Nutrient Requirements of Beef Cattle in Indochinese Peninsula

First Edition, 2010

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The Working Committee of Thai Feeding Standard for Ruminant (WTSR)

Department of Livestock Development, Ministry of Agriculture and Cooperatives, Thailand

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NOTICE: The project that is the subject of this report was approved by the Governing Board of The Working Committee of Thai Feeding Standard for Ruminant (WTSR), whose members are drawn from the Department of Livestock Development Ministry of Agriculture and Cooperatives, Thailand. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report is a part of the collaborative research between Japan International Research Center for Agricultural Sciences (JIRCAS), Department of Livestock Development of Thailand (DLD), Chiang Mai University (CMU), Khon Kaen University (KKU), Maejo University (MJU), Mahasarakham University (MSU), Prince of Songkla University (PSU), Rajamangala University of Technology-Isan (RMUTI), Suranaree University of Technology (SUT), Ubon Ratchathani University (UBU), National University of Laos (NUOL), Lao PDR, and Royal University of Agriculture (RUA), Cambodia

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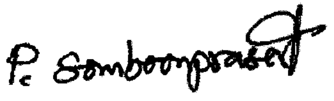
Preface

The First Indochinese Peninsula Feeding Standard of Beef cattle is an output of collaborative researches by a large number researchers of the Department of Livestock Development, Universities, private sectors and Japan International Research Center for Agricultural Sciences (JIRCAS). Objectives were to provide technical guidelines for practical evaluation on nutrient requirement of tropical origin beef cattle, in addition, standard nutrient compositions of raw materials in the tropics were provided.

Efficient feed management involved 2 vital factors including; precise information on nutrient requirement of livestock and information on chemical compositions and nutrient values of raw materials. The first edition of Indochinese Peninsula Feeding Standard of Beef Cattle 2010, consists of 2 sections; Section 1 Nutrients Requirement of Beef Cattle that provides information of feed intake, feeding recommendations and nutrient requirement; Section 2 provides chemical compositions and nutrient values of raw materials.

The feeding standards provided herein are results of large numbers of researches under supervision of the Working Committee of Thai Feeding Standard for Ruminant (WTSR). This manual will benefits on future development of beef production in Thailand and being initiate point of extension to other Asian Peninsula countries where global competitiveness and self sufficiency can be enhanced.

The Working Committee of Thai Feeding Standard for Ruminant (WTSR) will continue developing the manual. Therefore, your recommendations and suggestions are always welcome.



Director General

Department of Livestock Development

Preface

Japan International Research Center for Agricultural Sciences (JIRCAS), Department of Livestock Development, Thailand (DLD) and Khon Kaen University, Thailand (KKU) have started a project "Establishment of a feeding standard of beef cattle and a feed database for the Indochinese peninsula" in 2006 on 5 years plan. Since it is essential to construct a regional research cooperation network for the efficient achievement of the targets, other research organizations such as Mahasarakham University (MSU), Rajamangala University of Technology-Isan (RMUTI), Suranaree University of Technology (SUT), Chiang Mai University (CMU), Maejo University (MJU), Prince of Songkla University (PSU), Ubon Ratchathani University (UBU), Thailand, National University of Laos (NUOL), Lao PDR, and Royal University of Agriculture (RUA), Cambodia, have been also involved in the project. The first edition of feeding standard and feed database of beef cattle for the Indochinese peninsula is released by the exertion of many parties. And I want sincerely to express my gratitude to all of them who are involved in this project.

Previous feeding standard for beef cattle in tropical countries are mainly based on the data obtained from the cattle breeds raised in temperate zone such as Europe or North America. The climatic conditions for measurements in tropical environment are different from those temperate areas. Of course, the actual nutrient requirements of tropical cattle breeds would be different from those of temperate breeds. The efficient improvement of livestock production in tropical region is quite important to supply enough quantities of high value foods corresponding to the global population increasing and change in eating habit. It would also strongly relevant to reduction of greenhouse gases emission from agricultural sectors.

I believe that this feeding standard and feed database released here would contribute to the efficient improvement of livestock production in Indochinese peninsula nations, and also would be applicable in tropical area, such as Sub-Saharan African nations. Finally Moreover, it is a great pleasure for me if the researcher's network constructed in this project will work continuously together on the reversion of the feeding standard, and the encouragement of other joint projects in the near future.

Kenji Iiyama

President,

Japan International Research Center

for Agricultural Sciences (JIRCAS)

Acknowledgments

The Working Committee of Thai Feeding Standard for Ruminant (WTSR), whose members are drawn from the collaborative research between Japan International Research Center for Agricultural Sciences (JIRCAS), Department of Livestock Development of Thailand (DLD), Chiang Mai University (CMU), Khon Kaen University (KKU), Maejo University (MJU), Mahasarakham University (MSU), Prince of Songkla University (PSU), Rajamangala University of Technology Isan (RMUTI), Suranaree University of Technology (SUT), Ubon Ratchathani University (UBU), National University of Laos (NUOL), Lao PDR, and Royal University of Agriculture (RUA), Cambodia. This version is combined efforts of many individuals. We would like to thanks to all individuals and member committee for their review of this report and the organizations who participated and provided specific input, data and critiques of this revision during its development. We wish to thank the following author for their preparing a reviewed in draft form of this report are as follows; Chapter 1,2,3,4,5 and 10 - Dr. Kritapon Sommart, Dr. Anan Chaokaur, Dr. Natthamon Tangjitwattanachai, Dr. Peerapot Nitipot, Mr. Chatchai Kaewpila, Dr. Opart Pimpa; Chapter 6 - Dr. Chalermpon Yuangklang, Dr. Anut Chantiratikul, Dr. Wanwisa Ngampongsai; Chapter 7 and 9 - Ms. Areerat Lunpha; Chapter 8 - Dr. Anut Chantiratikul, Dr. Songsak Chumpawadee; Chapter 11- Dr. Somkid Promma, Chapter 12 - Ms. Sumon Pochan. Professor Dr. David Higgs supported of his English editor. Mr. Chatchai Kaewpila and Dr. Keisuke Hayashi shared them skills in preparing the report for publication. We would like to express our appreciation and sincere thanks to Dr. Worapong Suriyapat, Dr. Jowaman Khajarern and the advisory committee, for their advice, suggestions and comments. Thanks also to Professor Dr. David Higgs, University of Hertfordshire, Hatfield, UK for his kind in English editing.

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The Working Committee of Thai
Feeding Standard for Ruminant (WTSR)

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Chapter 1 Introduction

Ruminant livestock plays a very important role as an integral part of farming and rural life in tropical developing countries providing food, family income and employment. Consumption of beef and products are expanding in the Indochinese peninsula nations because of lifestyle changes. It is estimated that the expansion of demand will continue in the future. However, the global human population is increasing and it is believed that the food supply will become inadequate to meet the future demand.

The lack of appropriate feeding standards for the region is one of the main constraints for further development of feeding management. As the breed of cattle, climate conditions and available feed resources are different from those in temperate zone, the nutrient requirements of cattle in Indochinese peninsula may not be the same as in other zone recommended. For that reason, it is important to study the nutrient requirements of local cattle accurately and to develop an efficient usage method of local cattle feed resources that does not compete with human food resources. However, the increase of livestock population has roughly paralleled the increase in emission of methane as a greenhouse gases responsible for global warming. Moreover, a deficiency or imbalance of nutrients will result in failure to meet expectations, a low efficiency of nutrient utilization, and losses through incomplete energy combustion. Thus, strategies to enhance feed efficiency and match supplies energy with to animal's requirements, will make the industry more sustainable and lessen the environmental impact, and the economic opportunity will serve to enhance peace and stability as well.

Current feeding standards used for beef cattle in tropical countries are mainly based on the data obtained from the cattle breeds raised in temperate zone such as Europe or North America and the climatic conditions for measurements are also different from those in tropical environment. Thus, there are some possibilities that the actual nutrient requirements of tropical cattle breeds are different from those of temperate breeds and in temperate environmental conditions. So far, there are no systematic experimental data for the nutrient requirements of tropical beef cattle though several partial data were reported. Therefore, JIRCAS, DLD and KKU started a project "Establishment of a feeding standard of beef cattle and a feed database for the Indochinese peninsula" in 2006 on 5 years plan. Since it is essential to construct a regional research cooperation network for the efficient achievement of the targets, other research organizations such as Mahasarakham University (MSU), Rajamangala University of Technology Isan (RMUTI), Suranaree University of Technology (SUT), Chiang Mai University (CMU), Maejo University (MJU), Prince of Songkla University (PSU), Ubon Ratchathani University (UBU), National University of Laos (NUOL), Lao PDR, and Royal University of Agriculture (RUA), Cambodia are also involved in the project.

Chapter 2 is focus on overview of beef cattle production in Indochinese peninsula. Chapter 3 contains a discussion of factor influencing on feed intake and the result of meta-analysis on feed intake prediction. It follows, therefore that more data in energy requirement (Chapter 4) are required urgently in Thailand to establish a sustainable feeding management for beef cattle in the region. This meta-analysis approach offers considerable advantages in feed formulation for beef cattle. The equations have been derived from basic data studies determined the metabolizable energy requirements for maintenance and gain of beef cattle fed under humid tropical conditions in Thailand by an examination of the nutritive and energy values in some feedstuffs, and measurement of the energy metabolism and requirements in beef cattle by using standard methods. Chapter 4 is a review of energy definitions and terms used to evaluate energy content of feedstuffs. This chapter provides the extensive of meta-analysis of maintenance energy, energetics efficincy compare between *Bos indicus* and *Bos taurus*, metabolizable energy requirement of Thai native beef cattle and Brahman cattle.

Chapter 5 is a review of protein evaluation, digestion and absorption, protein requirement for maintenance and gain of beef cattle. Macromineral, micromineral, vitamins and feed additives supplementation and requirements are listed in Chapter 6, 7 and 8 respectively. Discussion of water requirement of beef cattle is presented in Chapter 9.

Chapter 10 provides all of the equations used in the model, nutrients requirement and feed formulation example for beef cattle. Feed formulation by using computer program is available in Chapter 11.

Chapter 12 provides tables of chemical composition and nutritive values of tropical feed resources.

Chapter 2 Overview of beef cattle production

Introduction

The event in world agriculture in the next 20 years predicted by the International Food Policy Research Institute (IFPRI) in the study "Livestock 2020 the next Food Revolution" (Delgado et al., 1999) have been referred to as the "Livestock Revolution" (Rowlinson et al., 2005). The demand for livestock products is set to continue rising at a high rate for the next 20–30 years. The ability to achieve the livestock revolution required to supply this demand center on the full consideration of all aspects of the industry and in appropriate policies being developed (Steane et al., 2002). There are growth opportunities as well as stagnation for smallholder livestock producers, and a return to a sufficiency economy would enhance peace and stability.

Beef cattle production and breeding constitute are an important sector of agriculture in most countries. Beef industry is a major component of agricultural economy in North-, and South-America, in Australia and New-Zealand as well as in India, Pakistan and in South Africa (Wagenhoffer, 2007). In the USA, receipts from cattle and calves are higher than those from any other agricultural commodity (FAOSTAT, 2007; Wagenhoffer, 2007). In addition, the challenges facing the beef cattle industry to improve rate and efficiency of growth, reproduction rate, milk production, carcass composition, meat quality, and reduce costs of production can be met through the existing pool of genetic variation (Wagenhoffer, 2007; Devendra, 2008). On the other hand, it is important that the developing world increases its livestock production as that is where much of the increasing demand is going to be located. To do so production per animal, in many countries, needs to rise (Rowlinson et al., 2005; Sere and Wright, 2008). The livestock sector in the developing world continues to experience rapid structural changes due mainly to globalization and increasingly liberalized domestic markets (Freeman et al., 2007). While, the indigenous breeds of animals found in these regions have such low levels of production, supplies will be inadequate to meet daily human nutrient requirements.

The case for increased production of animal products to meet the increased demand is clear, as is the fact that a lot of this increase must be in altered production systems which are more sustainable and reduced in environmental impact (Steinfeld et al., 2006; Sundrum, 2007; Chantalakhana and Falvey, 2008). In this regard, sustainable increases of livestock production should be achieved through the improvement of conservation and management of natural resources because production of feed resources is limited (Sundrum, 2007; Freeman et al., 2007; Devendra, 2008). As animal scientists with a mandate in animal nutrition and related fields, we have major responsibility to ensure appropriate and efficient use of the feed resources needed to meet the challenges of the increasing demand for high quality animal products (Kearl, 1982; NRC, 2000; De Brabander et al., 2007; Sere and Wright, 2008).

Domestic beef cattle

The origin of domestic beef cattle is shrouded in the mists of antiquity. To some extent, however, these can be dispersed using information obtained by integrating current archaeological, anthropological, historical, linguistic and genetic evidence. Within the sub-family Bovinae may be found all the varied types of cattle that have been domesticated. All together with information on the worldwide distribution and phenotypic characteristics of the different beef cattle breeds, three related types of cattle emerge; *Bos taurus*, *Bos indicus* and *Bos (bibos) banteng* (Payne and Hodges, 1997). They all possess the same number of chromosomes (2n = 60). The archaeological evidence suggests that not only was Western Asia a primary center for the first domestication of wild cattle (*Bos primigenius*; an extinct) but that three major types of domestic cattle evolved either within the region or at centers immediately adjacent to it. These types were the humpless longhorn (*Bos taurus*), the humpless shorthorn (*Bos taurus*), and the humped Zebu (*Bos indicus*), occurring at different locations and at somewhat different times (Payne, 1970; Payne and Hodges, 1997). The relationships of the wild and domestic species of the sub-family Bovinae are shown in Figure 2.1.

Beef cattle breeds

The humpless European breeds (*Bos taurus*) of beef cattle are the descendants of introduction from Western Asia of longhorn- and shorthorn-type *Bos taurus* cattle (Payne, 1970; Payne and Hodges, 1997). Some European breeds there have been infused with Zebu genes, and the Europeans introduced cattle into the Americas and Oceania (Payne, 1970; Payne and Hodges, 1997). European breeds of beef cattle today are different phenotypes such as Angus, Charolais, Friesian, Hereford, Jersey, Limousin, Simmental, and indigenous breeds etc. (Payne and Hodges, 1997; Thomas, 1998). Development of European breeds of beef cattle has continued to bring about reduction of production costs, lower input of high-energy feeds and intensive use of roughages, with efficient management and cooperation, a marked improvement in the genetic material, better marketing and new markets of meat production in developed countries; USA, Australia, New-Zealand, European countries (Jarrige and Beranger, 1992; Wagenhoffer, 2007). Therefore, these will be the keys to further research and development of European beef production in developed countries (Jarrige and Beranger, 1992). However, when humpless *Bos taurus* type cattle are introduced into a hot, humid, environment, such as exists in the Indus valley, fertility decreases and mortality increases (Payne, 1970; Payne and Hodges, 1997).

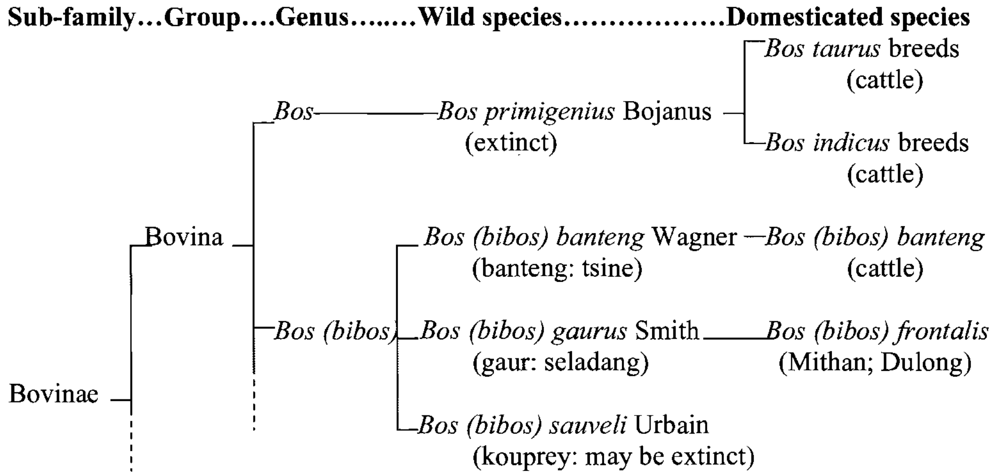

Figure 2.1 The relationship of the wild and domestic species of the sub-family Bovinae (adapted from Payne and Hodges, 1997).

Zebu breeds beef cattle include different genotypes such as Africander, Angoni, Barzona, Boran, Bengali, Brahman, Cyprus, Nelore, Sahiwal, Tuli, and indigenous breeds, etc. (Payne and Hodges, 1997; Thomas, 1998). In India, and elsewhere in the developing world, an effort to improve the production and reproduction of indigenous species of cattle through cross mating of Zebu with European breeds has occurred during the past decade. Presently, some evidence indicates that the crossbreds are capable of utilizing the available feed resource more efficiently than the indigenous breeds, and levels of production are increasing (Kearl, 1982). However, the summary in the NRC (2000) recommendation indicated that maintenance energy requirement of Zebu breeds cattle (*Bos indicus*) are about 10% lower, and European cross (*Bos taurus* × *Bos indicus*) with those breeds about 5% lower than European breeds cattle (*Bos taurus*).

Beef cattle production in the tropics: nutritional and climatic limits

In the tropics and most semi-arid areas, high environmental temperatures and levels of solar radiation increase the heat load experienced by the animal (Hunter and Buck, 1992). This includes those parts of the Asian, African, American and Australasian continents and the oceanic islands situated within the tropics (Payne, 1970; Hunter and Buck, 1992; Payne and Hodges, 1997). Heat produced by digestion and metabolism must be effectively dissipated if productivity is to be maintained. If heat load is greater than the animal's ability to dissipate it, food intake and productivity are severely affected (Hunter and Buck, 1992). The direct effects of climatic factors are on: (1) the nutritional environment for cattle production such as forage type; quality, variation of rainfall, seasonal changes in forage quality, mineral deficiency in forages, restricted availability of feed, and variation in voluntary food consumption, (2) the disease environment, ecto- and endoparasites and disease remains a limiting factor to increased animal production (Preston and Leng, 1987; Hunter and Buck, 1992; Bakrie et al., 1996). However, it is interesting that the beef cattle which have evolved in the humid tropics are typically rather small, e.g., Thai cattle in Southeast Asia (Suntraporn, 1980) and N'dama cattle in West Africa (Fall et al., 1984 cited by Hunter and Buck, 1992).

Small size would be associated with a grater skin surface area in relation to body mass for the dissipation of heat (Payne, 1970; Payne and Hodges, 1997).

Beef cattle production

Beef cattle production of the world

Cattle population and meat production in the world shows an upward trend with increase of 5.7 and 8.7%, respectively from 2000 to 2007 (FAOSTAT, 2008). Beef cattle are raised in diverse climatic environments utilizing various feed resources. It is a vital economic activity in many regions of the world where few alternatives for other agricultural production exist. Besides its economic importance, extensive beef production systems play an important role in the protection and management of the environment as well as in employment in rural areas (Wagenhoffer, 2007; Devendra, 2008).

The trend of cattle population and cattle meat production in some regions of the world, from 1998 to 2007 are shown in Figure 2.2. Main beef producers were the Americas where, over a 10 years period, cattle stock and meat production increased 10 and 13%, respectively especially in USA. (20% of world's meat production). In Europe (EU) the cattle stock and meat production trend continued downwards, EU confirming as a net importer of beef for 25 years (Wagenhoffer, 2007). Beef cattle and production were slightly changed in the Oceania region. On the other hand, cattle production in the tropical zone of Asia and Africa regions are increased, due to the increasing demand from human population and economic prosperity (Leng, 1997; Otte et al., 2005).

Beef represented 61.9 million ton of global meat (1,390 million head of world's cattle population) in 2007 (FAOSTAT, 2008). They show that the productivity of cattle (per head) in Europe, Oceania, and the Americas were more efficient than Africa and Asia (8.8, 7.5, 5.7, 3.0 and 1.8 %, respectively). In addition, the data show that most of the countries located in the tropical zone (Cameroon, Nigeria, Bangladesh, Sri Lanka, Cambodia, and Myanmar) show poor beef cattle production efficiency. Tropical livestock are normally fed in a system based on natural pasture and crop residues that often lack both protein and energy, major nutritional factors limiting animal production (Sommart, 1998). While temperate countries (USA, European countries, Australia and New-Zealand) have optimal temperatures which is an important factor for voluntary feed intake and productivity of cattle. Thus, improved production and breeds for beef industry are found here (Wagenhoffer, 2007). Therefore, improving productivity is the key to increase beef cattle and livestock production in tropical developing countries (Devendra et al., 1997; Chantalakhana and Falvey, 2008; Sere and Wright, 2008;).

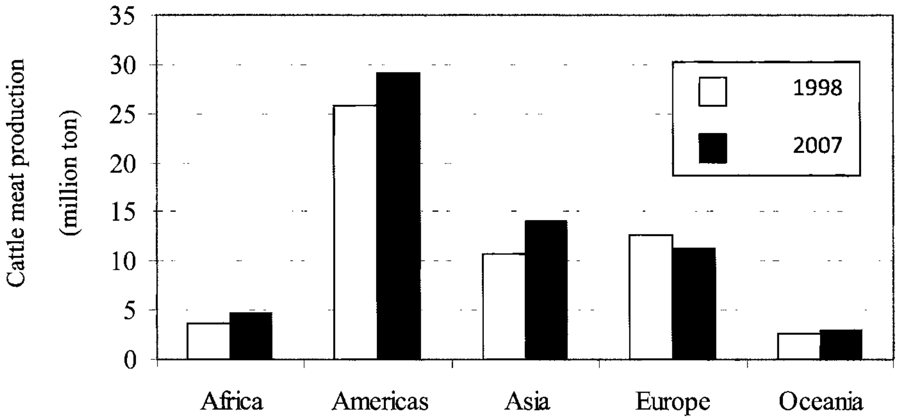

Figure 2.2 Cattle meat production in some regions of the world in 1998 and 2007 (FAOSTAT, 2008).

Development of beef cattle production in Asia

Asia has 465.8 million head of domestic cattle and 14 million ton of beef product in 2007 (FAOSTAT, 2008). Over the last 10 years (from 1998 to 2007), increasing growth rate of the cattle population was 5.2% (442 to 465 million heads) and beef production was 31.5% (10.6 to 14 million tons). The trends of cattle meat product growth rate after 10 years in Eastern Asia were accelerated. While in other parts of Asia as Central, Southern, South eastern, and Western have maintained stable long-term growth in meat product output from 1998 to 2007. Kawashima and Yano (2007) reported that there are roughly two types of livestock production systems existing in Asia. One is the traditional system and the other is the intensive system. While livestock production applying an intensive system grows very rapidly and receives attention from international market, traditional livestock system tends to be rather neglected.

The data indicate that the developing countries in Asia (Bangladesh, Sri Lanka, Thailand, Vietnam, Cambodia, Myanmar, and Laos PDR), need to improve beef production system in smallholder farms (Chantalakhana and Falvey, 2008; Devendra, 2008). Livestock production systems generally found in developing countries are based upon mixed farming where crop-livestock integration is the tradition. Moreover, a mixed-farming system is in relative harmony with the environment (Kearl, 1982; Devendra, 2008). Smallholder farmers play a very important role as an integral part of farming and rural life in tropical developing countries providing food, family income and employment (Chantalakhana and Falvey, 2008).

Current situation and development trends in Thailand

Thailand, an agricultural developing country, is situated on the Indochinese peninsula and located in the tropical zone, general weather conditions throughout the country are those of a tropical climate and remains hot throughout a year. Most of the beef cattle and buffalo in Thailand are kept under traditional management systems, usually in a small household herd of less than five animals (Wanapat, 1999; Na-Chiangmai, 2002). In these systems, crop waste, native pasture, communal lands, paddy fields after rice harvest, and croplands after crop harvest are the main sources of feed for cattle (Khemsawat and Phonbumrung, 2008). The cattle population in Thailand represented 14.2 and 1.4% of South-East Asia and total Asia cattle respectively (FAOSTAT, 2008). The database and trend of beef cattle production in Thailand, from 1993 to 2008 (DLD, 2008) are shown in Table 2.1. The population of beef cattle in Thailand from 1993 to 1998 declined at 36.8% (7.2 to 4.6 million heads), due to the increasing demands for beef were much greater than supply. As a result, cattle and beef importing to Thailand were accelerating increased during the same period. Trends of cattle population in Thailand climbed up again by 46% from 1999 to 2004 (4.6 to 6.7 million head) (Table 2.1), showed the fluctuated growth and declines of every 3–5 years cycles. In 2004, the government had proposed "The one million cattle project" to help the poor, this policy again stimulated cattle population growth 36% during 2004 to 2008 (6.7 to 9.1 million head).

In 2008, Thailand has 9.1 million beef cattle (DLD, 2008), where the Northeastern had the highest cattle population of 54% of total stock, followed by 20% in the Northern, 17% in the Central and 9% in the Southern part (Table 2.1). Beef production in Thailand provided 0.19 million tons of meat in 2007 (FAOSTAT, 2008), and represented 16.7 and 1.4% of South-East Asia and total Asia beef produce, respectively. Most of beef consumed in Thailand derived from small holder farms. Similar to other developing countries, cattle in Thailand had been domesticated for multiple purposes such as draft power, means of transportation, capital, credit, milk, social value, by-product uses and a source of organic fertilizer for personal cropping (Wanapat, 1999; Na-Chiangmai, 2002; Khemsawat and Phonbumrung, 2008). Therefore, the ability to achieve the livestock revolution (the next 20–30 years) required to supply the demand for meat product were depend solely on increasing research and development efficiency to improve quality and productivity efficiency of beef production.

Table 2.1 The database of beef cattle population in Thailand, from 1993 to 2008

Year	Cattle population (million head)				Total	Import	Export
	Central	North-East	North	South	(million head)	(head)	(head)
1993	1.71	2.71	2.05	0.76	7.24	11,256	-
1994	1.66	2.87	1.99	0.89	7.41	7,658	12,797
1995	1.63	2.81	1.96	0.93	7.32	5,312	16,111
1996	1.24	2.48	1.27	0.86	5.85	18,710	21,904
1997	1.06	2.30	1.05	0.88	5.29	26,024	21,157
1998	0.90	2.03	0.89	0.75	4.57	98,838	17,841
1999	0.86	2.22	0.88	0.69	4.64	126,319	4,064
2000	0.85	2.52	0.94	0.59	4.90	104,661	2,160
2001	1.02	2.57	1.03	0.61	5.23	185,319	3,344
2002	0.94	2.91	1.13	0.57	5.55	133,114	3,955
2003	0.98	3.08	1.30	0.56	5.92	71,844	4,212
2004	1.00	3.69	1.33	0.65	6.67	102,589	4,739
2005	1.30	4.09	1.64	0.77	7.80	83,784	1,074
2006	1.32	4.32	1.56	0.84	8.04	51,782	814
2007	1.52	4.50	1.95	0.88	8.85	13,548	4,806
2008	1.55	4.93	1.85	0.78	9.11	-	-

Source: DLD (2008)

Future research need to meet the challenges of beef cattle development in Thailand

Thailand is a developing country where demanding for meat trends to be faster than growth, as a result serious attention needs to be given to developing effective ways of increasing the numbers of animals for meat production (Wanapat, 1999; Na-Chiangmai, 2002; Tongthainan, 2002). The cattle industry in Thailand still remains a small holder industry where cattle are kept in a mixed crop-livestock systems (Khemsawat and Phonbumrung, 2008). In addition, there are many factors limiting commercial beef production such as cost of feeding (Devendra, 2001), low quality of feedstuffs (Kawashima et al., 2000), lack of breeding plans (Na-Chiangmai, 2002; Tongthainan, 2002), weather, disease, parasitic problems and lack of market incentive (Chantalakhana and Skunmun, 2002; Khemsawat and Phonbumrung, 2008). With both the human population and GDP increasing, the enlargement supply for meat is an urgent necessity in Thailand (Kawashima et al., 2000; Khemsawat and Phonbumrung, 2008). In general terms, the principles of breed, nutrition and managements are in place to improve animal production.

Further researches on feeding management to maintain beef productivity and sustain small-scale farming as well as the protecting of feed resource in Thailand are urgently needed. As a consequence, knowledge in feed requirement and feed formulations are required (Kawashima et al., 2000; Nishida et al., 2005; Khemsawat and Phonbumrung, 2008). Therefore, the establishment of sustainable feeding management for beef cattle for particular production systems in Thailand has been implemented through this collaborative research where government agencies, educational institutions, as well as international communities are involved. The prototype of feeding standard for Thailand will be extendable and applicable for other Asian countries in the near future.

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Chapter 3 Feed intake

Introduction

Feed intake is a considerable important factor that the more food an animal consumes each day, the greater will be the opportunity for increasing its daily production. An increase in production that is obtained higher food intake is usually associated with an increase in overall efficiency of the production process, sine maintenance costs are decreased proportionately as productivity rises (McDonald et al., 2002). Requirements expressed as dietary concentrations are commonly calculated from absolute requirements and estimates of feed intake. Thus which ever method of expression is used, the feed consumption of the animal must be known (ARC, 1980).

The consumption of feed is fundamental to nutrition: it determines the level of nutrients ingested and, therefore, the animal's response and function. Digestibility and utilization of nutrients are in a sense only qualitative descriptions of the net food intake (Van Soest, 1994). NRC (2000) suggests that several factors alter animal feed intake such as numerous physiological status (e.g., animal body composition, sex, age, growth stage, body weight or frame size), environmental condition (ambient temperature, seasonal or photoperiod), and management (grazing, growth promotion implants, feed additives, dietary nutrient deficiency, feed processing). Although, factors that regulate dry matter intake (DMI; kg/d; %BW; g/kgBW$^{0.75}$) by ruminants are complex and not understood fully, NRC (2000) has established relationships between dietary energy concentration and DMI by beef cattle.

Mechanism controlling feed intake in ruminants

It is generally considered that feed intake is controlled by a series of negative feedback signals from the digestive tract, liver and other organs in response to the presence of nutrients. In addition, animals learn the metabolic consequences of eating foods with particular sensory properties (appearance, flavor, texture) and can then use 'feed-forward' to choose preferentially or avoid foods which they have experienced previously (Forbes, 2000). There are several types of receptor in the stomach, intestines and liver which can inform the central nervous system (CNS) about the volume, osmolality, pH and concentration of some specific types of chemical in digesta and portal blood. Of course, the whole system is coordinated by the CNS in a diverse set of pathways that includes the hindbrain and the hypothalamus as important components to determine what food to eat and whether feeding should start or stop (Van Soest, 1994; Forbes, 2000).

The control of feed intake of ruminants, like that of other mammals, is still only poorly understood. Because ruminants are in some ways anatomically and physiologically different from other mammals, it is not surprising that some factors are not usually important in monogastric animals probably play a role in the control of feed intake in ruminants (Church and Pond, 1988). Intake of feed is itself regulated and limited by the requirements of the animal's physiology and metabolism (Van Soest, 1994). In addition, mechanisms involved in the control of feed intake of ruminant animals require the integration of many signals, including immediate and long-term energy needs, as well as environmental factors.

Physiological control

The central nervous system (CNS) and hormones regulate gastrointestinal motility and probably passage, causing some alleviation of fill by passing coarser material at higher intakes and set points. The fill and time available for eating are offset by time spent ruminating, which reduces fill and allows more gastrointestinal space for feed consumption, but at the expense of eating time. The fill undoubtedly interacts with tension receptors that feed into the CNS to restrict or turn off feed intake (Forbes, 2000).

The most of the sugar and starch are fermented in the rumen to volatile fatty acids (VFAs), and the metabolic glucose requirement must be supplied through gluconeogenesis from other metabolites. The metabolites (acetic acid, propionic acid, or possibly some other metabolite substitutes as the triggering substance) in turn may stimulate hormonal peptides such as cholecystokinin (CCK), particularly from the hypothalamus (Van Soest, 1994). CCK is secreted by the wall of the duodenum in response to the passage of digesta, particularly fat and protein, and stimulates receptors locally which relay their information to the CNS where it results in a decrease in feed intake (Forbes, 2000).

Metabolic control

The stretch receptors in the rumen wall are also sensitive to chemicals, including the acids produced by rumen fermentation. The expected relationship between digestibility and intake may be positive or negative. If one assumes that animals eat to satiety, then more of a less digestible diet would have to be consumed to achieve the required level of digestible calories obtained in smaller amounts of a more digestible diet. On the other hands, the assumption that poor-quality feeds contain factors that limit intake, such as bulk or dietary deficiency. In addition, the limiting factor of satiety is more important in intake of rations with high caloric density than in diets with low caloric density (Van Soest, 1994). The relative importance of changes in osmotic pressure of rumen fluid in the control of feed intake by ruminants is not yet clear, however, and mole for mole sodium acetate depresses intake more than sodium chloride when infused into the rumen (Forbes, 2000; Ortiz-Rubio et al., 2007).

Above all, we emphasize the need to acknowledge that metabolic factors, physical factors and learning all have important roles to play in the complexities of the control of food intake in ruminant animals. We need to recognize the true multifactorial nature of the control of voluntary intake and diet selection if we are to advance understanding and predictive ability (Forbes and Provenza, 2000).

Factors affecting intake

Factors in feed that affect intake

The intake of forages and other fibrous feeds can be increased substantially by grinding or pelleting them before feeding (Preston and Leng, 1987). Finer particles induce less rumination and have faster rate of passage, thus the penalty on digestibility that results from the passage and loss of potentially digestible fiber may offset the advantage of increased intake of some high cell wall forages (Van Soest, 1994). Chopping straw into short length tends to increase intake of the straw. Fine grinding and pelleting also increases intake of straw but has little applicability in developing countries because of the high energy costs associated with this form of processing (Preston and Leng, 1987).

Animal factors and feed intake

A higher energy demand requires greater rumen fill or faster passage such that fill becomes limiting at higher densities of dietary energy (Van Soest, 1994). Undoubtedly ruminants increase their feed intake in response to an increase in demand for energy and/or protein. Preston and Leng (1987) pointed out that feed intake is high in: 1) young growing animals and older animals that need to restore depleted body tissue, 2) adult ruminants in the last trimester of pregnancy when the fetus is growing most rapidly, 3) lactating animals, 4) animals undertaking heavy work.

The point of maximum dry matter intake has been the subject of several investigations. Several authors have suggested this point is not fixed, but depends on the density of the diet (ration), adequate fiber (forage quality), and the energy demand (set point) of the animal (Van Soest, 1994). It thus appears that nutrient demand is a major stimulus to the "feeding" centers the hypothalamus and that, in practical feeding of ruminants, it is nutrient imbalance that primarily limits the level of feed intake and therefore productivity (Preston and Leng, 1987). At the same time, the amount of feed consumed determines the productivity that is achieved (e.g., milk yield is directly related to feed intake). Selection for high milk yield in dairy cows has in fact led to the selection of animals of large body size with a capacity to consume large amount of feed (Preston and Leng, 1987; Hyer et al., 1991).

Cattle selected to feed in feedlots of the Great Plains differ in breed type and gender due to economic and management conditions. Because daily voluntary dry matter intake is the basis on which diets are formulated to meet nutrient requirements and on which gain and profit are calculated, information on the impact of breed type and gender on dry matter intake is critical (Hicks et al., 1990). One consequence of this appears to be a high basal metabolic rate in animals selected for high productivity. Such animals are inappropriate in developing countries since the resources available will support only moderate levels of production. The different in voluntary feed intake among ruminant species are related to basal metabolism. Intake is also affected by the interaction between the balance of nutrients in the absorbed products of digestion and environmental factors. Although *Bos indicus* cattle have a lower basal rate of metabolism, and therefore lower potential productivity, they do not reduce their feed intake as much as *Bos taurus* cattle when subjected to stress brought about by poor nutrition, disease or heat (Preston and Leng, 1987; Johnston and Graser, 2010).

Environmental factors affecting intake

Heat stress causes the reduced feed intake and general performance. Continuous heat stress may reduce feed intake to such an extent that a negative energy balance results and ruminants may not consume at all when a climatic temperature of 40°C is maintained. Increasing the temperature of rumen contents in cattle from the normal 38.0°C to 41.3°C with heating coils in the rumen depressed intake by 15% (Church and Pond, 1988). Cattle with some *Bos indicus* genes may have greater tolerance to some of the diseases that are endemic in developing countries and may also be able to disperse more body heat than cattle with a purely *Bos taurus* genome (Finch, 1986; Preston and Leng, 1987).

Prediction of feed intake

Animals are commonly fed on appetite or *ad libitum* and it is not possible to predict their performance by the use of feeding standards without an estimate of feed intake. Variations in animal production are high correlated with feed intake characteristics than other characteristics. Dry matter intake not only provides a satisfactory information guideline for diet formulation but also is used for planning of yearly purchase of feed. Consequently, accurate prediction of feed intake is a fundamental prerequisite of any nutritional model designed to provide feeding recommendations (Kearl, 1982; Molina et al., 2004; Zhao et al., 2008).

Predicting DMI of beef cattle is an important aspect of beef cattle nutrition programs, but predicting DMI of beef cattle has been challenging for several reasons. DMI prediction equations for beef cattle use body weight as independent variables to validate these equations. Thus, formal evaluation of the basic of published DMI equations to predict beef cattle DMI has not been conducted. Kaewpila et al. (2009) was developed an empirical model based on a meta-analysis from 16 *ad libitum* feeding experiments conducted in Thailand of 59 treatments mean databases. They had food used on the relationships between intake of dry matter and body weight or metabolic body weight. The prediction equations were obtained using a mixed model regression analysis (PROC MIXED; SAS, 1999) according to St-Pierre (2001).

The model consists of equation that prediction dry matter intake were validated based on the decomposition of the mean prediction error. The equations are all highly significant ($P < 0.001$) and high R^2 (0.80 to 0.91). The equation and predicted dry matter intake proposed by Kaewpila et al. (2009) are showed in equation 3.1 as follows;

$$DMI = 0.02887BW - 0.5778 \quad (n = 59, R^2 = 0.91, RSD = 0.10, P < 0.001) \quad \text{[equation 3.1]}$$

Where DMI is expressed in kg/d, BW is body weight expressed in kg.

Conclusion

Intake of feed is itself regulated and limited by the requirements of the animal's physiology and metabolism. The mechanisms involved in the control of feed intake of ruminant animals requires the integration of many signals, including immediate and long-term energy needs, as well as environmental factors. The equation and predicted dry matter intake for Thai native and Brahman beef cattle developed an empirical model based on a meta-analysis proposed in this guide as DMI (kg/d) = 0.02887BW – 0.5778.

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Chapter 4 Energy

Introduction

Energy can be defined as the capacity to do work. This can involve physical activity, biochemical processes, nerve impulses, or transmission of substances across membrane barriers (Kearl, 1982; Blaxter, 1989). Quantitatively, energy is the most important item in an animal's diet. All animals require energy. The amount will vary according to their physiological functions and environmental conditions (NRC, 2000; Johnson et al., 2003; Ferrell and Oltjen, 2008). An animal derived of food continues to require energy for those functions of the body immediately necessary for life. In the fed animal the primary demand on the energy of the food is in meeting this requirement for body maintenance and so preventing the catabolism of the animal's tissues (Blaxter, 1967; Williams and Jenkins, 2003a). Energy supplied by the food in excess of that need for maintenance is used for the various forms of production (McDonald et al., 2002; Ferrell and Oltjen, 2008).

Energy deficiency, the lack of sufficient total feed (energy) is probably the most common deficiency in beef cattle feeding practice. In limited feeding on farms or overstocked ranges, low energy intake occurs. The results are reduction or cessation of growth (including skeletal growth), loss of body weight, failure to conceive, and increased mortality (ARC, 1980; NRC, 2000, 2001). Also, low feed intake often results in increased mortality from eating toxic plant and from lowered resistance to parasites and disease (Pond et al., 2005). Usually, underfeeding is complicated by concomitant shortages of protein and other nutrients (Chowdhury and Ørskov, 1997; Schroeder and Titgemeyer, 2008).

Energy unit

Energy is an abstraction that can be measured only in its transformation from one form to another. Thus all of the defined units to measure energy are equally absolute. The joule (J) has been adopted by the International System of Units (SI) and the National Bureau of Standards (USA) as the preferred unit for expressing electrical, mechanical, and chemical energy. Thus units mostly used in the field of nutritional energetics of domestic animals are according to the SI units of energy metabolism (the joule). The joule is 10^7 ergs, where 1 erg is the amount of energy expended in accelerating a mass of 1 g by 1 cm/s "(centimeter per second)". Nutritionists generally standardized their bomb calorimeters using a thermochemical standard, usually specially purified benzoic acid whose heat of combustion has been determined in electrical units and computed in terms of joules/ gram mole (NRC, 1981; McDonald et al., 2002).

The joule has replaced the calorie (cal) as the unit for energy in nutritional work in some countries. The older unit measured in terms of heat and expressed as calories (or BTUs, British Thermal Units). A calorie is defined as the amount of heat required to raise the temperature of 1 g of water from 14.5 to 15.5°C. The conversion of the calorie to the joule has now been arbitrarily standardized as 1 cal = 4.184 J. In practice, both the joule and the calorie are so small that nutritionists work with multiple units: Kilojoule (kJ) and Megajoule (MJ) are 10^3 and 10^6 times greater than one joule, respectively (ARC, 1980; WTSR, 2008).

Energy evaluation

The animal obtains energy from its food. There are complex interrelationships among the various energy fractions of a food during their utilization by animal (Crampton and Harris, 1969; Pond et al., 2005). The utilization of food energy during digestion and metabolism by animal is shown schematically in Figure 4.1. Discussion of most of these fractions follows.

Gross Energy (GE) is the total heat or heat of combustion generated by oxidation of a feed sample in a bomb calorimeter (AOAC, 1990). There is no correlation between the amount of GE in a feed and its utilization by an animal. Gross energy does, however, provide a reference point from which GE digestibilities can be calculated (Blaxter, 1967, 1989). In spite of differences between food constituents, the predominance of the carbohydrates means that the foods of farm animals vary little in energy content. Only foods rich in fat have high values, and only those rich in ash, which has no calorific value, are much lower than average. Most common foods contain about 18.5 MJ/kg DM (McDonald et al., 2002; Pond et al., 2005). Of the gross energy of foods, not all is available and useful to the animal (Williams and Jenkins, 2003a, b; Ferrell and Oltjen, 2008). Some energy is lost from the animal in the form of the solid, liquid and gaseous excretion; another fraction is lost as heat. These sources of energy loss are illustrated in Figure 4.1.

Digestible Energy (DE) describes the proportion of GE not recovered in the feces. It is calculated by taking the GE of the feed consumed and subtracting the GE in the feces (see also Figure 4.1). Because small amounts of the fecal energy come from endogenous sources (mucosa cells, microflora residues, etc.), this term is sometimes referred to as apparent digestible energy (ARC, 1980; NRC, 1981). DE as a proportion of GE may vary from 0.3 for a very mature, weathered forage to nearly 0.9 for processed, high-quality cereal gains (NRC, 2000). DE has some value for feed evaluation because it reflects diet digestibility and can be measured with relative ease; however, DE fails to consider several major losses of energy associated with digestion and metabolism of food. As a result, DE overestimates the value of high-fiber, highly digestible feedstuffs such as grains (Pond et al., 2005).

Total Digestible Nutrients (TDN) is not shown in the scheme in Figure 4.1, but it is a measure of energy still used directly or indirectly in nutrition for ruminants. TDN is roughly comparable to DE but is expressed in units of weight or percent digestion. As compared to DE, TDN undervalues protein because protein is not oxidized completely by the animal body, whereas it is in a bomb calorimeter (Blaxter, 1967, 1989; Crampton and Harris, 1969; Pond et al., 2005). TDN is determined by carrying out a digestion trial and summing the digestible protein (DP) and carbohydrate (NFE and crude fiber) and plus 2.25 times digestible ether extract (crude fat). The formula for calculating TDN is: $TDN = DCP + DNFE + DCF + 2.25(DEE)$. TDN has no particular advantages or disadvantages over DE as the unit to describe feed values or to express the energy requirements of the animal. TDN can be converted to DE by the equation: 1 kg TDN = 4.4 Mcal DE or 18.4 MJ DE (NRC, 2000). Using TDN values for developing animal feeding standards or in formulating diets poses several problems which are discussed in detail in the most recent NRC (2001) publication on nutrition of dairy cattle.

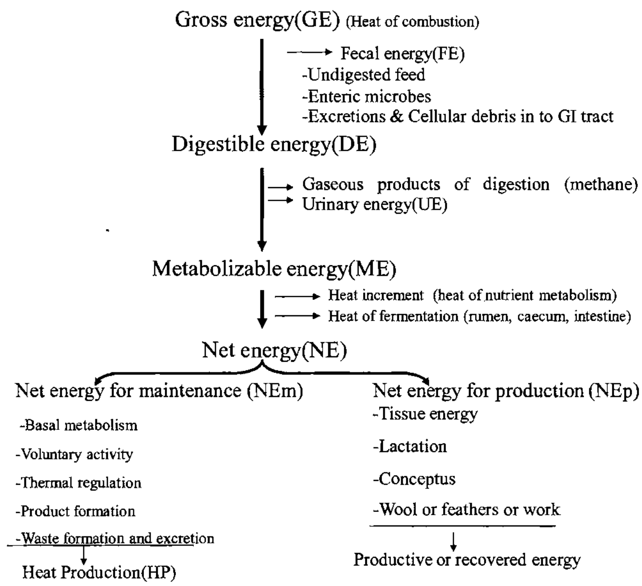

Figure 4.1 Schematic diagram of energy utilization by animals (adapted from Pond et al., 2005).

Metabolizable Energy (ME) is determined from DE by subtracting the urinary energy losses, losses from methane production. Endogenous sources from DE are shown in Figure 4.1 (Pond et al., 2005). Metabolizable energy refers to the energy available to maintain the body functions of an animal including minimum activity and the heat increment (HI). All ME remaining after satisfying the maintenance requirement is available for production (Blaxter, 1967; Ferrell and Oltjen, 2008). The metabolizability of the GE of a feed at maintenance (q_m), is defined as the proportion of ME in the GE of the feed: q_m = ME/GE (ARC, 1980; McDonald et al., 2002). The metabolizability of a diet, of low-quality foods (q_m = 0.4), whereas for high-quality foods (q_m = 0.7) (Blaxter, 1967; Owens and Geay, 1992).

There is normally a good correlation between DE and ME values of feeds or diets, with ME/DE ranging from 0.81 to 0.86 (ARC, 1980; AFRC, 1993). ME for ruminants is often calculated by the formula: ME = 0.82DE. Many of the NRC tabular values are calculated with this formula (Kearl, 1982; NRC, 2000). However, this is only an approximation as the ME/DE ratio may vary considerably, being affected by the nature of the diet and the level of feeding (Garrett and Johnson, 1983; NRC, 2000). For most forages and mixtures of forages and cereal grains, the ratio of ME to DE is about 0.8 but can vary considerably (ARC, 1980). This depends on intake, age of animals, and feed resource. Energy workers generally agree that ME is the most descriptive and reproducible measurement of feeds, especially at the maintenance level (Blaxter, 1967). ME values are seldom determined in practice, however, since very few laboratories have the facilities and budgets to collect and analyze respiratory gases and urine (Van Soest, 1994; Pond et al., 2005).

Net Energy (NE) is determined by subtracting the losses due to digestion fermentation (heat of fermentation, HF) and nutrient metabolism (heat increment, HI) from ME are shown in Figure 4.1 (Pond et al., 2005). Obtaining a reliable value for heat production (HP) in the fasting animal is not easy because ruminants must be fasted for an appreciable time (5–7 day), and collecting such data requires the use of large animal calorimeters (Blaxter, 1967; ARC, 1980; Williams and Jenkins, 2003a).

The NE of food is that portion that is available to the animal for maintenance or various productive purposes. The portion used for maintenance (NE_m) is utilized to satisfy the needs of fasting metabolism, activity of maintenance, and temperature control (above or below critical temperature); most of it will leave the animal body as heat. The portion used for productive purpose (NE_p) may be recovered as energy in the tissues for growth, fattening, or in some products such as milk, eggs, wool, fetus, or it may be used to perform work (Lofgreen and Garrett, 1968; Johnson et al., 2003; Ferrell and Oltjen, 2008).

However, heat production of both the HI and HF may serve useful purposes to the animal in a cold environment. The HI is not a constant for a given animal and a given feed, but it depends on how the nutrient is utilized (Blaxter, 1967; Williams and Jenkins, 2003a). Frequent feeding results in a lower HI than infrequent feeding, and an increased feed intake results in a larger HI (Pond et al., 2005). Blaxter (1967) estimated the HF in ruminant animals to be 5 to 10% of GE. However, in ruminant animals, limited data indicate that feeding of urea in place of protein tends to reduce heat production, and that production is less when minimal amounts of protein are fed (Pond et al., 2005). Using NE system for beef cattle; concepts, application, and future models are discussed in detail by other researchers (Ferrell and Oltjen, 2008).

Prediction of the energy values of tropical feedstuffs

Prediction of the energy value of feeds is useful when formulating rations for indoor feeding purposes or for supplementation of animals on pasture (Abate and Mayer, 1996). Dietary metabolizable energy (ME) concentration is the basal unit in energy feeding systems currently adopted across the world (ARC, 1980; NRC, 2001; Johnson et al., 2003). It is measured in respiration calorimeter experiments. However, respiration calorimeter experiments are labor-intensive and expensive approaches. It is thus unrealistic in practice to measure the ME concentrations for all concentrate supplements and forages used. Alternatively, as recommended in many energy feeding systems, it can be predicted from chemical compositions, digestibility, digestible energy (DE) and total digestible nutrients (TDN) (NRC, 1976; Abate and Mayer, 1996; Yan and Agnew, 2004). Kaewpila et al. (2008) was proposed the prediction equations to overcome the high costs and the extended time of *in vivo* metabolizable energy evaluation based on the data obtained in the tropics. A model to predict ME and DE value were developed based on existing data from fourteen respiration calorimeter experiments (57 treatment means) conducted at Khon Kaen Animal Nutrition Research and Development Center, Thailand. The model consists of equation that prediction ME content was validated based on the decomposition of the mean square prediction error. The equations are all highly significant ($P < 0.001$) and high R^2 (0.63–0.93). The equations gave the most accurate prediction are shown in Table 4.1.

Table 4.1 The regression equations for estimating metabolizable energy and digestible energy in cattle diets.

Sources	Equations[1/]	R^2	RSD[2/]	*P*-value	n
Kaewpila et al. (2008)					
(1)	ME = 0.1913OM + 0.0956EE − 0.0992ADF − 6.1887	0.63	0.27	< 0.001	27
(2)	ME = 0.1586TDN − 1.0738	0.74	0.16	< 0.001	45
(3)	ME = 0.0865OMD + 0.2355EE − 0.0445ADF + 4.0362	0.73	0.23	< 0.001	26
(4)	ME = 0.9613DE−1.2276	0.93	0.07	< 0.001	57
(5)	DE = 0.1663TDN + 0.1401	0.79	0.12	< 0.001	44
McDonald et al. (2002)	ME = 0.160OMD	NA	NA	NA	NA
NRC (2000)	ME = 0.2413DE − 0.1076	NA	NA	NA	NA
NRC (2000)	DE = 0.1845TDN	NA	NA	NA	NA

[1/]ME, metabolizable energy (MJ/kg); DE, digestible energy (MJ/kg); TDN, total digestible nutrients (%); OMD, organic matter digestibility (%); OM, organic matter (%); EE, ether extract (%); ADF, acid detergent fiber (%); [2/]RSD, residual standard deviation; NA, not available.

Measuring animal energetic efficiency and energy requirements

The development of energetic efficiency concepts followed a recognized pattern of knowledge evolution (Johnson et al., 2003; Ferrell and Oltjen, 2008). This evolutionary pattern began with novel, fundamental insights leading to creative new concepts. The second phase integrated concepts from other fields to create new applicable principles. The third phase was the adoptive or dissemination phase, yielding solutions to industry or societal problems. Animal efficiency may be measured as the balance between feed input and the output of work or products (McDonald et al., 2002; Pond et al., 2005). The ARC metabolizable energy system states that if the energy provided by feed is measured in terms of metabolizable energy, no great error is incurred by regarding the continuous curvilinear relationship between feed intake and energy retention as consisting of two direct proportionalities, one applying from fasting to maintenance and the other beyond maintenance (ARC, 1980; Williams and Jenkins, 2003a, b; WTSR, 2008).

In the classical systems, the energy cost of calculated or measured maintenance is deducted from the total energy balance to estimate NE (Van Soest, 1994; McDonald et al., 2002). Practically this means determining energy balance at two levels of intake (see also Figure 4.2). The efficiency of utilization of metabolizable energy for maintenance (k_m) is measured between fasting and the point at which energy retention is zero (slope of line AB in Figure 4.2). The efficiency of utilization of metabolizable energy for adult growth and fattening (k_g) is measured above the point at which energy retention is zero (slope of line BC Figure 4.2). Technically, the efficiency of NE_m/ME_m is represented by the linear slope.

The simplest and oldest measurement of animal efficiency is the direct determination of body weight and composition following slaughter after carefully measured feeding for a specific period (Lofgreen, 1965; Williams and Jenkins, 2003b). Assessments of initial and final body weights and compositions have to be made, according to the "comparative slaughter technique" (Lofgreen and Garrett, 1968; Garrett, 1980). In this kind of measurement the costs of maintenance are obscure, as is energy lost as methane, unless some other animal experimentation and respiration measurements are conducted along with the feeding trial (McDonald et al., 2002; Johnson et al., 2003; Ferrell and Oltjen, 2008). Energy losses in urine and methane production are usually estimated rather than directly determined (ARC, 1980).

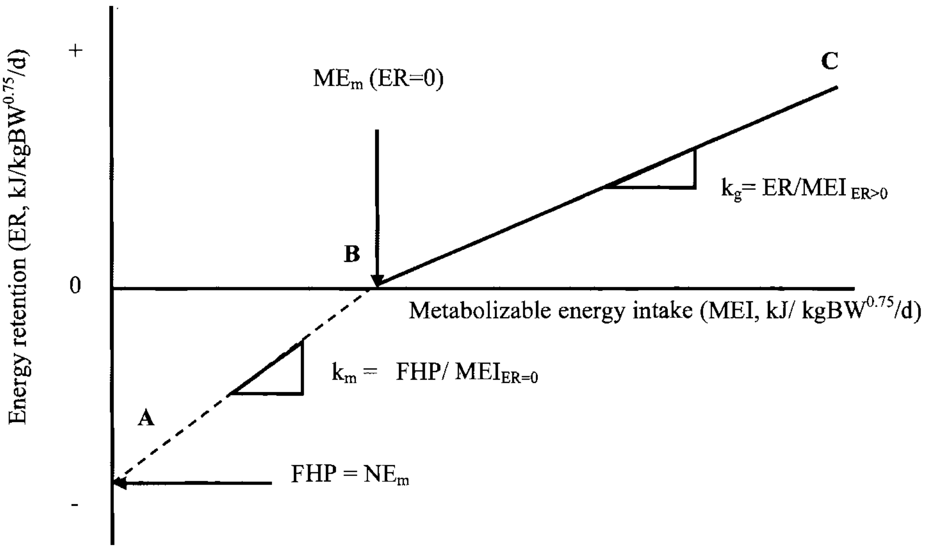

Figure 4.2 The relation between energy balance, metabolizable energy (ME) intake, fasting metabolism, maintenance, and gain (adapted from McDonald et al., 2002).

The general equation ME = ER + HE, the primary effort of energetics researchers was to describe and quantify the ME of food and heat energy (HE), with energy retention (ER) seemingly a secondary consideration (Johnson et al., 2003; Williams and Jenkins, 2003a; Ferrell and Oltjen, 2008). To study the utilization of ME, it is necessary to measure either (a) the animal's heat production or (b) energy retained in the tissues or that used for productive work, or energy deposited in a product. If one of these quantities (a or b) is known, then the other can be determined by subtracting the known one from ME. Discussion of some of these methods to determine HE or ER follows (Blaxter, 1967; Williams and Jenkins, 2003a).

Animal calorimetry

Calorimetry methods (ARC, 1965, 1980) have been discussed in detail by Blaxter (1967). Animals lose heat to the environment as sensible heat or as evaporative heat (Blaxter, 1967; McLean and Tobin, 1987). Sensible heat is lost through convection, conduction and radiation. Evaporative heat is lost through the skin and respiratory tract. Heat loss can be measured directly (direct calorimetry) using either heat skin or gradient layer calorimeters for the chamber (Blaxter, 1967; Pullar, 1969; McLean and Tobin, 1987). However, due to the extremely high cost, both in construction and in operation, few direct calorimeters for farm animals are presently in use (McDonald et al., 2002; Pond et al., 2005). Indirect calorimetry is based on the principle that metabolic heat production is the result of oxidation of organic compounds (Blaxter, 1967; Flatt, 1969). For ruminants, the most commonly used equation to estimate total heat production (HE, heat energy) for indirect calorimetry is: HE = 3.886 O_2 + 1.200 CO_2 – 0.518 CH_4 – 1.431 N, where HE is in kcal; O_2, CO_2 and CH_4 refer to gaseous exchange in liters; and N refer to urinary nitrogen in grams (Brouwer, 1965).

Indirect or respiration calorimeters may be of the closed or open circuit type (Abrams, 1961; Flatt, 1969; Van Soest, 1994). First, in the closed circuit type, the animal is enclosed in a temperature-controlled chamber. Air in the chamber is continuously circulated through an absorbent, which removes water and carbon dioxide. Oxygen use is determined as the amount of oxygen supplied to maintain pressure, and carbon dioxide production is determined from the amount collected by the absorbent. Methane production is calculated as the concentration difference between the beginning and the end of the test time multiplied by the volume of the system. Second, the most common type of calorimeter is the open circuit, indirect calorimeter. In this type of system, a mask, hood (head box), or animal chamber may be used. Oxygen, CO_2 and CH_4 concentration must be determined accurately in incoming and outgoing air. Rate of consumption or production of these gases is calculated as the concentration difference between incoming and outgoing air times air flow rate. Most calorimeters incorporate apparatus for measuring respiratory exchange and can therefore be used for indirect calorimetry as well (Blaxter, 1967; Johnson et al., 2003; Ferrell and Oltjen, 2008).

Carbon-Nitrogen balance

The carbon-nitrogen balance technique is one of the oldest of the indirect methods. Carbon-nitrogen balance is frequently calculated in association with indirect calorimetric measurements. The main forms in which energy is stored by the growing and fattening animal are protein and fat, for the carbohydrate reserves of the body are small and relatively constant (Pond et al., 2005). These methodologies are based on the recognition that the main forms in which energy is accumulated in the animal are protein and fat; accumulation of carbohydrate is very low. The quantities of protein and fat stored can be estimated by carrying out a carbon and nitrogen balance trial. The energy retained can be calculated by multiplying the quantities of nutrients stored by their calorific values (Blaxter, 1967; McDonald et al., 2002).

The common use of this assumption, is to use N balance to estimate body protein accretion, calculated as difference between intake (I) and losses (L) times 6.25, [6.25 (I – L)]. Body protein accretion times 0.512 (assuming body protein contains 16% of N and 51.2% of C) yields an estimate of C accretion in body protein. The remainder of carbon balance is stored as fat; thus, C balance minus C stored as protein divided by 0.746 (assuming fat contains 74.6% of C) yields an estimate of fat accretion. Energy accretion can then be calculated from protein and fat accretion (Pond et al., 2005). The advantages of the carbon-nitrogen balance technique are that no measure of oxygen consumption is required and that energy retention is subdivided into that stored as protein and that stored as fat (Blaxter, 1967; McDonald et al., 2002). The limitation of this approach is that it is very difficult to measure all losses of C and N from the animal. Therefore, this method generally results in an overestimate of energy, C or N accretion in the animal (Pond et al., 2005).

Comparative slaughter

In contrast to calorimetry, in which ME intake and HE are determined and ER (energy retention) is estimated by difference, comparative slaughter trial requires that ME intake and ER be determined and HE can be estimated by difference. The comparative slaughter method, (Lofgreen, 1965; Lofgreen and Garrett, 1968), is done by dividing the animals in two groups and slaughtering one (the sample slaughter group) at the beginning of trial. Body composition and energy content of the animals slaughtered are determined. The latter are slaughtered at the end of trial and determined energy content with the same manner as those in the sample slaughter group. Their energy gain or ER is then calculated as the difference in body energy contents between the initial and the final slaughter groups (Lofgreen and Garrett, 1968; McDonald et al., 2002; Ferrell and Oltjen, 2008). It is also worth noting that comparative slaughter trials often give lower estimates of energy retention than trials conducted with animals in calorimeters, possibility because the former allow more opportunity for animals to expend energy on muscular activity (McDonald et al., 2002; Johnson et al., 2003). As a result, these techniques are often used to calibrate alternative methods to estimate body composition indirectly, such as carcass density or specific gravity (Lofgreen and Garrett, 1968; Blaxter, 1989; Ferrell and Oltjen, 2008).

These techniques have advantages over calorimetric techniques in that they allow experiments to be conducted under situations more similar to those commonly found in practice (Blaxter, 1967; McLean and Tobin, 1987; Pond et al., 2005). Body composition and energy contents have often been determined by the accurate but expensive method of whole-body grinding and chemical analysis when applied to larger animal species (Johnson et al., 2003; Ferrell and Oltjen, 2008). In addition, these techniques are expensive, laborious, and destructive; that is, each animal can be used only once (Pond et al., 2005). Nevertheless, estimates of energy utilization obtained by comparative slaughter trial (Lofgreen, 1965; Lofgreen and Garrett, 1968) and specific gravity measurements have been used in the USA to establish a complete cattle feeding system (NRC, 2000; Johnson et al., 2003; Ferrell and Oltjen, 2008).

Feeding trials

In the feeding-trial method of measuring the energy requirement for growth, different levels of feed are fed to find the minimum one which will give a maximum rate of growth (Pond et al., 2005). The inclusion of slaughter tests to show the nature of the increase made provides valuable additional data in the case of meat animals, illustrate the feeding-trial method (ARC, 1980; NRC, 2000). The maintenance values obtained very simply from this method involves the determination of the amount of food required to hold adult animals at constant weight. Allowances can be made for changes in live weight by estimating the food equivalent of the losses or gains and correcting the observed intakes accordingly (McDonald et al., 2002).

Energy requirement for maintenance from feeding-trials are estimated by regression of average daily gain (ADG) and energy intake (EI). The linear regression equation as followed; EI = $a + b$ADG. From the obtained equation, when at the zero gain (ADG = 0), expresses the minimum of energy requirement for maintenance (Luo et al., 2004a, b). The maintenance values in the early feeding standards developed in the USA were based, for the most part, on data obtained in feeding trials. Also the recommended energy intakes for growth that are found in the feeding standards for various species have been arrived at primarily from feeding trial data (Pond et al., 2005).

Energy requirement of cattle

Animals require energy for the maintenance of essential life processes such as respiration and the circulation of blood. In addition, energy is required to provide the energy stored in various body tissues during growth and for products such as milk, and to actuate the synthetic processes involved in their production (Kearl, 1982; NRC, 2000; Williams and Jenkins, 2003b; Ferrell and Oltjen, 2008). The development of concepts of energetic efficiency and energy requirements followed a recognized pattern of knowledge evolution which is discussed in detail in the publications (Blaxter, 1967; NRC, 1981; Van Soest, 1994; Ferrell and Oltjen, 2008). From the other philosophers and researchers, the generalization that life is primarily a combustion process developed.

The concept relating metabolism to combustion permitted the formation of the following equation: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + heat (Lavoisier and La Place, 1780 cited by Ferrell and Oltjen, 2008). After those pioneering works, considerable effort, over a period of 100 yr or so, was devoted to establishing relationships between gas exchange and heat production. Work in this area culminated in 1965 with the publication of the Brouwer equation (Brouwer, 1965). The equation has developed since its publication to calculate heat production from indirect calorimetry measurements. Current energy systems used in the United Kingdom (ARC, 1965, 1980; AFRC, 1993), France (INRA, 1978, 1989), Australia (AAC, 1990), Japan (NARO, 2006, 2008), Thailand (WTSR, 2008), and developing countries (Kearl, 1982) are grounded in principles derived from those earlier efforts. The general equation ME = ER + HE has been recognized since the days of Baron Justus Von Liebig (1803 to 1873) cited by Johnson et al. (2003). Primary contributions to this concept by energetics researchers was to describe and quantify the ME of food and heat energy (HE), with energy retention (ER) seemingly a secondary consideration of beef cattle energetic efficiencies and requirements (Johnson et al., 2003; Williams and Jenkins, 2003a, b).

Basal and fasting metabolism

The concepts of animal energy metabolism describe the relationship of heat production to body size or weight (Blaxter, 1967, 1989; Lofgreen and Garrett, 1968; ARC, 1980; NRC, 1981). Early nutrition research found that heat production was not well correlated to body weight of animals, and much research effort was expended to develop means of predicting heat production and establish some overall "law" that would apply to animals in general. Surface area varies with the square of linear size or to the two-third power of weight ($W^{2/3}$) if specific gravity is constant. Thus, surface area varies with the square of linear size or two-thirds power of volume, so heat production can be related to body surface or volume (Van Soest, 1994; Johnson et al., 2003; Ferrell and Oltjen, 2008). However, the body surface of a living animal is quite difficult to measure and is not constant. Even though these various factors are involved in heat loss, they can be related reasonably well to surface area estimated by multiplying body weight (BW) by a fractional power and thus to body heat production (Blaxter, 1967, 1989). Classical mouse to elephant research with mature animals found heat production to be proportional to $BW^{0.75}$ (Kleiber, 1947 cited by Johnson et al., 2003; Ferrell and Oltjen, 2008), leading to the widely accepted concept of metabolic weight or metabolic size.

Heat production is expressed on the basis of surface area (estimated from BW). Efforts to account for maintenance are usually arbitrary and often based on the animal's metabolic size (ARC, 1980; Johnson et al., 2003). Another convention that must be considered is the use of $BW^{0.75}$ as the scaling coefficient for comparing energy metabolism data obtained on animals differing in body size. Many of the energy requirements of animals are expressed in terms of energy per unit time (AFRC, 1993; NRC, 2000; Ferrell and Oltjen, 2008). The accuracy of the 0.75 exponent, and the veracity and applicability to define maintenance requirements, has been widely challenged. Although this subject has been very controversial, all current feeding standards in the USA, Europe, New-Zealand, and Australia are now based on metabolic size (Blaxter, 1967; Pond et al., 2005).

Basal metabolism is generally defined as the condition in which minimal amount of energy is expended to sustain the body, or the heat production of a completely quiescent animal in a post-absorptive state, within a thermoneutral environment (Blaxter, 1967; Crampton and Harris, 1969; Pond et al., 2005). However, although this state can be achieved with humans, it is extremely difficult to achieve with other animals. Consequently the term "fasting metabolism" has been adopted for them (Blaxter, 1967; Ørskov and Ryle, 1998). However, in ruminants food requires many hours (usually 5 days) to pass out of the gastrointestinal tract and true state of post-absorption is rarely obtained, although it may be approached as indicated by a very low methane production (Blaxter, 1967; Pond et al., 2005).

Fasting metabolism measurements are normally taken on animals in a respiration chamber, where activities other than standing or lying. This condition may be difficult to obtain in animals, particularly those that have not had extensive training for such measurements (Ørskov and Ryle, 1998). The basal metabolism value depends on the biological size or metabolic size of the animal (ARC, 1980; Johnson et al., 2003; Williams and Jenkins, 2003a). A basal and fasting metabolism value of 77 kcal/kgBW$^{0.75}$ (322 kJ/kgBW$^{0.75}$) is considered to be an average value where BW is in kg. However, considerable variation exists between breeds and within species, *Bos indicus* appear to have fasting heat production and maintenance requirements that are about 10% less than those of European *Bos taurus* breeds with crossbreds being intermediate (NRC, 2000). Factors affecting basal metabolism are age, species, breed differences, neuroendocrine factors, and miscellaneous factors (Pond et al., 2005).

Energy requirement for maintenance

The maintenance requirement for energy has been defined as the amount of feed energy intake that will result in no net loss or gain of energy from the tissues of the animal body (NRC, 2000; Johnson et al., 2003; Ferrell and Oltjen, 2008). Thus, maintenance energy requirements are estimates of the amounts of energy necessary to achieve an equilibrium state (energy retention, ER = 0) (Maynard and Loosli, 1969; Blaxter, 1989; Pond et al., 2005). This definition excludes the possibility that maintenance requirements change as rate of growth increases; i.e., any increase in energy requirements as a result of a productive function is a production requirement. In addition, the maintenance requirement varies with level of feeding, previous plane of nutrition, and breed (NRC, 2000; Ferrell and Oltjen, 2008). Climate also influences energy metabolism and energy requirements (Fox et al., 1990; Hunter and Buck, 1992; Owens and Geay, 1992; NRC, 2000).

Basically, three methods have been used to measure maintenance energy requirements (Johnson et al., 2003; Williams and Jenkins, 2003a). These include: first, long-term feeding trials to determine the quantity of feed required to maintain body weight or, conversely, determine body weight maintained after feeding a predetermined amount of feed for an extended period of time (Taylor and Young, 1968; Taylor et al., 1981). Second, calorimetry methods (ARC, 1965, 1980; Blaxter, 1967, 1989) can estimate from measurements of feed intake which result in energy retention slightly below or above energy equilibrium in a calorimeter or respiration chamber. Third, comparative slaughter techniques (Lofgreen, 1965; Lofgreen and Garrett, 1968) can estimate of the quantity energy intake required for zero retained energy.

In Thailand, there is still very limited information on energy requirements for maintenance of beef cattle. The energy requirements of cattle in Thailand are based on information built up from countries in temperate zones, NRC (2000) and ARC (1980). However, the breed of cattle, climate conditions and available feed resources are completely different from those in temperate zones, and the energy balances of the cattle breeds in the tropics have been hardly measured (Nishida et al., 2005). In order to study energy metabolism in cattle, Kawashima et al. (2001) developed a respiration trial system using a ventilated flow-through method with a face mask in Thailand in 1997. They compared the data of metabolic trials carried out with Brahman cattle, swamp buffalo and Thai native cattle fed locally available feed resources under humid tropical conditions in Northeast Thailand. The metabolizable energy requirement for maintenance was obtained by the regression analysis of energy retention against ME intake on the basis of metabolic size. The values were 377, 334 and 245 kJ/kgBW$^{0.75}$/d in Brahman cattle, swamp buffalo and Thai native cattle, respectively (Kawashima et al., 2000). After that, in 2005, they constructed a new animal calorimeter using a ventilated hood system which is advantageous for conducting the gas exchange measurements throughout the day, and conducted a trial to estimate the energy balance in the cattle (Suzuki et al., 2008b). However, the research work and reports on value of energy requirement for maintenance of beef cattle in Thailand is still limited and varies.

The energy requirements for maintenance (ME_m), in the reviewed and meta-analysis synthesized the data of the metabolizable energy requirements for maintenance of *Bos indicus* and *Bos taurus* beef cattle from 20 publications are shown in Table 4.2 and Figure 4.3 (Chaokaur and Sommart, 2008). These estimate from the analyses of the data reported in 20 publications of energy studies in cattle of various breeds, stages, body weight, feed ratio and energy retention methods. They reported that the metabolizable energy requirement for maintenance of *Bos indicus* was 443 kJ/kgBW$^{0.75}$/d lower approximately by 12.3% than that, 505 kJ/kgBW$^{0.75}$/d, of *Bos taurus*, in which good agreement to NRC (2000). Moreover, ME_m of *Bos indicus* fed under tropical condition was 441 kJ/kgBW$^{0.75}$/d, approximately 11% lower than 495 kJ/kgBW$^{0.75}$/d, the ME_m of the animal fed in temperate condition. Thus, the results indicated that ME_m of *Bos indicus* differed from that of *Bos taurus*. The recommended ME_m for beef cattle fed under tropical conditions was lower, approximately by 4 to 10% than the recommended ME_m for cattle in Europe and USA conditions.

Table 4.2 Summary of database for comparison of ME_m and k_m in cattle[1/]

Reference	No.	Cattle[2/]	Method[3/]	ME_m	k_m
ARC (1980)	—	3, 4	—	527	0.64
Birkelo et al. (1991)	8	2	IC; FHP/k_m	496	0.75
Birkelo et al. (2004)	45	3	IC; ER ra MEI	570	—
Chaokaur et al. (2007)	19	1	ICH; ER ra MEI	458	0.58
Derno et al. (2005)	8	2	IC; HP ra MEI	416	
DiCostanzo et al. (1990)	28	2	D_2O; ER ra MEI	655.6	0.76
DiCostanzo et al. (1991)	16	2	D_2O; ER ra MEI	655.35	0.68
Ferrell and Jenkins (1998a)	70	4	CS; ER, HP ra MEI	495–529	0.65
Ferrell and Jenkins (1998a)	8–16	1x, 2x	CS; ER, HP ra MEI	249–501	0.65–0.69
Hotovy et al. (1991)	4–8	2x	IC; HP ra MEI	440–464	0.73–0.74
Kawashima et al. (2000)	20–44	1	ICM; ER ra MEI	245–377	0.82
Kearl (1982)	—	3, 4	—	493	—
Kirkland and Gordon (1999)	8	3	IC; ER, HP, BW ra MEI	610	0.66
Laurenz et al. (1991)	30	2	FT, D_2O; BWC, ER ra MEI	433–536	0.60–0.71
Liang and Young (1995)	8	1	TOH; ER ra MEI	335	0.64
NRC (1976)	—	4		540	0.65
Odai et al. (2005)	20	3	ICM; ER ra MEI	409	0.79
Solis et al. (1988)	4	3, 4	FT, D_2O; BWC, ER ra MEI	383–636	0.36–0.81
Tedeschi et al. (2002)	24–48	2	CS; ER, HP ra MEI	469–498	0.64–0.69
Warrington et al. (1988)	46	2	D_2O; ER ra MEI	661–707	—

Source: Chaokaur and Sommart (2008) [1/] ME_m, metabolizable energy requirement for maintenance (kJ/kgBW$^{0.75}$/d); k_m , efficiency of utilization of metabolizable energy for adult growth and fattening. [2/] 1, *Bos indicus*; 2, *Bos taurus*; 3, Dairy; 4, Beef; 1x, *Bos indicus* crossbred; 2x, *Bos taurus* crossbred [3/] ER, energy retention; HP, heat production; FHP, fasting heat production; BWC, body weight change; IC, indirect calorimetry; ICH, indirect calorimetry head cage; ICM, indirect calorimetry mask; CS, comparative slaughter; TOH, tritiated water (TOH) dilution; D_2O, deuterium oxide dilution; FT, feeding trial; ra, regressed against.

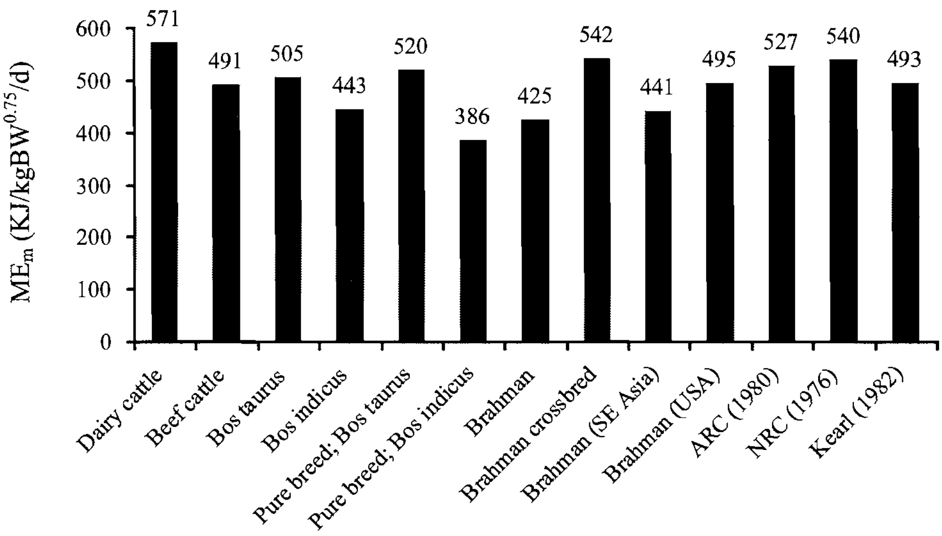

Figure 4.3 Comparison of metabolizable energy requirement for maintenance in cattle. (Chaokaur and Sommart, 2008)

Tangjitwattanachai et al. (2009) suggested that the efficiency of ME utilization for maintenance (k_m); using meta-analysis from 10 publications of *Bos indicus* (k_m = 0.64) was higher (9.38%) than that of *Bos taurus* (k_m = 0.58). This relates with Ferrell and Jenkins (1998b) who suggested that energetic efficiency for maintenance of *Bos indicus* (0.69) was higher than *Bos taurus* (0.67), while other reports indicate that higher energetic efficiency for maintenance of *Bos taurus* was 0.66–0.81 (Solis et al., 1988). However, energetic efficiency may be due to differences in genetic, mature size, quality of feed, climatic conditions and differences in nutrient utilization (Paul et al., 2003). The equations estimation of efficiency of ME utilization for maintenance (k_m) proposed by Tangjitwattanachai et al. (2009) are as folllows;

Bos indicus;

$$ER = 0.64MEI - 276.47\ (n = 80,\ R^2 = 0.85,\ RSD = 6.73,\ P < 0.001) \quad \text{[equation 4.1]}$$

Bos taurus;

$$ER = 0.58MEI - 326.03\ (n = 28,\ R^2 = 0.91\ RSD = 8.63,\ P < 0.001) \quad \text{[equation 4.2]}$$

Energy requirement for growth

We can express the energy need of adult animals in two separately measureable quantities, one for maintenance and another for specific activity in addition to maintenance. With growing animals overall increases in weight is continuously variable, and in practice one must not only feed to maintain the weight and size attained, but provide enough more to permit further gain in weight (ARC, 1980; Kearl, 1982; Blaxter, 1989; Ferrell and Oltjen, 2008). To determine energy requirements on the basis of the growth of animals, we conduct a bio-assay type of feeding trial (NRC, 2000). Comparable groups of animals are fed different amounts of a ration, the energy content of which is known. The intake of energy by the animals that grow at rates comparable to those of the normal growth curve is taken as the energy requirement (Flatt and Moe, 1969; Pond et al., 2005). In addition, the additional demand for the growth itself varies with the rate and with the composition of the tissue formed (McDonald et al., 2002). Requirements can be measured either by calorimetric balance or by the comparative slaughter technique. Values generally are 10–20% higher by the calorimetric balance method. Nevertheless, both techniques can detect relative differences (Williams and Jenkins, 2003b).

Tangjitwattanachai et al. (2009) shows that the efficiency of ME utilization for growth (k_g); using meta-analysis from 12 publications of *Bos indicus* (k_g = 0.51) was higher (11.76%) than that of *Bos taurus* (k_g = 0.45). *Bos indicus* cattle in these results were similar to Brahman cattle (k_g = 0.52) reported by Ferrell and Jenkins (1998b) and Nellore (k_g = 0.50–0.57) as reported by Tedeschi et al. (2002), while *Bos taurus* cattle have efficiency of metabolizable energy for growth similar to other reports (Hutcheson et al., 1997; Ferrell and Jenkins, 1998b). The equations estimation of efficiency of ME utilization for growth (k_g) proposed by Tangjitwattanachai et al. (2009) are as folllows (see also Table 4.3);

Bos indicus;

$$ER = 0.51MEI - 210.57 \ (n = 44, R^2 = 0.94, RSD = 3.86, P < 0.001) \quad \text{[equation 4.3]}$$

Bos taurus;

$$ER = 0.45MEI - 232.05 \ (n = 85, R^2 = 0.88, RSD = 4.11, P < 0.001) \quad \text{[equation 4.4]}$$

Table 4.3 The efficiency of ME utilization for growth (k_g) in *Bos indicus* and *Bos taurus*

Reference	Breed	n	BW (kg)	Method[1/]	k_g
Bos indicus					
Liang and Young (1995)	Kedah Kelantan	16	335	IC; ER/MEI	0.30
Tedeschi et al. (2002)	Nellore	22	327	CS; ER/MEI	0.57
	Nellore	26	300	CS; ER/MEI	0.50
Ferrell and Jenkins (1998b)	Boran	15	277	CS; ER/MEI	0.32
	Brahman	15	313	CS; ER/MEI	0.52
	Tuli	16	287	CS; ER/MEI	0.42
Chaokaur et al. (unpublished data)	Brahman	25	354	IC; ER/MEI	0.54
Tangjitwattanachai et al. (2009)	Beef cattle	44	317	MA	0.51
Bos taurus					
Hutcheson et al. (1997)	Angus crossbred	24	409	CS; ER/MEI	0.43
Solis et al. (1989)	Angus crossbred	37	351	CS; ER/MEI	0.46
	Simmental crossbred	34	306	CS; ER/MEI	0.45
Garrett (1979)	Hereford × Angus	86	234	CS; ER/MEI	0.42
	Hereford × Angus	NA	NA	CS; ER/MEI	0.37
Old and Garrett (1987)	Hereford	12	223	CS; ER/MEI	0.32
	Charolais	12	240	CS; ER/MEI	0.31
Ferrell and Jenkins (1998a)	Hereford crossbred	8	340	CS; ER/MEI	0.60
	Angus crossbred	16	340	CS; ER/MEI	0.38
	Belgian Blue crossbred	15	346	CS; ER/MEI	0.44
	Piedmontese crossbred	14	323	CS; ER/MEI	0.27
Ferrell and Jenkins (1998b)	Hereford	8	286	CS; ER/MEI	0.40
Gerrits et al. (1996)	Angus	8	346	CS; ER/MEI	0.32
	Holstein Friesian crossbred	36	120	CS; ER/MEI	0.67
	Holstein Friesian crossbred	36	200	CS; ER/MEI	0.58
ARC (1980)	Beef cattle	NA	465	NA	0.44
Tangjitwattanachai et al. (2009)	Beef cattle	85	355	MA	0.45

[1/]CS, comparative slaughter technique; IC, indirect respiratory calorimetry; ER, energy retention; MEI, metabolizable energy intake; NA, not available; MA, meta-analysis.

In Thailand, there is still very limited information on energy requirement and energetic efficiency for gain of growing Brahman beef cattle. The reviewed and synthesized data of 7 feeding trials of beef cattle in Thailand, including Thai native cattle and Brahman beef cattle fed under humid tropics condition in Thailand shown in Figure 4.4 (Nitipot et al., 2009). The energy requirement for gain was estimated by the regression analysis of metabolizable energy intake on the basis of metabolic size (MEI, kJ/kgBW$^{0.75}$/d) on average daily gain on the basis of metabolic size (ADG, g/kgBW$^{0.75}$/d). These studies followed by the standard method as reported by McDonald et al. (2002), Luo et al. (2004a, b), Pond et al. (2005), using the linear regression equation as follows; MEI = a + bADG. The graph shows intercept (a), when at the zero gain (ADG = 0), the minimum of ME requirement for maintenance and the slope (b) shows the minimum of ME requirement for gain. The equations estimation of energy requirement and energetic efficiency for gain proposed by Nitipot et al. (2009) are as follows;

Thai native cattle;

MEI = 31.37ADG + 483.60 (n = 18, R^2= 0.82, RSD = 18.33, $P < 0.001$) [equation 4.5]

Brahman;

MEI = 22.67ADG + 486.19 (n = 39, R^2= 0.73, RSD = 13.99, $P < 0.001$) [equation 4.6]

The results shown that the ME requirement for maintenance of Thai native cattle and Brahman beef cattle fed under humid tropics condition in Thailand was 483.6 and 486.2 kJ/kgBW$^{0.75}$/d, respectively. The ME requirement for gain of Thai native cattle and Brahman beef cattle was 31.37 and 22.67 kJ/gADG, respectively (see also Figure 4.4). The results indicated that ME requirement for maintenance of Thai native cattle was similar to Brahman beef cattle, but require 28% higher ME requirement for gain than Brahman cattle.

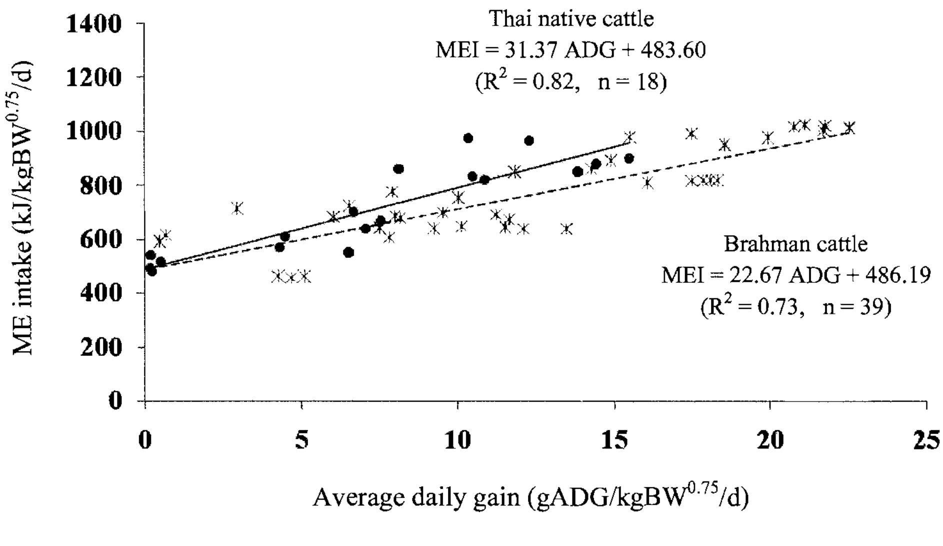

Figure 4.4 The relationship between average daily gain and metabolizable energy intake of Thai native cattle (•, solid line) and Brahman cattle (*, dash line) (Nitipot et al., 2009).

Factors affecting energy requirements

Many factors affect the energy requirements of ruminants and/or the extent of energetic efficiency and energy utilization. Several of the most important ones are described here.

(1) Breed or genotype: the summaries of NRC (2000) indicate that maintenance energy requirements of *Bos indicus* breeds of cattle are about 10% lower, and British crosses with those breeds about 5% lower than British breeds (*Bos taurus*) of cattle. Similarly, these researchers (Ferrell and Jenkins, 1998a, b; Sainz et al., 2005; Chizzotti et al., 2007; Tangjitwattanachai et al., 2009) reported that *Bos indicus* have a lower maintenance requirement than *Bos taurus*. In recent decades, marked improvement has occurred in the growth and efficiency of nutrient utilization of several domestic animal species (Pond et al., 2005). However, all adult and growing cattle show that a positive relationship exists between maintenance requirement and genetic potential for measures of productivity. Thus selection may result in a population of animals highly adapted to a specific environment but less adapted to different environments and with decreased adaptability to environmental changes (NRC, 2000).

(2) Age: the concept that maintenance per unit of size declines with age in cattle and sheep (Blaxter, 1967) has been generally accepted. Several studies indicate that age of animal has an influence on its energy requirement (Freetly et al., 2002; Sanz Sampelayo et al., 2003; Chizzotti et al., 2008; Zinn et al., 2008). Young cattle, sheep, and goats are essentially nonruminant, so that part of the effects of age on energy utilization is the transition to diets higher in fiber. This transition as well as the energy losses due to fermentation and the increasing proportion of fat in body tissue, tends to increase the energy requirements per unit of weight increment (Flatt and Moe, 1969). Moreover, the metabolic rate deviated substantially from allometric relationships; deviations were greatest during times of highest relative growth rate. NRC (2000) reported that the efficiency of utilization of a ration by growing heifers was greater for growth than for fattening. This decrease should lead to a lower maintenance requirement for older animals, and thus leave a greater proportion of the ration for productive purposes (Flatt and Moe, 1969).

(3) Sex: available data from the summaries of NRC (2000) show that FHP or net energy required for maintenance of steers and heifers is similar. ARC (1980) and AAC (1990) similarly concluded fasting metabolism of castrate males and heifers was similar. In addition, it has been shown that maintenance requirements of bulls are 15% higher than that of steers or heifers of the same genotype (NRC, 2000). Previous studies indicated that sex of animal has an influence on energy requirement (Chizzotti et al., 2007, 2008; Zinn et al., 2008).

(4) Activity: one of most common activities of mammal is standing up. The ARC (1980) estimation for standing requirements is 10 kJ/kgBW/d. Eating and rumination, requirements depend on the type of diet (large/long particles or ground and pellet, concentrate or roughage, solid or liquid) (Ørskov and Ryle, 1998). For walking, Blaxter (1967) summarized the available data and arrived at a value of about 2 J/kgBW/ horizontal meter, while out of doors was 10–15% greater than indoors. In addition, in a review of available literature, AAC (1990) estimated the increase in maintenance energy requirements of grazing as compared to penned cattle to be 10 to 20% in best grazing conditions and about 50% for cattle on extensive holdings. Therefore, several studies indicate that physical activity of the animal has an influence on energy requirement (Ortigues et al., 1993; Lachica and Aguilera, 2005a, b; Brosh et al., 2006; Freetly et al., 2006; Van Knegsel et al., 2007; Suzuki et al., 2008a).

(5) Effects of previous nutrition/compensatory gain: the phenomenon of compensatory gain is described as a period of faster or more efficient rate of growth following a period of nutritional or environmental stress (Blaxter, 1967; Van Soest, 1994). Differences among animal genotypes; severity, nature, and duration of restriction; and nutritional regime and interval of measurement of the response during realimentation are among the many variables contributing to differences (Drouillard, et al., 1991; NRC, 2000). Several studies indicate that previous nutrition/compensatory gain of animal has been influence on energy requirement (Fox et al., 1972; Carstens et al., 1991; Hayden et al., 1993; Yambayamba et al., 1996; Hornick et al., 1998; Yan et al., 2006; Clark et al., 2007; Roberts et al., 2007; Olson et al., 2008).

(6) Level of nutrition: the rate of protein and fat accretion is dependent upon the energy intake (Lofgreen and Garrett, 1968; ARC, 1980). Several studies indicate that level of feeding has an influence on energy requirement (Terada, 1991; Kirkland et al., 2002; Liu et al., 2005; Mahgoub et al., 2005; Castro Bulle et al., 2007; Freetly et al., 2008; Galvani et al., 2008). There is an increase in energy retention with increasing protein and energy intake (interrelationship). The exact position of the curves will depend on the stage of maturity of the animal, sex, genotype, etc., but the general principle is of an increase in protein and fat accretion with increasing energy intake or level of feeding (ARC, 1980; Schroeder and Titgemeyer, 2008).

(7) Environmental temperature: the effects of temperature on energy requirements vary with the relative humidity, wind velocity, season and length of hair coat (insulation) of the animal. Previous studies indicated that environmental temperature has an influence on energy requirement (Kurihara, 1991; Fox and Tylutki, 1998; Mader, 2003; Terada and Shioya, 2004; Landau et al., 2006). In addition, the type of ration and level of feed intake influence the effects of temperature on energy utilization of animals (Flatt and Moe, 1969). Both production and dissipation of heat are regulated to maintain a nearly constant body temperature. The body temperature control is primarily via regulation of heat dissipation (Blaxter, 1967; ARC, 1980; NRC, 2000). When effective ambient temperature increases above the zone of thermoneutrality (higher than the upper critical temperature, UCT) energy requirements for maintenance increase because increased of tissue metabolic rate and increased work for dissipating heat. On the other hand, when ambient temperature is lower than the lower critical temperature (LCT) energy requirements for maintenance also increase for animal metabolism increases to provide adequate heat to maintain body temperature (Van Soest, 1994; Ørskov and Ryle, 1998). Heat or cold stress occurs when effective ambient temperature is higher than UCT or less than LCT. Both UCT and LCT vary with the rate of heat production in thermoneutral conditions and the animal's ability to dissipate or conserve heat (Van Soest, 1994; Ørskov and Ryle, 1998). In addition, heat production of animals under thermoneutral conditions may differ substantially as functions of feed intake, physiological state, genotype, sex, and activity (ARC, 1980; NRC, 2000).

(8) Hormones: There are some interactions between hormones and energy metabolism, hormones regulating glucose supply and utilization. Hormones increasing anabolic activity will increase the need for energy supply (Flatt and Moe, 1969; McDowell and Annison, 1991; Weekes, 1991; Pittroff et al., 2006).

Conclusion

A quantitative meta-analysis was applied in order to quantify energy requirements of beef cattle fed under tropical condition. The results indicated that efficiency of metabolizable energy for maintenance of *Bos indicus* (k_m = 0.64) was higher (9.38%) than that of *Bos taurus* (k_m = 0.58). Efficiency of metabolizable energy for growth of *Bos indicus* (k_g = 0.51) was higher (11.76 %) than that of *Bos taurus* (k_g = 0.45). Net energy requirement for maintenance of *Bos indicus* (276.47 kJ/kgBW$^{0.75}$/d) was lower (15.20%) than that of *Bos taurus* (326.03 kJ/kgBW$^{0.75}$/d). The equations estimation of energy requirement and energetic efficiency for gain of beef cattle fed under tropical condition was recommended.

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Chapter 5 Protein

Introduction

Protein is one of the limiting factors in beef production, and the knowledge of protein requirements by livestock is crucial for the success of a commercial beef raising enterprise. Recommendation of ARC (1980), Kearl (1982) or NRC (2000) were based on evaluate feeding programs around the world.

Protein requirements of beef cattle depend on body size and growth or genetics production potential of animal, environmental condition and quality of feed (Paul et al., 2003). The appropriate feeding standards for beef cattle in Thailand were not yet clearly defined and very few studies have been conducted so far to measure protein requirements, which perhaps the most important consideration to obtain the best efficiency in production system.

The recommendations on nutrient requirements for beef cattle by the ARC of UK and NRC of USA are commonly referred. Nevertheless, NRC (2000) reported that *Bos indicus* breeds of cattle require about 10% less energy for maintenance than of *Bos taurus* cattle. Tangjitwattanachai et al. (2009) reported efficiency of metabolizable energy requirement for maintenance and growth of *Bos indicus* was higher than *Bos taurus*. However, there is very limit information to clarify the energy and protein requirement of beef cattle in Thailand.

Protein and digestion

Three sources of protein ingredient (vegetable protein, animal protein and nonprotein nitrogen, NPN) have been normally used in Thailand. Protein-rich leguminous forages are widely grown in many areas grazed by ruminants, vegetable protein or animal protein supplements are usually expensive or not available. The manufacture of urea for use as fertilizer has been greatly expanded in Thailand and many countries in Southeast Asia, and these compounds could be used more widely in feeds for ruminants. The ability of the microorganisms in the rumen of cattle to utilize these NPN sources to form true protein, that can be converted to meat and milk by the cattle.

Digestion of dietary protein, like dietary carbohydrates, is fermented by rumen microbes. The majority of true protein, and NPN, entering the rumen is broken down to ammonia, which bacteria require for synthesizing their own body protein. Ammonia is most efficiently incorporated into bacterial protein when the diet is rich in soluble carbohydrates, particularly starch. Ammonia, in excess of that used by the micro-organisms, is absorbed through the rumen wall into the blood, carried to the liver, and converted to urea, the greater part is excreted in the urine. Some urea is returned to the rumen *via* the saliva, and also directly through the rumen wall.

The undegraded true protein fraction, plus the microbial protein, passes from the rumen to the abomasum, where it is digested, and absorbed into the bloodstream through the walls of the small intestine. The metabolizable protein (MP) has been defined as the net quantity of true protein or amino acid absorbed in digestion. In ruminants, MP represents the net quantity of feed and microbial protein that is truly digested in the small intestine.

Two factors concerning rumen metabolism are likely to be important in effects of quantity of feeding on ration digestibility: 1) the effect of feeding on retention time of feed in the rumen, and 2) implications for microbial growth.

Although these effects of feeding on protein degradability seem clear, the general effect of quantity of feeding on fractional rates of outflow of feed particles from the rumen is not well established, although both quantity of feeding and forage content of the ration have pronounced effects on rates of liquid outflow. From a general survey it was concluded that quantity of feeding accounted for only 8% of variability of outflow estimates in cattle (although the simple regression of feed intake on outflow was described as significant).

If we accept the evidence that quantity of feeding reduces degradability of food proteins at higher feeding, there is still need to consider the second factor, the relationship between energy supply and microbial growth in the rumen of beef cattle.

Until recently, few measurements of energetic efficiency of microbial protein synthesis were available for cattle at moderate to high feeding. In view of the importance of quantity of feeding in influencing cattle protein effects on digestion in beef cattle, it is pertinent to confine attention only to those data in cattle at large quantities of feeding. This restricts severely the choice of data; most measurements have been obtained at lower feeding and in sheep, not cows.

Protected protein

Protected protein is the technology to improving the biological efficiency of utilization of protein in ruminant feeds by protection of such protein from substantial degradation in the rumen without markedly reducing the subsequent absorption of the amino acid constituents of the protein in the lower digestive tract. Various methods have been used for protecting proteins from ruminal degradation including the simple application of heat, chemical agents such as formaldehyde, alcohol, bentonites, zinc, tannins and sodium hydroxide have also been used successfully to treat protein as a means of reducing ruminal degradability. All these methods of treatment, including heating, are thought to act either by inhibiting proteolytic activity and/or by modifying protein structure in such a way that the number of protease specific bonds that can be cleaved by microbial enzymes is decreased.

The main types of ingredients used

A number of local protein sources have been used in animal rations. However, soybean meal/cake and fishmeal are the major protein sources used and are mostly imported. Alternative sources of protein material, especially vegetable-based protein sources that might derive from a variety of oilseed meals, protein crops such as soybeans, rice and maize gluten feed. In order to achieve the future goal of lowering imports and costs, alternative sources of competitively priced protein, such as cassava, cassava based products (e.g., cassarea) or other products from different crop origins could have potential and be exploited. Legume trees, other fodder trees and cereals are the main ingredient used (accounting for about half of all ingredients incorporated) and oilmeals are the second most important group of ingredients. Soybean meal and fishmeal dominates the use of proteins source for animal feed in Thailand. No other vegetable protein sources used for cattle (maize gluten feed, rapeseed meal, sunflower meal and pulses).

For cattle feed, *Leucaena* became widespread and popular in local farms. Although in some cases the local or common varieties are considered weeds, in many situations it is an important plant with its improved varieties purposefully introduced for varied uses. No other tree legumes had been given as much attention as *Leucaena.* Most feeding trials, reforestation, agroforestry and soil conservation projects in Thailand made use of or made reference to *Leucaena.*

Oil meals are the second most widely used group of ingredients in animal feed (mainly as a source of protein). Consequently, most protein sources are considered to be largely interchangeable from the point of view of feed manufacturers and hence, price tends to be the key determinant influencing which meals are used. The main reason for the dominance of soybean meal as a protein ingredient is its relatively high protein content of 44–46%. In contrast, legume has a lower protein level (20–30%) and higher fiber content (this means it has a slightly lower level of energy content) relative to soybean meal and maize gluten feed.

Several NPN compounds have been studied as ingredients of cattle feeds. Some of these are urea, urea phosphate, ammonia (anhydrous), and salts such as monoammonium and diammonium phosphate. Urea is most widely used in feeding cattle because it is a cheaper source of NPN. However, ruminants are most sensitive because urease is normally present in the functional rumen after 50 days of age. Dietary exposure of unacclimated ruminants to 0.3–0.5 g of urea/kgBW may cause adverse effects; doses of 1–1.5 g/kgBW are usually lethal.

Nonprotein nitrogen

It can be calculated that pure urea contains 46% of nitrogen compared to 16% for most proteins. Urea could replace 30 to 50% of the protein in rations of cattle. It is now clear that some of animal production resulted from the fact that the rations fed were often too high in true protein to demonstrate a value for the NPN source being tested. Urea-nitrogen fed to ruminants was indeed retained in the body. This demonstration by several groups of workers that young cattle gained body weight much more rapidly, over a substantial period of time, when urea was added to low-protein diets that otherwise would support little or no weight gain, was accepted as strong evidence that the urea was utilized for growth. Subsequently, digestion studies showed that urea supplements sometimes increased the digestibility of cellulose and crude fiber of low-protein rations. Balance studies gave evidence of increased nitrogen retention by animals that gained extra weight with supplemental urea. The *in vitro* fermentation techniques and analyses of rumen ingesta were useful in showing that, as urea or ammonia decreased, true protein content increased in the fermentation medium. Finally chemical and microbiological analyses and the use of tracers removed all doubt that urea nitrogen was, in fact, converted in the rumen into amino acids and true protein which subsequently appeared as tissue- and milk-proteins.

Urea may cause toxicity and even death in ruminants if it is fed inadequately mixed with other feeds or in too large a dose. The toxic signs can easily be recognized. Animals should never be permitted access to urea not mixed with other feeds.

Fertilizer-grade urea usually contains 46% nitrogen (290% crude protein) because smaller amounts of conditioners have been added to prevent lumping. One kilogram of urea plus 6 kg of maize or other grain furnishes the same amount of nitrogen as 7 kg of soybean meal or an equivalent high-protein feed, but it may be lower in energy content since urea adds no useful energy.

The amount of urea included in concentrate mixtures for cattle should not exceed 3% and usually the addition of 1 to 1.5% will prove adequate. In the total ration, the amount of urea should not exceed 1%. At these levels of intake, urea has proved an effective replacement for vegetable proteins in rations for growing and fattening beef cattle. As a supplement to low-protein roughages, mixtures of urea and molasses have usually given results equal to or slightly inferior to vegetable proteins.

Mechanism of urea utilization

When urea from feed sources enters the rumen, it is rapidly dissolved and hydrolyzed to ammonia by bacterial urease. The ammonia can then be utilized by the bacteria for synthesis of amino acids required for their growth. Amino groups are also split from amino acids and from intact proteins and used by bacteria in the same manner. Protein synthesis within the rumen by microorganisms is very closely associated with the activity of these same organisms in breaking down cellulose and other carbohydrate materials and in the formation of organic acids as by-products of this fermentation process. The solubilities of natural proteins vary greatly and thus the rate at which they are hydrolyzed and utilized by bacteria differs appreciably. There is evidence, however, that a fairly high proportion of the more soluable proteins such as casein will be utilized by bacteria in about the same way as the ammonia from urea. For the less soluble proteins, the process of ammonia liberation is much less rapid and fairly large proportions of the protein may pass through the rumen to the abomasum without being broken down. When ammonia is produced too rapidly in the rumen or if the concentration becomes too high, appreciable amounts are absorbed directly into the bloodstream, reconverted to urea in the liver, excreted through the kidneys in the urine and thus lost to the animal. There is, however, always a small amount of urea in the bloodstream and other body fluids. This urea finds its way into the saliva and re-enters the rumen. Urea has been shown to pass into the rumen directly through the rumen wall from the circulating blood.

Applied studies on use of urea

Supplementing low quality roughage

The urea supplementation of low-quality roughage such as rice straw was reported by Wanapat (1999), provided urea supplements, either with molasses in block (urea molasses block) or in pellets with grain and other feeds, to cattle grazing dry pasture in Thailand. In the Northeastern of Thailand, cattle lose body weight during the dry season, urea-molasses supplements during this period can improve biologically significant effect. Urea-molasses supplements are more effective and give economically worthwhile results. The true digestibility of urea nitrogen to be 94%, similar to soybean meal, but the biological value of urea was lower. Urea-fed calves gained only 70% as much as those fed casein. Riggs (1958) reviewed the research to that date on the use of urea in the nutrition of beef cattle. He pointed out that, in most experiments with growing cattle, replacement of 40 to 70% of the supplemental protein by urea lowered weight gains to 82–88% of that obtained with soybean meal, cottonseed meal and similar natural feeds. In some experiments urea has given results equal to protein supplements, but the bulk of the data show urea is slightly inferior. This same generalization is still true, but urea is now widely used in feeds for beef cattle to supply 30% or less of the ration nitrogen because of shortages of vegetable proteins and the lower price of urea nitrogen. For fattening cattle fed high grain rations results have been satisfactory when urea provides 25% of the nitrogen, but at higher levels palatability may become a problem.

Use of other nonprotein nitrogen compounds

Brief mention has already been made of the use of a number of NPN compounds other than urea in the nutrition of ruminants. These compounds included ammonium acetate, bicarbonate, carbamate and lactate, biuret and dicyanodiamide. Although amino acids have also been used, they are generally too expensive for practical use in diets of ruminants. Other NPN compounds studied include various ammonium salts, biuret, and urea phosphate.

Biuret is a condensation product of urea. Berry et al. (1956) reported that biuret was not toxic for sheep and cattle. They found, however, that it depressed the appetite and reduced the gains of both species and that these effects could be overcome by feeding more urea or vegetable protein. Using an *in vitro* fermentation procedure for evaluating various nitrogen sources, Belasco (1954) found that biuret supported only 7% as much cellulose digestion as an equal amount of nitrogen from urea, and he suggested that biuret was not a useful nitrogen source for rumen microorganisms. Biuret is not available commercially so that its utilization has no practical significance at present. It has no nutritional advantage over urea except that it is much less toxic at usual intake levels. Mixtures of urea and biuret might prove more practical than either one alone.

Poultry litter, consisting of the droppings and bedding used to absorb moisture, is high in nitrogen content. This material shows promise as a feed for ruminant animals. Chicken litter is a supplemental nitrogen source as when fed soybean meal and better than when fed ammoniated molasses. The chicken litter contained 4.85% nitrogen (30.3% crude protein), 19.2% of which was uric acid. There was no palatability problem with the feed.

All the NPN compounds have given relatively satisfactory results in feeding tests with ruminants, but none of them was better than urea while most were more expensive. However, one of the problems in using urea as a replacement for protein is its rapid breakdown to ammonia in the rumen. Any ammonia not utilized by the bacteria is absorbed through the rumen wall into the bloodstream and on high N intakes tends to be lost to the animal by excretion in the urine as urea. This loss is thought to explain the low value of urea in some studies as well as its toxic effects. Among the various attempts to overcome this loss of nitrogen has been the reacting of ammonia with feeds low in protein and high in carbohydrates so that the product provides a desirable combination of nitrogen and energy which are available simultaneously for bacterial growth.

Suggested methods of feeding urea and other NPN compounds

Urea in concentrate mixtures

In Thailand most feed-grade urea is mixed into commercially distributed concentrate feeds for growing or lactating dairy cattle or for finishing beef cattle. Concentrate mixtures containing 12 to 16% crude protein, designed for direct feeding to beef cattle, usually contain 1.0 to 2.0% urea to replace an equal amount of nitrogen from oilseed meals or protein-rich by-product feeds. These mixtures usually contain large amounts of cereal grains or by-products rich in starch such cassava meal. When as much as 3% urea has been incorporated into meal mixtures of cereal grains, palatability has sometimes been lower than desirable for high-producing cows, even when 5–7% cane molasses was included. It is important to maintain a high digestible energy content in meal mixtures containing urea in order to ensure a performance similar to that from rations containing only vegetable proteins. Urea is most frequently prepared into a premix or high-protein supplement which may be hand-fed in restricted amounts, in addition to other concentrate feeds, or mixed with cereals.

Energy and protein relationships of rumen microbe

The summary in the ARC (1980) and AFRC (1993) recommendation, reported that energy supply is normally the first limiting factor on microbial protein synthesis. Because microbial growth is dependent on the supply of fermentable carbohydrate, the end-products of protein metabolism are influenced by the availability of carbohydrate. When ATP (primarily from carbohydrate fermentation) is available, amino acids entering the microbes can be incorporated into microbial protein (Nocek and Russell, 1988). Energy available and proteins affect both total fermentation and production of microbial DM per unit of carbohydrate fermented (Hoover and Stokes, 1991; Van Soest, 1994; Chumpawadee, 2006).

However, if ATP (carbohydrate or energy available) is not sufficient to drive protein synthesis, amino acids will be fermented as an energy source and ammonia will accumulate (ARC, 1980; Nocek and Russell, 1988; Ørskov, 1992). In addition, if there is a deficiency or inefficient utilization of CP, the digestibility of carbohydrate can decrease. If there is insufficient carbohydrate to match protein, nitrogen can be lost as ruminal ammonia (Nocek and Russell, 1988; Van Soest, 1994). Recently, synchronizing for rapid fermentation with fast degradable starch and protein source stimulate greater synthesis or efficiency of synthesis of microbial crude protein (Sinclair et al., 1993; Chumpawadee, 2006; Seo et al., 2008).

Estimation of rumen microbial protein production

Under-nutrition due to inadequate or fluctuating nutrient supply is a major constraint to animal production in developing countries. Poor nutrition results in low rates of reproduction and production as well as increased susceptibility of livestock to disease. The smallholder farmers in developing countries have limited resources available for feeding their ruminant livestock. Unlike those in developed countries, they are unable to select their basal diet according to requirement for production. The strategy for improving production has therefore been to maximize the efficiency of utilization of the available feed resources in the rumen by providing optimum conditions for microbial growth, and then by supplementation to provide dietary nutrients to complement and balance the products of digestion to requirement. Microbial cells formed as a result of rumen digestion of carbohydrates under anaerobic conditions are a major source of protein for ruminants. They provide the majority of the amino acids that the host animal requires for tissue maintenance, growth and production. In roughage-fed ruminants, microorganisms are virtually the only source of protein. Therefore, the knowledge of the microbial contribution to the nutrition of the host animal is paramount to developing feed supplementation strategies for improving ruminant production. While this factor has been recognized for many years, it has been extremely difficult to determine the microbial protein contribution to ruminant nutrition (IAEA, 1997). The rumen microbes seem to be effected by diet (Perez et al., 1996; Martin Orue et al., 1999). Many techniques were used for determining microbial protein production. The amount of rumen microbial protein supply to the host animal is most commonly expressed as grams nitrogen per day (gN/d) or grams nitrogen per kg digestible organic matter apparently fermented in the rumen (DOMR) (Rode et al., 1985). Results from numerous studies indicate that approximately 16.9 g microbial CP are synthesized per 100 g DOMR, with values ranging from 6.3 to 30.7 (Stern and Hoover, 1979) or 14 to 49 g microbial N/kg DOMR (ARC, 1984). IAEA (1997) suggested that the microbial N yield was 32 g/kg DOMR. Pimpa (2002) reported that the relationship between rumen microbial nitrogen and digestible organic matter intake (DOMI) were 66.4 gN/kgDOMI for Zebu and buffaloes. The rumen microbial protein production during 5 days fasting period of native cattle was 29.99 gN/d (Pimpa, 2002). Chantiratikul (2004) reported that the microbial N supply to duodenum of dairy heifer was decreased linearly when alfalfa hay was substituted with kenaf in diet from 62.18 to 40.97 gN/d or 16.18 to 12.98 gN/kgDOMR. Ngamsaeng et al. (2006) reported that the mangosteen peel supplementation at 0, 50, 100 and 150 gDM/d was effected to rumen microbial protein synthesis of beef cattle. The rumen microbial protein was increased from 11.9 to 17.9 gN/d or 5.0 to 7.3 gN/kgDOMR. The microbial protein in rumen was enriched by lemongrass supplementation in diet of beef cattle. The microbial protein was highest (57.5 gN/d or 34.2 gN/kgDOMR) at 100 g/day lemongrass supplementation (Wanapat et al., 2008).

Energy and protein interrelationship in ruminants

The relationship between protein and energy supply on protein deposition has been described as protein and energy-dependent phases of growth (Geay, 1984; Oldham, 1984; Schroeder and Titgemeyer, 2008). Brown et al. (2005) reported that increase energy and protein intake can increase the rate of body growth of heifer calves and potentially reduce rearing costs. Gabler and Heinrichs (2003) also reported that linear effects in feed efficiency and some structural growth measurements demonstrate positive results when feeding CP:ME ration > 48.3 in Holstein heifers.

Lammers and Heinrichs (2000) suggested that feeding dietary high ratios of protein to energy above NRC recommendations improved feed efficiency (6%), increased ADG (9%) and increased structural growth (12–18%) compared with feeding dietary low ratios of protein to energy of heifers. Bartlett et al. (2006) reported that heifers fed increasing amounts of protein at higher levels of energy intake the potential for protein deposition was greater, resulting in linear increases in protein retention in response to all the amounts of protein intake evaluated. Schroeder et al. (2007) suggested that the increase energy and protein intake can improve feed efficiency and efficiency of amino acid for protein deposition, which result in increased structural growth and the growth rate.

These types of relationships, and the assumptions derived from them, have been the conceptual basis of many simulation models for estimating nutrient requirements for ruminant animals (Gabler and Heinrichs, 2003; Brown et al., 2005; Schroeder et al., 2007). However, the experimental evidence that supports this type of interaction between protein and energy supply is much less (and is more inconsistent) information from actual growing ruminants.

Protein requirement in tropical beef cattle

Tangjitwattanachai and Sommart (2009) was developed a database including 130 observations from 12 feeding trial of Thai native, Brahman and Brahman crossbred cattle in Thailand. They were constructed and analyzed to determine crude protein requirements for maintenance and for gain (24 observations of Thai native, 73 observations of Brahman and 33 observations of Brahman crossbred) using mixed linear model (SAS, 1999) by regressing average daily gain (g/kgBW$^{0.75}$) against crude protein intake (g/kgBW$^{0.75}$) according to St-Pierre (2001).

Performance of derived prediction equation was tested by calculating predicted values for each data using the prediction models and comparing those to the actual values. Degree of over or under prediction was expressed as mean proportion bias (%) which was calculated as the slope of the regression of actual on predicted values at zero intercept according to Mandal et al. (2005) and accuracy of prediction was analyzed using mean prediction error. Model prediction was evaluated for accuracy by paired *t*-test of actual and predicted values. A non-significant ($P > 0.05$) paired *t*-test between actual and predicted values indicated good match between values calculated using the derived prediction model and actual values (Paul et al., 2003).

Protein requirements for maintenance were estimated from linear regression of average daily gain (g/kgBW$^{0.75}$) against crude protein intake (g/kgBW$^{0.75}$). The results are shown graphically in Figure 5.1, 5.2 and 5.3. Protein requirement for maintenance calculated as the protein intake at which average daily gain equal zero, was 5.03 gCP/kgBW$^{0.75}$/d (in Thai native), 4.52 gCP/kgBW$^{0.75}$/d (in Brahman) and 5.47 gCP/kgBW$^{0.75}$/d (in Brahman crossbred), which was lower than requirements for maintenance of European cattle (Hereford × Angus) reported by Wilkerson et al. (1993) (5.94 gCP/kgBW$^{0.75}$/d). Protein requirements for maintenance of Thai native and Brahman crossbred was similar to Kearl (1982) who reported that (beef cattle 150–300 kg) required 5.35–5.38 gCP/kgBW$^{0.75}$/d. Protein requirements of Brahman was slightly lower than beef cattle which recommended by NRC (1976) approximately 7.5–8.0%. The estimated protein requirement for 100 g/kgBW$^{0.75}$ gain (CP_g) of Thai native, Brahman and Brahman crossbred cattle were 38, 56 and 59 gCP/kgBW$^{0.75}$/d, respectively.

Paengkoum (2010b) also studied extensively of protein requirements in male Thai native cattle (BW of 104 ± 10.3 kg) fed with Pangola grass hay as roughage, and calculated as the nitrogen intake at which nitrogen retention equal zero (maintenance) was 0.662 gN/kgBW$^{0.75}$ or 4.14 gCP/kgBW$^{0.75}$. Prediction equation N retention (g/kgBW$^{0.75}$) with relation to N intake (g/kgBW$^{0.75}$) was: N retention = 0.930 N intake − 0.616 (R^2 = 0.993, SE = 0.056, P < 0.001, n = 8). In addition, protein requirements of male Thai native cattle (BW of 125 ± 4.9 kg) fed with rice straw as roughage, calculated as the protein intake at which average daily gain equal zero (maintenance) was 4.22 gCP/kgBW$^{0.75}$. Prediction equation CP intake (gCP/kgBW$^{0.75}$) with relation to average daily gain (ADG, g/kgBW$^{0.75}$) was: CP intake = 0.409ADG + 4.22 (R^2 = 0.883, SE = 0.624, P < 0.01, n = 18). (Paengkoum, 2010a). This value was similar to Senarath et al. (2009) who reported that yearling Thai native cattle required CP for maintenance 4.36 gCP/kgBW$^{0.75}$. This value is lower than the NRC recommendation (5.3 gCP/kgBW$^{0.75}$), and was lower than Tangjitwattanachai and Sommart (2009) (5.03 gCP/kgBW$^{0.75}$), and Wilkerson et al. (1993) (5.94 gCP/kgBW$^{0.75}$) and Kearl (1982) (in beef cattle 150–300 kg required 5.35–5.38 gCP/kgBW$^{0.75}$), respectively.

The requirement of protein for crossbred Brahman heifers with average body weight of 350–450 kg with total mixed ration with rice straw as roughage, calculated as nitrogen intake at which nitrogen retention equal zero (maintenance) was 0.47gN/kgBW$^{0.75}$ or 2.94 gCP/kgBW$^{0.75}$. The prediction equation for average daily gain (gN/kgBW$^{0.75}$) was 12.909 N intake − 6.068 (R^2 = 0.538, P = 0.032, n =16) (Yuangklang, 2010).

Based on a study of Tangjitwattanachai and Sommart (2009), the accuracy of equations was evaluated by paired *t*-test between actual and predicted values. A paired *t*-test between actual and predicted values was non-significant (P > 0.05). The results indicated that calculated crude protein intake values using the derived prediction equation were matched well with the actual values. The mean proportional bias was ranged from 1.11–3.95% and mean prediction error was ranged from 0.08–0.33 indicated adequate accuracy of prediction across the studies in database.

They was suggested the estimates of protein requirement of beef cattle under feeding conditions in Thailand that protein requirement for maintenance of Thai native cattle was 5.03 gCP/kgBW$^{0.75}$/d while that of Brahman and Brahman crossbred were 4.52 gCP/kgBW$^{0.75}$/d and 5.47 gCP/kgBW$^{0.75}$/d, respectively. Requirements for 100 g/kgBW$^{0.75}$ gain (CP_g) of Thai native, Brahman and Brahman crossbred cattle were 38, 56 and 59 gCP/kgBW$^{0.75}$/d, respectively. This research indicated that protein requirements for maintenance of Brahman was lower than that Thai native and Brahman crossbred cattle approximately 10.14% and 17.37%, respectively. The equations estimation of protein requirement proposed

by Tangjitwattanachai and Sommart (2009) are as follows (see also Figure 5.1, 5.2 and 5.3, respectively);
Thai native cattle;

CPI = 0.38 ADG + 5.03 (n = 24, R^2 = 0.84, RSD = 0.04, $P < 0.001$) [equation 5.1]

Brahman;

CPI = 0.56 ADG + 4.52 (n = 73, R^2 = 0.50, RSD = 0.33, $P < 0.001$) [equation 5.2]

Brahman crossbred;

CPI = 0.59 ADG + 5.47 (n = 33, R^2 = 0.70, RSD = 0.04, $P < 0.001$) [equation 5.3]

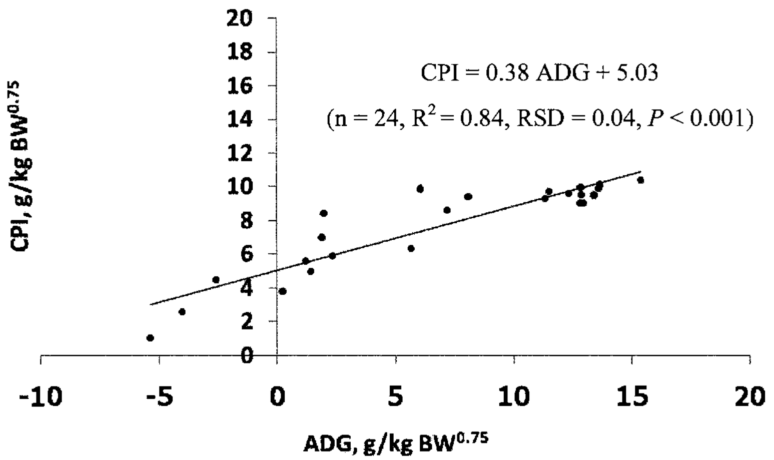

Figure 5.1 Relationship between crude protein intake (CPI, g/kgBW$^{0.75}$) and average daily gain (ADG, g/kgBW$^{0.75}$) for Thai native cattle describes equation: CPI = $5.03_{(SE=0.34)} + (0.38)_{(SE=0.04)}$ADG (n = 24, R^2 = 0.83, RSD = 0.23, $P < 0.001$).

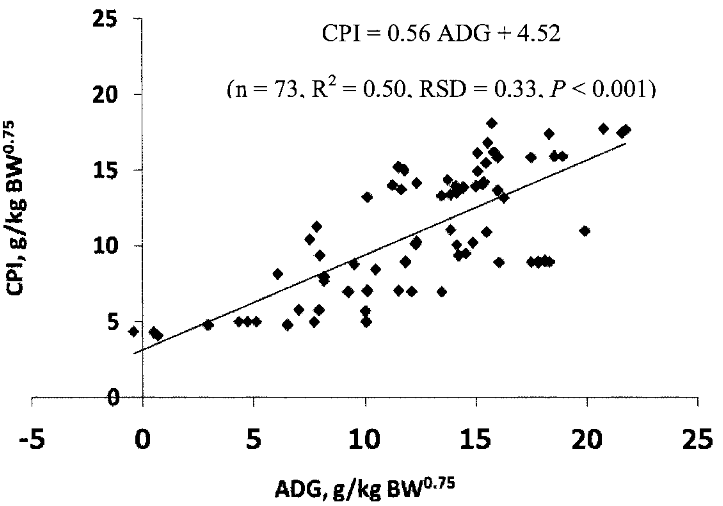

Figure 5.2. Relationship between crude protein intake (CPI, g/kgBW$^{0.75}$) and average daily gain (ADG, g/kgBW$^{0.75}$) for Brahman cattle describes equation: CPI = $4.52_{(SE=1.11)} + (0.56)_{(SE=0.44)}$ADG (n = 73, R^2 = 0.50, RSD = 0.33, $P < 0.001$).

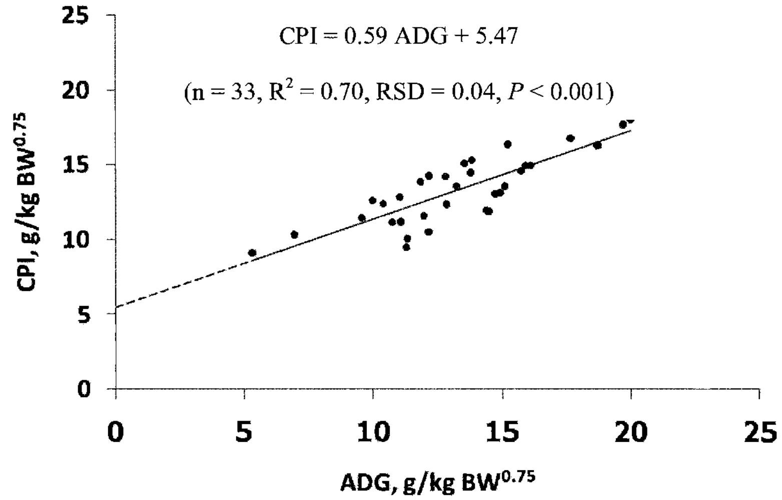

Figure 5.3 Relationship between crude protein intake (CPI, g/kgBW$^{0.75}$) and average daily gain (ADG, g/kgBW$^{0.75}$) for Brahman crossbred cattle describes equation: CPI = $5.47_{(SE=0.83)}$ + $(0.59)_{(SE=0.08)}$ ADG (n = 33, R^2 = 0.70, RSD = 0.22, $P < 0.001$).

Conclusion

The present study provides estimates of protein requirement of beef cattle under feeding conditions. The results showed that protein requirement for maintenance of Thai native cattle was 5.03 gCP/kgBW$^{0.75}$/d while that of Brahman and Brahman crossbred were 4.52 gCP/kgBW$^{0.75}$/d and 5.47 gCP/kgBW$^{0.75}$/d, respectively. Requirements for 100 g/kgBW$^{0.75}$ gain (CP_g) of Thai native, Brahman and Brahman crossbred cattle were 38, 56 and 59 gCP/ kgBW$^{0.75}$/d, respectively. The result indicated that protein requirements for maintenance of Brahman was lower than that Thai native and Brahman crossbred cattle approximately 10.14% and 17.37%, respectively.

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Chapter 6 Minerals

Introduction

Beside the other macronutrients such as protein, carbohydrates and lipids, minerals have been shown to be necessarily required by animals. Minerals can be divided as to animal requirement and concentration in their body. Underwood (1981) described that minerals can be divided into two groups: major and micro minerals. Table 6.1, 6.2 and 6.3 are shown the important of metalloenzymes in livestock, mineral requirement for beef cattle and sources and availability of minerals.

Functions of minerals

1. Structure: minerals have been known to form structural components of body organs and tissues, exemplified by minerals such as calcium, phosphorus, magnesium, fluorine and silicon in bones and teeth. Minerals such as zinc and phosphorus have been demonstrated to contribute structural stability to molecules and membranes of which they are part.

2. Physiological: minerals occur in body fluids and tissues as electrolytes, concerned with the maintenance of osmotic pressure, acid-base balance, membrane permeability and tissue irritability, sodium, potassium, chloride, calcium and magnesium in blood, cerebrospinal fluid and gastric juice provide examples of such functions.

3. Catalytic: minerals act as catalysts in enzymes and hormone systems, as integral and specific components of the structure of metalloenzymes or as less specific activators within those systems (Table 6.1).

4. Regulatory: Minerals have been found to regulate cell replication and differentiation.

Macro minerals

Macro minerals are required in greater quantities and presented in the animal tissues at higher levels including calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), sodium (Na), chlorine (Cl) and sulphur (S).

Calcium (Ca)

Calcium is the most abundant minerals in the body which retains in the bones and teeth at approximately 99% and the rest (1%) is founded in blood and soft tissues. Calcium is mainly absorbed at duodenum by active and passive transports. Calcium is mostly excreted from the body through feces and there is small amount of calcium excretion in urine and sweat.

The normal concentration of calcium in blood is 8–10 mg/100 mL. At parturition, milk fever is frequently occurred owing to the low concentration of calcium in blood. Rickets is a deficient of calcium in young animals and in mature animals is so called osteomalacia.

Phosphorus (P)

Phosphorus is generally founded in whole body especially in bone and teeth accounted for 80% of whole phosphorus in the body. Phosphorus is absorbed at duodenum by active and passive transports. Phosphorus is necessarily important for microbial activity in rumen especially fiber digester bacteria (Komisarczuk et al., 1987). Pica is a phenomenon of phosphorus deficiency. Phosphorus in blood is range between 6.0–8.0 mg/100 mL (McDowell, 1992).

Magnesium (Mg)

Magnesium is required for all animals for normal skeletal development as a component of bone. Mg is required for ATP synthesis. Mg is founded in body at approximately 0.5% of body weight. Grass tetany, Mg tetany, wheat pasture poisoning is a syndrome of grazing animals in periods of lush growth. The symptoms of tetany have been ascribed to hypomagnesaemia (low blood Mg) (Church and Pond, 1974). Hypomagnesaemia causes tremendous productive loss due to low Mg absorption. The normal range of serum Mg is 1.8–3.2 mg/100 mL.

Magnesium is founded in leaves of green plant, rice bran, milk, animal meat, liver, egg yolk, yeast, cottonseed meal and linseed. Typically, magnesium in animal diets is supplemented in form of magnesium oxide and magnesium sulfate.

Potassium (K)

Potassium is the third abundant minerals in animal tissues and potassium plays a vital role in maintaining osmotic pressure in the extracellular and intracellular fluids, nerve impulse conduction, acid-base balance, and enzymatic reactions and amino acid absorption.

The low serum potassium concentration, so called hypokalemia, may be caused by malnutrition, negative nitrogen balance, gastrointestinal losses, and endocrine malfunction (NRC, 1984). Forages are high in potassium.

Sodium (Na)

Sodium is primarily seen in extracellular fluid, soft tissues and bones (Kearl, 1982). Sodium plays an important role in acid-base balance, osmotic pressure, neutral functions, and metabolic activities. Sodium is mainly absorbed from the proximal portion of small intestine. Sodium concentration in plasma is 140 mEq/L. Cattle raised in the tropical region are required sodium in higher level than those cattle in temperate region. Generally, feedstuffs used in the ration for beef cattle are insufficient sodium to meet animal requirement. Sodium chlorine is typically used in the ration.

Chlorine (Cl)

Chlorine is generally associated with sodium, and the chlorine requirement is frequently assumed to be satisfied of sodium is adequate. Chlorine is the major anion of extracellular fluid. It functions in maintaining the acid-base equilibrium, osmotic pressure, and oxygen and carbon dioxide transportation. Chlorine is absorbed in the proximal portion of small intestine. Generally, feedstuffs used in the ration for beef cattle are insufficient chlorine to meet animal requirement. Sodium chloride is typically used in the ration.

Sulphur (S)

Sulphur is required by animals mainly as a component of organic compounds such as sulphur containing amino acids (methionine, cysteine, and cystine), the vitamins biotin and thiamin, glutathione and coenzyme A. The total body content of sulphur is approximately 0.15% (NRC, 1984). The sign of sulphur deficiency include reduced appetite, weight loss, weakness, excessive salivation, watery eyes, dullness, emaciation and death. The lack of sulphur can be checked by the serum sulphur concentration. When non-protein nitrogen is used in the ration, sulphur should be added to satisfy the microbial activity in the rumen. Source of sulphur can be founded in high protein feedstuffs.

Micro minerals

Micro minerals are required in small amount and presented in the animal tissues at lower levels including manganese (Mn), iodine (I), iron (Fe), copper (Cu), zinc (Zn), cobalt (Co), molybdenum (Mo), selenium (Se) and chromium (Cr).

Iron (Fe)

Iron is an essential component of hemoglobin, myoglobin, cytochromes. The iron requirements of mature animals are lower than young animals. Lack of iron in animal shows anorexia, retard growth and anemia. In veal calf production, iron is rather rare to induce white meat (pink meat). The concentration of iron in grasses and legumes are generally less available than in supplemental iron sources.

Copper (Cu)

Copper is necessary for hemoglobin formation, iron absorption from the small intestine. Ceruloplasmin, which is synthesized in the liver and contains copper, is necessary for the oxidation of iron, permitting it to bind with the iron transport protein, transferrin. The normal blood copper levels range from 70 to 170 μg/100 mL in most ruminants. Copper is absorbed from the upper portion of the duodenum. Copper excretion is an active process in which copper is released into bile and ultimately into feces. Grains are generally lower in copper than forages.

Zinc (Zn)

Zinc is found in high concentrations in soft tissues such as the pancreas, liver, pituitary gland, kidney, and adrenal gland. The normal range of plasma zinc is 80 to 120 μg per 100 mL (NRC, 1984). The absorption of zinc occurs primarily from the abomasum and lower small intestine. Feces is the primary route of zinc excretion. Zinc requirement of cattle is suggested to be between 20 and 40 mg/kg diet dry matter. The source of zinc is grass, legumes, plant protein and animal protein. Inorganic zinc such as zinc sulphate, zinc acetate, zinc carbonate and zinc chloride are usually used in the ration.

Manganese (Mn)

Manganese is essential for animals. Deficiencies of manganese lead to degenerative reproductive failure in both male and female, bone malformations and crippling, ataxia, depigmentation, and deterioration of the central nervous system. Manganese is found in low concentrations in all tissues. In general, forages contain higher levels of manganese than grains such as corn, oats, and barley.

Molybdenum (Mo)

Molybdenum is found in nearly all body cell, and fluids, but its essentially is due to its biochemical role in the enzymes xanthine oxidase, aldehyde oxidase, and sulfide oxidase. The absorption of molybdenum is in small intestine and the excretion route of molybdenum is primarily via urine. The supplementation of molybdenum is in the form of sodium or ammonium molybdate.

Selenium (Se)

Selenium is similar to sulphur in its chemical properties. Enzyme containing selenium such as glutathione peroxidase has been known to prevent membrane damage because its antioxidant property (NRC, 1984). The duodenum is the primary site of selenium absorption. Feces is the main route of selenium excretion. Selenium has been exclusively studied with vitamin E. Selenium can be reduced with vitamin E supplementation. White muscle disease, a selenium-resposive myopathy, is characterized by white muscle, heart failure, and paralysis (lameness, to an inability to stand) (Whanger et al., 1976). Selenium requirement is approximately 0.1 to 0.3 ppm.

Cobalt (Co)

Cobalt is a dietary essential for cattle because it is necessary for the synthesis by the gastrointestinal microbes of vitamin B12, which is used by both animal tissues and microorganisms. About 43% of body cobalt is stored in muscle, and approximately 14% is in bone (Underwood, 1977). The absorbed site of cobalt is a proximal portion of small intestine.

Iodine (I)

Iodine is present in most cells of the body. Inorganic iodine is taken up by the thyroid gland for the synthesis of thyroid hormones. Thyroid hormones have an active role in thermoregulation, intermediary metabolism, reproduction, growth and development, circulation and muscle function. Rumen is the main site of iodine absorption. The level of urinary iodine is positively correlated with plasma iodine concentration and dietary intake. Diet containing iodine in excess of 50 ppm depressed growth rate and feed intake. Source of iodine is iodized salt.

Chromium (Cr)

Chromium has been reported to be an essential nutrient for normal glucose metabolism with it potentiates insulin action (Lukaski, 1999; Kegley et al., 2000). The dietary requirement of cattle for chromium has not been defined but appears to be increased by stress. Strenuous exercise, transportation and infection may increase the dietary requirement by increasing the losses of chromium in urine. Furthermore, addition of organic trivalent chromium in the diet has generally improved appetite, early weight gain and humoral immune function in recently transported, vaccine calves (Underwood and Suttle, 1999). However, many different factors (including dietary protein level) influence or modulate the effectiveness of dietary chromium supplementation in ruminant diets. These factors needed to be addressed before recommendation can be made to the member of the feed industry and livestock producers (Gentry et al., 1999).

Table 6.1 Some important metalloenzymes in livestock

Metal	Enzyme	Function
Fe	Ferredoxine	Photosynthesis
	Succinate dehydrogenase	Aerobic oxidation
	Cytochromes	Electron transfer
	Catalase	Protection against H_2O_2
Cu	Cytochrome oxidase	Terminal oxidase
	Lysyl oxidase	Lysine oxidation
	Ceruloplasmin	Iron utilization
	Superoxide dismutase	Elimination of free radicals
Zn	Carbonic anhydrase	CO_2 formation
	Alcohol dehydrogenase	Alcohol breakdown
	Carboxypeptidase	Protein digestion
	RNA and DNA polymerase	Formation of nucleic acids
Mn	Pyruvate carboxylase	Pyruvate metabolism
	Superoxide dismutase	Elimination of free radicals
Mo	Xanthine oxidase	Purine metabolism
	Sulphite oxidase	Sulphite oxidation
Se	Glutathion peroxidase	Removal of H_2O_2

Source: Underwood (1981)

Mineral requirements

Mineral requirements of beef cattle are determined largely by the age of animal, then physiological condition (pregnancy and lactation) and by the type and level of productivity. Losses caused by the growth and mineralization of tissues (in growing animals), fetus formation (in pregnant animals), milk synthesis (in lactating animals), as well as the inevitable loss involved in the metabolic processes must be systematically replenished by minerals in feedstuffs and in water; they are infect, the yardstick of the animal's requirements of macro and micro minerals (Annenkov, 1982).

The requirements of cattle for minerals can be expressed in several ways: in amounts per day on per unit of product, such as milk or weight gain; in proportion, e.g. percentage, parts per million (ppm), mass/mass (e.g., mg/kg) on moles (sometimes micro- on millimoles)/ kg DM of the whole diet (Underwood and Suttle, 1999). Table 2 shows mineral requirements for beef cattle reported by NRC (2000), mineral requirements for beef cattle in Indochinese Peninsula are not listed because research data are inadequate to determine requirement.

Table 6.2 Mineral requirement for beef cattle

Minerals	Yearling -Mature	Beef Cows	
		Pregnant	Early-lactation
Calcium, %	0.31	0.18	0.27
Phosphorus, %	0.27	0.18	0.27
Magnesium, %	0.10	0.12	0.20
Potassium, %	0.60	0.60	0.70
Sodium, %	0.07	0.07	0.10
Sulphur, %	0.15	0.15	0.15
Cobalt, mg/kg	0.10	0.10	0.10
Copper, mg/kg	10.00	10.00	10.00
Iodine, mg/kg	0.50	0.50	0.50
Iron, mg/kg	50.00	50.00	50.00
Manganese, mg/kg	20.00	20.00	20.00
Selenium, mg/kg	0.10	0.10	0.10
Zinc, mg/kg	30.00	30.00	30.00

Source: NRC (2000)

Biological availability of mineral source

Efficient production and the maintenance of normal health in cattle require that minerals be provided in appropriate amounts and in forms that are biologically utilizable. Degree of bioavailability influences not only dietary requirement but also tolerance of a mineral. Thus, it is important to know the bioavailability of mineral in both common feed ingredients and dietary supplements that may be used in animal feeding. The bioavailability and percentage of mineral elements in some source commonly used in mineral supplements are show in Table 3. These variations must be taken into consideration when evaluating on formulating a mineral supplement (McDowell, 1992).

Table 6.3 Sources and availability of minerals

Minerals	Sources	%	Availability
Calcium	monocalcium phosphate	16.2	high
	dicalcium phosphate	23.2	high
	ground limestone	38.5	medium
	calcium carbonate	40.0	medium
Phosphorus	dicalcium phosphate	18.5	medium
	calcium phosphate	18.6–21	high
	phosphoric acid	23–25	high
	steamed bone meal	12.6	high
Magnesium	magnesium carbonate	21–28	high
	magnesium chloride	12.0	high
	magnesium sulfate	9.8–17	high
Potassium	potassium chloride	50.0	high
	potassium sulfate	41.0	high
Cobalt	cobalt carbonate	46–55	–
	cobalt sulfate	21.0	–
	cupric sulfate	25.0	high
Copper	cupric carbonate	53.0	medium
	cupric chloride	37.2	high
	cupric oxide	80.0	low
Iodine	calcium iodate	63.5	high
	potassium iodide	69.0	high
	cuprous iodide	66.6	high
Iron	ferrous carbonate	36–42	low
	ferrous sulfate	20–30	high
Manganese	manganous sulfate	27.0	high
	manganous oxide	52–62	high
Selenium	sodium selenite	40.0	high
	sodium selenate	45.6	high
Sulphur	calcium sulfate	12–20	low
	potassium sulfate	28.0	high
	calcium sulfate	12–20	low
	potassium sulfate	28.0	high
	sodium sulfate	10.0	medium
Zinc	zinc carbonate	52.0	high
	zinc chloride	48.0	medium
	zinc sulfate	22–36	high
	zinc oxide	46–73	high

Source: McDowell (1992)

Chelated and organic Minerals

In ruminants, chelated minerals have been used to improve rumen fermentation and nutrient digestion. In present circumstance, there are some minerals are marketed in chelated form, for examples zinc, iron, manganese, cobalt and copper. The objectives of utilization of chelated minerals are to improve their availability and performances. In the trial of Nockels et al. (1993) who reported that copper lysine was more available than copper sulfate. However, Wittenberg et al. (1990) found no difference in the availability of Cu from Cu proteinate and copper sulfate in steers fed high-Mo diets. Supplementations of chelated minerals in ruminants have been shown inconsistent results which it needs further investigations.

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Chapter 7 Vitamins

Introduction and importance of vitamins

Vitamins are carbon-containing organic substances. Vitamins are required among dietary nutrients fed to ruminants and are required in adequate amounts to enable animals to efficiently utilize other nutrients. Many metabolic processes are initiated and controlled by specific vitamins during various stages of life. Ruminants can synthesize some vitamins by microorganisms in the rumen.

Functions of vitamins

Vitamins are related to carbohydrates, lipids and protein metabolism in the body. Vitamins are essential for normal growth and production. Ruminants may become vitamin deficient in confined feeding situations and when increased levels of production increase metabolic requirements for vitamins. Then growth and production are reduced and risk of diseases increased.

Requirement

Determining optimal vitamin concentrations depends on age, breed, environment and other factors such as production and facilitates management. A young calf does not have a fully functional rumen or active microorganisms and cannot synthesize vitamins. Rumen microorganisms can produce the water soluble vitamins and vitamin K in adult cattle and therefore the requirement of vitamins for adult beef cattle are only vitamin A, D and E.

Classifies of vitamins

Vitamins can be divided into two major groups;
1) Fat soluble vitamins are Vitamin A, D, E and K
2) Water soluble vitamins are Vitamin B-complex and C

Fat soluble vitamins

Vitamin A

Vitamin A is the most important vitamin than any other for ruminants, because it cannot be produced. If ruminants eat low quality feed with no green color there will be high risk of suffering vitamin A deficiency.

Vitamin A is colorless to a light yellow crystal form. In animals, the only tissue in the body which is a source of vitamin A is the liver. In plants there are pigments called "carotenoids" which are able to transform to vitamin A. The most important pigment is beta carotene, which can oxidize to 2 molecule of vitamin A and when absorbed has half the efficiency of vitamin A of same weight.

The functions of vitamin A relate to sight, establishment and stability of bone, and the function of epithelial tissue in organs such as eye, respiration system, digestion system, nervous system, reproductive and excretion system and also the glucolysis process.

The requirements of vitamin A in classes of beef cattle are presented in Table 7.1. The amounts for fattening cattle are 2,200 IU/kg of feed, 2,800 IU/kg of feed for pregnant heifers and 3,900 IU/kg of feed for milking cattle and bulls (Guibert and Hart, 1935; Jones et al., 1938; Guibert et al., 1940; Madsen et al., 1948; Church et al., 1956; Chapman et al., 1964; Cullison and Ward, 1965; Perry et al., 1965, 1968; Kohlmeier and Burroughs, 1970; Meacham et al., 1970; Kirk et al., 1971; NRC, 1996). The vitamin A requirement in beef cattle also relates to other factors such as species and breed of cattle, feed and stress conditions. For example, it is recommended that cattle kept on corn silage as the main roughage be injected with 1.0 million IU of vitamin A intramuscularly every 28 days. Injection of 0.5−1.0 million IU of vitamin A for stress condition cattle into muscles or rumen, or added to 50,000 IU per head per day in feed or water 2–3 times/week is recommended. However the injection method is better than adding to feed or water (Perry et al., 1967).

Most deficiencies occur in calves, especially newborn calves, from cows receiving insufficient vitamin A for herself and the fetus which is also lower in vitamin A than normal while pregnant, then continuing on to feed colostrum. These calves present symptoms of vitamin A deficiency, although calves born to cows that received enough vitamin A but whose calves received low vitamin A from feed or milk can also suffer vitamin A deficiency symptoms.

One of the first easily detected signs of vitamin A deficiency in cattle is night blindness. Other signs are loss of appetite, diarrhea, rough hair coat, dull eyes, slow weight gains and reduced feed efficiency. Steers can also suffer from vitamin A deficiencies when fed silage for too long, even though they receive enough carotene. In mature cattle however, it is not likely to occur. In cows there may be decreased reproductive performance, shortened gestation and retained placenta. Some cases of abortion, calf weakness, and high mortality can occur. In bulls, there can be decreased reproductive performance and more abnormal sperm.

Usually beef cattle grazed in pasture or fed good quality roughage are not deficient but cattle kept in a yard all the time and fed to high concentrate can be deficient and it is therefore necessary to supply vitamin A to these animals.

Vitamin D

There are several forms of vitamin D but two forms are important to animal nutrition; Vitamin D_2 (Ergocalciferol) and Vitamin D_3 (Cholecalciferol). Ergosterol, a sterol in green plants and microorganisms, is converted to vitamin D_2 when the plant is harvested and cured in sunlight. A sterol in the skin of animals, 7–dehydrocholesterol, is converted to vitamin D_3 by ultraviolet rays of sunlight. Milk is low in vitamin D, except for colostrum, which has more than 6 times that of milk. Plants are also low in vitamin D, except sun-dried hay.

Vitamin D is required for Ca and P absorption for normal mineralization of bone. Therefore vitamin D is important to growth of bone and young animals. The vitamin D requirement of beef cattle is 275 IU/kg of diet (Table 7.1) (NRC, 2000). Experiments with calves indicate a requirement of approximately 300 IU of vitamin D.

The most clearly defined sign of vitamin D deficiency in calves is rickets and in mature cows is osteomalacia. However, animals kept outdoors in tropics receive adequate vitamin D from exposure to direct sunlight and deficiency of vitamin D usually does not occur.

Table 7.1 Requirement of vitamin A, D and E in beef cattle (NRC, 2000)

Vitamins	Growing Finishing	Stressed Calves	Dry, Gestation cows	Lactating cows
	IU/kg			
Vitamin A	2,200	4,000–6,000	2,800	3,900
Vitamin D	275	275	275	275
Vitamin E**	15–60	75–100	–	–

**Vitamin E requirements depend upon concentrations of antioxidants, sulfur-containing amino acids, and selenium in the diet.

Vitamin E

Vitamin E is present in several forms;

1) Tocopherols are alpha, gamma, beta and sigma tocopherol

2) Tocotrienols are alpha, gamma, beta and sigma tocotrienol

Vitamin E activity is present in several tocopherols that occur in nature as high molecular weight alcohols, but alpha-tocopherol is the principal one with any significant biological value and is added to feed. Sources of vitamin E in nature are green plants or oil plants. Young plants contain more than older plants and leaf 20–30 times more than stem. Hay dried by sunlight contains less vitamin E than oven-dried hay or silage.

Vitamin E functions as an antioxidant that prevents oxidation of fats (unsaturated fatty acids) and indirectly reduces oxidation of oxymyoglobin. In addition, vitamin E is a coenzyme in hydrogen transferring systems (hydrogen donor). Vitamin E is important for reproductive performance such as fertility of sperm, estrus and conception rate. It also prevents oxidation of vitamin A. The vitamin E requirement of calves is between 15 to 60 IU/kg of diet (NRC, 2000).

Vitamin E deficiency is found in young animals more than mature animals. Signs of deficiency in young calves are characteristic by white muscle disease; they include general muscular dystrophy, weak leg muscles, crossover walking, impaired suckling ability caused by dystrophy of tongue muscles, heart failure, paralysis and hepatic necrosis. The conditions often respond to either vitamin E or selenium supplementation. Both may be needed in some instances.

Vitamin K

The term vitamin K is used to describe a group of quinine fat soluble compounds. Two major natural sources of vitamin K are the phylloquinones (vitamin K_1) found in plants and multiprenylmenoquinone (vitamin K_2), which is produced by bacterial flora. The best known function of vitamin K is in the formation of prothrombin, which is essential for normal clotting of blood. For ruminants, vitamin K_2 is the most important source of vitamin K, since it is synthesized in large quantities by bacterial flora in the rumen. Vitamin K_1 is abundant in pasture and green roughages.

Dietary vitamin K deficiency is not likely to occur, since the vitamin is fairly well distributed in feeds and has been shown to be synthesized in the rumen.

Water soluble vitamins

The water soluble vitamins include all the B-vitamins; thiamine, riboflavin, niacin, pyridoxine, pantothenic acid, lipoic acid, biotin, folic acid, inositol, para-aminobenzoic acid, cyanocobalamin and choline, and vitamin C. The vitamins are required as co-factors in animal metabolic processes.

Microbes in the rumen synthesize most B-vitamins in excess of the probable requirements. Cattle with reduced intakes due to stress or disease may suffer from short-term B-vitamin deficiencies, due to reduced synthesis, increased requirements, and limited reserves of B-vitamins within the body. Adding B-vitamins to the animal feed is recommended.

Thiamine (Vitamin B_1)

Thiamine is required to activate enzymes involved in carbohydrate metabolism. Thiamine is the coenzyme responsible for all enzymatic carbohydrates of alpha-keto acids in the tricarboxylic acid cycle, which provides energy to the body.

Symptoms of deficiency include reduced appetite, apathy, incoordination and death. Thiamine deficiency is not likely to occur, since the vitamin has been shown to be synthesized in the rumen. One exception is the problem of nutrient metabolism in rumen, due to reduced thiamine synthesis.

Niacin (Vitamin B_3)

Niacin (sometimes called nicotinic acid) is the vitamin component in two important coenzymes called nicotinamide adenine dinucleotide (NAD) and nicotinamide adenine dinucleotide phosphate (NADP). The coenzymes NAD and NADP are concerned with carbohydrate, fat and protein metabolism systems. Niacin deficiency can occur, when dietary niacin or tryptophan is low.

Niacin is supplied to the ruminant from three primary sources; dietary niacin, conversion of tryptophan to niacin and ruminal synthesis.

Cyanocobalamin (Vitamin B_{12})

Vitamin B_{12} is a generic descriptor of a group of compounds that have vitamin B_{12} activity. One feature of vitamin B_{12} is that it contains 4.5% of cobalt. The primary functions of vitamin B_{12} involve metabolism of nucleic acids, proteins, fats and carbohydrates. Vitamin B_{12} is of special interest in ruminant nutrition because of its role in propionate metabolism, as well as the practical incidence of vitamin B_{12} deficiency as a secondary limiting factor for ruminal microorganism synthesis of vitamin B_{12}.

The vitamin B_{12} deficiency is difficult to distinguish from a cobalt deficiency. In young ruminant animals, vitamin B_{12} deficiency can occur when the rumen microbe ecosystem is not yet fully developed. In this case, vitamin B_{12} needs to be added.

Choline

Choline is essential for building and maintaining cell structure and for the formation of acetylcholine, the compound responsible for transmission of nerve impulses.

Unlike most vitamins, choline can be synthesized by most animal species. Because ruminants synthesize choline, a requirement has not been determined. However it has been determined for choline supplementation for young ruminants fed an all concentrate diet.

Conclusion

The functions of several vitamins are related to carbohydrate, fat and protein metabolism in the cell. The vitamins requirements for beef cattle depend on the class of animal and species. Young ruminants required the same vitamins as young non-ruminants, while adults can obtain their requirement of water soluble vitamins and vitamin K by rumen microorganism synthesis.

Vitamins needed by beef cattle can be confined largely to A, D and E. This is because bacteria in the rumen of cattle are considered to have the ability to synthesis vitamin K and the B vitamins in sufficient quantities to meet the animal's requirement.

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Chapter 8 Feed additives supplementation in beef cattle

Introduction

Feed additives are the pharmaceutical or nutritional substances that are not natural feedstuffs are added to made-up and stored feeds for various purposes. In animal nutrition, feed additives are typically added in small quantities and used in order to affect favorably the characteristics of feed materials or of compound feeding stuffs or of animal products, to satisfy the nutritional needs of animals or improve animal production, in particular by affecting the gastrointestinal flora or the digestibility of feeding stuffs, to introduce into nutrition, elements conductive to attaining particular nutritional objectives or to meet the specific nutritional needs of animal at a particular time and to prevent or reduce the harmful effect caused by animal excretions or improve the animal environment. Therefore, feed additives have played an essential role in the development of modern animal husbandry on a large and economic scale, to the benefit of producers as well as consumers of the resulting food products of animal origin. A number of feed additives increase the performance of beef cattle. Wise use of feed additive is necessary to get top performance of beef cattle fed growing and finishing rations (Sewell, 1993).

Feed additives can be divided into two categories

1. Nutrient feed additives
   This category includes vitamins, amino acids and trace minerals
2. Non nutrient feed additives
   The compounds can cause a response without directly contributing to the animal requirement for energy, amino acids, minerals and/or vitamins.

Nutrient feed additives

Vitamin, provitamin and vitamin-like substance

Vitamins are organic substances, which are necessary for the proper operation of vital functions in animals. They are essential for maintaining health and productivity. Fat-soluble vitamins (A, D, E) must be provided in the diet, since beef cattle is generally incapable of synthesizing those vitamins in sufficient quantities. However, rumen microorganisms synthesize water-soluble vitamins (B, C) in sufficient requirement of cattle. Therefore, supplementation of water-soluble vitamins is practically not necessary. All vitamins used today as additives in animal feed are produced industrially by chemical or microbiology processes. They are identical to neutral-occurring vitamins and exert the same beneficial effects. The cost of adding vitamins to feed are very low, regarding the advantages such as better productivity, and freedom from diseases.

Provitamins are a class of substances closely related to the vitamins. Most of them resemble carotene. The term carotenoid is derived from carotene, the pigment of carrots. Carotenoids are widely distributed in nature and are found in grasses, carrots, paprika and citrus fruits. Chemically they are very similar to vitamin A. In the body β-carotene is transformed to vitamin A that is why it is also called provitamin A. Apart from being a source of vitamin A, β-carotene also play an important role in fertility improvement.

Vitamin-like substances are organic substances exerting an equal activity as vitamins. Through their development these products, with a function in metabolic processes, are more and more important. The following items are products with vitamin characteristics:

Para-amino-benzoic acid (PABA)		
Betaine		
Inosit0l		
Essential fatty acids	-	vitamin F
Rutin	-	vitamin P
Orotic acid		
Pangamic acid	-	vitamin B_{15}
Carnitine	-	vitamin Bt
Termitin, Torutilin	-	vitamin T
Cabagin	-	vitamin U

Trace minerals

Trace minerals generally contain in animal body in rather low concentrations. Many of these trace minerals are indispensable because they are components of important substances such as hormones, enzymes and other active protein. For this reason they are essential dietary factors. If these trace minerals are in short supply, some characteristic deficiency symptom, such as anemia in iron deficiency, may develop. It is important to know which trace minerals are likely to need supplementation. Some trace minerals are present in the diet in quantities which are sufficient to meet the animal requirements; others are not sufficient available and need to be supplemented. The level of iron, copper, zinc, cobalt, manganese, iodine and selenium in natural feedstuffs is often too low to meet all requirements of beef cattle. Therefore, these trace minerals have to be added to the beef cattle diet sufficient to meet requirement. The current standards as set by NRC (2000) for cattle are as follows: 0.1 mg of cobalt/kgDM, 10 mg of copper/kgDM, 0.5 mg of iodine/kgDM, 50 mg of iron/kgDM, 20 mg of manganese/kgDM, 0.1 mg of selenium/kgDM, and 30 mg of zinc/kgDM.

Protected amino acids

Amino acids are building blocks of protein which are obtained from e.g., milk, meat and eggs. Feed and food proteins contain approximately 20 different amino acids. Plants can form all essential amino acids themselves. However, animal can synthesize some amino acids. Currently amino acids can be manufactured in three different ways, such as, chemical manufacture, fermentation and extraction from denatured proteins. Pure amino acids such as methionine and lysine have been used as supplements to compound feed more than 30 years. Amino acids can be added directly to the diets of monogastric animals to overcome nutritional deficiencies (Parr and Summers, 1991). However, free-form amino acids are rapidly degraded by rumen bacteria and are of little or no practical benefit in alleviating amino acids deficiencies for ruminants (Dinn, 1996). Rumen-protected amino acids must be either modified or protected in some way so that they are not susceptible to rumen degradation. Several methods have been used to develop commercial rumen protected amino acids products (Papas et al., 1984). Ideally, rumen protected amino acids should be generally recognized as safe to avoid lengthy governmental clearances. Furthermore, a balance must be achieved so that amino acids protected from ruminal degradation are still available for intestinal absorption. Currently, rumen protected methionine and lysine have been used as supplement to ruminant feed, because ruminant need sufficient methionine and lysine to produce milk and milk proteins (Rulquin, 1994).

Non nutrient feed additives

Hormone and hormone like products

Growth-promoting hormones help stimulate growth by increasing the efficiency in which feed (+5 to 15%) is converted to muscle. Certain products, when administered to animals in very small amounts, supplement their natural hormone production, improve growth rates (+10 to 30%) and carcass quality (+5 to 8%) by allowing the animal to produce more muscle and less fat (Preston, 1999). This helps the industry produce leaner beef for consumers. A growth promotant is typically a small pellet that is implanted under the skin on the back of an animal's ear. The pellet releases tiny amounts of hormone and safely dissolves as the treatment is completed. The use of growth promotants in cattle production has been declared safe by scientific organizations worldwide, including the Food and Agriculture Organization/World Health Organization, the European Commission Agriculture Division and the Codex Committee on Veterinary Residues.

Estrogens

Estrogens are the major class of compounds used on growth promoting implant. As shown in the chronology, estradiol, its benzoate ester as zeranol are the estrogen compound used commercially. All implant products are estrogen based and this seems to be the first requirement for a growth response. Combinations with other compounds often enhance the growth response, including trenbolone acetate (TBA), testosterone (as the propionate ester) and progesterone. Several other synthetic estrogens (polydiethystibestrol, hexestrol, diallyhexestrol and dienestrol) give responses comparable to diethystibestrol (Preston, 1999).

Androgens

The synthetic anabolic steroid trenbolone acetate has been shown to increase growth and nitrogen balance in cattle. The relative androgenic and anabolic activity of TBA is 3–5 and 8–10 fold greater, respectively, compared to testosterone. In combination with an estrogen, gain, efficiency and leanness are increased by TBA over and estrogen alone in cattle (Preston, 1999).

Somatotropin, releasing hormone, somatostanin

The effects of using daily injection, sustained release injections or pellets containing recombinant growth hormone has generally shown increased gain and feed efficiency. In cattle, required daily amounts of injected growth hormone for increased gain ranged between 16 and 64 μg/kgBW.

Growth hormone releasing factor (GRF) has also been shown to promote growth in steers. Daily doses required (1–10 μg/kgBW), however, are not that much lower compared to growth hormone (Preston, 1999).

Malengestrol acetate

Malengestrol acetate is a synthetic hormone similar in structure and activity to progesterone. It improves 3 to 7% of gain and feed efficiency of intact open heifers and suppresses estrus. The suppression of estrus reduces injuries due to riding, as well as reducing energy losses of cattle from riding and chasing. The implants containing increasing doses of norgestomet, a potent synthetic progestogen, reduced pregnancy rate in heifers on pasture for 154 days and increased rate of gain in a dose dependent manner. The growth response of steers to MGA at dose commonly fed to heifers is equivocal (Preston, 1999). The reported response to MGA is variable and may depend on: 1) the age of the heifers being fed; 2) the number of sources of heifers fed together; 3) the amount of space per heifer; and 4) implant effect. MGA is approved for use in liquid supplement at 0.25 to 0.5 mg/head/d and required 48 h withdrawal time prior to slaughter (Stock and Mader, 1985).

Pelletting additives

Pelletting binders

Pellet binders are used in the manufacture of pelleted feeds. They increase the pellet integrity by binding the various feed components together. With pelleting binders, the pellet gets more durable: feed losses as dust are minimized while the pellets are harder. Many products have been tested and a limited number have become widely used as binders in pelleted animal feeds. Currently commercial animal feed binders can generally be classified under one of the following categories:

Lignin based binders/Lignosulphonates
Hemi-cellulose binders
Mineral binders (clay)
Specialty binders (gum, starches, formulated products, etc.)

A number of the current binders in use are based on by-products from making wood and paper products. Some of the binders are mined minerals such as bentonite clays. In addition, there are numerous specialty binders that are based on certain types of products that manufactured and/or selected or formulated for use as binders (Ziggers, 2004).

Pelleting emulsifiers

Emulsifiers known as Bredol can improve the pellet quality and the pellet process by managing moisture content when pelleting. This additive retains precisely the right amount of moisture in the feed and at the same time help to reduce energy costs. Bredol can combine water and fat in a stable emulsion after homogenization. Bredol also removes surface tension and permit the emulsion to penetrate the feed particle. As a result the conditioning of the feed is improved and the surface of the particle is more able to bind with surrounding particles. Due to this effect the pellets can travel faster and more smoothly through the diet, which substantially reduces the electricity load on the pellet press (Ziggers, 2004).

Anthelmintics

Many anthelmintics (dewormers) are available as feed additives. Delivery of anthelmintics is advantageous when animal handling for direct delivery of dewormers is difficult. As with other feed additives, effectiveness of anthelmintics delivered through feed depends on cattle consuming adequate quantities of the product (Parish, 2008).

Fly control

Oral larvicides are fed to cattle through a feed ration or mineral to kill fly larvae as they hatch in the manure. They are effective only when animals consume the proper amount of the active ingredient. Oral larvicides do not control migrating adult flies. Adult flies can still be a problem if a producer in using an oral larvicide but a neighbor is not practicing any fly control (Parish, 2008).

Enzymes

Enzymes are bio-catalysts which are produced in diversity by all living cells. They are protein molecules that produced by animals body or micro-organism. Enzyme products currently used in animal nutrition are mixtures of enzyme with differing characteristics (Vahjen and Simon, 1999). Several enzymes such as amylase, cellulase, phytase and pectinase have been use as additives to enhance animal performance with success in poultry and swine diets. However, feeding enzyme for improve fiber digestion in ruminant has been successfully by fibrolytic enzyme. Ruminant feed enzyme additives, primarily xylanases and cellulases, are concentrated extracts resulting from bacterial or fungal fermentations that have specific enzymatic activities. Improvements in animal performance due to the use of enzyme additives can be attributed mainly to improvements in ruminal fiber digestion resulting in increased digestible energy intake (Beauchemin et al., 2003). Recent studies have shown that adding exogenous fibrolytic enzymes to ruminant diets increases milk production (Yang et al., 2000) and ADG (Beauchemin et al., 1999).

Antibiotics

Antimicrobial growth promoters have become widely used in elsewhere. They act on micro-organisms within the intestine to increase growth and efficiency through permitting full use of dietary nutrients. Antibiotics are non-nutritive feed additives, which mean that they do not provide further nourishment to the animal. Studies on the effects of antibiotic feed additives have indicated significant improvements in growth rate and feed efficiency. However, used of antibiotics for growth promotion in animal has been banned in Europe and United states (Ahmad, 2006). Therefore, nutritionists and production managers are interested in compounds that may serve as possible replacements.

Palatant

Palatability is a term used to describe how well cattle like the taste, smell, and texture of a food. To increase the palatability, processors often use palatants such as aromas, flavors, sweeteners or their combinations. These feed additives are designed to provoke a sensory response that in the end, affects feed intake and performance. The ruminant feed intake is influenced by environmental stressors, animal itself, physical and chemical characteristics of diet. Taste and odor are important chemical characteristics in feed attraction. Therefore, in the ruminant nutrition, aromas, flavors and sweeteners are commonly used to improve palatability. Recent research has shown that calves, dairy cows or beef cattle react effectively to flavors and sweeteners in specific production systems ultimately offering the producer a positive return on investment (Schlegel, 2005).

Feed preservatives

There are three different ways of preserving feed such as cold, heat and use of feed preservatives. Feed preservatives are naturally occurring or synthetic substance that is added to feeds for prevent decomposition by microbial growth or by undesirable chemical changes. Feed preservatives can be divided into three categories

1. Antimicrobial preservatives include calcium propionate, sodium propionate, calcium formate, protasium sorbate, sodium nitrate, sodium nitrite, sulfite, propylene glycol, citric acid, formic acid, propionic acid, sorbic acid and disodium EDTA.

2. Antioxidants include butyrated hydroxyanisole (BHA) and butyrated hydroxytoluene (BHT).

3. Other preservatives include formaldehyde, glutaraldehyde, ethanol and methylchoroisthiazolidone

Probiotic

Probiotic are beneficial micro-organisms that are fed to animal. They are antagonist of putrefying and ammonifying bacteria, which are usually found in the large intestine (O'Keefe, 2005). Probiotics present an attractive alternative to the use of chemical and hormonal growth promoters in the livestock production industry. The preparations contain micro-organisms that have been used for many years in food production and thus are generally accepted as safe by both the farmer and the final consumer (Newbold, 1996). Yeast, particularly *Sacchromyces cerevisiae* a common probiotic used in ruminant. The mode of action in ruminants involves modification of rumen fermentation, related to increased bacterial numbers. Yeast effect in ruminants is strongly dependent on the diet. Aqueous extracts prepared from *Saccharomyces cerevisiae* stimulated the growth of certain rumen micro-organisms. Yeast has been shown to provide vitamins (especially thiamin) to support the growth of rumen fungi (Chaucheyras et al., 1995). Additionally, (Yoon, 2003) reported that yeast culture tended to increases feed intake milk yield and milk fat. High dicarboxylic acids, particularly malic acid, content of the yeast has also been shown to be the possible cause of stimulation (Nisbet and Martin, 1991) *in vitro*, but it does not appear to cause the most important effects of yeast *in vivo* (Newbold et al., 1996).

Prebiotic

Prebiotics are non-digestible food ingredients that stimulate the growth and/or activity of bacteria in the digestive system which are beneficial to the health of the body. They were first identified and named by Marcel Roberfroid in 1995 (Gibson and Roberfroid, 1995). Prebiotics that feed the beneficial bacteria in gut mostly come from carbohydrate fibers called oligosaccharides. Common prebiotics in use include inulin, fructo-oligosaccharides (FOS), galactooligosaccharides (GOS), soya-oligosaccharides, xylo-oligosaccharides, pyrodextrins, isomalto-oligosaccharides and lactulose. There is also a range of new prebiotic compounds emerging, and these include: pecticoligosaccharides, lactosucrose, the sugar alcohols, gluco-oligosaccharides, levans, resistant starch, xylosaccharides and soya-oligosaccharides (FAO, 2007). The use of prebiotics in cattle has been limited due to the ability of ruminants to degrade most prebiotics.

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Chapter 9 Water

Introduction

Water is the most important nutrient for all animals and is required in greater amounts than other nutrients for growth and production. It accounts for 50 to 80% of an animal's weight, depending on age, species, physiology and degree of fatness. An animal can lose almost all of its fat and about 50% of its body protein and survive, but the loss of 10–20% of its body water can be fatal.

Function

The main functions of water in the body are body temperature regulation, growth, reproduction, lactation, digestion, nutrient use, mineral balance maintenance, pH buffering of body fluids, waste removal, joint lubrication, nervous system cushioning, hearing and eyesight.

Water source

Animal fulfill their needs for water from three major sources;

1. Free drinking water
2. Water contained in feed
3. Metabolic water

Each animal in the water sources are important differences depending on the type of animal.

Requirement

Water consumption requirements depend on factors such as species and size of animal, breed, rate and composition of gain, pregnancy, lactation, type of diet, environmental moisture and temperature, and water quality.

Units of water requirement can be units of water per body weight, per dry matter intake, per metabolic body size and per day.

Factors determining water requirement

These factors can be divided into three major groups;

1. Animal factors; which include breed differences, age and condition of the stock.

Young animals, heavily pregnant or lactating females, and aged or weakened stock require more water than stock in normal condition. Brown (2006) reported that pregnant cows and growing animals increased water consumption by 30 to 50% and lactating cows required an extra 0.86 liters of water per kg of milk. Young stock need 25–50 liters of water per head per day, dry stock (400 kgBW) need 35–80 liters, saltbush lactating cows need 70–140 liters and grassland lactating cows need 40–100 liters per head per day (Marxwick, 2007). Ward (2007) referred that lactating cows with calves need 43–67 liters of water per head per day and dry cows, bred heifers and bulls need 22–54 liters of water per head per day (Table 9.1).

Table 9.1 Water requirements for beef cattle

Type of animal	Water Requirement (L/d)	Sources
Cow with calf (590 kgBW)	45	
Dry/mature cow (590 kgBW)	38	
Calf (114 kgBW)	11	
Bull	45	Brown (2006)
Feedlot cattle: Backgrounder (181–364 kgBW)	15–40	
Feedlot cattle: Short keep (364–636 kgBW)	27–55	
Lactating cows with calves	43–67	
Dry cows, bred heifers & bulls	22–54	Ward (2007)

2. Environmental factors which include temperature and feed quality.

In hot weather, animals use more water for evaporative cooling. Marxwick (2007) found that water consumption of sheep can increase by 78% under extreme conditions, while under normal conditions with good quality water, consumption in summer will be about 40% higher than in winter. In cool weather (below 15°C) 4 liters per day per 45 kgBW is required, while in hot weather (above 25°C) 8 liters per day per 45 kgBW is required. Also lactating cows require up to twice the water of dry cows (Brown, 2006). In Table 9.2, temperature increases from 10–32°C can increase daily water requirements by two and a half times (NRC, 2000). And Rossi (2007) found that water requirements double when temperature increases from 10-32°C. However, providing shade in summer can reduce water intake.

Water intake also depends on water temperature. Warming of water can reduce intake and cooling of water can increase both water and feed intake. Parish and Rhinehart (2008) reported that water intake by cattle increased when water temperatures were below 25°C. This increase in water intake is often associated with improved feed intake and cattle weight gains.

Diet also affects the amount of additional water an animal will need every day. Good green pasture can supply all an animal's water needs. Sheep under these conditions may not need to drink for many weeks. Good pasture allows stock to use water which would normally be unsuitable at higher levels of consumption (Marxwick, 2007). Rossi (2007) reported that cattle grazing lush growth that contains 75% water need much less additional water than cattle fed dry feeds or hay containing only 10% water.

3. Water quality

Water quality is important to livestock, especially with respect to the content of salts and toxic compounds. This is because the water quality affects the quantity of water consumed. Most ground or surface water is satisfactory for livestock. If the drinking water for livestock is not satisfactory, it is most often due to excessive salinity. Marxwick (2007) reported that with salty water, the summer intake may be 50 to 80% higher than consumption in the cooler months. Marx (2005) reported that all water contains dissolved substances. Most of these are ions of inorganic salts. The most predominant of these are calcium, magnesium, sodium, chloride, sulfate and bicarbonate. Occasionally, the levels of salts are high enough to cause harmful osmotic effects that result in poor performance, illness or even death in animals forced to drink them. Various salts have slightly different effects, but these differences normally are of no practical significance. Sulfates are laxative and cause some diarrhea. At very high salt concentrations, animals may refuse to drink a large amount at one time and some can become suddenly sick or die. Total dissolved solids with less than 1,000 ppm is excellent for any class of livestock and between 5,000–6,999 ppm safe for beef cattle, but should be avoided for use by pregnant and lactating animals.

In addition, water quality also depends on the levels of pH, nitrates, microorganisms, algae, toxic elements and chemicals. An acceptable pH range for water consumed by cattle is from 7 to 8 (Brown, 2006; Marx, 2005). Marx (2005) reported that most waters have less than 500 ppm of alkalinity and as such are not considered satisfactory for all livestock. Above that level it may be unsatisfactory and can cause physiological and digestive upsets in livestock. Nitrate content in water for cattle should be less than 100 ppm because bacteria in the rumen convert nitrates in fed, water with high nitrate untreat can become a serious problem. Death can occur when cattle consume water high in nitrates, and nitrate toxicity causes the animal to eat less and thus have lower performance.

Table 2 Beef cattle water intake estimates at temperature difference (adapted from NRC, 2000)

	Water intake estimate (liter)					
	Temperature (°C)					
Weight (kgBW)	4.4	10.0	15.5	21.1	26.6	32.2
Growing beef calves						
182	15.14	16.28	18.93	21.95	25.36	35.96
273	20.06	21.95	24.60	29.52	33.69	48.07
364	23.85	25.74	29.90	34.82	40.12	56.78
Finishing cattle						
273	22.71	24.60	28.01	32.93	37.85	54.13
364	27.63	29.90	34.44	40.50	46.56	65.86
454	32.93	35.58	40.88	47.69	54.88	77.97
Pregnant cows, 409	25.36	27.25	31.42	36.72	-	-
Lactating cows, 409	43.15	47.69	54.88	63.97	67.75	61.32
Mature bulls						
636	30.28	32.55	37.47	44.29	50.72	71.92
727+	32.93	35.58	40.89	47.69	54.88	77.97

Other substances that produce water quality problems are iron, sulfate and manganese. These minerals decrease water intake because of foul flavors and odor. If iron and sulfate levels are high, they can bind and prevent the absorption of copper and zinc.

Water for animals should not be contaminated with manure, toxic elements (arsenic, mercury lead and cadmium), bacteria and blue-green algae (Cyanobacteria). These factors can cause sudden death or reduced animal performance and production.

Conclusion

Water is the most important nutrient for cattle because it is a critical nutrient required for a wide variety of body functions in cattle. Restricting water intake to less than the animal's requirement reduces animal performance and production. The requirements for cattle depend on animal factors, environmental factors and water quality. Therefore, producers should consider these factors and give cattle access to adequate and good quality water at all times.

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Chapter 10 Table of energy and protein requirements

The equations for prediction

The equation developed based under beef cattle production situation in Thailand provides a convenient method of predicting feed intake and nutrient requirements. It is also possible to use it for formulation of rations to give desired levels of beef cattle performance. The equations for prediction nutrient requirements developed based on metabolic size ($kgBW^{0.75}$). The equations for prediction recommended are as follows;

Feed Intake;

DMI (kg/d) = 0.02887BW (kg) – 0.5778 [equation 3.1]

Energy requirement for Thai Native cattle;

MEI ($kJ/kgBW^{0.75}/d$) = 31.37ADG ($g/kgBW^{0.75}/d$) + 483.60 [equation 4.5]

Energy requirement for Brahman cattle;

MEI ($kJ/kgBW^{0.75}/d$) = 22.67ADG ($g/kgBW^{0.75}/d$) + 486.19 [equation 4.6]

Protein requirement for Thai Native cattle;

CPI ($gCP/kgBW^{0.75}/d$) = 0.38ADG ($g/kgBW^{0.75}/d$) + 5.03 [equation 5.1]

Protein requirement for Brahman cattle;

CPI ($gCP/kgBW^{0.75}/d$) = 0.56ADG ($g/kgBW^{0.75}/d$) + 4.52 [equation 5.2]

Protein requirement for Brahman crossbred cattle;

CPI ($gCP/kgBW^{0.75}/d$) = 0.59ADG ($g/kgBW^{0.75}/d$) + 5.47 [equation 5.3]

Example tables for growing and finishing cattle

Tables contain requirement for Thai native cattle, Brahman and Brahman crossbred cattle respectively (see also Table 10.1, 10.2 and 10.3).

Table 10.1 Energy and protein requirements for Thai native cattle

Body weight range	100–400 kg							
ADG range	0–1.00 kg							
Breed Code	Thai native							
Body Weight, kg		100	150	200	250	300	350	400
Dry Matter Intake (kg/d)		2.31	3.75	5.20	6.64	8.08	9.53	10.97
Maintenance and Growth Requirements								
ADG (kg/d)			ME required for gain (MJ/d)					
0.00		15.29	20.73	25.72	30.40	34.86	39.13	43.25
0.25		23.13	28.57	33.56	38.25	42.70	46.97	51.10
0.50		30.98	36.41	41.40	46.09	50.54	54.82	58.94
0.75		38.82	44.25	49.24	53.93	58.39	62.66	66.78
1.00		46.66	52.09	57.09	61.77	66.23	70.50	74.62
ADG (kg/d)			CP required for gain (g/d)					
0.00		159	215	267	316	362	407	450
0.25		254	311	363	411	458	502	545
0.50		349	406	458	506	553	597	640
0.75		445	501	553	602	648	692	735
1.00		540	596	648	697	743	788	830

Table 10.2 Energy and protein requirements for Brahman cattle

Body weight range	150–500 kg							
ADG range	0–1.75 kg							
Breed Code	Brahman							
Body Weight, kg	150	200	250	300	350	400	450	500
Dry Matter Intake (kg/d)	3.75	5.20	6.64	8.08	9.53	10.97	12.41	13.86
Maintenance and Growth Requirements								
ADG (kg/d)	ME required for gain (MJ/d)							
0.00	20.84	25.86	30.57	35.05	39.34	43.49	47.50	51.41
0.25	26.51	31.52	36.24	40.71	45.01	49.15	53.17	57.08
0.50	32.17	37.19	41.90	46.38	50.68	54.82	58.84	62.74
0.75	37.84	42.86	47.57	52.05	56.34	60.49	64.50	68.41
1.00	43.51	48.53	53.24	57.72	62.01	66.16	70.17	74.08
1.25	49.18	54.19	58.90	63.38	67.68	71.82	75.84	79.75
1.50	54.84	59.86	64.57	69.05	73.35	77.49	81.51	85.41
1.75	60.51	65.53	70.24	74.72	79.01	83.16	87.17	91.08
ADG (kg/d)	CP required for gain (g/d)							
0.00	194	240	284	325	365	404	441	477
0.25	334	381	425	466	506	545	582	618
0.50	475	522	566	607	647	686	723	759
0.75	616	663	706	748	788	826	864	900
1.00	757	803	847	889	929	967	1004	1041
1.25	898	944	988	1030	1069	1108	1145	1182
1.50	1038	1085	1129	1170	1210	1249	1286	1322
1.75	1179	1226	1270	1311	1351	1390	1427	1463

Table 10.3 Energy and protein requirements for Brahman crossbred cattle

Body weight range	100–400 kg						
ADG range	0–1.25 kg						
Breed Code	Brahman crossbred						
Body Weight, kg	100	150	200	250	300	350	400
Dry Matter Intake (kg/d)	2.31	3.75	5.20	6.64	8.08	9.53	10.97
Maintenance and Growth Requirements							
ADG (kg/d)	ME required for gain (MJ/d)						
0.00	------	------	Na	------	------	------	------
0.25	------	------	Na	------	------	------	------
0.50	------	------	Na	------	------	------	------
0.75	------	------	Na	------	------	------	------
1.00	------	------	Na	------	------	------	------
1.25	------	------	Na	------	------	------	------
ADG (kg/d)	CP required for gain (g/d)						
0.00	173	234	291	344	394	443	489
0.25	320	382	438	491	542	590	637
0.50	468	529	586	639	689	737	784
0.75	615	677	733	786	837	885	931
1.00	763	824	881	934	984	1032	1079
1.25	910	972	1028	1081	1131	1180	1226

Na = Not available

Chapter 11 Ration formulation (BRATION) program with recent Thai feeding standard and feed database

The beef cattle ration formulation program (BRATION) was developed to assist users for allocation feed to meet the requirements. The program consisted of six parts; feed database, animal data and nutrient requirements, ration formulation and nutrient balance, least cost concentrate formulation, mineral mixture formulation and report. Feed nutrient composition database and the nutrient requirements model are based on the summary of the Thai working groups supported by JIRCAS. The NRC requirement may be used for comparison. The nutrient balance, feed amounts and some advice on improper ration are shown. The program could make the feeding managements more accuracy for beef cattle. However, some ruminant nutrition background may be necessary in formulation.

Installation of the BRATION program

The **BRATION** program has been developed using the Microsoft Office Excel function. Numbers of macro were set up to combine feed formulation functions and calculations in different files. The program should be fixed in a folder named BRATION and requires specific solver file attached with for effective functioning. Program set up can be done as follows.

1. Install in a PC fixed discs from CD. Placing BRATION CD disc in CD drive then using My Computer and move mouse on folder BRATION. Click right button to **Copy** and click right button to **Paste** individually on any drives; C, D or E. No correction, remove, divide, rename or making a main folder for this BRATION folder.
2. Adjustments of **Microsoft Office Excel** to the program. For Excel 2003, users should set the security of Excel to the medium level by moving mouse to a Menu bar and click on **Tools** then **Macro** and **Security.** Click the left button on **Medium** then click **OK**. In general the computer should be restarted to fix the new change. For Excel 2007, the security may not be adjusted but users must install Office 2003 in the same computer since BRATION macros were developed under Office 2003. The Office 2003 macros were found not totally compatible with Office 2007 especially the solver calculation part. In some case, Windows may be set up to accept the oriental language as Thai. Nevertheless, the computer should be free from virus since it could interrupt the program macros function.
3. In the case of using program from removable discs; CD, handy drive, hump drive etc., no installation process is required.

Manual for using the program

After opening Excel and the file BRATION or clicking on the BRATION file directly, the main page as shown in Figure 11.1 is seen. Users can choose language (Thai/English) and display dimension by clicking on bars. Steps for operation are as follows.

1. Choose one toolbar at the main page. If ration formulation is required, click **Feed rationing** and **Start the rationing** on the starting page as in Figure 11.2

Figure 11.1 Main page.

Figure 11.2 Starting page.

- Fill in animal data, weight gain, and details. Some items can be selected by pull down menus. A 230 kg Brahman with 1 kg gain was used as an example.
- Select the requirement prediction model, Thai or NRC. Feeding level can be 1; equal to calculated requirements, 1.1; equal to 10% higher than requirements or others as in Figure 11.3 After seeing the requirements as 11.45 Mcal ME/d and 0.53 kgCP/d when using Thai model, users can click **Close** bar to return to the starting page.

Figure 11.3 Animal data and requirement page.

2. From the starting page, click the **Feed and nutritive value** tool bar then select bar **Concentrate**, **Roughages and Ingredients**, or **Least cost concentrate and Mineral** as in Figure 11.4. If Roughages and Ingredients bar is chosen users can go to the recent feed selection page as in Figure 11.5.

- Choose feed by classifying to which group they belong; roughages or ingredients, and fill in cost per kg of fresh basis.
- If mineral mixture should be formulated, click **Least cost...**bar. Users should tell the drive where BRATION program located, and call for Solver. When click **Mineral** bar, the page as seen in Figure 11.6 will appear. Mineral mixture can be formulated as the manual shown on right hand side. This new mixture may be kept in the feed file as **Made mineral**.

Figure 11.4 Feed and nutritive value page.

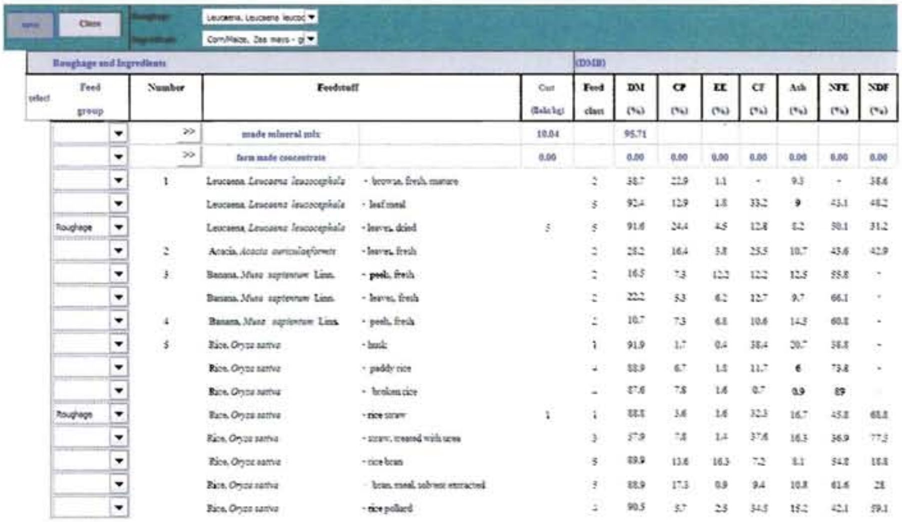

Figure 11.5 Recent feed selection page.

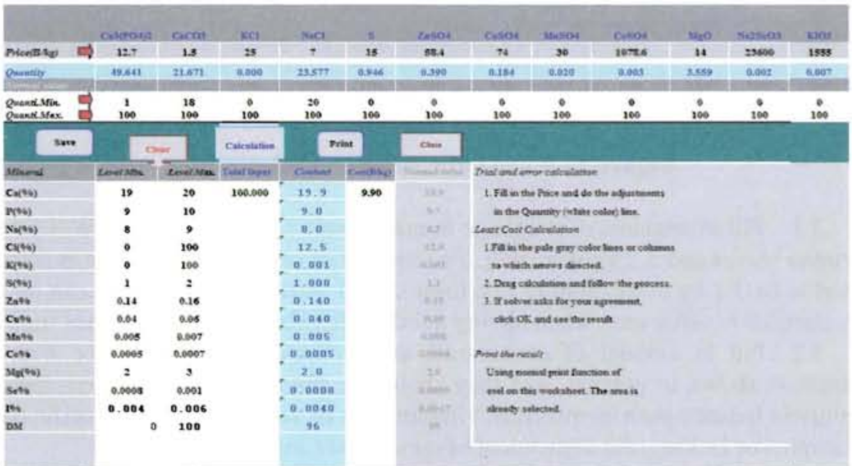

Figure 11.6 Mineral mix formulation page.

After completion this part, click **Close** bar to return to the requirements page.

3. Selection feed for new formulation by dragging pull down menus and select roughage, concentrate or supplemental ingredients as required for a new formulation as shown in Figure 11.7 then click OK. The formulation and balance page will be seen as shown in Figure 11.8.

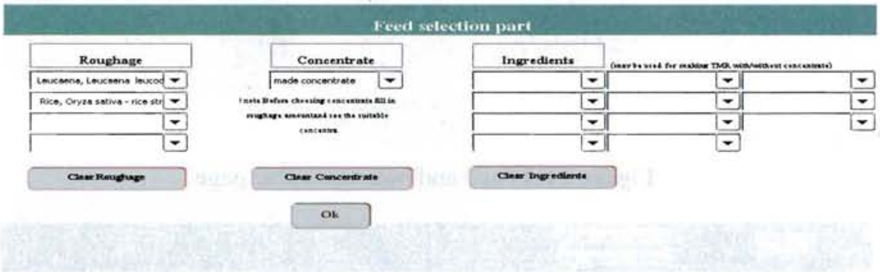

Figure 11.7 New feed selection for formulation page.

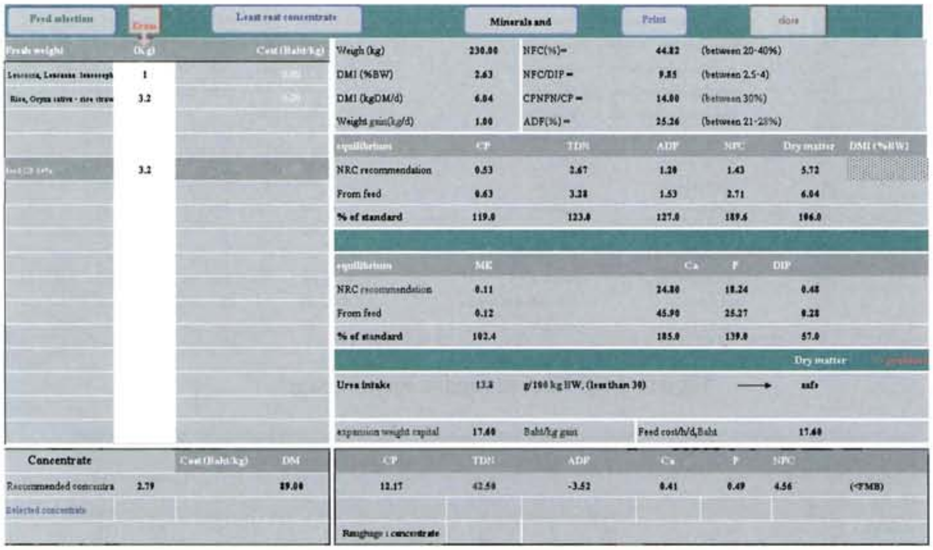

Figure 11.8 The formulation and balance page.

3.1 Fill in amounts of roughage to meet about 1.4% of DMI of BW. In this case, 1 kg *Leucaena* leaves and 3.2 kg were met. The amount of selected concentrate is automatically calculated to be 3.2 kg at the bottom line (blue color). Amount of roughage can be increased to 3% maximum in some case when having good quality feed or using legumes supplement.

3.2 Fill in amount of concentrate as recommended, the balance with standard requirement is shown in percent, and they should be more or equal to 100%. The result of others nutrient balance such as minerals, vitamins can be seen by clicking specific bars. In the case of surplus or lacking, the adjustment of concentrate amount is necessary.

3.3 In the case of some particular nutrient lacking or making TMR, specific supplements are required for being protein, energy, mineral and vitamins sources. They can be selected by pull down menus as done in Figure 11.7. In general, the quantity of first 2 selected supplements is automatically calculated. The inadequate nutrient name will be shown in "Problem" line. The example as in Figure 11.9 shows TMR ration formulated for the same animal but using NRC requirements for comparison. Coconut meal, cassava chips and mineral mix are used as supplements.

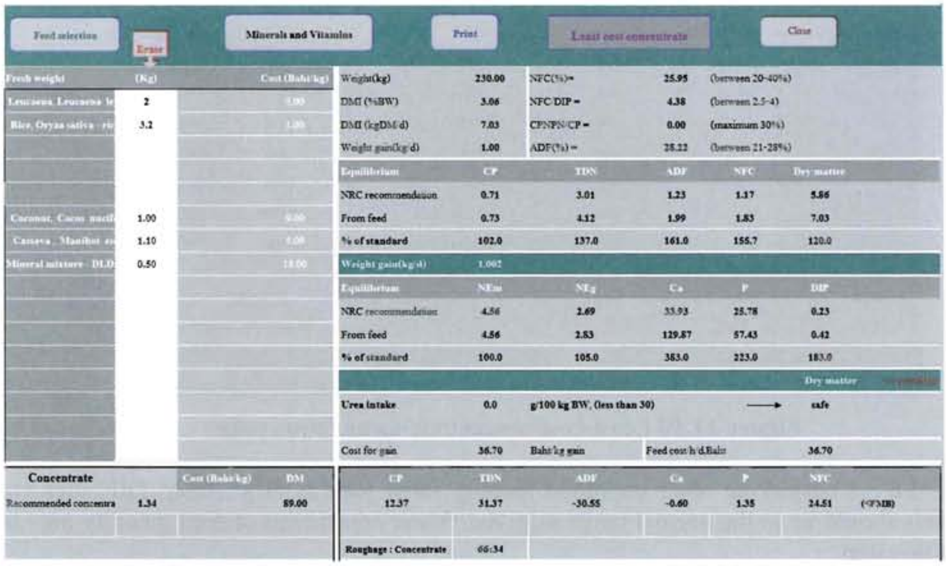

Figure 11.9 formulation of TMR diet and nutrient balance.

3.4 If concentrate needed to be in farm prepared, click **Least cost concentrate** then call for "Solver". Users should identify to which drive the BRATION program located. If trial and error function will be done, click **No** bar to refuse "Solver".

In this part, maximum 11 ingredients can be selected by pull down menus. For trial and error function, after filling in quantities of selected ingredients and meet 100 kg of total weight, the result of nutrient composition is shown on the right hand side. Some adjustment may be done to get a required nutrient content.

3.5 If least cost concentrate formulation is required, filling in the minimum and maximum quantity of each ingredient and the required nutrients content of feed. After clicking **Calculation** bar, the program will calculate a least cost composition. User can repeat formulation several times to get the satisfactory result. Total quantity of concentrate needed to be at 100 kg as shown in Figure 11.10. Amounts of Rice bran, Corn, Soybean meal, Coconut meal, *Leucaena* leaves and mineral mix to make a 13.7% CP concentrate calculated to be 67.2, 5.0,5.0,13.8,7.0 and 2.0% respectively. Cost of concentrate was at 9.28 Baht/kg. The NFE content was at 48.0% and ADF was at 12.5%.

When pressing **Use for rationing** bar, the program will calculate the concentrate amount that meet the requirement in the formulation page. Moreover, this concentrate formula can be saved as a "made concentrate" or as one ingredient for future use.

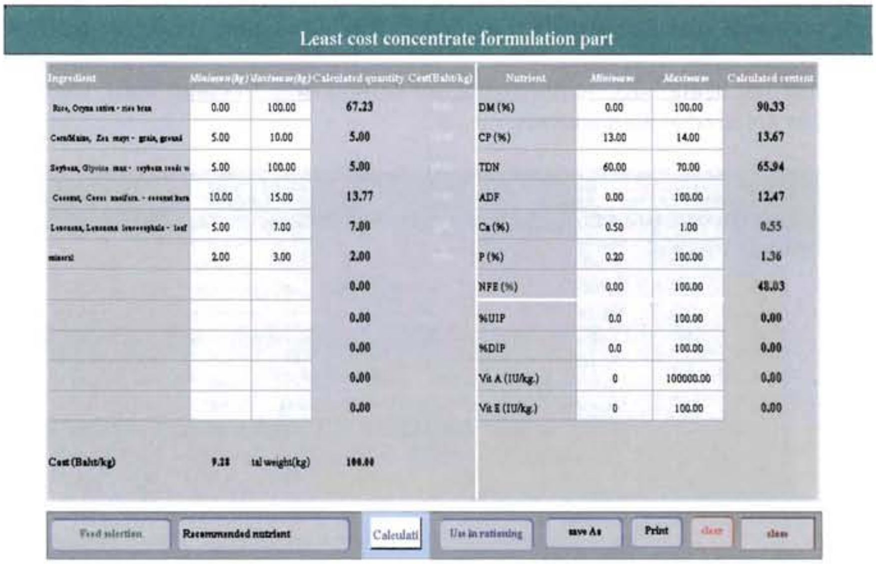

Figure 11.10 Least cost concentrate formulation page.

3.6 Considering other important feeding value such as NFC, fiber, DIP, urea etc. The levels should be in the normal range as given. Some adjustment of feed quantity may be done at this step.

3.7 Comparing cost of feed per day and cost of 1 kg gain of each ration, the minimum is preferred.

4. See minerals and vitamins contents of ration and concentrate by clicking the **Mineral and vitamin** bar and see the contents comparing to the standard level or recommendation as shown in Figure 11.10 and 11.11. If inadequate warning is shown, choose some supplements and fill in their quantities that make sufficient minerals and vitamins ration.

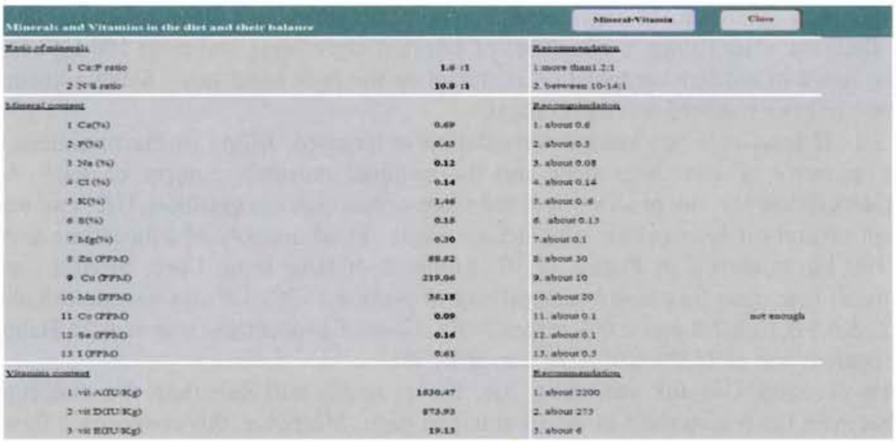

Figure 11.11 Minerals and vitamins balance page.

5. Print and save the result

- Type in the ration name, formulator name, number of animal to be fed, feeding frequency and press the **Print** button. The print out is similar to that in Figure 11.12.

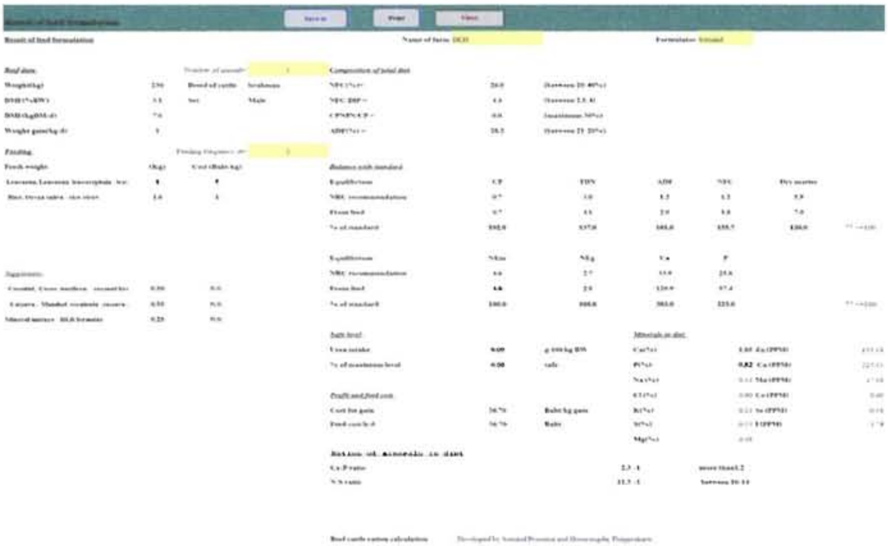

Figure 11.12 Printout of formulation result.

- If the results needed to be saved for future use, click the **Save** button, it will be saved before leaving the program under the other name.

6. Changes of feed, feed name, nutritive content and cost of feed

- Follow the procedure as doing in 2. Users can enter new feed or replace on the former feed that not regularly used. Nutritive contents and cost of feed are done as well.

- To save the corrected data and feed, press the **Save** button every times of changes.

In this program, some nutrient such as DE, ME, NE_m and NE_g are automatically calculated from the TDN content. Unit of energy is expressed as Mcal/kg instead of MJ/kg due to better comparison of Thai and NRC requirements since NRC reported in term of Mcal/kg. The DIP and UIP are calculated as % content not as % of CP. In the case of special correction, users can contact the authors.

7. Leaving the program

In general, before leaving the program or **Close**, users are asked for saving the temporary data. If **No** bar is chosen, the temporary data will be deleted thus make the program clean before leaving. In order to save the present cattle and feed formulation data and all contents for future use, the **Save** button should be dragged on.

Chapter 12 Table of chemical composition and energy content of feedstuffs

In order to formulate feed to meet nutrient requirement, it is necessary to know nutrient content in feed. This chapter provides tables of chemical composition and energy content of most feedstuffs available in Thailand.

Feedstuffs in Table 12.1–12.2 are grouped into 6 classes as following;

Class 1	Dry forages and roughages	Class 4	Energy sources
Class 2	Fresh forages	Class 5	Protein supplements
Class 3	Silages	Class 6	Mineral supplements

Table 12.1 presents chemical composition and energy content of feedstuffs in class 1–5 and Table 12.2 presents mineral content of feedstuffs in class 6 (mineral supplements).

Table 12.1

Data of chemical composition of feed stuffs in Table 12.1 are consisted of the constituents analyzed by proximate analysis i.e., crude protein (CP), ether extract (EE), crude fiber (CF), ash and nitrogen free extract (NFE), constituents analyzed by detergent analysis i.e., neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL), and minerals. These data were compiled directly from published and unpublished data. All data provided mainly by feed analysis laboratories, Department of Livestock Development, from 1994 to 2006, and some from research institutes, universities and commercial laboratories in Thailand. All data were pooled, analyzed and outlier values were discarded. The values are expressed in average based on both fresh and dry matter (DM). In case of values were unavailable in Thailand, the appropriate values from the table of Harris et al.(1982), NRC (1984) and NARO (2001) were fulfilled. These are indicated with superscript number. Data of energy content are expressed as total digestible nutrient (TDN), digestible energy (DE) and metabolizable energy (ME). Most of TDN contents of feed stuffs are estimated by using equations except from *in vivo* experiments where superscript numbers are indicated. The estimated TDN equations are from Wardeh (1981) cited by Harris et al. (1982). They are divided into 5 equations depend on feed classes as following:

Class 1: Dry forages and roughages

TDN (% of DM) = –17.2649 + 1.2120 (CP %) + 0.8352 (NFE %) + 2.4637 (EE %) + 0.4475 (CF %)

Class 2: Fresh forages

TDN (% of DM) = –21.7656 + 1.4284 (CP %) + 1.0277 (NFE %) + 1.2321 (EE %) + 0.4867 (CF %)

Class 3: Silage

TDN (% of DM) = –21.9391 + 1.0538 (CP %) + 0.9736 (NFE %) + 3.0016 (EE %) + 0.4590 (CF %)

Class 4: Energy source

TDN (% of DM) = 40.2625 + 0.1969 (CP %) + 0.4228 (NFE %) + 1.1903 (EE %) – 0.1379 (CF %)

Class 5: Protein supplement

TDN (% of DM) = 40.3227 + 0.5398 (CP %) + 0.4448 (NFE %) + 1.4218 (EE %) + 0.7007 (CF %)

Most of DE and ME content are taken from the table of Harris et al. (1982), NRC (1984) and NARO (2001), and some from *in vivo* experiments. Some ME content also estimated by *in vitro* using gas production technique. The sources of data are indicated by superscript number. The dash (–) in any item indicates unavailable data. Name of Feedstuffs: The scientific names are used for the feedstuffs from biological origins. The common names are used with some process feedstuffs where scientific names are not available such as brewery yeast, whey. The names are sorted by alphabet.

The details of feeds i.e., portions, parts, growing or cutting stage and processing of those feedstuffs are indicated under the scientific name. For example soybean straw or soybean meal will be appeared at the scientific name of soybean: '*Glycine max*'.

Table 12.2

Data in Table 12.2 consist of macro minerals including calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), sodium (Na) and sulfur (S), and micro minerals including copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), cobalt (Co), chlorine (Cl), fluorine (F), iodine (I) and selenium (Se). As data of composition of mineral supplements in Thailand is less available, all is taken from the tables of Harris and et al. (1982) and NRC (1984). The values are expressed in percentage based on both fresh and dry matter. The names of mineral elements are sorted by alphabet where their sources are listed underneath.

Definitions and abbreviations in Table 12.1–12.2

fresh	Forage in fresh direct cut condition.
dried	Feedstuffs in dry condition
wet	Processed raw materials with high moisture content such as cassava pulp after ethanol fermentation
hay	Sun cured forage for conservation
straw	Remained aerial plant where main product is harvested

DM	Dry matter	S	Sulfur
CP	Crude protein	Cu	Copper
EE	Ether extract	Fe	Iron
CF	Crude fiber	Mn	Manganese
NFE	Nitrogen free extract	Zn	Zinc
NDF	Neutral detergent fiber	Cl	Chlorine
ADF	Acid detergent fiber	Co	Cobalt
ADL	Acid detergent lignin	F	Fluorine
Ca	Calcium	I	Iodine
P	Phosphorus	Se	Selenium
K	Potassium	TDN	Total digestible nutrient
Mg	Magnesium	DE	Digestible energy
Na	Sodium	ME	Metabolizable energy

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
1	*Acacia auriculaeformis*, ACACIA.										
	- leaves, fresh	2	28.2	4.6	1.1	7.2	3.0	12.3	12.1	9.0	5.1
			100	16.4	3.8	25.5	10.7	43.6	42.9	32.0	18.0
2	*Acroceras macro,* NILE GRASS.										
	- aerial part, fresh	2	27.6	3.3	0.6	-	3.0	-	17.3	9.9	-
			100	12.1	2.2	-	11.0	-	62.6	35.9	-
3	*Alysicarpus vaginalis,* ALYCE CLOVER.										
	- aerial part, dried, 45 days growth	1	-	-	-	-	-	-	-	-	-
			100	17.3	2.1	24.0	9.8	46.8	45.0	31.8	8.0
	- aerial part, dried, 60 days growth	1	-	-	-	-	-	-	-	-	-
			100	16.5	1.7	26.6	9.0	46.2	48.3	34.4	10.4
	- aerial part, dried, 75 days growth	1	-	-	-	-	-	-	-	-	-
			100	13.0	1.3	26.9	11.0	47.8	58.8	46.7	10.3
4	*Ananas comosus,* PINEAPPLE.										
	- aerial part, fresh	2	47.8	2.2	0.4	7.8	4.0	33.4	21.5	11.1	1.1
			100	4.6	0.8	16.3	8.4	69.9	45.0	23.2	2.2
	- crowns, fresh	2	19.0	1.8	0.3	3.4	1.8	11.8	9.7	5.2	0.6
			100	9.5	1.5	17.7	9.4	61.9	51.2	27.2	3.2
	- leaves	2	-	-	-	-	-	-	-	-	-
			100	6.5	2.0	19.7	5.9	65.9	46.6	25.8	3.6
	- peels, cannery residue, wet	2	14.2	0.8	0.2	2.5	1.1	9.7	8.1	4.3	0.4
			100	5.7	1.2	17.3	7.7	68.1	56.9	29.9	2.7
	- pineapple core, dried	1	87.1	1.7	1.3	7.4	2.0	74.7	-	-	-
			100	1.9	1.5	8.5	2.3	85.8	-	-	-
	- pineapple peels, pellet	1	87.0	3.1	2.4	13.8	3.9	64.0	-	-	-
			100	3.5	2.7	15.9	4.4	73.5	-	-	-
5	*Andropogon gayanus,* GAMBA GRASS.										
	- aerial part, fresh, 45 days growth	2	25.9	1.8	0.4	-	1.1	-	18.7	11.0	1.6
			100	7.1	1.4	-	4.4	-	72.1	42.6	6.2
6	*Arachis hypogaea,* PEA NUT/GROUND NUT.										
	- pods, sun cured	1	89.0	7.5	0.9	51.3	5.4	24.0	68.1	60.5	-
			100	8.4	1.0	57.6	6.0	27.0	76.5	68.0	-

1/ in vitro   2/ in vivo   3/ Harris et. al ,1982   4/ NRC , 1984   5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
1													
	17	-	-	-	-	-	-	-	-	-	-	-	-
	61	-	-	-	-	-	-	-	-	-	-	-	-
2													
	16	-	-	0.13	0.04	-	-	-	-	-	-	-	-
	56	-	8.79[1/]	0.48	0.13	-	-	-	-	-	-	-	-
3													
	10	-	-	-	-	-	-	-	-	-	-	-	-
	58	-	-	0.93	0.13	1.33	0.58	0.08	0.10	5.84	468.66	65.15	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	57	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	57	-	-	-	-	-	-	-	-	-	-	-	-
4													
	31	-	-	0.25	0.06	-	-	-	-	-	-	-	-
	64	-	-	0.53	0.12	-	-	-	-	-	-	-	-
	12	-	-	0.13	0.04	-	-	-	-	-	-	-	-
	64	-	-	0.69	0.19	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	65	-	-	0.68	0.13	-	-	-	-	-	-	-	-
	9	-	-	0.06	0.03	-	-	-	-	-	-	-	-
	64	-	-	0.44	0.19	-	-	-	-	-	-	-	-
	65	-	-	0.05	0.04	-	-	-	-	-	-	-	-
	74	-	-	0.06	0.05	-	-	-	-	-	-	-	-
	54	-	-	0.20	0.09	-	-	-	-	-	-	-	-
	62	-	-	0.23	0.10	-	-	-	-	-	-	-	-
5													
	12	-	-	0.11	0.04	0.46	-	-	-	-	-	-	-
	48	-	6.69[1/]	0.43	0.16	1.78	-	-	-	-	-	-	-
6													
	39	-	-	0.31	0.07	-	0.25[3/]	0.05[3/]	0.09[3/]	16[3/]	8.[3/]	6.[3/]	22[3/]
	44	-	-	0.35	0.08	-	0.28[3/]	0.05[3/]	0.10[3/]	18[3/]	9[3/]	7[3/]	24[3/]

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
6	*Arachis hypogaea*, PEA NUT/GROUND NUT.										
	- seeds with some pods,meal, solent	5	91.6	39.8	0.8	11.0	6.7	33.2	15.6	12.5	-
	extracted		100	43.5	0.8	12.0	7.4	36.3	17.0	13.6	-
	- seeds without hulls, mechanical extracted	5	92.8	41.2	7.7	8.0	7.2	28.8	-	-	-
			100	44.4	8.3	8.6	7.8	31.0	-	-	-
	- straw, dried	1	86.6	11.5	1.8	24.8	9.0	39.4	44.3	36.4	5.7
			100	13.3	2.1	28.7	10.4	45.5	51.2	42.1	6.6
7	*Arachis pintoi* cv. Amarillo, AMARILLO /										
	PINTO PEANUT.	2	23.4	3.6	0.2	-	2.4	-	9.9	7.1	1.7
	- aerial part, fresh, 45 days growth		100	15.4	0.8	-	10.4	-	42.7	30.3	7.3
	- aerial part, fresh, 60 days growth	2	29.0	4.2	0.2	6.3	3.5	14.7	12.4	10.0	2.4
			100	14.6	0.7	21.8	12.1	50.8	42.7	34.4	8.4
8	*Axonopus compressus*, BROADLEAF										
	CARPET GRASS.	2	33.0	3.5	-	-	-	-	22.0	11.3	1.4
	- aerial part, fresh, 45 days growth		100	10.6	-	-	-	-	66.7	34.3	4.2
9	*Brachiaria brizantha*, PALISADE SIGNAL										
	GRASS.	2	27.8	2.2	0.3	9.0[3/]	3.0	13.9	19.7	11.3	1.3
	- aerial part, fresh, 45 days growth		100	7.9	1.2	30.0[3/]	10.8	50.1	70.9	40.7	4.9
10	*Brachiaria humidicola*, CREEPING SIGNAL										
	GRASS/KORONIVIA GRASS.	2	25.8	2.2	0.3	7.7	1.3	13.9	17.3	9.0	0.7
	- aerial part, fresh, 30 days growth		100	8.4	1.3	29.8	4.9	53.7	67.2	35.0	2.7
	- aerial part, fresh, 45 days growth	2	27.7	2.3	0.4	8.6	1.9	14.5	19.6	10.6	1.1
			100	8.2	1.5	31.0	6.8	52.5	70.9	38.2	3.9
	- aerial part, fresh, 60 days growth	2	28.3	2.1	0.4	9.1	1.7	15.5	20.2	11.1	1.2
			100	7.5	1.5	32.3	6.0	54.8	71.4	39.2	4.2
	- aerial part, hay, 75 days growth	1	89.7	5.2	0.9	30.6	2.5	50.4	68.4	36.2	-
			100	5.8	1.0	34.2	2.8	56.2	76.3	40.4	-
11	*Brachiaria miliiformis*, CORI GRASS.										
	- aerial part, fresh	2	28.1	2.7	0.4	-	3.3	-	19.2	11.9	1.0
			100	9.5	1.4	-	11.9	-	68.4	42.5	3.6
12	*Brachiaria mutica*, PARA										
	GRASS/MAURITIUS GRASS.	2	20.7	2.0	0.4	5.6	2.2	10.2	13.5	7.2	0.7
	- aerial part, fresh, 30 days growth		100	9.6	2.2	27.2	10.8	49.2	65.0	34.8	3.2

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
6													
	67	-	-	0.37	0.65	1.05	0.23	0.09	0.30[3/]	15[3/]	-	-	119[3/]
	73	-	-	0.41	0.71	1.15	0.25	0.10	0.33[3/]	17[3/]	-	-	128[3/]
	78	-	-	0.22	0.58	1.12[3/]	0.28[3/]	0.20[3/]	0.26[3/]	15[3/]	-	-	32[3/]
	84	-	-	0.23	0.63	1.25[3/]	0.31[3/]	0.23[3/]	0.29[3/]	16[3/]	-	-	35[3/]
	48	-	-	-	-	-	-	-	-	-	-	-	-
	55	-	-	-	-	-	-	-	-	-	-	-	-
7													
	13	-	-	0.35	0.08	0.42	0.20	0.01	0.04	2.06	169.13	27.82	10.53
	54	-	-	1.50	0.36	1.79	0.87	0.03	0.19	8.81	722.79	118.90	45.02
	17	-	-	0.53	0.07	0.60	0.15	0.01	0.07	2.50	63.22	42.20	11.88
	60	-	-	1.84	0.26	2.07	0.53	0.03	0.23	8.61	217.99	145.53	40.76
8													
	19	-	-	0.11	0.08	0.48	-	-	-	-	-	-	-
	58	-	-	0.32	0.23	1.43	-	-	-	-	-	-	-
9													
	16	3.01[3/]	-	0.08	0.06	0.43	-	0.02	-	-	-	-	-
	58	10.84[3/]	8.79[1/]	0.28	0.20	1.56	-	0.06	-	-	-	-	-
10													
	15	-	-	0.05	0.05	0.45	0.05	0.04	0.03	0.92	92.00	14.50	5.99
	59	-	-	0.21	0.21	1.76	0.20	0.15	0.12	3.58	356.60	56.22	23.22
	16	-	-	0.06	0.08	0.51	0.11	0.03	0.03	1.11	136.22	31.71	9.98
	57	-	8.37[1/]	0.22	0.28	1.83	0.39	0.11	0.11	4.00	491.76	114.48	36.04
	16	-	-	0.07	0.08	0.76	0.10	0.11	0.03	0.77	19.95	12.07	6.70
	58	-	-	0.25	0.27	2.70	0.36	0.37	0.10	2.73	70.51	42.64	23.69
	48	-	-	0.28	0.05	3.69	0.52	-	-	-	-	-	-
	54	-	-	0.31	0.06	4.11	0.58	-	-	-	-	-	-
11													
	15	-	-	0.12	0.06	0.37	-	0.02	-	-	-	-	-
	54	-	-	0.42	0.23	1.32	-	0.06	-	-	-	-	-
12													
	12	-	-	-	-	-	-	-	-	-	-	-	-
	56	-	-	-	-	-	-	-	-	-	-	-	-

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
12	*Brachiaria mutica*, PARA GRASS/MAURITIUS GRASS.										
	- aerial part, fresh, 45 days growth	2	22.6	1.8	0.3	6.6	2.4	11.9	15.1	8.5	0.9
			100	8.0	1.5	29.2	10.4	52.8	66.8	37.8	4.2
	- aerial part, fresh, 60 days growth	2	24.6	1.7	0.5	7.4	2.8	12.3	16.6	9.6	1.1
			100	6.8	1.9	29.9	11.3	50.1	67.4	38.9	4.4
13	*Brachiaria ruziziensis*, RUZI GRASS/CONGO GRASS.										
	- aerial part, fresh, 30 days growth	2	19.8	2.4	0.4	4.4	1.5	11.1	12.1	5.6	0.7
			100	12.0	2.0	22.5	7.5	56.0	61.2	28.5	3.5
	- aerial part, fresh, 45 days growth	2	20.2	1.7	0.4	5.7	1.9	10.4	13.2	7.6	0.9
			100	8.5	1.9	28.4	9.6	51.5	65.5	37.6	4.4
	- aerial part, fresh, 60 days growth	2	26.9	1.7	0.5	8.2	2.6	13.8	18.5	10.5	1.1
			100	6.4	1.7	30.6	9.8	51.4	68.9	38.9	4.2
	- aerial part, hay, 30 days growth	1	90.4	9.2	5.3	21.1	7.8	47.0	57.1	26.4	-
			100	10.2	5.9	23.4	8.6	52.0	63.2	29.2	-
	- aerial part, hay, 45 days growth	1	89.6	6.5	1.9	26.6	6.2	48.3	59.3	31.4	4.2
			100	7.3	2.1	29.7	6.9	54.0	66.2	35.1	4.7
	- aerial part, hay, 60 days growth	1	88.0	4.9	0.9	29.9	5.9	46.5	62.3	37.4	5.6
			100	5.6	1.0	33.9	6.7	52.8	70.8	42.4	6.3
14	*Brachiaria decumbens*, SIGNAL GRASS.										
	- aerial part, fresh, 45 days growth	2	26.5	1.9	0.4	9.3[3/]	2.3	13.4	18.5	10.4	1.1
			100	7.4	1.6	31.5[3/]	8.8	50.7	70.0	39.1	4.0
15	*Brachiaria hybrid* cv.Mulato, MULATO GRASS.										
	- aerial part, fresh, 45 days growth	2	24.1	2.6	-	-	-	-	13.9	7.8	0.8
			100	10.8	-	-	-	-	57.7	32.4	3.3
	- aerial part, fresh, 60 days, growth	2	25.1	2.6	-	-	-	-	14.4	8.0	1.0
			100	10.3	-	-	-	-	57.4	32.0	4.0
16	*Brachiaria reptans*, RUNNING GRASS.										
	- aerial part, fresh, 45 days growth	2	27.5	2.7	0.6	7.4	4.2	12.5	16.5	8.6	1.3
			100	9.9	2.3	27.0	15.2	45.6	60.1	31.4	4.9
17	*Brassica napus*, CANOLA.										
	- Canola or rapeseed meal, solvent extracted	5	90.5	34.4	0.7	8.5	8.1	38.8	14.9	14.5	-
			100	38.0	0.8	9.4	8.9	42.9	16.5	16.0	-

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
12													
	13	-	-	0.10	0.05	0.44	0.07	0.02	0.05	2.20	40.11	24.61	7.60
	56	-	6.28[1/]	0.43	0.22	1.95	0.33	0.10	0.24	9.72	177.46	108.90	33.64
	13	-	-	0.07	0.07	0.43	0.06	0.02	0.06	1.77	32.74	13.56	8.28
	53	-	-	0.29	0.30	1.76	0.26	0.07	0.24	7.18	110.98	55.12	33.67
13													
	12	-	-	0.10	0.07	0.55	-	0.01	0.04	-	-	-	-
	58	-	-	0.48	0.33	2.79	-	0.04	0.22	-	-	-	-
	11	-	-	0.12	0.05	0.41	0.09	0.00	0.03	0.48	90.93	19.18	5.75
	54	-	9.62[1/]	0.57	0.26	2.05	0.44	trace	0.14	2.39	450.15	94.94	28.46
	15	-	-	0.11	0.06	0.51	0.09	0.00	0.04	0.72	18.96	8.14	9.11
	56	-	-	0.40	0.23	1.90	0.34	trace	0.14	2.68	70.49	30.27	33.87
	53	-	-	0.31	0.18	-	-	-	-	-	-	-	-
	59	-	-	0.35	0.20	-	-	-	-	-	-	-	-
	51	-	-	-	-	-	-	-	-	-	-	-	-
	57	-	-	-	-	-	-	-	-	-	-	-	-
	46	-	-	0.64	0.19	0.9	0.58	-	0.10	3.64	375.58	139.01	21.04
	52	-	-	0.73	0.22	1.02	0.54	trace	0.11	4.14	426.79	157.97	23.91
14													
	16	3.17[3/]	-	0.08	0.06	0.42	0.07	0.01	0.02	-	-	-	-
	60	11.97[3/]	8.79[1/]	0.30	0.23	1.60	0.25	0.03	0.09	-	-	-	-
15													
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
16													
	14	-	-	0.14	0.09	0.55	-	-	-	-	-	-	-
	52	-	-	0.51	0.35	2.00	-	-	-	-	-	-	-
17													
	68	-	-	0.76	0.92	-	-	0.05	-	-	-	-	-
	75	-	-	0.84	1.02	-	-	0.05	-	-	-	-	-

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
18	Brewer										
	- brewer's grain, dried	5	91.3	22.9	5.2	15.5	7.1	40.7	46.3	20.8	3.0
			100	25.0	5.7	17.0	7.8	44.5	50.7	22.8	3.3
	- brewer's yeast, dried	5	91.3	36.3	0.3	3.2	6.8	44.8	-	-	-
			100	39.7	0.3	3.5	7.4	49.1	-	-	-
19	*Broussonetia papyrifera*, PAPER MULBERRY.	2	23.0	5.3	1.0	2.5	3.1	11.1	-	-	-
	- leaves, fresh		100	23.0	4.4	10.8	13.6	48.2	-	-	-
20	*Caesalpinia pulcherrima*, BARBADOS PRIDE.	2	34.9	7.6	3.6	4.3	2.2	17.3	8.4	6.8	1.7
	- leaves, fresh		100	21.7	10.2	12.3	6.2	49.6	24.1	19.6	5.4
21	*Cajanus cajan*, PIGEON PEA.										
	- aerial part, dried, 45 days growth	1	-	-	-	-	-	-	-	-	-
			100	20.5	4.8	-	5.1	-	49.4	33.8	12.7
	- aerial part, dried, 75 days	1	-	-	-	-	-	-	-	-	-
			100	16.7	-	-	5.3	-	57.8	35.0	14.0
	- aerial part, fresh, 60 days growth	2	35.9	7.0	1.9	-	1.8	-	19.4	12.5	4.9
			100	19.6	5.3	-	5.0	-	54.0	34.7	13.5
	- leaf, dried	1	94.1	18.5	6.9	21.2	6.8	43.3	54.5	22.7	-
			100	19.2	7.1	22.0	7.1	44.7	56.4	23.5	-
22	*Calopogonium mucunoides*, CALOPO.										
	- aerial part, fresh, 45 days growth	2	36.3	5.4	1.2	10.5	4.2	15.1	18.2	13.3	2.6
			100	14.8	3.2	28.8	11.6	41.6	50.1	36.6	7.1
23	*Ceiba pentandra*, KAPOK.										
	- kapok seeds, meal, mechanical extracted	5	90.3	27.7	5.6	21.4	7.3	24.8	31.4	27.8	14.2
			100	31.9	6.4	24.7	8.4	28.6	36.2	32.1	16.3
24	*Cenchrus biflorus*, AQUATICA FORSK GRASS.	2	30.0	3.9	0.6	7.8	4.4	13.2	-	-	-
	- aerial part, fresh		100	13.1	2.1	26.1	14.7	44.0	-	-	-
25	*Cenchrus ciliaris*, BUFFEL GRASS.										
	- fresh	2	21.4	2.3	0.4	6.6	2.8	9.4	14.7	9.1	0.9
			100	10.6	1.9	30.9	12.9	43.7	68.6	42.5	4.4
26	*Centrosema pascuorum* cv. Bundy, BUNDY CENTURION.	2	12.6	2.3	-	-	-	-	5.9	4.1	0.9
	- aerial part, fresh, 45 days growth		100	17.7	-	-	-	-	47.1	32.6	7.1

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
18													
	64	12.11[5/]	10.38[5/]	0.33	0.43	-	-	0.05	-	-	-	-	-
	70	13.26[5/]	11.34[5/]	0.36	0.47	0.04[5/]	0.23[5/]	0.06	0.21[5/]	18.6[5/]	234.[5/]	53.[5/]	104.[5/]
	75	-	-	0.24	0.97	-	-	-	-	-	-	-	-
	82	14.56[4/]	12.13[4/]	0.26	1.06	1.79[4/]	0.27[4/]	0.08[4/]	0.45[4/]	35[4/]	117[4/]	6[4/]	41[4/]
19													
	16	-	-	0.68	0.07	-	-	-	-	-	-	-	-
	70	-	-	2.97	0.29	-	-	-	-	-	-	-	-
20													
	27	-	-	-	-	-	-	-	-	-	-	-	-
	77	-	-	-	-	-	-	-	-	-	-	-	-
21													
	-	-	-	-	-	-	-	-	-	-	-	-	-
	59	-	-	0.60	0.23	1.30	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	54	-	-	-	-	-	-	-	-	-	-	-	-
	20	-	-	0.27	0.12	-	-	-	-	-	-	-	-
	56	-	6.69[1/]	0.75	0.33	-	-	-	-	-	-	-	-
	65	-	-	-	-	-	-	-	-	-	-	-	-
	69	-	-	-	-	-	-	-	-	-	-	-	-
22													
	21	-	-	0.40	0.10	-	-	-	-	-	-	-	-
	57	-	6.69[1/]	1.14	0.16	-	-	-	-	-	-	-	-
23													
	56	9.71[3/]	7.74[3/]	0.33	1.02	-	-	-	-	-	-	-	-
	62	10.75[3/]	8.95[3/]	0.38	1.17	-	-	-	-	-	-	-	-
24													
	16	-	-	0.13	0.10	-	-	-	-	-	-	-	-
	54	-	-	0.44	0.33	-	-	-	-	-	-	-	-
25													
	11	-	-	0.07	0.03	0.71	0.05	-	-	-	-	-	-
	52	-	-	0.34	0.15	3.30	0.24	-	-	-	-	-	-
26													
	7	-	-	0.11	0.02	-	-	-	-	-	-	-	-
	56	-	-	0.88	0.14	-	-	-	-	-	-	-	-

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
26	*Centrosema pascuorum* cv. Bundy, BUNDY CENTURION.	2	18.9	4.0	0.3	5.8	2.7	6.2	8.4	5.9	1.2
	- aerial part, fresh, 60 days growth		100	20.9	1.6	30.6	14.1	32.8	44.5	31.3	6.4
	- aerial part, hay, 90 days growth	1	-	-	-	-	-	-	-	-	-
			100	14.9	1.3	31.5	9.9	42.4	49.1	33.6	8.5
27	*Centrosema pascuorum* cv.Cavalcade, CAVALCADE CENTURION.	2	19.9	3.3	0.4	5.6	2.4	8.3	9.9	6.5	1.5
	- aerial part, fresh, 45 days growth		100	16.6	1.8	28.2	12.0	41.4	49.8	32.9	7.8
	- aerial part, fresh, 60 days growth	2	22.9	3.7	0.3	7.2	2.6	9.1	11.5	7.7	1.6
			100	16.1	1.3	31.5	11.5	39.6	50.0	33.6	7.2
	- aerial part, fresh, 75 days growth	2	25.0	4.0	0.8	8.4	2.0	9.7	14.1	9.5	2.1
			100	15.8	3.3	33.8	8.2	38.9	56.5	38.0	8.4
	- aerial part, fresh, 90 days growth	2	25.5	4.0	0.4	8.2	2.0	10.9	13.3	9.5	2.1
			100	15.7	1.5	32.3	7.7	42.8	52.3	37.3	8.1
	- aerial part, fresh, 120 days growth	2	26.0	3.7	0.4	8.3	2.1	11.5	13.3	8.7	2.2
			100	14.3	1.4	31.9	8.0	44.4	51.3	33.6	8.6
	- aerial part, hay, 60 days growth	1	91.4	13.5	0.7	28.8	6.4	41.9	45.2	30.7	6.3
			100	14.8	0.8	31.5	7.1	45.8	49.5	33.6	6.9
28	*Centrosema pubescens* cv. Common, CENTRO.	2	22.0	4.2	0.5	6.9	2.8	7.6	12.2	8.1	2.1
	- aerial part, fresh, 45 days growth		100	19.2	2.4	31.5	12.5	34.4	55.3	36.7	9.7
29	*Chloris gayana*, RHODES GRASS. - aerial part, fresh, 30 days growth	2	26.6	2.8	0.7	8.5	2.0	12.5	18.4	9.6	2.3
			100	10.6	2.7	31.9	7.6	47.1	69.2	36.0	8.6
	- aerial part, fresh, 45 days growth	2	27.4	2.0	0.7	9.4	2.4	12.9	19.9	11.7	-
			100	7.4	2.6	34.4	8.6	47.0	72.8	42.8	-
	- aerial part, fresh, 60 days growth	2	28.5	1.9	0.9	10.2	-	-	20.8	11.8	-
			100	6.8	3.1	35.9	-	-	73.1	41.3	-
30	*Chrysopogon orientalis*, YA-PHUNGCHU. - aerial part, fresh	2	30.0	1.5	0.5	9.8	2.7	15.6	-	-	-
			100	4.9	1.5	32.7	8.9	52.0	-	-	-

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
26													
	10	-	-	0.25	0.05	0.45	0.06	-	-	-	-	-	-
	55	-	-	1.33	0.26	2.36	0.31	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	53	-	-	0.97	0.24	1.86	0.23	-	-	-	-	-	-
27													
	11	-	-	0.21	0.05	0.08	-	-	-	-	-	-	-
	57	-	-	1.07	0.24	0.42	-	-	-	-	-	-	-
	13	-	-	0.22	0.06	0.48	0.08	0.00	0.04	-	-	-	-
	55	-	-	0.94	0.25	2.08	0.35	0.00	0.19	-	-	-	-
	14	-	-	0.27	0.08	0.66	-	-	-	-	-	-	-
	57	-	-	1.06	0.31	2.65	-	-	-	-	-	-	-
	15	-	-	0.14	0.05	0.53	0.07	-	0.05	-	-	-	-
	58	-	7.95[1/]	0.55	0.21	2.06	0.26	-	0.21	-	-	-	-
	15	-	-	0.19	0.06	0.47	0.07	-	0.05	-	-	-	-
	58	-	-	0.74	0.23	1.80	0.26	-	0.20	-	-	-	-
	50	-	-	0.67	0.20	2.02	0.27	-	0.17	7.84	-	147.01	31.14
	55	-	-	0.73	0.22	2.21	0.30	trace	0.19	8.58	-	160.84	34.07
28													
	12	-	-	0.18	0.05	0.33	-	-	-	-	-	-	-
	56	-	6.69[1/]	0.83	0.24	1.49	-	-	-	-	-	-	-
29													
	13	2.82[3/]	-	0.12	0.05	0.62	-	0.25[3/]	-	-	-	-	-
	49	10.59[3/]	7.53[1/]	0.48	0.21	2.46	-	1.00[3/]	-	-	-	-	-
	16	2.84[3/]	2.51[3/]	0.12	0.06	0.37	0.04	0.11	0.07	1.25	122.17	15.73	6.93
	53	10.38[3/]	8.58[3/]	0.43	0.22	1.35	0.15	0.41	0.27	4.56	445.87	57.42	25.28
	15	-	-	0.06	0.06	0.35	0.03	0.10	0.07	1.02	67.15	4.20	3.76
	54	-	-	0.22	0.22	1.22	0.09	0.34	0.25	3.58	235.60	29.53	13.19
30													
	16	-	-	0.04	0.01	-	-	-	-	-	-	-	-
	53	-	-	0.13	0.03	-	-	-	-	-	-	-	-

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
31	*Cocos nucifera*, COCONUT.										
	- coconut kernels with coats, meal,	5	92.3	15.8	10.8	10.7	6.1	48.8	43.7	28.9	-
	mechanical extracted, caked		100	17.1	11.7	11.6	6.7	52.9	47.4	31.3	-
	- coconut milk residues	4	91.3	5.9	24.5	11.3	2.2	47.4	49.1	34.9	-
			100	6.5	26.8	12.4	2.4	51.9	53.8	38.2	-
32	*Coix lacrymajobi*, JOB'S TEARS.										
	- husk	4	91.4	10.7	2.7	26.9	-	-	-	-	-
			100	11.7	2.9	29.4	-	-	-	-	-
	- seed	4	88.0	12.8	5.5	0.8	1.9	67.1	20.6	3.8	-
			100	14.5	6.2	0.9	2.1	76.3	23.4	4.3	-
33	*Commelina bengalensis*, DAYFLOWE.										
	- aerial part, fresh, 45 days growth	2	18.0	3.3	0.5	8.6	3.1	2.5	8.4	6.0	1.6
			100	18.2	2.9	47.6	17.2	14.1	46.6	33.5	9.0
34	*Cynodon dactylon*, BERMUDA GRASS.										
	- aerial part, fresh	2	27.1	1.7	0.6	8.0	2.4	14.4	-	-	-
			100	6.4	2.1	29.5	8.8	53.2	-	-	-
35	*Cyperus rotundus*, NUTGRASS.										
	- aerial part, hay	1	-	-	-	-	-	-	-	-	-
			100	8.7	1.8	25.8	12.7	51.0	59.6	35.8	6.0
36	*Dactyloctenium aegyptium*, CROWFOOT										
	GRASS.	2	30.5	2.4	0.3	9.2	4.6	13.9	19.9	10.6	1.3
	- aerial part, fresh, 45 days		100	8.0	1.0	30.3	15.1	45.6	65.4	34.9	4.2
37	*Desmanthus virgatus*, HEDGE LUCERNE										
	/DESMANTHUS.	2	27.1	4.8	0.6	-	1.6	-	10.8	7.5	2.7
	- aerial part, fresh, 45 days growth		100	17.8	2.1	-	6.1	-	39.9	27.5	9.8
	- aerial part, fresh, 60 days growth	2	32.3	5.3	0.7	-	2.4	-	14.4	10.4	3.5
			100	16.4	2.3	-	7.4	-	44.6	32.2	10.8
	- aerial part, fresh, 75 days growth	2	37.9	5.9	0.9	-	3.1	-	18.2	14.4	5.2
			100	15.6	2.3	-	8.3	-	48.1	38.1	13.7
38	*Desmodium heterocarpon*, DESMODIUM.										
	- aerial part, fresh, 45 days growth	2	26.0	3.6	-	-	-	-	12.6	10.5	4.2
			100	14.0	-	-	-	-	48.6	40.2	16.2
39	*Desmodium intortum*, GREEN LEAF										
	DESMODIUM.	2	20.3	3.3	0.7	5.9	2.2	8.2	9.3	6.8	1.1
	- aerial part, fresh		100	16.3	3.5	29.0	10.6	40.6	46.0	33.3	5.3

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
31	76	-	-	0.24	0.46	-	-	0.03	-	-	-	-	-
	82	-	-	0.26	0.50	-	-	0.04	-	-	-	-	-
	86	-	-	0.43	0.22	-	-	-	-	-	-	-	-
	94	-	-	0.47	0.24	-	-	-	-	-	-	-	-
32	68	-	-	-	-	-	-	-	-	-	-	-	-
	75	-	-	-	-	-	-	-	-	-	-	-	-
	73	-	-	0.04	0.33	-	-	-	-	-	-	-	-
	83	-	-	0.05	0.37	-	-	-	-	-	-	-	-
33	4	-	-	0.74	0.06	0.79	0.07	0.00	-	2.79	105.64	88.74	8.93
	40	-	-	4.10	0.31	4.40	0.40	0.00	-	15.50	586.9	493.00	49.60
34	15	-	-	0.11	0.04	-	-	-	-	-	-	-	-
	55	-	-	0.39	0.13	-	-	-	-	-	-	-	-
35	-	-	-	-	-	-	-	-	-	-	-	-	-
	51	-	-	0.60	0.40	3.30	0.20	0.10	-	6.90	367.70	101.50	21.40
36	15	-	-	0.16	0.09	0.46	0.09	-	-	1.60	140.70	80.90	15.10
	49	-	-	0.52	0.28	1.51	0.30	trace	-	5.40	461.40	265.30	49.50
37	15	-	-	0.26	0.04	0.67	-	-	-	-	-	-	-
	55	-	-	0.95	0.15	2.41	-	-	-	-	-	-	-
	17	-	-	0.32	0.06	0.48	0.14	0.01	0.14	1.75	16.59	15.97	7.45
	54	-	-	1.00	0.20	1.48	0.43	0.02	0.43	5.41	51.37	49.45	23.06
	20	-	-	-	-	-	-	-	-	-	-	-	-
	53	-	-	-	-	-	-	-	-	-	-	-	-
38	11	-	-	0.29	0.08	0.31	-	-	-	-	-	-	-
	44	-	-	1.17	0.33	1.24	-	-	-	-	-	-	-
39	12	-	-	-	-	-	-	-	-	-	-	-	-
	58	-	7.11[1/]	-	-	-	-	-	-	-	-	-	-

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
40	*Dichanthium aristatum,* ANGLETON GRASS.										
	- aerial part, fresh	2	24.0	2.2	0.5	7.3	2.4	11.6	16.8	11.3	1.1
			100	9.0	2.0	30.6	10.0	48.4	70.2	47.4	4.7
41	*Dichantium caricosum,* NADI BLUE GRASS.										
	- aerial part, fresh, 45 days growth	2	37.0	3.6	0.5	11.2	4.9	16.8	24.5	15.3	1.6
			100	9.6	1.4	30.4	13.1	45.5	66.1	41.3	4.4
42	*Digitaria adscendens,* LARGE CRAB GRASS.										
	- aerial part, fresh	2	25.0	2.6	0.8	7.4	2.5	11.8	-	-	-
			100	10.2	3.2	29.6	9.8	47.2	-	-	-
43	*Digitaria eriantha,* PANGOLA GRASS/COMMON FINGER GRASS.										
	- aerial part, fresh, 30 days growth	2	24.4	2.2	0.4	6.6	1.9	13.2	15.9	8.4	0.7
			100	9.1	1.7	27.2	7.8	54.2	65.1	34.3	2.8
	- aerial part, fresh, 45 days growth	2	26.9	1.9	0.4	7.9	2.7	14.0	17.8	9.3	0.9
			100	10.5	1.3	29.4	10.0	52.1	66.2	34.5	3.5
	- aerial part, fresh, 60 days growth	2	29.9	1.9	0.4	10.5	3.1	10.4	21.3	11.5	1.4
			100	6.5	1.3	35.1	10.5	46.7	71.3	38.5	4.8
	- aerial part, hay, 30 days growth	1	90.6	7.6	-	-	7.8	-	58.6	-	-
			100	8.4	-	-	8.6	-	64.7	-	-
	- aerial part, hay, 45 days growth	1	87.0	8.7	1.4	28.1	6.8	42.0	61.2	32.2	3.9
			100	9.5	1.6	32.3	7.8	48.3	70.3	37.1	4.5
44	*Dimocarpus longon,* LONGAN.										
	- seeds	1	65.1	5.9	1.6	5.3	1.5	66.7	-	-	-
			100	7.3	2.0	6.5	1.8	82.4	-	-	-
45	*Eichornia crassipes,* WATER HYACINTH.										
	- leaves, fresh	2	12.0	2.0	0.2	2.2	2.0	5.6	-	-	-
			100	17.0	1.8	18.1	16.3	46.8	-	-	-
	- stems and leaves, fresh	2	8.1	1.0	0.2	2.2	1.6	3.1	-	-	-
			100	12.3	2.4	27.3	19.4	38.6	-	-	-
46	*Elaeis guineensis,* OIL PALM.										
	- palm frond	2	88.3	2.2	34.7	0.2	3.5	48.5	-	-	-
			100	2.4	39.0	0.2	3.9	54.5	-	-	-
	- palm fruits, meal, mechanical extracted	5	87.3	5.3	6.3	35.4	2.5	38.1	47.8	40.3	-
			100	6.1	7.2	40.4	2.9	43.4	54.5	43.3	-

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
40													
	13	-	-	0.09	0.04	-	-	-	-	-	-	-	-
	55	-	7.95[1/]	0.39	0.17	-	-	-	-	-	-	-	-
41													
	19	-	-	0.21	0.09	0.81	0.10	-	-	2.21	108.47	23.83	10.18
	51	-	-	0.57	0.23	2.20	0.27	trace	-	5.97	293.17	64.40	27.50
42													
	14	-	-	0.08	0.07	-	-	-	-	-	-	-	-
	56	-	-	0.32	0.28	-	-	-	-	-	-	-	-
43													
	14	-	-	0.09	0.05	-	-	-	-	-	-	-	-
	58	-	9.20[1/]	0.37	0.20	-	-	-	-	-	-	-	-
	15	-	-	0.25	0.07	0.28	0.10	0.06	0.03	1.63	233.10	106.58	4.97
	55	-	8.79[1/]	0.91	0.24	1.03	0.37	0.23	0.12	6.07	866.54	396.20	18.46
	17	-	-	0.14	0.08	0.47	0.07	0.16	0.04	1.26	49.67	46.76	7.55
	56	-	-	0.47	0.27	1.58	0.22	0.52	0.14	4.22	166.13	156.38	25.25
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	46	-	-	-	-	-	-	-	-	-	-	-	-
	53	11.05[2/]	8.87[2/]	-	-	-	-	-	-	-	-	-	-
44													
	52	-	-	0.11	0.00	-	-	-	-	-	-	-	-
	80	-	-	0.13	0.00	-	-	-	-	-	-	-	-
45													
	7	-	-	0.24	0.07	-	-	-	-	-	-	-	-
	59	-	-	2.03	0.58	-	-	-	-	-	-	-	-
	-	-	-	0.17	0.06	-	-	-	-	-	-	-	-
	48	-	-	2.06	0.68	-	-	-	-	-	-	-	-
46													
	62	-	-	0.60	0.10	-	-	-	-	-	-	-	-
	70	-	-	0.67	0.11	-	-	-	-	-	-	-	-
	39	-	-	0.36	0.13	-	-	-	-	-	-	-	-
	45	-	-	0.41	0.15	-	-	-	-	-	-	-	-

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
46	*Elaeis guineensis*, OIL PALM.										
	- palm kernels cake, mechanical extracted	5	91.3	15.2	5.1	7.9	5.9	57.2	54.6	38.2	-
			100	16.6	5.6	8.7	6.5	62.6	59.7	41.9	-
	- palm kernels with coat, meal, mechanical extracted	5	92.8	9.1	11.5	23.6	5.8	43.0	47.6	33.7	-
			100	9.8	12.3	25.4	6.2	46.3	51.2	36.3	-
	- palm kernels with coat, meal, mechanical extracted, pelleted	5	93.3	14.7	7.4	19.3	4.3	47.6	62.8	-	-
			100	15.7	8.0	20.7	4.6	51.0	67.3	-	-
	- palm leaves	2	89.9	10.1	2.2	21.8	9.3	55.5	-	-	-
			100	11.2	2.5	24.2	10.4	61.7	-	-	-
47	*Erythrina subumbrans*, DECEMBER TREE.										
	- leaves, fresh	2	29.0	5.6	1.3	8.4	3.0	10.6	13.5	10.4	2.5
			100	19.4	4.5	29.0	10.4	36.7	46.5	35.9	8.7
48	Fish meal.										
	- fish meal, CP ≥ 40 %	5	91.7	47.7	7.4	1.1	28.8	6.6	-	-	-
			100	52.0	8.1	1.2	31.5	7.2	-	-	-
	- fish meal, CP ≥ 50 %	5	92.1	52.7	10.0	0.6	22.4	6.4	2.8	1.3	5.8
			100	57.2	10.9	0.7	24.3	6.9	3.0	1.4	6.3
	- fish meal, CP ≥ 55 %	5	91.9	56.8	8.5	0.7	20.5	5.4	-	-	-
			100	61.8	9.3	0.7	22.3	5.9	-	-	-
	- fish meal, CP ≥ 60 %	5	92.1	62.4	7.8	0.5	18.7	2.6	-	-	-
			100	67.8	8.5	0.6	20.3	2.8	-	-	-
49	*Gliricidia sepium*, GLIRICIDIA.										
	- leaves, fresh	2	24.8	6.3	0.7	4.5	2.6	10.7	8.8	7.6	2.9
			100	25.4	2.8	18.0	10.6	43.2	35.4	30.6	11.7
50	*Glycine max*, SOYBEAN.										
	- full fat soybean	5	90.9	33.4	18.0	6.5	4.4	28.7	-	4.4	-
			100	36.8	19.8	6.9	4.9	31.6	-	4.8	-
	- soya milk residue, fresh	5	12.3	3.7	1.1	1.6	0.6	5.2	3.1	2.3	0.2
			100	30.3	9.1	12.9	5.2	42.5	25.5	18.9	1.6
	- soybean hulls	1	89.5	10.6	1.4	32.5	3.8	41.3	55.7	41.4	-
			100	11.8	1.6	36.3	4.2	46.1	62.3	46.3	-

1/ in vitro   2/ in vivo   3/ Harris et. al ,1982   4/ NRC , 1984   5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
46													
	72	-	-	0.35	0.52	-	0.24	-	-	-	-	-	-
	79	-	-	0.38	0.56	-	0.26	-	-	-	-	-	-
	61	-	-	0.44	0.34	-	-	-	-	-	-	-	-
	66	-	-	0.48	0.37	-	-	-	-	-	-	-	-
	63	-	-	0.32	0.54	-	-	-	-	-	-	-	-
	68	-	-	0.34	0.57	-	-	-	-	-	-	-	-
	48	-	-	0.94	0.15	-	-	-	-	-	-	-	-
	53	-	-	1.05	0.17	-	-	-	-	-	-	-	-
47													
	17	-	-	0.68	0.07	-	-	-	-	-	-	-	-
	59	-	9.20[1/]	2.36	0.23	-	-	-	-	-	-	-	-
48													
	75	-	-	7.78	2.77	-	-	-	-	-	-	-	-
	82	-	-	8.49	3.02	-	-	-	-	-	-	-	-
	82	13.18[5/]	11.38[5/]	6.24	3.13	-	-	-	-	-	-	-	-
	89	14.31[5/]	12.30[5/]	6.78	3.40	-	-	-	-	-	-	-	-
	82	13.34[5/]	11.55[5/]	5.39	2.86	-	-	-	-	-	-	-	-
	89	14.52[5/]	12.51[5/]	5.86	3.11	-	-	-	-	-	-	-	-
	83	13.83[5/]	11.88[5/]	4.75	2.69	-	-	-	-	-	-	-	-
	90	15.02[5/]	13.01[5/]	5.16	2.92	-	-	-	-	-	-	-	-
49													
	9	-	-	0.45	0.10	-	-	-	-	-	-	-	-
	36	-	8.79[1/]	1.82	0.41	-	-	-	-	-	-	-	-
50													
	88	-	-	0.24	0.50	1.60	0.22	0.02	-	12.36	144.50	35.08	48.17
	97	-	-	0.26	0.55	1.76	0.24	0.02	-	13.60	159.00	38.60	53.00
	10	1.66[3/]	1.47[3/]	0.07	0.04	-	-	-	-	-	-	-	-
	79	13.51[3/]	11.92[3/]	0.54	0.36	-	-	-	-	-	-	-	-
	50	-	-	0.44	0.11	-	18.41	0.03	-	-	-	-	-
	56	-	-	0.49	0.13	-	20.57	0.03	-	-	-	-	-

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
50	*Glycine max*, SOYBEAN.										
	- soybean pods, sun cured	1	89.8	5.6	1.5	30.5	7.1	45.1	52.9	40.3	7.7
			100	6.2	1.6	34.0	7.9	50.3	58.9	44.9	8.5
	- soybean seeds with hull, meal, solvent extracted	5	88.5	41.6	1.1	4.7	5.7	35.4	12.9	7.9	2.6
			100	47.0	1.2	5.3	6.5	40.0	14.5	9.0	2.9
	- soybean seeds, meal, mechanical extracted, caked	5	90.7	41.6	9.9	6.9	6.1	26.5	15.7	12.1	-
			100	45.7	10.9	7.6	6.7	29.1	17.2	13.3	-
	- soybean straw, sun cured	1	86.8	6.1	1.7	30.5	6.6	42.0	49.8	36.6	7.6
			100	7.0	1.9	35.1	7.6	48.4	57.4	42.1	8.7
51	*Gosypium spp*, COTTON.										
	- cotton seeds without hulls, meal, mechanical extracted, 41 % protein	5	90.2	42.2	5.2	6.1	7.7	29.0	15.3	10.1	-
			100	46.7	5.8	6.8	8.5	32.2	17.0	11.2	-
	- cotton seeds	5	91.1	18.0	15.2	27.0	3.9	27.1	38.0	32.0	3.8
			100	19.8	16.7	29.6	4.2	29.7	41.7	35.2	4.2
52	*Helianthus annus*, SUNFLOWER.										
	- sunflower seeds, meal solvent extracted	5	90.9	30.8	1.5	19.6	6.6	32.5	32.9	29.1	4.8
			100	33.8	1.7	21.5	7.2	35.8	36.2	32.0	5.3
	- sunflower seeds meal, mechanical extracted	5	91.5	20.9	6.6	28.2	6.6	29.3	-	-	-
			100	22.8	7.2	30.8	7.2	32.0	-	-	-
	- flowers	1	87.8	6.8	3.3	17.9	12.6	47.2	33.8	30.9	-
			100	7.7	3.8	20.4	14.3	53.8	38.5	35.2	-
	- hulls	1	90.8	7.5	2.0	41.2	7.0	35.9	-	-	-
			100	8.3	2.1	43.9	7.5	38.2	-	-	-
	- seeds without hulls	5	94.6	19.2	39.2	13.1	4.0	19.2	-	-	-
			100	20.3	41.4	13.8	4.2	20.3	-	-	-
53	*Hymenachne acutigluma*, NATIVE HYMENACHNE GRASS.	2	30.2	2.7	0.7	8.7	2.7	15.5	19.9	10.9	3.9
	- aerial part, fresh		100	8.9	2.4	28.8	8.7	51.2	66.0	36.2	12.9
54	*Lablab purpureus*, DOLICHOS / LABLAB.										
	- aerial part, fresh	2	18.2	3.4	0.7	5.4	2.1	6.7	9.3	-	-
			100	18.5	3.7	29.7	11.3	36.8	51.3	-	-

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
50													
	47	9.05[5/]	7.44[5/]	0.84	0.13	-	-	-	-	-	-	-	-
	52	10.08[5/]	8.28[5/]	0.94	0.14	-	-	-	-	-	-	-	-
	73	-	-	0.30	0.61	1.99[3/]	0.25[3/]	0.04[3/]	0.43[3/]	21[3/]	120[3/]	29[3/]	58[3/]
	82	-	-	0.34	0.69	2.20[3/]	0.28[3/]	0.04[3/]	0.47[3/]	23[3/]	133[3/]	32[3/]	64[3/]
	80	-	-	0.39	0.47	-	-	-	-	-	-	-	-
	88	-	-	0.43	0.52	-	-	-	-	-	-	-	-
	47	-	-	1.24	0.13	-	-	-	-	-	-	-	-
	52	7.74[3/]	4.27[3/]	1.43	0.15	-	-	-	-	-	-	-	-
51													
	75	-	-	0.20	1.19	-	-	-	-	-	-	-	-
	83	-	-	0.22	1.32	-	-	-	-	-	-	-	-
	61	13.19[3/]	11.63[3/]	0.15	0.55	1.73	0.34	-	1.73	5[3/]	277[3/]	24[3/]	39[3/]
	67	14.48[3/]	12.76[3]	0.16	0.60	1.91	0.38	-	1.91	6[3/]	303[3/]	26[3/]	42[3/]
52													
	56	-	-	0.39	1.08	-	-	-	-	-	-	-	-
	62	-	-	0.43	1.19	-	-	-	-	-	-	-	-
	51	9.42[3/]	7.81[3/]	0.54	0.55	-	-	-	-	-	-	-	-
	56	10.29[3/]	8.54[3/]	0.60	0.60	-	-	-	-	-	-	-	-
	48	-	-	2.65	0.18	-	-	-	-	-	-	-	-
	55	-	-	3.02	0.21	-	-	-	-	-	-	-	-
	49	-	-	0.42	0.22	-	-	-	-	-	-	-	-
	54	-	-	0.45	0.23	-	-	-	-	-	-	-	-
	85	20.10[3/]	18.52[3/]	0.27	0.50	0.68[3/]	0.37[3/]	0.28[3/]	-	23[3/]	50[3/]	22[3/]	69[3/]
	90	21.25[3/]	19.58[3]	0.29	0.53	0.72[3/]	0.39[3/]	0.29[3/]	-	25[3/]	54[3/]	23[3/]	73[3/]
53													
	17	-	-	0.08	0.04	0.57	0.09	0.03	-	2.90	178.20	122.50	13.00
	57	-	-	0.27	0.16	1.90	0.30	0.10	-	9.60	590.20	405.60	43.20
54													
	11	-	-	0.22	0.05	-	-	-	-	-	-	-	-
	58	7.53[1/]	-	1.22	0.27	-	-	-	-	-	-	-	-

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
55	*Leucaena leucocephala*, LEUCAENA.										
	- browse, fresh, mature	2	38.7	8.9	0.4	-	3.6	-	14.9	9.6	3.1
			100	22.9	1.1	-	9.3	-	38.6	24.9	8.0
	- leaf meal	5	92.4	11.9	1.6	30.6	8.3	39.8	44.6	36.4	18.9
			100	12.9	1.8	33.2	9.0	43.1	48.2	39.4	20.4
	- leaves, dried	5	91.6	22.3	4.1	11.7	7.5	45.9	28.6	21.9	8.5
			100	24.4	4.5	12.8	8.2	50.1	31.2	23.9	9.3
56	*Lycopersicon esculentum*, TOMATO.										
	- tomato pomace, dried	5	92.5	19.3	10.3	31.9	4.9	26.1	58.2	45.0	-
			100	20.8	11.2	34.5	5.3	28.2	62.9	48.6	-
57	*Manihot esculenta*, CASSAVA.										
	- cassava chips	4	89.8	2.1	0.4	2.7	3.4	81.2	9.1	5.1	2.0
			100	2.3	0.5	3.0	3.8	90.4	10.1	5.7	2.2
	- cassava pulp, ethanol process residue,	4	30.0	1.2	0.1	3.9	1.6	23.2	11.6	7.3	-
	wet		100	4.0	0.4	12.9	5.3	77.4	38.6	24.3	-
	- cassava tuber, pellet	4	89.0	2.3	0.6	5.3	4.1	76.8	14.7	7.7	-
			100	2.6	0.6	5.9	4.6	86.3	16.5	8.6	-
	- leaves, dried	1	90.6	20.1	5.1	17.8	7.5	40.0	37.5	28.4	6.7
			100	22.2	5.6	19.7	8.3	44.2	41.4	31.3	7.4
	- leaves, silage	3	24.9	3.5	2.7	4.4	2.4	11.9	9.3	5.7	1.6
			100	13.9	11.0	17.6	9.7	47.8	37.3	23.0	6.5
	- peelings, fresh	2	37.4	1.6	0.3	5.1	2.8	27.5	14.5	10.0	-
			100	4.3	0.9	13.6	7.6	73.6	38.8	26.6	-
	- starch process residue	4	87.6	2.5	0.3	13.2	4.9	66.8	34.6	25.8	-
			100	2.8	0.3	15.1	5.6	76.2	39.5	29.5	-
	- top with stem, fresh	2	18.2	2.6	0.7	4.7	1.7	8.5	8.6	5.4	-
			100	14.5	3.6	25.6	9.4	46.9	47.3	29.6	-
58	*Medicago sativa*, ALFALFA/LUCERNE.										
	- aerial part, fresh, 45 days growth	2	18.0	4.0	0.5[3/]	2.9[3/]	2.8[3/]	7.8	-	6.0[3/]	1.6[3/]
			100	22.3	2.6[3/]	16.2[3/]	15.7[3/]	43.2	-	31.0[3/]	8.2[3/]

1/ in vitro   2/ in vivo   3/ Harris et. al ,1982   4/ NRC , 1984   5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
55													
	23	-	-	0.41	0.07	0.71	0.16	0.00	0.12	3.42	-	33.61	10.42
	60	-	7.53[1/]	1.07	0.19	1.84	0.41	0.01	0.31	8.84	-	86.84	26.93
	42	-	-	0.93	0.12	-	-	-	-	-	-	-	-
	46	-	-	1.00	0.13	-	-	-	-	-	-	-	-
	68	-	-	1.64	0.20	-	-	-	-	-	-	-	-
	73	-	-	1.79	0.22	-	-	-	-	-	-	-	-
56													
	52	-	-	0.35	0.56	-	-	-	-	-	-	-	-
	56	10.71[4/]	8.79[4/]	0.38	0.61	-	-	-	-	-	-	-	-
57													
	71	15.26[3/]	13.71[3/]	0.16	0.09	0.83	0.08	0.02	-	3.69	-	-	-
	79	16.99[3/]	15.27[3/]	0.10	0.10	0.92	0.09	0.02	-	4.11	-	-	-
	22	-	-	0.20	0.03	-	-	-	-	-	-	-	-
	72	-	-	0.67	0.09	-	-	-	-	-	-	-	-
	69	-	-	0.24	0.06	-	-	-	-	5.10	-	-	-
	77	-	-	0.27	0.07	-	-	-	-	5.73	-	-	-
	63	12.13[3/]	10.54[3/]	1.85	0.22	-	-	-	-	-	-	-	-
	69	13.39[3/]	11.63[3/]	2.05	0.24	-	-	-	-	-	-	-	-
	20	-	-	-	-	-	-	-	-	-	-	-	-
	80	-	-	-	-	-	-	-	-	-	-	-	-
	25	-	-	0.19	0.03	-	-	-	-	-	-	-	-
	66	-	-	0.51	0.07	-	-	-	-	-	-	-	-
	62	-	-	0.61	0.05	-	-	-	-	-	-	-	-
	71	-	-	0.70	0.06	-	-	-	-	-	-	-	-
	11	-	-	0.44	0.04	-	-	-	-	-	-	-	-
	60	-	-	2.42	0.23	-	-	-	-	-	-	-	-
58													
	10	2.20[3/]	1.88[3/]	0.20[3/]	0.17[3/]	0.42[3/]	0.05[3/]	0.04[3/]	0.09[3/]	2.[3/]	22.[3/]	8.[3/]	-
	58	12.22[3/]	10.46[3/]	1.05[3/]	0.35[3/]	2.14[3/]	0.27[3/]	0.21[3/]	0.48[3/]	11.[3/]	111.[3/]	41.[3/]	-

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
58	*Medicago sativa*, ALFALFA/LUCERNE.										
	- aerial part, fresh, 60 days growth	2	24.0	5.1	0.7[3/]	6.2[3/]	3.6[3/]	8.5	-	5.1	0.2
			100	21.1	3.1[3/]	25.7[3/]	14.8[3/]	35.3	-	21.4	0.8
	- aerial part, fresh, 75 days growth	2	25.7	4.9	0.9[3/]	7.6[3/]	2.7[3/]	9.6	8.8	5.9	1.3
			100	18.9	3.5[3/]	29.7[3/]	10.7[3/]	37.2	34.4	22.9	5.1
59	*Melinis repens*, NATAL GRASS.										
	- aerial part, fresh, 45 days growth	2	37.0	3.1	-	-	-	-	25.7	14.5	0.2
			100	8.4	-	-	-	-	69.4	39.2	5.7
60	*Musa sapientum*, KLUAI NAMWAA.										
	- peels, fresh	2	16.5	1.2	2.0	2.0	2.1	9.2	-	-	-
			100	7.3	12.2	12.2	12.5	55.8	-	-	-
	- leaves, fresh	2	22.2	1.2	1.4	2.8	2.2	14.7	-	-	-
			100	5.3	6.2	12.7	9.7	66.1	-	-	-
	Musa sapientum, KLUAI HOM.										
	- peels, fresh	2	10.7	0.8	0.7	1.1	1.6	6.5	-	-	-
			100	7.3	6.8	10.6	14.5	60.8	-	-	-
61	*Nephelium lappaceum*, RUMBUTAN.										
	- peeling, dried	1	91.3	6.4	1.4	13.9	2.8	66.8	0.51	0.38	-
			100	7.1	1.5	15.3	3.1	73.0	0.56	0.42	-
	- seeds	4	90.0	8.0	21.5	4.5	1.6	45.4	-	-	-
			100	9.9	26.5	5.6	2.0	56.0	-	-	-
62	*Oryza glutinosa*, GLUTINOUS RICE.										
	- broken glutinous rice	4	88.3	6.4	1.3	0.5	0.8	78.6	-	-	-
			100	7.3	1.5	0.6	0.9	89.0	-	-	-
	- glutinous rice straw	1	87.2	3.9	1.1	27.5	15.6	39.2	56.1	33.8	3.3
			100	4.4	1.3	31.5	17.8	45.0	64.3	38.7	3.7
63	*Oryza sativa*, RICE.										
	- bran, meal, solvent extracted	5	88.9	15.4	0.8	8.4	9.6	54.8	24.9	10.8	-
			100	17.3	0.9	9.4	10.8	61.6	28.0	12.1	-
	- broken rice	4	87.6	6.8	1.4	0.6	0.8	78.0	-	-	-
			100	7.8	1.6	0.7	0.9	89.0	-	-	-
	- husk	1	91.9	1.0	0.2	22.2	12.0	22.5	-	-	-
			100	1.7	0.4	38.4	20.7	38.8	-	-	-

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
58													
	-	2.68[3/]	2.26[3/]	-	-	-	-	-	-	-	-	-	-
	-	11.17[3/]	9.41[3/]	-	-	-	-	-	-	-	-	-	-
	15	3.09[3/]	2.63[3/]	0.41[3/]	0.08[3/]	0.49[3/]	0.01[3/]	-	0.08[3/]	-	57.[3/]	-	-
	57	12.01[3/]	10.25[3/]	1.87[3/]	0.36[3/]	2.21[3/]	0.06[3/]	-	0.36[3/]	-	260.[3/]	-	-
59													
	20	-	-	0.13	0.14	0.53	0.04	-	-	1.40	47.20	17.90	8.90
	55	-	-	0.35	0.37	1.42	0.10	Trace	-	3.80	127.50	48.30	24.10
60													
	11	-	-	0.04	0.05	-	-	-	-	-	-	-	-
	66	-	-	0.24	0.30	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-
	66	-	-	-	-	-	-	-	-	-	-	-	-
	7	-	-	0.03	0.01	-	-	-	-	-	-	-	-
	63	-	-	0.28	0.09	-	-	-	-	-	-	-	-
61													
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	71	-	-	0.45	0.26	-	-	-	-	-	-	-	-
	79	-	-	0.55	0.33	-	-	-	-	-	-	-	-
62													
	72	-	-	0.01	0.12	-	-	-	-	-	-	-	-
	81	-	-	0.01	0.14	-	-	-	-	-	-	-	-
	38	-	-	0.31	0.14	-	-	-	-	-	-	-	-
	43	-	-	0.35	0.16	-	-	-	-	-	-	-	-
63													
	61	-	-	0.11	2.06	-	-	0.04	-	-	-	-	-
	69	-	-	0.13	2.31	-	-	0.05	-	-	-	-	-
	71	-	-	0.04	0.14	-	-	-	-	-	-	-	-
	81	-	-	0.04	0.16	-	-	-	-	-	-	-	-
	48	-	-	0.03	0.01	-	-	-	-	-	-	-	-
	52	-	-	0.06	0.02	-	-	-	-	-	-	-	-

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
63	*Oryza sativa*, RICE.										
	- paddy rice	4	88.9	6.0	1.6	10.4	5.4	65.6	-	-	-
			100	6.7	1.8	11.7	6.0	73.8	-	-	-
	- rice bran	5	89.9	12.2	14.6	6.4	7.3	49.3	16.9	8.0	2.5
			100	13.6	16.3	7.2	8.1	54.8	18.8	8.9	2.8
	- rice pollard	4	90.5	5.1	2.3	31.3	13.8	38.1	53.5	40.22	-
			100	5.7	2.5	34.5	15.2	42.1	59.1	44.4	-
	- rice straw	1	88.8	3.2	1.5	28.8	14.9	40.8	61.2	37.7	3.3
			100	3.6	1.6	32.3	16.7	45.8	68.8	42.3	3.7
	- straw, treated with urea	3	57.9	4.5	0.8	21.8	9.4	21.4	44.8	32.8	2.7
			100	7.8	1.4	37.6	16.3	36.9	77.5	56.7	4.6
64	*Pachyrhizus erosus*, YAM BEAN.										
	- aerial part, dried	1	91.5	21.0	1.6	-	13.9	-	36.2	27.5	-
			100	22.9	1.7	-	15.2	-	39.5	30.1	-
65	*Paederia linearis*, FEVER VINE.										
	- aerial part, fresh, 30-60 days growth	2	26.8	4.0	0.5	-	5.4	-	13.0	10.3	2.9
			100	14.9	1.7	-	20.3	-	48.5	38.5	10.7
66	*Panicum antidotale*, BLUE PANIC										
	GRASS.	2	24.9	3.0	0.5	7.3	2.3	11.7	16.7	11.0	1.3
	- aerial part, fresh		100	12.2	2.0	29.3	9.4	47.1	67.2	44.0	5.1
67	*Panicum maximum* cv. Hamil, HAMIL										
	GUINEA GRASS.	2	24.5	2.3	0.3	8.1	2.7	11.1	16.4	10.3	-
	- aerial part, fresh		100	9.2	1.4	32.9	11.0	45.5	66.9	42.2	-
68	*Panicum coloratum* var. *makarikari*,										
	MAKARIKARI GRASS.	2	27.2	2.4	0.8	8.7	2.2	13.1	19.3	9.7	1.0
	- aerial part, fresh, 60 days growth		100	8.8	3.1	31.9	8.2	48.0	71.1	35.6	3.7
69	*Panicum maximum* TD 58, PURPLE										
	GUINEA GRASS.	2	21.3	2.2	0.3	6.7	2.5	9.7	14.6	8.4	0.7
	- aerial part, fresh, 30 days growth		100	10.3	1.5	33.3	11.1	45.4	68.3	39.5	3.1
	- aerial part, hay, 30 days growth	1	87.5	7.4	1.0	-	-	-	60.8	-	-
			100	8.5	1.1	-	-	-	69.5	-	-
	- aerial part, fresh, 45 days growth	2	22.5	1.7	0.3	7.6	2.3	10.6	15.9	9.2	0.9
			100	7.4	1.2	34.0	10.4	47.1	70.5	40.9	4.1

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
63													
	65	12.61[5/]	10.82[5/]	0.03	0.18	-	-	-	-	-	-	-	-
	73	14.18[5/]	12.18[5/]	0.04	0.20	-	-	-	-	-	-	-	-
	80	14.26[3/]	12.71[3/]	0.07	1.61	1.27[3/]	-	0.06	-	12.0[3/]	578[3/]	130[3/]	10[3/]
	75	15.86[3/]	14.14[3/]	0.07	1.79	1.41[3/]	-	0.07	-	13.0[3/]	642[3/]	146[3/]	11[3/]
	54	-	-	0.11	0.17	0.01	-	-	-	-	-	-	-
	57	-	-	0.12	0.19	0.01	-	-	-	-	-	-	-
	39	-	-	0.28	0.11	-	-	-	-	-	-	-	-
	44	-	-	0.32	0.13	-	-	-	-	-	-	-	-
	29	-	-	0.17	0.03	-	-	0.12	-	-	-	-	-
	59	-	-	0.30	0.05	-	-	0.20	-	-	-	-	-
64													
	53	-	-	1.66	0.20	-	-	-	-	-	-	-	-
	-	-	-	1.81	0.22	-	-	-	-	-	-	-	-
65													
	16	-	-	-	-	-	-	-	-	-	-	-	-
	58	-	7.11[1/]	-	-	-	-	-	-	-	-	-	-
66													
	14	-	-	0.08	0.05	-	-	-	-	-	-	-	-
	57	-	-	0.32	0.19	-	-	-	-	-	-	-	-
67													
	13	-	-	0.13	0.04	0.65	-	-	-	-	-	-	-
	52	-	-	0.54	0.16	2.66	-	-	-	-	-	-	-
68													
	15	-	-	0.08	0.05	-	-	-	-	-	-	-	-
	56	-	-	0.31	0.17	-	-	-	-	-	-	-	-
69													
	11	2.10[3/]	-	0.08	0.02	0.29	-	-	-	-	-	-	-
	51	9.87[3/]	8.37[1/]	0.36	0.11	1.34	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	11	-	-	0.09	0.06	0.46	0.08	0.04	0.04	6.47	53.73	34.99	4.99
	49	-	8.37[1/]	0.42	0.25	2.06	0.36	0.17	0.17	29.16	242.03	157.61	22.48

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
69	*Panicum maximum* TD 58, PURPLE GUINEA GRASS. - aerial part, hay, 45 days growth	1	89.0 100	6.0 6.7	1.3 1.5	29.6 33.2	10.0 11.2	42.2 47.4	65.1 73.1	35.7 40.1	- -
	- aerial part, fresh, 60 days growth	2	24.4 100	1.7 6.9	0.3 1.3	8.7 35.7	2.6 10.6	11.1 45.5	17.2 70.6	10.1 41.4	1.0 4.2
	- aerial part, hay, 60 days growth	1	89.5 100	5.1 5.7	0.7 0.7	- -	7.9 8.8	- -	66.2 73.9	37.9 42.4	3.7 4.2
70	*Panicum maximum* var.*trichoglume*, GREEN PANIC GRASS. - aerial part, fresh, 30 days growth	2	24.9 100	2.3 9.2	0.4 1.4	7.1 28.5	2.8 11.3	12.4 49.6	16.2 65.2	9.2 36.8	0.9 3.7
	- aerial part, fresh, 45 days growth	2	28.5 100	2.2 7.6	0.4 1.4	8.4 29.5	3.1 10.7	14.5 50.8	18.9 66.1	11.3 38.7	1.2 4.3
	- aerial part, fresh, 60 days growth	2	31.1 100	2.0 6.5	0.4 1.4	9.6 30.8	3.1 10.1	15.9 51.2	20.9 67.2	12.4 39.9	1.4 4.6
71	*Panicum repens*, TORPEDO GRASS. - aerial part, fresh, 45 days growth	2	28.0 100	3.3 11.8	- -	- -	- -	- -	18.9 67.6	9.8 35.0	1.3 4.6
72	*Paspalum atratum*, ATRATUM GRASS. - aerial part, fresh, 30 days growth	2	20.6 100	1.8 9.0	0.2 0.9	5.8 28.3	2.2 10.8	10.5 51.0	13.1 63.6	7.5 36.2	1.0 4.8
	- aerial part, fresh, 45 days growth	2	21.9 100	1.5 7.1	0.2 0.9	6.6 30.2	2.1 9.6	11.4 52.2	14.6 66.7	8.8 40.1	1.1 5.1
	- aerial part, fresh, 60 days growth	2	24.4 100	1.6 6.6	0.2 1.0	7.3 29.8	2.5 10.3	12.8 52.3	16.0 65.7	9.5 38.8	1.0 4.0
73	*Paspalum conjugatum* Bergius, BUFFALO GRASS. - aerial part, fresh, 45 days growth	2	27.8 100	2.2 8.1	0.5 1.7	7.5 27.0	2.9 10.3	14.7 52.9	17.7 63.6	9.9 35.6	1.6 5.6
74	*Paspalum dilatatum*, DALLIS GRASS. - aerial part, fresh	2	23.8 100	2.38 10.0	0.7 3.0	6.6 27.8	2.3 9.5	11.8 49.7	16.7 70.1	10.6 44.6	1.1 4.5
75	*Paspalum longifolium*, LONG-LEAVED PASPALUM GRASS. - aerial part, fresh, 45 days growth	2	31.0 100	3.1 10.0	0.4 1.2	10.8 34.9	3.8 12.4	12.9 41.5	21.8 70.3	14.6 47.2	3.0 9.7

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
69													
	44	-	-	-	-	-	-	-	-	-	-	-	-
	49	9.50[2/]	8.83[2/]	-	-	-	-	-	-	-	-	-	-
	13	2.23[3/]	1.79[3/]	0.07	0.07	0.70	0.08	0.08	0.04	0.87	55.99	17.19	4.27
	53	9.12[3/]	7.32[3/]	0.28	0.27	2.74	0.31	0.31	0.14	3.38	217.87	66.87	16.63
	38	-	-	0.72	0.21	1.06	0.41	0.12	0.10	-	-	279.42	22.39
	42	-	8.37[1/]	0.47	0.24	1.18	0.46	0.13	0.11	-	-	312.20	25.02
70													
	14	-	-	0.13	0.08	0.64	0.05	0.14	0.06	-	-	-	-
	55	-	8.79[1/]	0.51	0.33	2.55	0.19	0.58	0.24	-	-	-	-
	15	-	-	0.13	0.09	0.79	0.05	0.18	0.05	3.03	-	35.42	6.22
	54	-	7.95[1/]	0.46	0.31	2.78	0.18	0.64	0.16	10.64	-	124.29	21.83
	17	-	-	0.13	0.08	0.73	0.05	0.17	0.06	1.30	29.68	78.96	15.20
	53	-	-	0.41	0.27	2.35	0.17	0.54	0.19	4.19	95.44	253.90	48.88
71													
	16	-	-	0.09	0.08	0.35	-	-	-	-	-	-	-
	56	-	-	0.31	0.27	1.24	-	-	-	-	-	-	-
72													
	11	-	-	0.17	0.03	0.52	0.07	-	0.05	-	-	-	-
	55	-	7.95[1/]	0.85	0.14	2.51	0.32	trace	0.22	-	-	-	-
	12	-	-	0.20	0.04	0.32	0.14	0.00	0.04	1.12	71.84	67.90	5.33
	54	-	7.95[1/]	0.91	0.19	1.48	0.63	0.01	0.17	5.10	328.02	310.06	24.33
	13	-	-	0.16	0.04	0.40	0.16	0.00	0.05	1.13	53.68	16.78	5.59
	54	-	-	0.64	0.16	1.62	0.65	0.01	0.21	4.65	219.00	68.78	22.93
73													
	16	-	-	0.16	0.06	0.44	-	-	-	-	-	-	-
	56	-	-	0.57	0.21	1.58	-	-	-	-	-	-	-
74													
	14	-	-	0.08	0.04	-	-	-	-	-	-	-	-
	58	-	7.95[1/]	0.35	0.17	-	-	-	-	-	-	-	-
75													
	15	-	-	0.12	0.05	0.52	0.06	-	-	1.70	115.10	72.20	7.80
	49	-	-	0.40	0.16	1.67	0.20	Trace	-	5.40	371.70	232.80	25.00

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
76	*Paspalum plicatulum*, PLICATULUM GRASS.										
	- aerial part, fresh, 30 days growth	2	20.1	1.9	0.2	5.8	1.4	10.8	13.0	7.1	0.6
			100	9.6	1.1	28.7	7.1	53.5	64.9	35.2	3.0
	- aerial part, fresh, 45 days growth	2	24.9	1.7	0.3	7.4	1.8	13.7	17.2	10.0	1.4
			100	6.9	1.0	29.8	7.2	55.1	69.1	40.3	5.5
	- aerial part, fresh, 60 days growth	2	28.7	0.9	0.4	-	2.5	-	-	-	-
			100	3.1	1.2	-	8.0	-	-	-	-
77	*Pennisetum pedicellatum*, COMMUNIST GRASS.	1	-	-	-	-	-	-	-	-	-
	- aerial part, hay		100	8.4	1.8	33.7	11.7	44.4	64.4	42.0	4.2
78	*Pennisetum purpureum* cv.Mott, DWARF NAPIER GRASS.	2	15.7	2.0	0.3	-	2.8	-	9.6	5.4	0.4
	- aerial part, fresh, 30 days growth		100	12.8	1.6	-	17.6	-	61.0	34.7	2.7
	- aerial part, fresh, 45 days growth	2	23.6	2.5	0.5	-	2.4	-	15.3	8.6	0.7
			100	10.8	2.0	-	10.3	-	65.0	36.5	2.8
	- aerial part, fresh, 60 days growth	2	24.4	2.5	0.5	6.9	3.1	11.3	16.4	9.6	0.8
			100	10.4	2.3	28.2	12.7	46.4	67.2	39.3	3.3
	- aerial part, hay, 30 days growth	1	90.6	10.7	-	-	10.5	-	55.9	-	-
			100	11.8	-	-	11.6	-	61.7	-	-
79	*Pennisetum purpureum* x *Pennisetum gluacum*, KING GRASS.	2	16.6	2.2	0.4	5.4	2.5	5.8	-	-	-
	- aerial part, fresh, 15 days growth		100	13.0	2.4	32.5	15.1	35.5	-	-	-
	- aerial part, fresh, 30 days growth	2	20.4	2.1	0.3	6.8	3.3	7.8	13.0	7.4	0.5
			100	10.3	1.5	33.5	16.3	38.4	63.5	36.1	2.3
	- aerial part, fresh, 45 days growth	2	21.1	1.8	0.4	8.1	-	-	14.2	7.8	0.5
			100	8.6	1.8	38.4	-	-	67.3	36.9	2.6
	- aerial part, fresh, 60 days growth	2	22.6	2.2	-	-	-	-	16.6	7.7	-
			100	9.7	-	-	-	-	73.6	34.0	-
80	*Pennisetum purpureum*, NAPIER/ELEPHANT GRASS.	2	15.8	1.9	0.2	3.9	2.2	7.4	10.1	5.7	0.5
	- aerial part, fresh, 30 days growth		100	12.1	1.1	24.9	14.1	46.7	63.9	36.4	3.3

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
76	-	-	-	0.19	0.02	-	-	-	-	-	-	-	-
	56	-	7.53[1/]	0.93	0.11	-	-	-	-	-	-	-	-
	11	-	-	0.17	0.04	0.33	0.07	0.01	0.04	1.39	40.43	25.93	4.98
	57	-	7.53[1/]	0.69	0.16	1.34	0.27	0.03	0.17	5.58	162.38	104.14	20.02
	15	-	-	0.31	0.04	0.55	0.09	0.07	0.06	1.07	84.82	40.87	5.50
	53	-	-	1.07	0.14	1.90	0.32	0.25	0.20	3.72	295.54	142.42	19.15
77	-	-	-	-	-	-	-	-	-	-	-	-	-
	50	-	-	0.30	0.20	3.10	0.30	trace	-	5.60	291.80	139.70	19.30
78	9	-	-	0.08	0.05	0.59	0.05	0.31	0.04	0.80	54.20	7.45	3.98
	56	-	7.95[1/]	0.53	0.34	3.77	0.30	1.95	0.25	5.08	345.24	47.45	25.37
	12	2.09[3/]	-	0.16	0.07	0.45	0.12	0.00	0.04	0.39	74.30	13.45	5.24
	52	8.87[3/]	9.62[1/]	0.66	0.31	1.91	0.52	0.00	0.15	5.90	314.82	56.98	22.20
	13	-	-	0.15	0.08	0.45	0.11	0.48	0.04	1.24	84.24	11.58	6.19
	54	-	-	0.63	0.34	1.83	0.47	1.95	0.15	5.08	345.24	47.45	25.37
	47	9.02[3/]	7.39[3/]	0.43	0.33	1.59	0.53	-	-	-	-	-	-
	52	9.96[3/]	8.16[3/]	0.47	0.36	1.75	0.58	-	-	-	-	-	-
79	8	-	-	-	-	-	-	-	-	-	-	-	-
	46	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	0.14	0.08	0.44	0.12	-	-	-	-	-	-
	47	-	7.95[1/]	0.67	0.38	2.15	0.57	-	-	-	-	-	-
	11	-	-	0.13	0.07	0.38	0.12	-	-	-	-	-	-
	51	-	9.62[1/]	0.62	0.31	1.81	0.56	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
80	9	-	-	0.07	0.06	0.28	0.09	-	0.04	-	-	-	-
	54	-	-	0.46	0.36	1.75	0.58	-	0.26	-	-	-	-

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
80	*Pennisetum purpureum*, NAPIER/ELEPHANT GRASS.										
	- aerial part, fresh, 45 days growth	2	18.7	1.9	0.3	5.0	2.5	8.9	12.2	7.0	0.7
			100	10.1	1.8	26.7	13.6	47.8	65.4	37.2	3.5
	- aerial part, fresh, 60 days growth	2	23.7	1.8	0.3	-	3.5	-	16.0	9.4	1.2
			100	7.4	1.3	-	14.6	-	67.6	39.6	5.0
81	*Phaseolus aureus,* MUNG BEAN.										
	- aerial part after harvesting	2	92.0	6.0	0.5	35.1	-	-	49.0	37.5	-
			100	6.5	0.5	38.2	-	-	53.3	40.8	-
	- mung bean protein, CP < 30 %	5	91.4	22.1	1.1	16.6	3.3	48.4	-	-	-
			100	24.1	1.2	18.2	3.6	52.9	-	-	-
	- mung bean protein, CP > 30 %	5	94.9	74.6	3.5	-	7.2	-	-	-	-
			100	78.7	3.7	-	7.6	-	-	-	-
	- pods, dried	1	92.7	6.3	0.5	35.5	7.2	43.1	48.3	39.9	8.3
			100	6.8	0.6	38.3	7.8	46.5	52.1	43.1	9.0
	- seed coats from mung bean sprout, fresh	2	26.1	4.6	0.7	6.6	1.5	12.6	14.8	11.4	-
			100	17.8	2.8	25.3	5.8	48.3	56.8	43.8	-
	- seeds without hull	5	89.8	18.3	1.3	-	3.0	-	-	-	-
			100	20.4	1.4	-	3.4	-	-	-	-
82	*Phaseolus vuloais* var. humilis, SNAP BEAN.										
	- pods with seeds, dried	1	89.4	24.0	0.6	6.4	5.3	53.2	27.0	14.6	-
			100	26.8	0.7	7.1	5.9	59.5	30.2	16.3	-
83	*Pithecellobium dulce,* MANILA TAMARIND.										
	- leaves, fresh	2	29.1	6.1	1.4	5.3	3.1	13.2	9.8	8.5	3.2
			100	21.0	4.8	18.1	10.8	45.3	33.8	29.3	11.0
84	*Pomacea canaliculata,* GOLDEN APPLE SNAIL.										
	- meat, dried	5	90.2	45.7	0.7	3.3	25.5	15.1	-	-	-
			100	50.6	0.8	3.6	28.3	16.7	-	-	-
	- whole, dried	5	97.3	12.3	0.3	0.7	74.1	9.7	-	-	-
			100	12.7	0.3	0.8	76.2	10.0	-	-	-
85	*Pterocarpus indicus,* BURMA PADAUK.										
	- leaves, fresh	2	36.7	8.6	0.7	8.0	3.2	16.2	13.2	10.1	3.4
			100	23.5	2.0	21.7	8.6	44.2	36.1	27.4	9.4

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
80													
	10	-	-	0.07	0.06	0.41	0.09	0.00	0.03	1.10	58.87	10.65	4.15
	54	-	7.95[1/]	0.35	0.33	2.18	0.47	0.00	0.15	5.90	314.82	56.98	22.20
	11	-	-	0.07	0.08	0.60	0.06	0.25	0.03	1.00	89.03	14.27	6.53
	48	-	-	0.28	0.32	2.52	0.25	0.21	0.13	4.22	375.67	60.20	27.54
81													
	38	-	-	2.81	0.16	-	-	-	-	-	-	-	-
	42	-	-	3.06	0.17	-	-	-	-	-	-	-	-
	60	-	-	0.44	0.24	-	-	-	-	-	-	-	-
	66	-	-	0.48	0.26	-	-	-	-	-	-	-	-
	82	-	-	0.10	0.72	-	-	-	-	-	-	-	-
	86	-	-	0.11	0.76	-	-	-	-	-	-	-	-
	45	-	-	1.21	0.10	-	-	-	-	-	-	-	-
	48	-	-	1.30	0.11	-	-	-	-	-	-	-	-
	14	-	-	0.18	0.07	-	-	-	-	-	-	-	-
	52	-	-	0.70	0.27	-	-	-	-	-	-	-	-
	38	-	-	0.21	0.27	-	-	-	-	-	-	-	-
	42	-	-	0.23	0.30	-	-	-	-	-	-	-	-
82													
	41	-	-	0.30	0.37	-	-	-	-	-	-	-	-
	46	-	-	0.34	0.41	-	-	-	-	-	-	-	-
83													
	20	-	-	0.52	0.06	-	-	-	-	-	-	-	-
	67	-	-	1.78	0.21	-	-	-	-	-	-	-	-
84													
	67	-	-	7.17	0.52	-	0.28	0.11	-	-	-	-	-
	74	-	-	7.95	0.58	-	0.31	0.12	-	-	-	-	-
	50	-	-	30.98	0.10	-	0.06	0.15	-	-	-	-	-
	51	-	-	31.84	0.10	-	0.06	0.15	-	-	-	-	-
85													
	25	-	-	0.63	0.07	-	-	-	-	-	-	-	-
	67	-	-	1.72	0.20	-	-	-	-	-	-	-	-

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
86	*Saccharum officinarum*, SUGAR CANE.										
	- bargasses	2	91.5	3.5	3.0	24.5	7.5	53.0	-	-	-
			100	3.8	3.3	26.8	8.2	57.9	-	-	-
	- leaves	2	-	-	-	-	-	-	-	-	-
			100	4.4	1.1	36.5	5.7	52.3	80.2	47.9	6.6
	- molasses	4	73.7	3.3	0.6	0.4	6.6	62.8	-	-	-
			100	4.5	0.8	0.5	9.0	85.2	-	-	-
	- tops of aerial part, fresh	2	28.0	2.0	0.5	9.6	2.0	13.9	20.0	12.5	1.8
			100	7.2	1.8	34.2	7.3	49.5	71.3	44.5	6.3
87	*Samanea saman*, RAIN TREE.										
	- leaves, dried	1	-	-	-	-	-	-	-	-	-
			100	26.2	7.9	26.6	3.7	35.6	39.1	32.5	17.5
	- pods, dried mature	1	86.0	16.1	2.8	10.2	2.6	53.7	-	-	-
			100	18.7	3.3	11.9	3.7	62.4	-	-	-
	- young pods, fresh	2	24.3	5.8	0.5	5.2	1.1	11.7	11.4	10.7	5.6
			100	23.7	1.9	21.6	4.5	48.3	47.0	43.9	23.2
88	*Sesamum indicum*, SESAME.										
	- seed meal, mechanical extracted	5	92.8	34.0	13.6	11.1	10.9	23.4	23.8	17.8	1.1
			100	36.6	14.6	11.9	11.7	25.2	25.6	19.2	1.2
89	*Sesbania grandiflora*, SESBANIA.										
	- leaves, fresh	2	17.1	4.5	0.8	3.0	1.8	7.1	3.8	3.2	0.7
			100	26.1	4.7	17.4	10.5	41.3	22.2	18.6	4.3
90	*Setaria sphacelata*, SETARIA.										
	- aerial part, fresh, 30 days growth	2	11.3	1.3	0.2	-	1.4	-	7.1	3.7	-
			100	11.1	1.9	-	12.8	-	63.1	32.7	-
	- aerial part, fresh, 45 days growth	2	19.2	1.7	0.2	-	2.3	-	13.5	7.7	0.8
			100	8.9	1.1	-	11.9	-	70.5	40.2	4.0
	- aerial part, fresh, 60 days growth	2	22.2	1.5	0.2	-	2.0	-	16.3	9.9	1.1
			100	6.9	1.1	-	8.9	-	73.5	49.4	4.8
	- aerial part, hay, 30 days growth	1	89.0	8.9	-	-	8.3	-	57.2	-	-
			100	10.0	-	-	9.4	-	64.3	-	-

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
86													
	51	-	-	0.37	0.24	-	-	-	-	-	-	-	-
	56	-	-	0.41	0.26	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	54	-	-	0.29	0.15	-	-	-	-	-	-	-	-
	47	12.27[3/]	11.01[3/]	0.59	0.04	-	-	-	-	-	-	-	-
	64	16.65[3]	14.94[3/]	0.80	0.05	-	-	-	-	-	-	-	-
	15	2.68[3/]	2.18[3/]	0.08	0.04	-	-	-	-	-	-	-	-
	54	9.58[3/]	7.78[3/]	0.30	0.13	-	-	-	-	-	-	-	-
87													
	-	-	-	-	-	-	-	-	-	-	-	-	-
	76	-	-	0.44	0.20	-	-	-	-	-	-	-	-
	61	-	-	0.23	0.13	-	-	-	-	-	-	-	-
	71	-	-	0.27	0.15	-	-	-	-	-	-	-	-
	18	-	-	0.11	0.06	-	-	-	-	-	-	-	-
	72	-	-	0.46	0.23	-	-	-	-	-	-	-	-
88													
	78	14.49[3/]	12.89[3/]	2.01	0.94	-	-	-	-	-	-	-	-
	84	15.61[3/]	13.89[3/]	2.16	1.02	-	-	-	-	-	-	-	-
89													
	6	-	-	0.41	0.06	-	-	-	-	-	-	-	-
	35	-	9.62[1/]	2.38	0.34	-	-	-	-	-	-	-	-
90													
	7	-	-	0.03	0.03	-	-	-	-	-	-	-	-
	63	-	6.69[1/]	0.22	0.25	-	-	-	-	-	-	-	-
	12	-	-	0.05	0.04	0.58	0.03	0.03	0.03	0.84	38.05	31.27	7.09
	60	-	-	0.26	0.20	3.02	0.17	0.15	0.14	4.36	198.20	162.86	36.91
	11	-	-	0.06	0.04	0.48	0.03	0.09	0.03	0.94	16.75	9.00	7.66
	50	-	-	0.25	0.19	2.18	0.16	0.42	0.14	4.24	75.43	40.53	34.51
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
91	*Sorghum almun*, SORGHUM GRASS.										
	- aerial part, fresh, 30 days growth	2	17.7	1.6	0.5	5.6	-	-	-	-	-
			100	9.3	2.9	31.4	-	-	-	-	-
	- aerial part, fresh, 45 days growth	2	17.8	1.5	0.5	6.2	-	-	-	-	-
			100	8.5	2.9	34.7	-	-	-	-	-
	- aerial part, fresh, 60 days growth	2	22.4	1.8	0.6	8.0	-	-	-	-	-
			100	8.0	2.8	35.6	-	-	-	-	-
92	*Sorghum bicolor*, SORGHUM.										
	- aerial part, fresh, 45 days growth	2	17.3	1.7	0.3	4.4	2.0	8.9	11.4	6.5	1.4
			100	9.8	1.7	25.2	11.7	51.7	65.8	37.8	8.2
	- aerial part, fresh, 60 days growth	2	21.1	1.6	0.3	6.8	1.1	11.3	14.3	8.2	1.4
			100	7.1	1.5	32.0	5.2	53.6	67.6	38.8	6.4
	- aerial part, fresh, 75 days growth	2	31.0	1.7	-	-	1.3	-	18.8	10.8	1.6
			100	5.4	-	-	4.2	-	60.7	34.9	5.2
	- aerial part, fresh, 90 days growth midbloom	2	30.2	1.5	-	-	-	-	16.2	9.5	-
			100	5.1	-	-	-	-	53.7	31.4	-
	- aerial part, fresh, 120 days growth dough	2	31.4	1.6	-	-	-	-	16.5	9.7	-
			100	5.2	-	-	-	-	52.4	30.8	-
	- aerial part, silage	3	18.2	1.5	0.5	5.6	1.0	9.6	11.7	7.6	-
			100	8.4	2.6	30.6	5.5	52.9	64.2	42.0	-
	- ground grains	4	88.4	8.5	2.6	1.6	1.3	74.6	12.1	3.6	-
			100	9.6	2.9	1.8	1.4	84.3	13.6	4.1	-
93	*Sorghum sudanese*, SUDAN GRASS.										
	- aerial part, fresh	2	22.0	2.1	-	-	-	-	14.4	9.5	1.2
			100	9.5	-	-	-	-	65.4	43.1	5.5
94	*Stylosanthes guianensis* CIAT184, STYLO.										
	- aerial part, fresh, 30 days growth	2	10.9	2.3	0.2	2.2	1.1	5.0	4.3	3.0	0.7
			100	21.2	2.1	20.5	10.1	46.1	39.8	27.9	6.2
	- aerial part, fresh, 45 days growth	2	25.4	4.0	0.3	6.5	1.9	12.6	12.9	9.2	2.2
			100	15.9	1.2	25.5	7.6	49.8	50.8	36.2	8.5

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
91	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-
92	10	-	-	0.08	0.04	-	-	-	-	-	-	-	-
	57	-	-	0.45	0.25	-	-	-	-	-	-	-	-
	12	-	-	0.08	0.06	-	-	-	-	-	-	-	-
	57	-	-	0.39	0.27	-	-	-	-	-	-	-	-
	-	-	-	0.10	0.07	-	-	-	-	-	-	-	-
	-	-	7.53[1/]	0.32	0.24	-	-	-	-	-	-	-	-
	-	-	-	0.09	0.07	-	-	-	-	-	-	-	-
	-	-	-	0.28	0.23	-	-	-	-	-	-	-	-
	-	-	-	0.10	0.07	-	-	-	-	-	-	-	-
	-	-	-	0.32	0.24	-	-	-	-	-	-	-	-
	12	-	-	-	-	-	-	-	-	-	-	-	-
	67	-	-	-	-	-	-	-	-	-	-	-	-
	79	-	-	0.02	0.28	-	-	-	-	-	-	-	-
	89	-	-	0.03	0.32	-	-	-	-	-	-	-	-
93	13	-	-	0.13	0.06	0.78	0.05	-	-	-	-	-	-
	60	-	-	0.60	0.28	3.53	0.21	-	-	-	-	-	-
94	7	-	-	0.17	0.04	0.07	0.06	-	0.03	-	-	-	-
	66	-	-	1.58	0.37	0.64	0.58	trace	0.27	-	-	-	-
	14	-	-	0.35	0.06	0.64	0.11	0.00	0.04	2.02	-	37.12	7.85
	56	-	-	1.36	0.25	2.51	0.44	0.01	0.15	7.95	-	146.14	30.89

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
94	*Stylosanthes guianensis* CIAT184, STYLO.										
	- aerial part, fresh, 60 days growth	2	26.6	4.2	0.2	8.1	2.0	12.1	15.8	11.4	2.5
			100	15.8	0.9	30.3	7.4	45.6	58.8	42.5	9.4
	- aerial part, fresh, 75 days growth	2	26.9	3.9	0.3	10.2	2.0	10.5	16.5	11.6	2.5
			100	14.5	1.0	38.1	7.5	38.9	61.2	43.1	9.2
	- aerial part, fresh, 90 days growth	2	27.0	3.8	0.4	9.7	2.4	10.7	14.8	10.8	2.1
			100	14.2	1.5	35.8	8.7	39.7	54.8	40.0	8.0
	- aerial part, fresh, 120 days growth	2	27.4	3.7	0.5	9.7	1.6	11.8	13.8	10.4	2.0
			100	13.6	1.9	35.6	5.8	43.1	50.4	37.9	7.2
95	*Stylosanthes hamata* cv.Verano, HAMATA /										
	VERANO STYLO.	2	25.8	4.7	0.4	5.7	2.6	12.5	12.4	7.1	1.5
	- aerial part, fresh, 30 days growth		100	18.2	1.5	22.0	9.9	48.4	48.0	27.6	5.7
	- aerial part, fresh, 45 days growth	2	26.5	4.2	0.4	6.7	2.2	12.9	13.4	8.4	1.9
			100	15.9	1.3	25.4	8.5	48.9	50.6	31.6	6.6
	- aerial part, fresh, 60 days growth	2	27.0	4.4	0.4	7.6	2.1	12.8	14.3	9.3	2.0
			100	15.3	1.3	28.1	7.8	47.5	53.0	34.5	7.3
	- aerial part, hay, 60 days growth	1	87.9	13.4	1.2	33.5	6.4	33.4	48.2	34.4	8.1
			100	15.2	1.4	38.1	7.3	38.0	54.9	39.1	9.2
96	*Thysanostigma siamensis*,										
	THYSANOSTIGMA.	1	89.6	11.1	3.1	26.2	8.8	40.4	41.9	25.4	-
	- aerial part, dried, 45 days growth		100	12.4	3.5	29.2	9.8	45.1	46.8	28.4	-
97	*Tripsacum lascum*, GUATEMALA GRASS.										
	- aerial part, fresh	2	23.4	2.3	0.4	6.8	2.2	11.7	15.4	8.7	-
			100	9.9	1.7	29.0	9.3	50.1	65.6	37.3	-
98	*Triticum aestivum*, WHEAT.										
	- wheat bran	4	87.5	14.3	2.6	7.5	4.0	59.6	30.4	9.0	2.2
			100	16.3	3.0	8.5	4.6	67.7	34.5	10.2	2.5
99	*Vetiveria zizanioides*, VETIVER GRASS.										
	- aerial part, dried	1	29.0	2.2	0.3	12.3	1.8	12.4	-	-	-
			100	7.5	1.1[3/]	42.5[3/]	6.1[3/]	42.8	77.9	44.0	5.2
100	Whey										
	- Delactose whey	5	91.8	21.9	0.2	-	23.1	46.6	-	-	-
			100	23.9	0.2	-	25.1	50.8	-	-	-

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
94													
	15	-	-	0.41	0.11	0.80	0.09	-	0.08	-	-	-	-
	57	-	-	1.55	0.41	3.01	0.33	-	0.29	-	-	-	-
	15	-	-	0.27	0.09	0.62	0.07	-	-	-	-	-	-
	54	-	-	1.00	0.32	2.29	0.26	-	-	-	-	-	-
	15	-	-	0.20	0.10	0.70	0.10	-	0.10	-	-	-	-
	54	-	-	0.86	0.30	2.50	0.33	-	0.24	-	-	-	-
	16	-	-	0.06	0.05	0.45	0.11	-	0.03	-	-	-	-
	57	-	-	0.21	0.17	1.65	0.41	-	0.10	-	-	-	-
95													
	17	-	-	0.35	0.06	0.51	0.10	0.01	0.09	-	-	-	-
	64	-	-	1.38	0.23	1.96	0.40	0.05	0.34	-	-	-	-
	16	-	-	0.43	0.05	0.45	0.10	0.01	0.09	2.05	137.30	33.98	8.05
	62	-	-	1.62	0.20	1.68	0.36	0.03	0.35	7.73	518.15	125.98	30.38
	-	-	-	0.44	0.05	0.40	0.10	0.01	0.06	-	-	-	-
	61	-	-	1.61	0.19	1.48	0.36	0.05	0.24	-	-	-	-
	17	-	-	1.16	0.11	0.77	0.42	-	0.08	5.12	286.44	183.00	29.60
	53	-	9.20[1/]	1.32	0.13	0.88	0.48	trace	0.09	5.83	325.87	208.20	33.70
96													
	51	-	-	1.24	0.64	1.97	0.04	-	-	-	-	-	-
	57	-	-	1.38	0.72	2.20	0.05	-	-	-	-	-	-
97													
	13	-	-	0.05	0.03	-	-	-	-	-	-	-	-
	57	-	-	0.22	0.14	-	-	-	-	-	-	-	-
98													
	68	10.73[3/]	9.19[3/]	0.09	0.80	1.07[3/]	0.31[3]	0.02[3/]	0.22[3/]	11[3/]	115[3/]	70[3/]	67[3/]
	78	12.26[3/]	10.50[3/]	0.11	0.91	1.21[3/]	0.35[3/]	0.02[3/]	0.25[3/]	13[3/]	131[3/]	79[3/]	77[3/]
99													
	17	-	-	-	-	-	-	-	-	-	-	-	-
	59	-	-	0.20	0.16	-	0.13	-	-	-	-	-	-
100													
	78	-	-	3.81	1.76	-	-	-	-	-	-	-	-
	86	-	-	4.15	1.92	-	-	-	-	-	-	-	-

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
100	Whey										
	- processed whey powder	5	90.6	4.5	0.1	-	7.3	-	-	-	-
			100	4.9	0.1	-	8.0	-	-	-	-
	- whey powder	5	92.5	10.9	0.2	0.4	6.6	74.3	-	-	-
			100	11.7	0.3	0.5	7.2	80.3	-	-	-
101	*Zea mays,* BABY CORN.										
	- corn stover, fresh	2	25.6	2.1	0.4	7.0	1.8	14.3	15.9	9.6	0.9
			100	8.0	1.4	27.2	7.0	56.1	62.1	37.4	3.6
	- husk, dried	1	88.5	10.5	1.9	21.6	5.6	48.8	55.3	26.9	3.1
			100	12.0	2.2	24.4	6.4	55.1	62.5	30.4	3.5
	- husk, fresh	2	15.7	1.8	0.2	3.5	0.8	9.4	9.1	4.3	0.3
			100	11.5	1.6	22.0	5.2	59.7	57.8	27.2	1.8
	- husk, silage	3	11.6	1.6	0.5	3.5	0.8	5.2	-	-	-
			100	14.1	4.5	29.8	6.5	45.1	-	-	-
	- tassel, fresh	2	19.0	2.4	0.5	4.7	1.1	10.4	9.8	5.6	0.6
			100	12.6	2.4	24.9	5.7	54.4	51.3	29.4	3.3
	Zea mays, CORN/MAIZE.										
	- aerial part, fresh, 70 days, growth	2	21.0	1.7	0.4	6.0	1.8	11.0	12.7	6.8	-
			100	8.3	1.8	28.8	8.6	52.5	60.5	32.3	-
	- aerial part, silage	3	26.2	2.0	0.6	6.3	1.8	15.5	15.0	8.1	-
			100	7.8	2.2	24.2	6.7	59.2	57.3	31.0	-
	- corn gluten meal	5	91.2	57.2	1.3	1.0	3.3	28.4	-	-	-
			100	62.8	1.4	1.1	3.6	31.1	-	-	-
	- grain and cob, ground, dried	1	87.4	7.2	2.7	5.3	1.4	70.9	-	-	-
			100	8.2	3.1	6.1	1.5	81.1	-	-	-
	- grain, ground	4	87.4	7.2	4.2	2.2	1.2	72.5	11.3	3.3	0.7
			100	8.3	4.8	2.5	1.4	83.0	12.9	3.8	0.8
	- cobs, cannery residue, fresh	4	25.8	1.3	0.9	8.6	0.7	14.4	19.6	10.2	1.8
			100	4.9	3.5	33.2	2.7	55.7	76.1	39.4	7.1

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
100													
	78	-	-	0.53	0.60	-	-	-	-	-	-	-	-
	86	-	-	0.58	0.66	-	-	-	-	-	-	-	-
	76	14.78[5/]	12.89[5/]	0.55	0.49	-	-	-	-	-	-	-	-
	82	15.98[5/]	13.93[5/]	0.60	0.54	-	-	-	-	-	-	-	-
101													
	15	-	-	0.09	0.06	-	-	-	-	-	-	-	-
	59	-	-	0.36	0.23	-	-	-	-	-	-	-	-
	52	-	-	-	-	-	-	-	-	-	-	-	-
	59	-	-	-	-	-	-	-	-	-	-	-	-
	10	-	-	0.04	0.05	-	-	-	-	-	-	-	-
	66	-	-	0.27	0.33	-	-	-	-	-	-	-	-
	9	-	-	-	-	-	-	-	-	-	-	-	-
	75	-	-	-	-	-	-	-	-	-	-	-	-
	12	-	-	0.04	0.06	-	-	-	-	-	-	-	-
	64	-	-	0.20	0.31	-	-	-	-	-	-	-	-
	12	2.35[3/]	1.97[3/]	0.06	0.04	0.44	0.19	0.01	-	1.26	48.09	6.51	5.04
	57	11.17[3/]	9.37[3/]	0.26	0.19	2.11	0.89	0.03	-	6.00	229.00	31.00	24.00
	17	-	-	0.07	0.04	-	-	-	-	-	-	-	-
	56	-	-	0.26	0.17	-	-	-	-	-	-	-	-
	81	-	-	0.04	0.26	-	-	-	-	-	-	-	-
	89	-	-	0.05	0.28	-	-	-	-	-	-	-	-
	69	-	-	-	-	-	-	-	-	-	-	-	-
	79	-	-	-	-	-	-	-	-	-	-	-	-
	72	14.88[5/]	13.06[5/]	0.03	0.24	0.39	0.07	0.01	-	2.88	-	4.20	18.88
	82	17.03[5/]	14.94[5]	0.04	0.28	0.45	0.08	0.01	-	3.30	-	4.81	21.60
	15	-	-	0.01	0.02	0.22	0.01	-	0.01	1.98	92.06	2.70	4.23
	59	-	-	0.05	0.09	0.84	0.03	-	0.03	7.67	356.95	10.48	16.42

Table 12.1 Chemical Composition and Energy Contents of Feedstuffs.

Number	Feedstuff	Feed class	DM (%)	CP (%)	EE (%)	CF (%)	Ash (%)	NFE (%)	NDF (%)	ADF (%)	ADL (%)
101	*Zea mays*, SWEET CORN.										
	- corn stover, fresh	2	25.5	2.2	0.6	7.0	2.1	13.7	15.6	8.8	1.2
			100	8.6	2.3	27.2	8.1	53.8	61.0	34.6	4.6
	- corn stover, silage	3	29.1	2.5	0.8	8.1	1.7	-	17.9	10.0	1.1
			100	8.5	2.7	28.0	6.0	-	61.7	34.5	3.8
	- DDGS (distillers grains with solubles,	5	87.2	23.1	8.1	7.9	4.0	44.0	-	-	-
	dehydrated)		100	26.5	9.3	9.1	4.6	50.5	-	-	-
	- husk, fresh	2	20.1	1.2	0.3	6.2	0.7	11.8	15.4	7.7	0.6
			100	5.8	1.3	30.7	3.4	58.8	76.8	38.4	3.2
	- husks with cobs, fresh	2	20.9	1.4	0.6	2.6	0.7	-	15.5	7.3	0.9
			100	6.6	2.8	12.5	3.4	-	74.1	34.8	4.2
	- husks with cobs, silage	3	20.8	1.5	0.5	2.3	0.6	-	16.3	8.8	-
			100	7.0	2.3	11.0	3.1	-	78.6	42.4	-

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	TDN (%)	DE (MJ/kg)	ME (MJ/kg)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
101													
	16	-	-	0.09	0.08	-	-	-	-	-	-	-	-
	64	-	-	0.35	0.30	-	-	-	-	-	-	-	-
	20	-	-	-	-	-	-	-	-	-	-	-	-
	70	-	-	-	-	-	-	-	-	-	-	-	-
	67	-	-	0.06	0.63	-	-	-	-	-	-	-	-
	77	-	-	0.07	0.72	-	-	-	-	-	-	-	-
	12	-	-	0.02	0.03	-	-	-	-	-	-	-	-
	60	-	-	0.09	0.17	-	-	-	-	-	-	-	-
	15	-	-	0.01	0.04	-	-	-	-	-	-	-	-
	72	-	-	0.04	0.20	-	-	-	-	-	-	-	-
	15	-	-	-	-	-	-	-	-	-	-	-	-
	72	-	-	-	-	-	-	-	-	-	-	-	-

Table 12.2 Mineral Source.

Number	Feedstuff	Feed class	DM (%)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)
1	**Calcium**								
	- Calcium carbonate	6	-	-	-	-	-	-	-
			100	39.40[4/]	0.04[4/]	0.06[4/]	0.05[4/]	0.06[4/]	-
	- Charcoal (bone black/bone char)	6	90[4/]	27.10[4/]	12.70[4/]	0.14[4/]	0.53[4/]	-	-
			100	30.11[4/]	14.14[4/]	0.16[4/]	0.59[4/]	-	-
	- Dicalcium phosphate	6	97.0	21.30[4/]	18.70[4/]	0.07[4/]	0.57[4/]	0.05[4/]	1.11[4/]
			100	22.00[4/]	19.30[4/]	0.07[4/]	0.59[4/]	0.05[4/]	1.14[4/]
	- Dolomitie	6	99[4/]	22.10[4/]	0.04[4/]	0.36[4/]	9.89[4/]	0.36[4/]	-
			100	22.30[4/]	0.04[4/]	0.36[4/]	9.99[4/]	0.36[4/]	-
	- Ground limestone	6	-	-	-	-	-	-	-
			100	34.00[4/]	0.02[4/]	0.12[4/]	2.06[4/]	0.06[4/]	0.04[4/]
	- Monocalcium phosphate	6	97[4/]	15.90[4/]	20.95[4/]	0.08[4/]	0.59[4/]	0.06[4/]	1.18[4/]
			100	16.40[4/]	21.60[4/]	0.08[4/]	0.61[4/]	0.06[4/]	1.22[4/]
	- Oystershell, ground	6	99[4/]	30.84	0.03	-	-	-	-
			100	30.54	0.03	-	-	-	-
2	**Cobalt**								
	- Cobalt carbonate	6	99[4/]	-	-	-	-	-	-
			100	-	-	-	-	-	0.20[4/]
3	**Copper (Cupric)**								
	- Cupric sulfate pentahydrate	6	-	-	-	-	-	-	-
			100	-	-	-	-	-	12.84[4/]
4	**Iron (Ferrous)**								
	- Ferrous sulfate heptahydrate	6	98[4/]	-	-	-	-	-	-
			100	-	-	-	-	-	12.35[4/]
5	**Magnesium**								
	- Magnesium carbonate	6	98[4/]	0.02[4/]	-	-	30.19[4/]	-	-
			100	0.02[4/]	-	-	30.81[4/]	-	-
	- Magnesium oxide	6	98[4/]	3.01[4/]	-	-	55.08[4/]	-	-
			100	3.07[4/]	-	-	56.20[4/]	-	-
6	**Manganese**								
	- Manganous oxide	6	99[4/]	-	-	-	-	-	-
			100	-	-	-	-	-	-

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	Feed class	Cu (%)	Fe (%)	Mn (%)	Zn (%)	Cl (%)	Co (%)	F (%)	I (%)	Se (%)
1	6	- -	- 0.03[4/]	- 0.03[4/]	- -	- -	- -	- -	- -	- -
	6	- -	- -	- -	- -	- -	- -	- -	- -	- -
	6	9.70[4/] 10.00[4/]	1.40[4/] 1.40[4/]	0.03[4/] 0.03[4/]	0.01[4/] 0.01[4/]	- -	- -	0.17[4/] 0.18[4/]	- -	- -
	6	- -	0.08[4/] 0.08[4/]	- -	- -	- -	- -	- -	- -	- -
	6	- -	- 0.35[4/]	- -	- -	- -	- -	- -	- -	- -
	6	9.70[4/] 10.00[4/]	1.50[4/] 1.60[4/]	0.03[4/] 0.04[4/]	0.01[4/] 0.01[4/]	- -	- -	0.20[4/] 0.21[4/]	- -	- -
	6	- -	- -	- -	- -	- -	- -	- -	- -	- -
2	6	- -	- 0.05[4/]	- -	- -	- -	- 46.00[3/]	- -	- -	- -
3	6	- 25.45[4/]	- -	- -	- -	- -	- -	- -	- -	- -
4	6	- -	- 21.84[4/]	- -	- -	- -	- -	- -	- -	- -
5	6	- -	0.02[4/] 0.02[4/]	- -	- -	- -	- -	- -	- -	- -
	6	- -	- -	0.01[4/] 0.01[4/]	- -	- -	- -	- -	- -	- -
6	6	- -	- -	76.68[4/] 77.45[4/]	- -	- -	- -	- -	- -	- -

Table 12.2 Mineral Source.

Number	Feedstuff	Feed class	DM (%)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)
7	**Phosphorus**								
	- Defluorinated phosphate	6	-	-	-	-	-	-	-
			100	32.00[4/]	18.00[4/]	0.08[4/]	0.42[4/]	4.90[4/]	-
	- Diammonium phosphate	6	97[4/]	0.50[4/]	19.98[4/]	0.01[4/]	0.45[4/]	0.05[4/]	2.10[4/]
			100	0.52[4/]	20.60[4/]	0.01[4/]	0.46[4/]	0.05[4/]	2.16[4/]
	- Monoammonium phosphate	6	97[4/]	0.27[4/]	23.99[4/]	0.01[4/]	0.45[4/]	0.06[4/]	1.42[4/]
			100	0.28[4/]	24.74[4/]	0.01[4/]	0.46[4/]	0.06[4/]	1.46[4/]
	- Rock phosphate	6	-	-	-	-	-	-	-
			100	35.00[3/]	13.00[3/]	0.06[3/]	0.41[3/]	0.03[3/]	-
	- Rock phosphate, low fluorine	6	-	-	-	-	-	-	-
			100	36.00[3/]	-	-	-	-	-
	- Rock phosphate, soft	6	99[4/]	17.00[3/]	9.00[3/]	-	0.38[3/]	0.10[3/]	-
			100	17.17[3/]	9.09[3/]	-	0.38[3/]	0.10[3/]	-
	- Steamed bone meal	6	97[4/]	30.70[4/]	13.79[4/]	0.18[4/]	0.62[4/]	0.39[4/]	0.20[4/]
			100	31.50[4/]	14.22[4/]	0.19[4/]	0.64[4/]	0.40[4/]	0.21[4/]
8	**Potassium**								
	- Potassium bicarbonate	6	99[4/]	-	-	38.66[4/]	-	-	-
			100	-	-	39.05[4/]	-	-	-
	- Potassium chloride	6	-	-	-	-	-	-	-
			100	0.05[4/]	-	50.54[4/]	0.11[4/]	1.00[4/]	0.19[4/]
	- Potassium iodide	6	-	-	-	-	-	-	-
			100	-	-	21.00[4/]	-	-	-
9	**Selenium**								
	- Sodium selenite	6	98[4/]	-	-	-	-	26.10[4/]	-
			100	-	-	-	-	26.60[4/]	-
10	**Sodium**								
	- Monosodium phosphate	6	97[4/]	-	21.80[4/]	-	-	16.18[4/]	-
			100	-	22.50[4/]	-	-	16.68[4/]	-
	- Sodium bicarbonate	6	-	-	-	-	-	-	-
			100	-	-	-	-	27.00[4/]	-

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	Feed class	Cu (%)	Fe (%)	Mn (%)	Zn (%)	Cl (%)	Co (%)	F (%)	I (%)	Se (%)
7	6	- 10.00[4/]	- 0.67[4/]	- 0.02[4/]	- -	- -	- -	- -	0.18[4/] 0.18[4/]	- -
	6	9.70[4/] 10.00[4/]	1.20[4/] 1.24[4/]	0.04[4/] 0.04[4/]	0.01[4/] 0.01[4/]	- -	- -	0.20[4/] 0.21[4/]	- -	- -
	6	9.70[4/] 10.00[4/]	1.69[4/] 1.74[4/]	0.04[4/] 0.04[4/]	0.01[4/] 0.01[4/]	- -	- -	0.24[4/] 0.25[4/]	- -	- -
	6	- 10.00[3/]	- 1.68[3/]	- 0.02[3/]	- 0.01[3/]	- -	- -	0.50[3/] 0.50[3/]	- -	- -
	6	- -	- -	- -	- -	- -	- -	- -	- -	- -
	6	- -	1.90[3/] 1.92[3/]	0.10[3/] 0.10[3/]	- -	- -	- -	1.49[3/] 1.50[3/]	- -	- -
	6	13.60[4/] 14.00[4/]	0.08[4/] 0.08[4/]	- -	0.03[4/] 0.03[4/]	- -	- -	- -	- -	- -
8	6	- -	- -	- -	- -	- -	- -	- -	- -	- -
	6	- -	- 0.06[4/]	- -	- -	- 47.26[3/]	- -	- -	- -	- -
	6	- -	- -	- -	- -	- -	- -	- -	- 68.17[3/]	- -
9	6	- -	- -	- -	- -	- -	- -	- -	- -	44.69[4/] 45.60[4/]
10	6	- -	- -	- -	- -	- -	- -	- -	- -	- -
	6	- -	- -	- -	- -	- -	- -	- -	- -	- -

Table 12.2 Mineral Source.

Number	Feedstuff	Feed class	DM (%)	Ca (%)	P (%)	K (%)	Mg (%)	Na (%)	S (%)
10	Sodium								
	- Sodium chloride	6	-	-	-	-	-	-	-
			100	-	-	-	-	39.34[4/]	-
	- Trisodium phosphate	6	96[4/]	-	24.00[4/]	-	-	29.80[4/]	-
			100	-	25.00[4/]	-	-	31.00[4/]	-
11	Sulfur								
	- Ammonium sulfate	6	-	-	-	-	-	-	-
			100	-	-	-	-	-	24.10[4/]
	- Calcium sulfate dihydrate (gypsum)	6	85[4/]	22.02[4/]	0.01[4/]	-	2.22[4/]	-	20.01[4/]
			100	25.90[4/]	0.01[4/]	-	2.61[4/]	-	23.54[4/]
	- Sodium sulfate decahydrate	6	-	-	-	-	-	13.84[4/]	-
			100	-	-	-	-	14.27[4/]	-
12	Zinc								
	- Zinc sulfate	6	99[4/]	0.02[4/]	-	-	-	-	17.50[4/]
			100	0.02[4/]	-	-	-	-	17.68[4/]
	- Zinc oxide	6	-	-	-	-	-	-	-
			100	-	-	-	-	-	-

1/ in vitro 2/ in vivo 3/ Harris et. al ,1982 4/ NRC , 1984 5/ NARO, 2001

Number	Feed class	Cu (%)	Fe (%)	Mn (%)	Zn (%)	Cl (%)	Co (%)	F (%)	I (%)	Se (%)
10	6	-	-	-	-	-	-	-	-	-
		-	-	-	-	60.66[4/]	-	-	-	-
	6	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-
11	6	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-
	6	-	0.17[4/]	-	-	-	-	-	-	-
		-	0.20[4/]	-	-	-	-	-	-	-
	6	-	-	-	-	-	-	-	-	-
		-	-	-	-	-	-	-	-	-
12	6	0.01[4/]	0.10[4/]	0.01[4/]	36.00[4/]	0.02[4/]	-	-	-	-
		0.01[4/]	0.10[4/]	0.01[4/]	36.36[4/]	0.02[4/]	-	-	-	-
	6	-	-	-	-	-	-	-	-	-
		-	-	-	78.00[4/]	-	-	-	-	-

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