiencies, cost savings and play the role of a facilitator for the development of the feed industry. The membership includes feed processors, forage feed and seed producers, feed supplement producers and input suppliers as well as dairy and poultry producers and dairy cooperatives. The overall objective of the Association should be promotion of the interests of its members in a manner that will fulfil the interests of its customers and the public at large insofar as they relate to each other. In addition, the Association is expected to develop codes of conduct to be followed by member industries and develop its own guidelines to regulate conformance of member industries to the set codes of conduct.

Challenges and opportunities for enhancing utilization of locally available feed resources and enhancing feed use efficiency

The main challenges of livestock feed supply in the country can be summarized as follows:

- Shrinkage of grazing areas.
- Restricted livestock mobility and loss of key grazing areas.
- Recurrent droughts.
- Encroachment of rangelands by invasive species.
- Seasonal fluctuation of feed availability and quality.
- Lack of well-developed tradition of fodder conservation.

- Low adoption of improved forage production.
- Low nutritive quality of crop residues and poor adoption of technologies that can help to enhance the quality or feeding value of crop residues and other low quality roughages.
- Inadequate and fluctuating supply of agro-industrial by-products and lack of domestic supply of premixes and feed additives. The import of these supplements exacerbates the price hike compound feeds thereby affecting affordability of the feed.
- High price of marketed feeds (agro-industrial by-products, compound feeds, feed additives etc.).
- Unfavourable tax rate imposed on feed supplements imported from abroad and levying value added tax (VAT) on all marketed feed and feed ingredients makes the price of the feed beyond what most livestock producers can afford.
- Inadequate awareness of feed producers and traders concerning the quality and safety of marketed feed. When the quality and safety are compromised, it may cause health risk or result in poor animal performance and may create lack of trust between feed companies and livestock producers.
- Limitations with respect to domestic availability of machineries and equipment needed for feed production, processing and preservation.
- Unavailability of efficient, dependable and affordable analytical service lab that can provide analytical services aimed at ensuring feed quality and safety.

Opportunities and strategies for enhancing feed utilization efficiency

The following are some of the opportunities and strategies to enhance the utilization efficiency of available feed resources

- Increase production of some feed ingredients and make effective use of available feed resources. This includes reducing feed wastage through conservation and use of appropriate feeding systems, use of balanced rations to improve feed efficiency, and assessing and utilization of underutilized alternative feed resources.
- Improve nutritive value of feed through appropriate supplementation practices and production of high quality forages. In this context, it is worthwhile to consider the feasibility for improvement of metabolic efficiency of feed resources through use of growth promoters in commercial systems.
- Integration of fodder production into crop production, which could involve planting forage in soil conservation schemes and use agro-forestry systems that integrate trees, crops and livestock. Access to improved forage seeds, technical knowhow, and market opportunity for farm outputs would be of vital importance for the success of this approach.
- Improvement of grazing management. This includes empowering and capacitating customary institutions in pasture management and utilization, promoting cut-and-carry feeding systems and delineation of areas for haymaking, grazing reserves, restoration etc.
- Rangeland management options: Identifying and mapping restoration and utilizing measures and controlling invasive species through bush clearing and use of pods as animal feed.
- Increased government emphasis for development of market oriented livestock production. This will eventually increase the demand of high quality forage and compound feed production and is likely to increase market opportunities for such high quality feeds.
- Develop technologies and mechanisms for conserving and economically transporting seasonally excess forage from surplus producing areas (western lowlands) to areas of feed deficit.

- Establishment of fodder banks in irrigated and wetter areas in the pastoral lowlands. This is very important to bridge feed gap and will reduce the need for transporting crop residues and grass hay from highlands for emergency feeding during drought period.

Conclusion

Ethiopia has diverse agro-ecologies suitable for different livestock production systems. Availability and quality of feed resources also vary for the different agro-ecologies and livestock production systems. Crop residues, other agricultural by-products and natural pastures form the main source of feed in smallholder mixed crop-livestock production systems, whereas extensive grazing and browsing of range vegetation is the main source of feed for pastoral herds and flocks. On the other hand, most urban and peri-urban livestock producers entirely depend on purchased feeds (both roughages and concentrates), as they do not have land for grazing or for feed production. Overall, crop residues and natural pastures are the main feed resources. The contribution of cultivated forage and pasture crop to the livestock feed supply is quite insignificant and commercial feed industries are also at infant stage of development. However, the feed industry has shown a significant progress in recent years with increasing number of actors and different enterprises joining the sub-sector during the last decade. There is still a huge unmet demand for good quality feed to boost the productivity of the country's untapped livestock resources. Most premixes and feed additives are imported from abroad and the price is often prohibitive. Thus, there is a big potential and business opportunities for the private sector to be engaged in the sub-sector. This would be more effective with strong technical and policy support in the form of research, extension, regulatory framework and conducive policy environment from the public domain.

References

1. The Borana plateau of southern Ethiopia: synthesis of pastoral research, development, and change, 1980-91. ILRI (aka ILCA and ILRAD), 1994, 418.

2. Makkar H. Support to Institutionalization of Livestock Feed Security System in Ethiopia. A Report Submitted to Veterinaires Sans Frontieres, Berlin/Nairobi, 2018.

3. Yemane B, Mesfin T. Pastoralism and Agro-pastoralism: past and present. Conference of Ethiopian Society of Animal Production, 8, Addis Abeba (Ethiopia), 24-26 Aug 2000. Ethiopian Society of Animal Production, 2000, 54-68.

4. Kamara AB. Role of policies and development interventions in pastoral resource management: The Borana rangelands in southern Ethiopia. ILRI (aka ILCA and ILRAD), 2003, 42.

5. Mesele S, Gebrekidan H, Gizachew L, *et al.* Changes in land cover and soil conditions for the Yabelo District of the Borana Plateau, 1973-2003. Research Brief, 2006, 6.

6. Mogus S. The Effect of Processing Method of Oilseed Cakes in Ethiopia on Their Nutritive Value: In vitro N-Degradability and N-Metabolism in Growing Sheep Fed a Basal Diet of Maize Stover. University of Bonn, Germany, 1992, 152 p.

7. Varela-Alvarez H. Availability and utilization of alternative feeds. Report prepared for ACDI/VOCA., Addis Ababa, Ethiopia, 2006.

8. Tegegne F, Assefa G. Feed Resources Assessment in Amhara National Regional State. Ethiopia Sanitary & Phytosanitary Standards and Livestock & Meat Marketing Program (SPS-LMM) Report. 109pp, 2010.

9. FAO Livestock Sector Brief. Livestock information sector analysis and policy branch. FAO, Rome, 2004.

10. Benin S, Ehui S, Pender J. Policies for livestock development in the Ethiopian highlands. Environment, Development and Sustainability, 2003, 5(3-4): 491-510.

11. Ffoulkes D, Espejo S, Marie D, *et al.* The banana plant as cattle feed; composition and biomass production. Tropical Animal Production, 1978, 3: 45-50.

12. Getachew G. Experiences on prosopis management: Case of Afar region. FARM Africa. Pp. 6, 2008, 31.

13. Tegegne F. Nutritional value of Opuntia ficus-indica as a ruminant feed in Ethiopia. FAO Plant Production and Protection Papers,

2001: 91-100.

14. Gebremariam T, Melaku S, Yami A. Effect of different levels of cactus (*Opuntia ficus-indica*) inclusion on feed intake, digestibility and body weight gain in tef (*Eragrostis tef*) straw-based feeding of sheep. Animal Feed Science and Technology, 2006, 131(1-2): 43-52.

15. Bediye S, Neme G and Makkar H. Ethiopian feed industry: current status, challenges and opportunities. Feedipedia. Broadening Horizons, 2018.

A review on livestock production systems, and feed production and feeding systems in Iran: Challenges and Opportunity

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Abstract

Iran is the second largest country in the Middle East. Agriculture is one of the most important sectors of Iran's economy. Currently, agriculture constitutes 13.9% of the total gross domestic product (GDP) and 30% of non-oil exports from the country. The poultry industry of Iran is the largest in the Middle East, ranked third in Asia (after China and India) and 8th in the world. Also the industrial dairy cow farms has established during past decades. However, the country is able to produce the domestic demand for the milk, egg and poultry meat. But it is dependent to the imported feedstuff as approximately 70% of the raw materials for animal feed are imported from abroad. By working on strategies like efficient method of water usage in agricultural sector (modern irrigation method), enhance the efficiency of livestock farms and poultry stocks, practices in growing and harvesting forage with higher quality, and a wider use of local agro-industrial by-products as animal feed can reduce the demand of the imported feedstuff and help country to attain more self-sufficiency.

Introduction

Iran is the second largest country in the Middle East and covers an area of 1,648,000 km^2. Due to Iran's climate and topography, only around 12-15% of the country's land surface is cultivated; another 25% of the total land surface is considered rangeland. The non-agricultural land consists of large areas covered by desert, salt lakes, mountains and forest woodlands (http://www.tradingeconomics.com/iran/gdp, http://www.tradingeconomics.com/iran/gdp-from-agriculture). The Iranian climate varies considerably across the country. The Northwestern areas are among the coldest parts of the country, with winter temperatures falling well below zero. In the Southern areas, on the central plateau and the regions bordering the Persian Gulf, it is not unusual for summer temperatures to reach 50 °C. The majority of precipitation falls on the mountain areas in the North of Iran and along the Southern shores of the Caspian Sea. The main rainfall season in Iran is between October and March, leaving the land parched for the remaining periods of the year. In the Central and Eastern regions of the country, the climate is arid with an average annual rainfall of less than 200 mm and average summer temperatures above 38 ºC[1]. As the result, a large portion of the country is not suitable for the cultivation of main crops species. In addition, with a population of 80 million, Iran has a high demand for grains. These reasons contribute to the country's inability to overcome its deficit of feed ingredients.

Agriculture is one of the most important sectors of Iran's economy. Currently, agriculture constitutes 13.9% of the total gross domestic product (GDP) and 30% of non-oil exports from the country[2]. According to FAO, Iran ranks among the top 7 countries in the production of 22 important agricultural products.

Livestock farming constitutes 6% of the total GDP of Iran. There are nearly 83 million animal units in the country. Only 37 million animal units can be fed by rangeland pastures for 7 months in a year, leaving the rest 46 million animal units to rely on other feedstuffs[3]. Therefore, some of the arable land is under cultivation for feedstuff for livestock and thus is in competition with foodstuff production. However, a significant share of feedstuff is imported, depending on the yearly rainfall. A short description on the livestock production in Iran is presented below.

Livestock production and feeding systems

Cattle

At present, there are three categories of cattle breeds: pure exotic, crossbred of native and exotics, and pure native breeds. Based on the statistics published in 2016 by Ministry of Jihad-e-Agriculture (http://www.maj.ir), there is 8.2 million heads of cattle and the number of native cows is about 2.7 million heads (more than 10 distinctive breeds of local cattle) in Iran. The mean body weight and level of production do not vary in different generations. The birth weight of calves is about 15 to 20 kg and the mature live weight of male and female cows is about 370 and 275 kg, respectively[2]. The average of milk yield in about 150 to 160 days of lactation period is between 600 to 900 kg with a fat content of about 4%. Also, there are 4.4 million heads of crossbreds of native and exotics in Iran. Crossing the native breeds with the high producing exotic cattle improves the production. The milk yield of F1 cows in one lactation period is about 2600 kg[2]. The number of crossbred cattle has been increasing rapidly during the last 10 years. It should be noted that the native breed and crossbred cattle are reared under a traditional system. It is estimated that the herd size for each family is about 4 to 5 cattle (Figure 1). Usually these cows (pure native and crossbreds) graze in pastures in spring and early summer. During late summer and early autumn are on stubble feeding in harvested lands (crops residues) and in late autumn and winter they are in stable and are fed with roughage and some barley and wheat bran. They are generally, well adapted to the available native feed resources, management and environmental factors. Local and crossbreds cattle do not rely much on formulated feeds, which contain substantial amount of imported feed ingredients.

Figure 1 An Iranian pure native breed

Since 60 years ago, some exotic cattle breeds such as Holstein, Brown Swiss, Jersey, Guernsey and Red Danish were imported to Iran. However, at present, the Holstein is the most popular and dominating breed and a few dairy farms are rearing Brown Swiss and Jersey breeds. The population of pure exotic dairy cattle is about 1.1 million heads (http://www.maj.ir). The infrastructure necessary for genetic improvement of these cattle, such as pedigree registration, recording of the traits and artificial insemination have been organized since last 50 years. The animal breeding center in near Tehran (Karaj) is in charge of dairy herd's milk recording, data analysis, breeding value estimation for the dairy cows, embryo transfer and semen collection from proven sires, freezing of semen and distribution to the farms. Based on the data from Iranian animal breeding center (http://www.abc.org.ir/) these exotic cattle are rearing in 1,284 herds with the average herd size of 226 cows. The average milk yield per cow per lactation is 10,100 kg with 3.23% fat and 3.11% of protein. The average length of lactation is 327 days, which results in an average milk yield of 34 kg/day (http://www.abc.org.ir/).

The two main systems of cattle farming are traditional and industrial. As reported by the statistic center of Iran in 2011, traditional livestock farming was generally practiced in rural locations and comprised approximately 85% of the total cattle population, while industrial farms had a share of only 15% of the total cattle population (http://www.maj.ir).

Total national milk production has increased from 7 million tonnes of milk in 2008 to 9.6 million tonnes in 2016 (Figure 2), of which 6 million tonnes were processed by 400 processing plants. Ten processors control 80 to 90% of the market. Amongst these 10 are: Pegah (2,500 tonnes/day), Kalleh (2,000 tonnes/day), Mihan (1,000 tonnes/day), Sabah cheese (1,000 tonnes/day) and Damdaran (700 tonnes/day).

Sheep and Goats

The numbers of Sheep and goats is 47.6 million and 18.6 million head and their share was about 45% of the red meat production in 2016 (Table 1). Due to geographical topography and mountains and plains areas, various breeds of sheep and goats in different parts of the country exist[4]. There are about 28 known sheep and goat breeds, which are raised by the villagers and nomadic tribes (https://pdfs.semanticscholar.org). In general, sheep are mainly bred for meat, milk and wool production. There is a large variation in mature size between and within breeds. In Iran, Flocks of small ruminants are mainly managed under two different systems, namely, village and migratory (nomadic) systems[5]. In both systems the animals are mostly kept on natural grasslands and farmlands with little supplementary feeding[5].

In the nomadic system, the flocks migrate annually from the lowland winter ranges to the higher mountain grazing areas in the summer. However, the nomadic population is decreasing and they are settling down in different parts of the country. Still, this type of production system plays an important role in the livestock production sector[5]. Traditionally, supplementary feeding has not been common among the nomadic tribes, and periodic drought periods have caused high mortality and low productivity of the animals. In these harsh situations and through natural selection, only animals that are well adapted to the environmental conditions, survive. Therefore, breeding programmes such as selection for fast growth rates, higher productivity and bigger size, etc., which are common in intensive production systems, are not suitable for such a system. In fact, for such production systems, breeding plans should be for traits that natural selection favours.

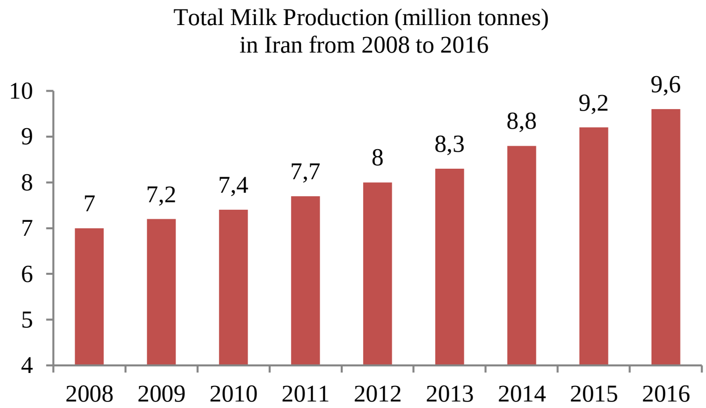

Figure 2 Total milk production in Iran from 2008 to 2016

In the village system, the flocks are allowed to rear on natural communal grazing pastures, irrigated farm lands, and even mountain ranges. The vegetation ranges provide part of the annual fodder requirements throughout the year. The majority of the sheep and goats (about 70% and 60%, respectively) are being raised in this type of production system. Based on the availability of the feed resources, there are large differences in various parts of the country. In some parts, there are suitable rangelands, harvested forages, grasses and agricultural by-products throughout the year that may provide enough feed. In the villages, supplementary feeding is normally practiced throughout the year, especially in the winter. In this system, suitable breeding, feeding and management programs, as well as new technologies (estrus synchronization and artificial insemination) and range management, are practiced through cooperatives and individual producers. It should be noted that there are now a significant number of sheep and goat breeding farms in Iran that they have intensively managed and animals are maintain throughout the year in the farm and there is no access to the rangeland (http://www.irfia.ir).

Table 1 The population of livestock and their share in national milk and red meat production (Ministry of Jihad-e-Agriculture Livestock Data, 2016)

Species	Numbers (x1000 head)	Milk (x1000 tonnes)	Meat (x1000 tonnes)
Pure exotics cattle	1083.7	3836.6	71
Crossbreds cattle	4389.8	4378.3	238
Local breeds cattle	2677.2	724.2	130
Buffalo	210.9	139	9.7
Camel	178.4	-	5
Sheep	47638.6	291.4	278
Goat	18719	283.6	91
Total	74897.6	9653	823

Fattening feedlot units, where sheep and cows are intensively fed for a period, could also be included in the category of supplementary feeding. In this system, the commercially prepared pellets and concentrate mixtures are of special importance. In general, stocking rates on the natural ranges are not controlled and depend on the seasonal rainfall and conditions of the pastures. Overgrazing, drought and lack of protection over many years have decreased the grazing capacity of the ranges. For most of the year, the grazing animals are on very low levels of nutrition. The effect of low-quality forages is accentuated by seasonal variation. The degree of seasonal variation varies with the climatic conditions. In most parts of the country, the growing season is from March until June, thus forages (mainly grasses) are available during this period. Parts of the pastures in the lowlands are preserved for next autumn, when the nomads move from highlands to lowlands[5].

The dry season lasts until September or October. In the dry season, feed largely consists of grasses in which the fiber content is high and protein content is low. During autumn and winter, the nomads may use the preserved pastures in the lowlands which have a moderate quality or supplementary feeding is practiced[6].The present system of nutritional management, which largely depends on natural vegetation, is unsatisfactory. On one side, there is a sizeable gap between the actual and potential productivity of small ruminants. On the other side, lack of suitable feeding strategies result in inefficient use of the available feed resources. However, while the intensive system may yield higher output, it requires a large amount of high-quality concentrate mixtures. Partly intensive systems are commonly practiced in some agro-industrial farms that cultivate different crops and can produce suitable feed for animals[6]. Small ruminants are grazed in lands after harvesting the crops and there is ample roughage to feed them. In these systems, it is possible to raise large-sized and highly productive breeds of sheep and goats, and to apply the new techniques of breeding, nutrition and production.

To overcome the present nutritional constraints of poor ranges, small ruminants should be taken off the ranges as much as possible to reduce the grazing pressure on the vegetation and to allow regeneration of the range species. So, in order to take small ruminants out of the ranges, it is recommended that the present extensive system of production should be gradually changed to a more productive semi-intensive system[5]. Recently, more attention has been paid to increasing the available amount of concentrates and to overcoming the nutritional problems of poor ranges. Any increase in the number of grazing animals is prevented. Since 2003, a 10-year national plan was launched, which aimed at reducing the number of grazing animals to balance rangelands productivity and carrying capacity. More attention has been paid to enhance the contribution of fibrous crop residues and agricultural by-products as the main feed sources. With suitable feeding strategies, the output per each unit of feed intake should increase. In the long term, this should lead to a reduction in the number of animals without affecting the total productivity of the system.

Poultry

Vegetable proteins do not appeal to the taste of most Iranians and, for religious reasons; pig farming has no place in Iran. Although Iran has both the resources and means to provide vast amounts of fish for its population, but again because of the lack of a taste for fish this source of protein is largely unexploited; and plans to expand the fish industries are still at the preliminary stage. This leaves the poultry meat, egg and red meat industries as the dominant suppliers of protein to the Iranian population[7].

The production of broilers in Iran has tripled since 2000. The per capita consumption of poultry meat has also increased significantly since 2000 (Table 2). At the moment, Iran produces more than 2 million tonnes of poultry, primarily chicken, and 0.95 million tonnes of eggs per year (Ministry of Jihad-e-Agriculture Livestock Data, 2016).

Table 2 Broiler meat and egg production and their per capita consumption: comparison for 2000, 2008 and 2016

Year	Broiler meat		Egg	
	Production (billion tonne)	**Per capita consumption (kg)**	**Production (billion tonne)**	**Per capita consumption (kg)**
2000	0.75	8.8	0.42	7.5
2008	1.56	10.5	0.73	9.75
2016	2.07	25.1	0.94	11.2

Much of the broiler production industry is located close to more densely populated regions and in the north (the moister) part of the country. The six leading provinces in broiler production in 2016 were Esfahan, Mazandaran, Golestan, Gilan, Razavi Khorasan, and Fars. These six states produce approximately 50% of the total broiler production in Iran. The production of eggs has doubled since 2000 (Table 2). Much of the egg production is concentrated in large commercial operations. The six leading provinces in numbers of laying hens are Tehran, East Azarbayjan, Razavi Khorasan, Esfahan, Ghazvin and Qom. These six states produce approximately 60% of the total egg production in Iran.

The poultry industry of Iran is the largest in the Middle East, ranked third in Asia (after China and India) and 8th in the world. At present, there is a pure broiler line farm and many farms for rearing grandparents (GP), parent stock (PS), broilers and layers. There are about 15 GP farms, which can supply the required PS flocks. The pure broiler line farms are established well, and have the capacity to supply high quality GP flocks for the local market and export. In 2016 the numbers of broiler and layer parent stock farms were 678 and 20, respectively, and the numbers of commercial broiler and layer farms were 20886 and 1603, respectively (http://www.maj.ir). Meanwhile, different European breeding companies are also in the market and provide their products such as GP and PS.

The size of poultry enterprises ranges from small farm flocks to large commercial operations. Most of the poultry raised in Iran is produced in medium commercial operations. Regardless of the size of the enterprise, success in poultry production depends on three important factors: good management, proper nutrition and sanitation. In general, there are three types of chicken enterprises: broiler production, egg production and raising replacement pullets. Most of the turkeys, ducks, quails and geese in Iran are raised for meat production. In the last 15 years, the trend in ostrich rearing has been upward. Laying hens are mostly confined in cages and in a few cases, the farmers may use a floor-pen system. Cleaning, grading, and packaging of eggs usually occurs on the farm. When the production cycle is completed, the hens are sold for meat. Broiler production operations involve raising chickens for meat. High-quality rations are fed to secure efficient and rapid gains[5].

At present Iran has the potential of designing and constructing poultry and livestock slaughterhouse units. In 2016, 62.6 thousand tonnes of poultry meat and 45 thousand tonnes of egg were exported from Iran (less than 3% of poultry meat production) (http://www.irfia.ir/). It should be mentioned that the next few years are very critical for the poultry industry in Iran. It is doubtful whether the government will be able to provide hard currency to import feedstuffs. It is being argued that one way to overcome lack of hard currency would be to export some of the finished products to finance the purchase of feedstuffs. Therefore, the Iranian poultry industry may need to export more of its products in order to survive.

In 1975, the population of native chickens was estimated to be about 16 million. A project for increasing the number of native poultry breeds started in 1983. In this project, various native breeds are rearing in 77 poultry center in different parts of the country and the vaccinated pullets distributed to the villagers. One important assumption for the native poultry sector is that, they do not rely on formulated feed, most ingredients of which are imported from abroad. The project led to rapid increase in the number of native poultry which was 66 million in 2007[5]. However, the author is not able to find a reliable current number of native poultry.

Available feed resources

The government policy on self-sufficiency and the local production of food is likely to be increasingly challenged in the years to come, due to a number of factors. First, the is shortage of water and salinization of land means that important natural resources for agriculture are inaccessible to farmers. Although in 2016, Iran produced 6 million tonnes of alfalfa hay, 0.5 million tonnes of clover, 11.3 million tonnes corn silage but the livestock demand for forage was higher and some alfalfa hay was imported from countries such as Georgia and Spain (http://www.maj.ir) .

Approximately 70% of the raw materials for animal feed are imported from abroad (Table 3). Based on the figures from (https://www.indexmundi.com/) Iran imported 6.5, 1.6 and 1.8 million tonnes of corn, soybean meal and soybean seed respectively (mostly for feed industry) in 2016. Soybean meal is an essential source of nutrition for poultry and livestock. While the global production of this oilseed amounts to 300 million tonnes annually, Iran imports close to 2 million tonnes per year, which meets approx. 70% of its domestic demand. Also corn and barley are the major source of energy for poultry and livestock in Iran. It should be mentioned that corn and soybean meal are the major part of poultry diet in Iran. Also corn, barley and soybean meal are the most used components of livestock diet in Iran. Statistics shows that 30% of demand, that is almost 1 million tons of corn and 0.2 million tonnes of soybean, are produced domestically and the rest is imported mainly from Brazil and Argentina (http://www.irfia.ir, https://www. iranpartner.com).

Table 3 Total requirement, domestic production and import volume (million tons) of the strategic grain and meals in 2016

Ingredients	Total requirement	Domestic production	Import	Import value (million US $)
Corn	7.5	1	6.5	1.4
Soybean meal	1.8	0.2	1.6	0.61
Barley	4.7	3	1.7	0.4

Normally, all pure exotic cattle breed (1.1 million heads), lamb and cattle fattening farm, broilers, layers, GP and PS are reared in intensive farm with formulated diets, in which the major ingredients are those imported from abroad. So, it is quite clear that in spite the Iranian government policy for self-sufficiency, actually Iran now is more dependent than ever before on imported feed ingredients.

In the recent years, there has been growing interest in by-product management by food processing industry for their utilization as alternative animals feeds due to enhanced environmental and economic concerns. Most food by-products could pose problems for the environmental if not properly disposed[8]. Feeding agro-industrial by-/co-products and food residues to farm animals reduces the environmental impact of the food industry and improves profitability through valorization of the agricultural by-products[9]. In addition, it is an efficient way to upgrade a low quality materials (by-products) into high-quality food such as meat, and also reduces the dependence of livestock on feeds that could be consumed by humans[9]. Some agro-industrial by-products that are used as animal feed in Iran are given below.

Tomato pomace

Tomato pomace is a by-product of tomato paste industries. The potato pomace is produced in huge amounts in Iran. The chemical composition of final pomace is linked to the morphology of the original feed stock and the extraction technique used (Table 4).

Abdollahzadeh *et al.* evaluated the effects of replacing alfalfa hay with ensiled mixed tomato and apple pomace (EMTAP) on performance of Holstein dairy cows[10]. They found that substitution of alfalfa hay by EMTAP in diet of lactating cows did not affect milk composition but significantly increased milk production, dry matter intake, feed efficiency and digestibility of dry matter in diets. The results showed that EMTAP can be replaced up to 30% of dairy cows diet[10-11].

Table 4 Chemical composition of some agro-industrial by-products which are used as animal feed in Iran

Item	DM	OM	CP	EE	NDF
Tomato pomace	26	87.8	21.7	13.4	57.4
Apple pomace	30.7	97.4	5.6	4.7	45.3
Oak Acron	88.2	92.2	5.3	1.5	27.4
Vinasse	50.5	76.1	27.7	23.2	-
Sugar cane top	32.5	91.6	5.4	1.7	61.5
Sugar cane bagasse	46	96.1	2.86	0.8	78.6
Pistachio pericarp	32.6	87.9	11.3	5.6	26.2

Note: DM, dry matter; OM, organic matter; CP, crude protein; EE, ether extract; NDF, neutral detergent fiber.

Apple Pomace

Apple pomace is a by-product from the apple processing industry. Generally, the apple processing industry generates 25-30% apple pomace and 5-10% sludge. Apple pomace residues are normally rich in carbohydrates, and other functionally important bioactive compounds, such as polyphenols and other natural antioxidants (Table 4). Apple pomace is presently used to feed animals in Iran[10-11].

Oak Acron

On the basis of a recent report of the Iranian Agriculture and Food Council, the oak acorn (oak fruit) production by natural forests in Iran is 800 thousand tonnes per year and this huge amount of production shows the importance of oak acorn as a low-cost feed It has been shown that in spite of a relatively high carbohydrate content, oak acorns contain (on dry matter, DM basis) low concentrations of crude protein (30-40 g/kg) and variable amounts of lipids (15-60 g/kg) and sterols (Table 4)[12] . Starch is the main carbohydrate in oak acorns, amounting to over 55% of the kernel[13]. Oak acorns, however, have some adverse effects on animal production, which arise from the presence of some anti-nutritional factors such as tannins and phenolic compounds[14]. There is evidence that goats may be less susceptible to toxic effects of tannins, and the presence of microbial tanninase enzymes are thought to be responsible[14]. Froutan *et al.* evaluated the effect of different levels of ground oak acorn on growth performance, blood parameters and carcass characteristics of goat kids and they concluded that ground oak acorn can be used up to 25% in the diets of young goats without any adverse effects on growth performance and carcass characteristics[15].

Condensed molasses solubles (Vinasse)

Vinasse originating as the condensed molasses residue is a co-product of industrial production of alcohol from sugar, citric acid and yeasts. It is also called condensed molasses solubles (CMS)[16]. After withdrawing the sugar fractions in the industry, the remaining organic non-sugar compounds and the mineral fraction in the molasses accumulate in the condensed remnant. Vinasse has the greatest polluting load of the effluents produced by alcohol distilleries because it presents biochemical oxygen demand ranging from 20,000 to 30,000 mg/L vinasse[17]. Vinasse can be used as a source of nonprotein nitrogen (NPN: including mainly betaine, glutamic acid and ammonia), in ruminant feeding. The main organic acids present in the vinasses are oxalate, lactate, acetate and malate, together with pyruvate. It is high in potassium and sulphate contents[18], so vinasse can be used for animal feed ingredient as a source of nutrients and minerals (Table 4).

In a recent study, Zali *et al.* studied the effects of vinasse supplementation on growth, carcass and meat chemical composition and total-tract digestibility of Holstein male calves, and they found that vinasse can be included in the growing calves ration at around 5% without adverse effects and would promote carcass composition (leaner carcases) [19].

Sugar cane top

Sugar cane industry in Iran with a total harvested area of approximately 120 thousand hectares is located completely in south of Iran (Khuzestan Province). Sugar cane tops (SCT) is generally known to be a major byproduct of the sugarcane industry which is left in the field after cane harvest (Table 4). SCT production varies considerably with variety, age at harvest, growing conditions and management practices. Based on the data from Animal Science Research Institut the volume of sugar cane top production is around 1 million tonnes annually (5 tonnes of DM per hectare).

Sugar cane bagasse

Bagasse is the fibrous residue which remains after sugar juice has been crushed from the sugar cane stalk. Quantitatively it is the most important by-product of the sugar milling industry. Based on the data from Animal Science Research Institute (http://www.asri.ir) the volume of sugar cane top production is around 1 million tonnes annually (Table 4).

Pistachio Pericarp

Iran is one the main pistachio producers in the world. There is about 299000 hectares of pistachio garden in Iran and annual pistachio production is 307 thousand tonnes[20]. Pistachio pericarp (PP) usually has some anti-nutritional substances such as tannin, which have different effects on animal performance (Table 4). In Iran, production of PP exceeds 400 thoushand tonnes per year. The nutritive value of pistachio pericarp varies depending on variations in the pistachios cultivars, growing practices, kernel maturity and the de-hulling process. Salehi *et al.* evaluated the effects of different levels of feeding of pistachio pericarp silage on wool characteristics of growing Afshari lambs and concluded that feeding lambs with 25% pistachio pericarp silage (based on dry matter) didn’t have significant negative effect on wool characteristics[20].

Status of feed industry and regulatory authority

In total there are 644 feed manufacturing factories in Iran, with a capacity of 21 million tonnes, 8 million tonnes for poultry, 10.5 million tonnes for large animals, 0.3 million tonnes for fish and 0.250 million tonnes for pets and horses. But they do not operate with full capacity because, at the moment, 60% of the feed is produced on the farm. For example, these feed factories produced 8.2 million tonnes of compound feed in 2016 (include 3.5 million tonnes for poultry, 4.5 million tonnes for cattle and 0.2 million tonnes for aquaculture). In 2016, 0.3 million tonnes were exported to Iraq and Afghanistan. There are 21 state-of-the-art factories.

As mentioned already, Iran is reliant on the import of finished feed production and raw materials. In total, the Iranian feed industry imports 80% of its raw materials. In the Central and Eastern regions of the country, the climate is arid with an average annual rainfall of less than 200 mm and average summer temperatures above 38 ^{o}C. As the result, a large portion of the country is not suitable for cultivation of main crops species. In addition, with a population of 80 million, Iran has a high demand for grain for use as food. These contribute to the country's inability to overcome its raw materials deficit.

The quality of feed which is produced in feed factories is strictly controlled by Iranian Veterinarian Organization (IVO). A feed nutritionist has to be employed by the factory. Random checks are done by IVO. Heavy fines are imposed if producers do not comply.

Challenges and opportunities in enhancing utilization of locally available feed resources and enhancing feed use efficiency

Challenges

- The government policy on self-sufficiency and the local production of food are likely to be increasingly challenged in the years to come, due to a number of factors. The shortage of water and salinization of land are the most important, because as a result of these important natural resources for agriculture are inaccessible for farmers.
- Alfalfa plant is harvested in a full mature stage in Iran and its nutritive value has declined already.
- The variety of corn silage is cultivated in Iran is a late maturing variety with a low grain to stover ratio. In a survey was done by the author on corn silage samples collected from 25 large dairy farms, the average of starch concentration was only 10% (based on the DM).
- However a huge amount of cereal straw (wheat, barley and rice) is produced in Iran but there is not an organized knowledge transfer mechanism to teach the rural dairy farmers about straw treatment and enrichment to enhance utilization of this kind of feedstuff as animal feed.

Opportunities

- Iranian farmers should use water more efficiently. In the past the farmers used water from canals to irrigate with flood irrigation. The water was not used very efficiently. Now they use wells to pump water to the surface to be used for irrigation. Experts and farmers reported that new irrigation techniques will strongly improve the kg growth (in DM) per kg of water.
- Recent varieties of corn should result in higher dry matter yields and improved practices in growing and harvesting alfalfa should raise the protein content of this crop.
- Working on alternative forage species is needed. For example, harvesting barley earlier and making whole plant silage. Using this, crop farmers have more time to plant the corn (which is used as corn silage) and harvest it in a more mature stage (with 25% or higher DM). Because, in most of the area in Iran, crop farmers to prevent the frost damage of corn silage harvest it in a premature stage which result to low dry matter of corn silage (around 20% of DM). The next example is exploring to make alfalfa silage. The silage preparation will enable the farmers to enhance the protein content of the end product to 18-20% from 15% when used as hay.
- Promote use of agro-industrial by products in rural dairy farms.

Conclusion

The feed industry in Iran is a dynamic and active sector. Also dairy cow and poultry industries are mature to provide animal source foods for the national requirements. However, approximately 70% of the raw materials for animal feed are imported from abroad. There is a huge room to increase the feed efficiency of livestock and poultry farms. The wider use of locally available feed resources will result in higher feed self-sufficiency.

References

1. Maysami M. Energy Efficiency in Dairy Cattle Farming and related Feed Production in Iran. Humboldt University Berlin, 2013.

2. Rajabbaigy M, Kamalzadeh A. The scope of the livestock production in developing countries: a case study of Iran. International Business: Research, teaching and practice.2011, 5(1).

3. Badripour H. Country Pasture/Forage Resource Profiles, Iran. FAO, Rome, 2006.

4. Kamalzadeh A, Shabani A. Maintenance and growth requirements for energy and nitrogen of Baluchi sheep. International Journal of Agriculture and Biology, 2007, 9(3), 523-529.

5. Kamalzadeh A, Rajabbaigyen A. Kiasat. Livestock production systems and trends in livestock industry in Iran. Journal.of Agriculture & Social Sciences, 2008, 04: 183–88.

6. Kamalzadeh A. Modeling the productivity of a breeding sheep flock for different production systems. Asian-Australasian Journal of Animal Sciences, 2005, 18(5), 606-612.

7. Shariatmadari F. Poultry production and the industry in Iran. World's Poultry Science Journal, 2000, 56(1): 55-65.

8. Tufarelli V, Introna M, Cazzato E, *et al.* Suitability of partly destoned exhausted olive cake as byproduct feed ingredient for lamb production. Journal of Animal Science, 2013, 91, 872–877.

9. Cooke RF, Di Lorenzo N, Di Costanzo A, *et al*. Effects of Fermenten supplementation to beef cattle. Animal Feed Science and Technology 2009, 150, 163-170

10. Abdollahzadeh F, Pirmohammadi R, Fatehi F, *et al.* Effect of feeding ensiled mixed tomato and apple pomace on performance of Holstein dairy cows. Slovak Journal of Animal Science, 2010, 1(1): 31-35.

11. Abdollahzadeh F, Pirmohammadi R, Farhoomand P, *et al.* The effect of ensiled mixed tomato and apple pomace on Holstein dairy cow. Italian Journal of Animal Science, 2010, 9(2): e41.

12. Lopes IMG, Bernardo-Gil MG. Characterization of acorn oils extracted by hexane and by supercritical carbon dioxide. European Journal of Lipid Science and Technology, 2005, 107, 12–19.

13. Saffarzadeh A, Vincze L, Csapo J. Determination of the chemical composition of acorn (*Quercus branti*), Pistacia atlantica and Pistacia khinjuk seeds as non conventional feedstuffs. Acta Agraria Kaposvariensis: 1999, 3, 59–69.

14. Perez-Maldonado RA, Norton BW. The effect of condensed tannins from Desmodium intortum and Calliandra calothrsus on protein and carbohydrate digestion in sheep and goats. The British Journal of Nutrition, 1996, 76, 515–533.

15. Froutan E, Azizi O, Sadeghi G, *et al.* Effects of different concentrations of ground oak acorn on growth performance, blood parameters and carcass characteristics of goat kids. Animal Production Science, 2015, 55(1): 87-92.

16. Fernández B, Bodas R, López-Campos Ó, *et al.* Vinasse added to dried sugar beet pulp: Preference rate, voluntary intake, and digestive utilization in sheep. Journal of Animal Science, 2009, 87(6): 2055-2063.

17. Leite GF. Avaliac¸ao economica da adubac¸ao com vinhacaeda adubac¸ao mineral de soqueiras de cana-deacdeac ucarna Usina Monte Alegre Ltda-Monte Belo-MG. Revista Universidade Alfenas. 1999, v5:189–191.

18. Stemme K, Gerdes B, Harms A, *et al.* Beet-vinasse (condensed molasses solubles) as an ingredient in diets for cattle and pigs-nutritive value and limitations. Journal of Animal Physiology and Animal Nutrition, 2005, 89(3-6): 179-183.

19. Zali A, Eftekhari M, Fatehi F, *et al.* Effect of vinasse (condensed molasses solubles) on performance and meat chemical composition of Holstein male calves. Italian Journal of Animal Science, 2017, 16(3): 515-520.

20. Salehi M, Mirzaei F, Mahdavi A. Effects of different levels of feeding of pistachio epicarp silage on wool characteristics of growing Afshari lambs. Agricultural Sciences, 2012, 3(03): 351.

Livestock production systems and feed resources in Greece

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Abstract

The livestock industry of Greece is determined by the typical characteristics of the Mediterranean ecosystem. Greece is a rather small country situated on the south-eastern part of Europe. The land area of Greece is 13.2 million hectares of which 30% is devoted to crops, 40% to pasture, and 20% to forestry. The average size of the agricultural holdings falls within a broad range of 2 to 10 hectares with a considerable number of mixed holdings (crops and livestock). Agriculture represents only around 7% of the Gross National product, with 75% of it coming from crops and 25% from livestock production. The seasonality of production of the natural vegetation, combined with low rainfall, high temperature and low organic content of the soil are some of the main constraints on the development of livestock production in relation to crops. Greece is one of the largest producers of crops such as olives, cereals, vegetables, vineyards, fruits, tobacco and cotton in the European Union (EU). Moreover, Greece has the largest diversity and production of aromatic plants among the EU countries. Regarding livestock production, Greece is first in aquaculture, goat population and sheep milk production in EU countries. Small ruminants, i.e. dairy sheep (9 millions) and goats (4 millions) are considered as the most significant livestock sector in Greece with a long continuity of the ancient tradition. Small ruminants are traditionally kept in rural areas, in rather small sized flocks, as dairy flocks, and their milk is mainly used for traditional products, such as Feta cheese, as well as other cheeses of Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI) or yoghurt. Dairy cows (120 thousand), fattening cattle (300 thousand), pigs (1 million) and poultry (30 million) are reared mainly by intensive methods. Annual meat production in Greece is around 180 thousand tonnes of poultry meat, 120 thousand tonnes of pork meat, 110 thousand tonnes of sheep and goat meat, 60 thousand tonnes of beef and 4 thousand tonnes of other types of meat. Annual milk production in Greece is around 600 thousand tonnes of both cow and sheep milk and 150 thousand tonnes of goat milk. The self-sufficiency of the country in products of animal origin is 90% in sheep and goat meat, almost 100% in sheep and goat milk, 85% in poultry meat, 97% in eggs and 87% in honey and a high surplus in aquaculture, whereas it is insufficient in pork, being only 40%, very limiting in beef meat 20% and 50% in cow's milk and milk products. Greece is the first exporter among EU countries in sea bass, seabream and mussels. Greece produces significant amounts of cereals (corn, wheat, barley) and alfalfa for use as feeds for livestock, but is not self-sufficient. The main imported feedstuffs are soybean meal and oil, other proteinaceous feeds and feed additives (vitamins, minerals, medicinal products, etc). In the last decade, production of new local feedstuffs has risen such as lupins, rapeseed, and locally produced soy bean, as well as by-products of important agricultural industries: olive oil, winemaking, citrus, biofuel/bioethanol, and stevia. Novel feed additives for all animal categories are being produced based on material retrieved from medicinal-aromatic and halophyte plants. There are several challenges and opportunities in aquaculture, ruminant and monogastric animal production in Greece for the next decades. Utilization of novel locally available feed resources and innovative feed additives based on herbal extracts can support sustainability of the livestock industry, exports of both complete feeds and products of animal origin and coverage of local self-sufficiency.

Introduction

Greece is located at the south east part of Europe, on the southern tip of the Balkan Peninsula. The Mediterranean Sea lies to the south of Greece with a large number of islands. About 80% of the mainland of Greece is mountainous, with mount Olympus being the highest peak, whereas extensive plains are primary located in the three regions of Thessaly, Central Macedonia and Thrace. Agriculture remains an important sector of economic activity and employment for Greece, with exports of agricultural products accounting for one third of total exports in Greece. It is estimated that agriculture contributes around 4.1 percent of gross domestic product (GDP) and is characterized by small farms and low capital investment. Greece's utilized agricultural area is approximately 5 million hectares, of which 57 percent is in the plains and 43 percent is in mountainous or semi-mountainous areas. There are about 150 million olive trees in the country, either in systematic orchards or scattered across the country, ranking the country as 3rd global olive oil producer. Lower agricultural productivity in Greece, compared to other EU Member States, is correlated to the smaller average-size of holdings. The economies of scale offered by modern farming practices have limited impact on the small plots of land typically used in Greece. Its economy mainly comprises the service sector (85.0%) and industry (12.0%), while agriculture makes up 3.0% of the national economic output. The gross income from the agricultural section is estimated at about 10,000 million euro, of which 75% of its coming from crops and 25% from livestock production. Agricultural labour force was estimated to be a quarter of active population in 2010. The self-sufficiency of the country in products of animal origin is 20% in beef meat, 40% in pork, 88% in sheep and goat meat, 77% in poultry, 50% in cow's milk and milk products, 100% in sheep and goats milk, 97% in eggs and 87% in honey. Annual meat production in Greece is 180 thousand tonnes poultry meat, 115 thousand tonnes pork meat 110 thousand tonnes sheep and goat meat, 59 thousand tonnes beef and 4 thousand tonnes other types of meat (Table 1). Annual milk production in Greece is around 600 thousand tonnes of both cow and sheep milk and 150 thousand tonnes of goat milk. Other important industries include tourism and merchant shipping, while the country is a considerable agricultural producer (including fisheries) for the EU[1, 2, 3, 4, 5].

The land area of Greece is 13.2 million hectares of which 30% is used to cultivate crops, 40% as pasture, and 20% are forests. The average size of the agricultural holdings falls within a broad range of 2 to 10 hectares with a considerable number of mixed holdings (crops and livestock). Greece is among the EU members with the lowest average area per farm (4.4 - 4.8 hectares per farm). The grasslands of Greece (83% state owned) are more suitable for sheep and goats grazing. They are composed mainly of annual plant species with great botanical interest (~6.500 species). These grazing areas of Greece receive no application of artificial fertilizers, nor agrochemicals and no agricultural management other than grazing which benefits a wide range of flora and fauna (e.g. birds, insects, snails, turtles, hedgehogs, hares, rabbits, foxes etc.) and could be regarded as pre-organic feeding for small ruminants[1, 2, 3, 6].

Table 1 Animal capital and livestock production in Greece

Year	2001	2012	2015
Animal capital (Thousand heads)			
Bovine	621	611	597
Pigs	934	793	714
Sheep	9124	8778	8746
Goats	5662	4895	4128
Livestock Production (Thousand tonnes)			
Meat	462	431	411
Milk	2032	2020	1972
Cheese, hard	36	39	36
Cheese, soft	126	114	92

The feed industry sector

Feed production is an important part of the rural economy of Greece. It is divided into primary feed production which is a direct result of agricultural activity (cereals, fruits, alfalfa, etc.) and in the production of feed after processing (raw materials such as by-products of food industries and other agricultural industries such as wheat or rice bran, cotton cake, and others: soybean meal, fishmeal, etc.), feed materials, such as cereals, and mainly raw materials not produced in our country. The needs of our country for compound feeds are almost met by domestic production. Some animal feeds or specialized ingredients are imported from other EU member states or from other countries of Europe. Moreover, feed additives used in animal nutrition such as vitamins and enzymes are imported mainly from EU countries, China, USA, and India. Today, with the exception of on-site feed production for their own livestock production, there are 1600 approved registered feed factories that produce raw materials, compound feeds, premixtures of additives and feed additives/premixes (Figure 1). Dog and cat feed production is also increasing [1, 2, 3, 6].

Greece has considerable production of crops, cereals, roots, vegetables, cotton, tobacco, olive trees, vineyards, fruits and alfalfa (substantial production of: cotton, 1st ranking in EU countries, pistachios, rice, olives, figs, almonds, tomatoes, watermelons, tobacco). The country produces significant amounts of cereals (corn, wheat, barley and others) and Lucerne for use as livestock feed, but is not totally self-sufficient for these feeds. The main imported feedstuffs are soybean meal and oil, other proteinaceous feeds and feed additives (vitamins, minerals, medicine, etc). An estimated total annual amount of feeds consumed is about 3.5-4.0 million tonnes (60% cereals, 20-25% soybeans, 15-20% other feeds). The annual amount spent for feed imports is estimated at 500 million euro. Several raw materials and completed feeds are exported to Balkan neighbouring countries [1, 2, 3, 5, 7].

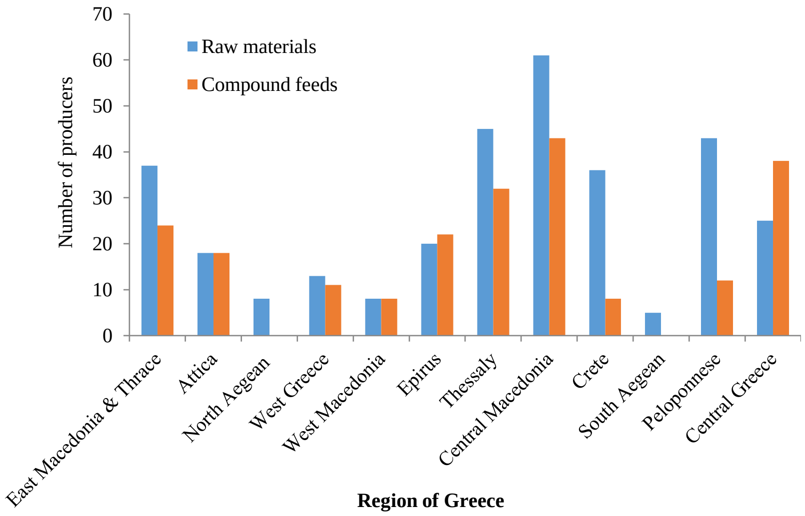

Figure 1 Number of feed producers in different regions of Greece

The ruminant sector

Small ruminants, i.e. dairy sheep (9 millions) and goats (4 millions) are considered as the most significant livestock sector in Greece with a long continuity of the ancient tradition. They are traditionally kept mainly in less favoured areas, in rather small sized flocks, and produce milk which is transformed mainly into traditional products like Feta cheese and yoghurts. Dairy cows (120,000) and fattening cattle (300,000) are reared mainly intensively indoors. Sheep and goat farming is considered to be one of the most dynamic sectors of the rural economy in Greece, both in terms of employment and overall income. These systems contain elements that can provide high added value under modern farming conditions, related with the need for the protection of the environment and biodiversity and with consumer demands for safe and quality products. Majority (over 85%) of the sheep and goat flocks are being reared in mountainous and semi-mountainous areas, having important economic, social and ecological roles, and contributing to the conservation of the environment. The extensive production system is predominant, with 78% of the Greek sheep flocks and 90% of the goat flocks are being reared in low-input production systems. It is estimated that more than 100,000 farming units with more than 50 animals each exist, whereas the average size of a unit is around 100 adult animals. The two major systems of sheep farming are pasture grazing and indoor based systems. Under the current globalized economy, the term improvement should encompass the sustainability principles in which agricultural activities are economically, environmentally and socially sustainable. Feta cheese is composed of at least 70% of ovine milk from ewes reared under semi- or extensive conditions in Greece. Kaseri cheese is made from at least 80% of ovine milk. In Greece, more than 22 different cheeses that are certified as protected geographical indications (PGI) or protected designations of origin (PDO) are produced and consumed either within the country or are being exported [1, 3, 4, 5, 6].

Bovine meat industry is not efficiently developed in Greece. Farm units with fattening bulls are usually totally engaged in fattening (with only a small degree with reproduction) of animals imported at an early age and then their slaughter. As calf production is not enough to meet the needs of the country, massive imports of calves, either from European or from other countries take place. A main feature of dairy industry has been a rapid increase in the unit size and corresponding decrease in the number of units. Greek dairy cow farmers are mostly young entrepreneurs, who do not base their viability on the direct EU subsidies, have made significant investments and are aimed to create a modern livestock farming tradition [1, 3, 4, 5, 6].

The poultry, pig and aquaculture sector

The Greek poultry industry is one of the main pillars of the farming in Greece, with a large share of fully integrated systems. Broilers (120 million) and more than 30 million of laying hens are mainly intensively reared indoors. The expansion of the poultry industry began over 50 years ago and continues to grow, but with lower rates showing a tendency to stabilize with slight variations. The poultry industry is located mainly in the regions of Epirus (Ioannina and Arta), Evia - Viotia - Attica and Macedonia. According to statistics (Greek Ministry of Rural Development and Food) recorded in end-2009, 66.2% of total broiler breeder farms and 45% of broiler farms have been located in Ioannina county, whereas 50% of layer farms have been located in Attica county. Total numbers of breeders, layers and broiler farms in Greece are estimated at 254, 361 and 1350 respectively (Figure 2). The 89 breeder farms had, until the end of 2009, 358 flocks of hens, of which 84.6% consisted of broiler breeders, 10.6% were mixed production flocks and 4.7% were layer breeders flocks. A total of 355 layer farms existed, with 652 flocks having 8,369,800 birds, and the broiler farms had a total of 7,384 flocks with a total of 97,503,078 birds kept at the end of 2009. There were 26 hatcheries, of which 20 are located in the regions of Epirus, Evia - Viotia - Attica and Macedonia [1, 3, 4, 5, 6].

The poultry industry is well organised, integrated and modern and hence provides attractive prospects for growth and further development. Investments by the industry at all stages of production (feed mills, poultry farms, hatcheries, slaughterhouses) are increasing, aiming to be in full compliance with the EU legislation. According to data from the Association of Poultry Processors and Poultry Trade (AVEC), in Greece, the average consumption of poultry meat per capita is about 20 kg, which leaves room for further growth when compared with the average consumption per capita in the EU, which is 22.7 kg. The self-sufficiency of Greek poultry industry is approximately 75-80% and therefore it invested a significant amount in the last years to improve production, reduce costs, improve production indicators and to create new, innovative and fully compatible products following the European legislations [1, 3, 4, 5, 6, 8].

Pig farming in Greece is considered one of the most dynamic livestock farming industries, although due to heavy economic pressures its size decreased significantly in the last decade. It represents the 25% of the total domestic production of meat. Nevertheless, the country self-sufficiency for pork meat has decreased in the last 5 years and is now at 35%. The production of pig meat is around 150,000 tonnes from 100,000 sows. Intensive pig rearing system contributes 80% of this meat production. Pigs (1 million) are reared mainly intensively indoors, although there is a local breed of black pigs that is reared mostly in the organic way. The economics of pig farming in Greece is quite satisfactory with a number of piglets produced and fattened exceeding 20 per sow per year. Farms with lower production, is not possible for gross return to cover production costs, to be viable and competitive. On the contrary, pig farms which produce and fatten more than 22 piglets per sow per year are not only viable but also competitive. It is believed that the viability and competitiveness of the Greek pig farming must be based on the increase of the productivity. Suggested goals include: at least 24 pigs fattened per sow per year; decrease of the feed required per piglet of 25 kgs live weight to 90 kgs, with cost lower than 25 ECU per 100 kgs; average daily gain over 700 grams; decrease of the feed conversion rate under 2.80; decrease of the interest rate of short and long term loans under 10%. The continually increasing consumption of pork, in combination with high demands consumers create, are opening new avenues for competition and enhanced efficiency of production. The application of modern forms of production while respecting animal health and welfare, product quality and safety and other public concerns is expected to lead to growth in the industry. The sector provides employment to thousands of families[1, 3, 4, 5, 6].

Greek aquaculture is dominated by the farming of marine finfish in offshore cages, specifically of gilthead sea bream and European sea bass with the combined production capacity of about 110,000 tonnes in 2015. This is followed by the culture of Mediterranean mussels with an annual production capacity up to 35,000–40,000 tonnes in 2015. After several crises mainly because of imbalance between supply and demand, the marine fish sector has been restructured, with the aim of doubling its production by 2030. To meet this target, strategies including: targeted research, development and innovations to optimize production; diversification of products; and concerted marketing actions through development of new schemes, such as producers' organizations, are under consideration. Freshwater species and extensive lagoon aquaculture have a limited growth potential mainly because of the lack of natural resource (water, wild stocks) availability. Marine fish is the top Greek exported animal product and contributes about 11% of the total national agricultural exports (which altogether account for 19% of the total Greek exports) [1, 3, 4, 5, 6].

Herbal products

The geographical position of Greece, its geomorphology, the presence of flora of past geological eras and the coexistence and interplay of biotic and non-biotic factors have defined Greece as a country of high plant diversity and endemism. This vast diversity is also reflected in medicinal and aromatic plants as Greece has a long ethnopharmacological tradition, partly due to diverse landscape and the numerous mountainous and insular systems, viz. 109 out of the 255 habitat types encountered throughout Europe. Medicinal and aromatic plants are expected to play an important role in the Greek rural economy and facilitate change in the national agro-food sector. In 2013 aromatic plants occupied merely 0.04% of the country's cultivated land and is expected that this cultivation area will be doubled by 2020[1, 4, 9, 10, 11].

Nowadays the needs of both producers and consumers are changing dynamically. Common Agricultural Policy (CAP) played an essential role in crop selection throughout the last decades in Greece. Developments in CAP during the period of 2007 to 2013 indirectly influenced the culture and production of aromatic plants in Greece. The two most important developments were the release policy (decoupling) of subsidies from production and their conversion to area subsidies based on historical production. As a result a critical number of farmers shifted to growing herbs or legumes or even to non-agricultural activities such as rural tourism, and energy production via photovoltaic systems. The global economic crisis of 2008, affected the cultivation in different ways. One was a shift of many young people to the agricultural sector, mostly to non-conventional crops. All the factors above somehow seem to facilitate a change in Greek crop selection in which medicinal and aromatic plants should reflect an important part due to land allotment, Greek biodiversity and the Mediterranean climatic conditions that offer very favourable factors in the production of indigenous medicinal and aromatic plants that will offer a substantial qualitative advantage to Greek herbal products (Figure 3). Furthermore, their production offers advantages because of their low demands for water and organic way of cultivation when compared to high-maintenance crops[1, 4, 9, 10, 11].

Challenges and opportunities in enhancing utilization of locally available feed resources and enhancing feed use efficiency

The agriculture sector in Greece faces several challenges, such as the existence of medium or small production units, the relatively high production cost of feeds than imported feed materials, the limited production of proteinaceous feeds, the climate pressure of the Mediterranean basin with arid hot summers, and the partial modernized methods of feed plant cultivation and of livestock production. However, there are several opportunities for further development, based on the rather low self-sufficiency of products of animal origin, the high potential for increase of high-value rated quality products, such as feta cheese, yoghurt, lamp and goat-kid meat and the production of novel herbal feed additives. These also offer in numerous opportunities for young scientists to implement the leading innovation in agricultural methodology[1, 3, 4, 7].

References

1. Hellenic Statistical Authority. Greece in figures: January-March 2018. Athens: Statistical Information and Publications Division, Hellenic Republic, 2018.
2. ELSTAT. Hellenic Statistical Authority. <http://www.statistics.gr/en/home/>. Accessed 2018.
3. Hellenic Statistical Authority. Greece in figures: January-March 2018. Athens: Statistical Information and Publications Division, Hellenic Republic, 2018.
4. Eurostat. Eurostat - European Commission. <http://ec.europa.eu/eurostat>. Accessed 2018.
5. FAOSTAT. Food and Agriculture Organization of the United Nations. <http://www.fao.org/faostat/en/>. Accessed 2018.
6. General Directorate of Animal Production. Greek Animal Production. Athens: General Directorate of Animal Production, 2011.
7. IndexMundi. <https://www.indexmundi.com>. Accessed 2018.
8. AVEC. Association of Poultry Processors and Poultry Trade. Annual Report 2017.
9. Christaki E, Bonos E, Giannenas I, *et al.* Aromatic Plants as a Source of Bioactive Compounds. Agriculture, 2012, 2(3): 228-243.
10. Giannenas I, Bonos E, Christaki E, *et al.* Essential Oils and their Applications in Animal Nutrition. Medicinal & Aromatic Plants-OMICS, 2013, 2: 6.
11. Solomou A, Martinos K, Skoufogianni E, *et al*. Medicinal and aromatic plants in Greece and their future prospects: a review. Agricultural Science, 2016, 4(1): 9-20.

Livestock production systems and feed resources in The Netherlands

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Abstract

The current feeding systems used to produce feed in The Netherlands are discussed. Since the Dutch animal production has been highly dependent on the imports of feedstuffs to produce compound feeds, the development of reliable feed tables containing a wide range of feedstuffs and regression lines that correct for the differences in quality has been essential for the industry. It also has resulted in detailed knowledge of the use of co-products. The competition for nutrients between feed, food and fuel and the increasing global human population necessitate a continuous search for alternative feedstuffs. There are several possibilities. By either using more residues of the food industry, upgrading existing feedstuffs and crop residues by fractionation, enzyme treatment or technological treatments. Not only feedstuff availability will be a challenge for the feed industry, but also the increasing demands of the food chain and regulatory agencies on product quality and safety will create additional challenges for the industry.

Introduction

The Netherlands is a densely populated country with 17 million inhabitants (520 inhabitants per km^2). Yet it also has high density of livestock. The country has approx. 1.7 million dairy cows, 12.4 million pigs and 104 million chickens. Of the animal production more than 60% is exported, mainly to other Western European countries. The large animal production could only be realized through imports of feedstuffs. The continuous search for the cheapest nutrients has resulted in a sector which has been able to use various feedstuffs and co-products.

On the down side, the high livestock density has resulted in large emissions into the environment. The regulations on P and N release and ammonia emission into the environment and the ban on the use of antibiotics have led to restrictions in the formulation of feeds, and thus on the composition of the diets. Furthermore, the large scale livestock production in urban areas can lead to conflicts with citizens, varying form odor complaints and health concerns. Not only regulations of the Dutch government and the EU but also food chain partners influence the composition of feed. The influence on non-nutritional criteria will become more important. In this paper the various drivers that affect the feed composition are discussed.

The feeding systems, ruminants as well monogastrics

Ruminants

Dairy cow diets are formulated based on a net energy system in combination with protein system that is based on intestinal available amino acids. This system will be changed in the near future to a system based on glucogenic, aminogenic and lipogenic energy. The basis for this future system will be the nutrients that are required for milk production. Majority of the farmers produce roughages such as grass, grass silage or maize silage themselves. The roughage is supplied *ad libitum*. The ration is supplemented with compound feed and wet co-products of the food industry, such as beet pulp and brewers distillers. On average approx. 60% of the energy originates from roughages. The compound feed is supplied by feeders that recognizes the individual cow so the amount of concentrate can be linked to the production level of the individual animal. Around 10% of the farms feed the animals as total mixed ration (TMR).

Pigs

Pig diets are formulated based on a net energy system combined with an ileal digestible amino acid system. Feed matrices differentiate the energy value of the feedstuffs for pigs of different ages and physiological stages. Different energy value diets are provided for piglets, growing finishing pigs, lactating and gestating sows. All pig feeds are compound feeds that are pelleted. Most farmers use only compound feed. Approx. 20% of the growing finishing units have a wet feeding system. These farms are able to use wet co-products like potato peels and whey.

Poultry

Poultry feeds are formulated based on an Apparent Metabolic Energy corrected for N (AMEn) and standardized ileal digestible amino acids (SID) systems. Feeds for broilers are pelleted. There are 2 production schemes:

- Fast, maximum growing till 32 to 35 days of age till a weight of approx. 2300 g.
- Slower growing till at least 49 days, also to a weight of 2300 g.

Most feeding schemes have 4 to 5 different feeds with decreasing energy content and decreasing amino acid/energy ratios. All layer diets are in mash form. During the laying period till 85 weeks of age, 2 different feeds are used.

Available feed sources

The national production of feedstuffs is limited. Nationally produced are mainly wheat and barley. Besides these many co-products of the food industry are used as animal feed. All other feedstuffs are imported. These are imported from all over the world[1]. A list of feed ingredients commonly used is provided in Table 1.

Table 1 Commonly used feedstuffs in The Netherlands

Feedstuffs	Feedstuffs
Citrus pulp	Wheat bran
Peas	Wheat midlings
Barley	Soyoil
Soybeans toasted	Poultry fat
Soy hulls	Fish meal.
Molasses	Oats/ oats hulls
Linseed	Corn gluten feed meal
Linseed expellers	DDG&S from all cereals
Rape seed meal/expellers	Sunflower meal
Rapeseed expellers	Triticale
Rye	Palm oil fatty acids
Wheat	Potato protein
Maize	Whey powder
Palm kernel expellers	Grass meal
Coconut meal/expellers	Sweet potatoes
Beet pulp	Cassave/manioc
Soy bean meal (various qualities)	Bread meal
Pure amino acids	Candy meal
Meat and bone meal	Crewer distillers grains
	Potato peels steamed

Status of feed industry and regulatory authority

The feed industry in the Netherlands produces around 12 million tonnes compound feed per year. Over the years a strong consolidation of the feed industry has taken place. Due to mergers and take-overs fewer companies have larger production. Currently 28 feed companies having around 110 feed mills with an average production of 132,000 tons per year are producing compound feeds[2]. The 5 largest companies have become international players. The profits of feed companies are relatively low. Their profit is around 1% of their turn-over. Currently the trend is that the larger feed producers expand their activities towards premixes and additives, which provide higher profitability.

The regulation is on different levels; EU, the national feed association and production chains. Most regulations are formulated at the EU level[3]. It regulates the safety of feed for both humans and animals and the fairness in trade. Regulation includes maximum levels of toxic compounds, contaminations, mycotoxins, the use of products of animal origin (meat and bone meal, bans on the use of antibiotics and ZnO, labelling, which feedstuffs can be used in the feed and the registration of additives. The national government in a limited form can divert from the European levels.

The national government sets standards for the production system and controls the regulations. The national feed industry can make some internal agreements. In the Netherlands the federation for the feed industry has decided that their members are not allowed to produce medicated feeds. They also represent the industry at national and international levels. The Dutch feed companies have a common control on the quality scheme for feed safety. Together they check the quality assurance of imported feedstuffs and additives. Only feedstuffs are allowed that are produced and certified under an international scheme for Good Manufacturing Practices (GMP+) (www.gmpplus.org). The processing industry and the retail organizations impose additional requirements to the feed industry. The most important one is that they often do not allow the use of genetically feedstuffs that are modified organism (GMO)[4].

Challenges and opportunities in enhancing utilization of locally available feed resources and enhancing feed use efficiency

The feed industry faces a number of challenges of a different order. They have to compete with the food industry and the biofuel industry for feed ingredients. The demand for cereals for food will increase due to the increasing world population. Since the amount of arable land is limited, the increased demand for arable land will lead to more deforestation. This is in conflict with the increasing awareness of the value of ecosystems. Another challenge is to deal with the increasing pressure to reduce the use of antibiotics in the livestock industry. The increased genetic production potential of animals require feeds that meet their increased demands. The metabolic stress that it causes in animals will put more pressure on the feed industry to formulate feeds that meet the nutritional demands of these animals. Another challenge will be to meet all demands of government and the consumers towards the way in which animal products are produced.

However, there are several opportunities for the feed industry. More emphasis should be given to the use of co-products of food production, removal of anti-nutritional factors (ANF) from feedstuffs, fractionation of feedstuffs, improvement of the digestibility of low quality feedstuffs either by using enzymes or through solid state fermentation. Some examples of these are:

- The use of co-products of the food industry in The Netherlands is already well developed. However, there are still possibilities to use by-products such as residues of coffee and oatmeal production, among others.
- Treatments to reduce the ANF in feedstuffs: peas contain ANFs such as tannins. Through separation of the hulls from the peas the ANF content will be reduced. This can be achieved by wind shifting.
- Fractionation of feedstuffs. Many plants that have green leaves are not used as feedstuff since the digestibility of the fibrous fraction is low. By pressing, the liquid fraction can be separated from the fibrous fraction. The soluble fraction may contain high quality nutrients like sugars, proteins and pro-vitamins. These compounds might be potentially an ingredient for feeds for monogastrics. The fibrous fraction has potential for use as a stock for the paper industry. Alternatively, these can be fed to ruminants.
- Improvement of low quality feedstuffs by solid state fermentation: a major constraint that does not allow efficient use of many bio materials as animal feed is that they are highly lignified. During solid state fermentation it is possible to grow fungi on these substrates. Selected fungi can break down the lignin and thus make the feedstuff more digestible for ruminants. Similar results might be obtained by the use of lignases.

Conclusion

The Dutch feed industry is highly developed and is used to incorporate alternative feedstuffs. A correct evaluation of these feedstuffs for nutritional characteristics and possible negative components that either affect the health of the animals or contaminate the resulting animal products will enhance their utilization as animal feed. Feed composition will be more and more determined by the demands of the animal sourced food chain and regulatory agencies. The largest challenge however will be to ensure feedstuffs supply in the future since both the human population and the consumption of animal products will increase globally. The feed industry will have to invest in methods to improve the nutritional value of currently used feedstuffs or seek for new resources. The techniques are available but should be optimized for effectiveness and cost.

References

1. Rabobank, 2017. The European Feed Mix: Successful Ingredients for the World's Second-Largest Feed Market
2. FEFAC, 2018. FEFAC Position on the development of a European Protein Plan.
3. Publications Office of the European Union, 2018. The European Union: What it is and what it does.
4. European commission, 2018. EU Register of authorised GMOs