Chapter 5. Utilization of Alfalfa Products

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Besides alfalfa's unique characteristics as a highly productive perennial legume, alfalfa has very good forage quality attributes. Alfalfa can be used as the sole diet for most livestock in the form of pasture, haylage or hay. Processed alfalfa is a major ingredient for feed manufacturers as a source of protein, energy and specific amino acids or vitamins. This chapter introduces the various descriptors of forage quality and the utilization of alfalfa in the major animal husbandry industries in China.

Section 1: Forage Quality Parameters

Forage quality is defined as the characteristics which cause a desired effect in animal husbandry such as maintenance, growth (meat, wool, eggs) or reproduction (offspring, milk). Forage quality is appraised by many different factors. Around the world, livestock producers with expertise in managing pasture or hay resources have a general understanding about forage quality, and the nutrient demands of their livestock. However much of this expertise is site-specific or localized. In the current global economy, it is important that forage quality evaluation and descriptors are uniform for scientific ration formulation and trade.

1.1 Organoleptic characteristics

Hay and processed alfalfa are appraised by appearance, colour, odour and texture. While these traits are valuable, they should be used in conjunction with a laboratory analysis. Hay is evaluated by:

A. <u>Colour</u>: High quality alfalfa hay is dark green, which is generally correlated to low loss of soluble compounds such as carotene and other nutrients.

B. <u>Leaf condition</u>: The quantity of leaves ("leafiness") in hay is directly related to forage quality. The biomass of alfalfa harvested at the initiation of bloom should consist of over 30% leaves. In addition, a majority of the leaves should be fairly intact to avoid their loss during the numerous handling processes.

C. <u>Odour</u>: Alfalfa hay that is properly cured, baled and stored has a characteristic pleasant aroma that can stimulate its palatability for livestock. Mouldy, musty or burnt odours indicate that quality or palatability of the hay are questionable.

D. <u>Diseases and moulds</u>: Alfalfa leaves and stems should be inspected. Mould can develop in localized areas within alfalfa hay after it is baled, and in very rare cases the mould is toxic. The toxic moulds can cause abortions or death if ingested in high quantities. In some cases, toxic moulds have a fish odour, but unknown moulds should be identified by a laboratory. Most foliar diseases of alfalfa are not toxic, however they may have irritable dusts, odours or tastes. Further, rare or objectionable alfalfa diseases can be spread by hay transportation, such as *Verticillium albo-atrum* which is currently being tested in imported hay at the ports in China.

E. <u>Weeds and insects</u>: As with plant diseases, weed and insect pests can be distributed to new areas in hay, so this should be avoided by visual inspection. A specific example for alfalfa hay exporters in North America with markets in eastern Asia is that the hay must be completely free of wheatgrass (*Agropyron* spp.) in hay. Wheatgrass is a host for Hessian fly (*Mayetiola destructor*, Diptera: Cecidomyiidae) which could become a serious pest of rice in Japan, Korea and Taiwan where the pest is not endemic. Several weeds can be present in alfalfa hay that have objectionable plant structures such as burrs, thorns or awns. Other weeds can contain toxins or other anti-quality chemicals.

Blister beetles are insects that are occasionally found in alfalfa. Numerous species of blister beetles such as *Mylabris phalerate* (Coleoptera: Meloidae) found in China produce the toxin cantharidin. Blister beetles in most cases are beneficial by their feeding on eggs and larvae of crop pests; however the adults present in alfalfa can be problematic in hay depending on their species and population. Cantharidin can be a skin irritant to most mammals, and is primarily toxic to nonruminant animals such as horses and poultry.

F. Other foreign material: The hay should be free of stones, soil, and plastic or metal debris. Rarely, dead animals can occur in hay from field baling or infestations during storage. During the decay of the animal, the botulism toxin can be formed by the common bacterium *Clostridium botulinum* under anaerobic conditions, and the toxicity can be very severe.

In most production systems, alfalfa that is grown under best management practices and hay that is harvested and stored properly will not have the rare problems discussed above. Forage contaminated with foreign biological or inert materials should be discarded when hay is separated for feeding or transferred into processing equipment. Alfalfa meal, pellets or cubes can be evaluated by the same organoleptic tools as above, but processing often disguises most potential problems.

1.2 Laboratory forage analyses

Sensory evaluation of forage is valuable, but it does not always correlate directly to animal productivity. In most livestock feeding operations and in all commercial hay transactions, a chemical forage analysis should be conducted. Alfalfa is a rich source of protein, energy, vitamins and minerals but these can vary considerably by site, season of harvest, crop maturity, variety, haymaking conditions, storage and many other factors. Therefore forage analyses should be a routine practice.

A. Proper sampling: A representative forage sample must come from each "lot" of hay or haylage. Each of the cuttings of alfalfa harvested from the same field during a season should be considered a separate lot. Fields of different stand age, variety or different management (part of a field with rain damage) should be stored and tested as distinct lots. Various hay probes are available for sampling, ranging from 0.15- to 2.5-cm diameter coring tubes that are pushed or powered into the hay. From 15 to 20 random samples should be obtained from each hay lot by inserting the probe in the centre of the bale cross section. A bulked sample for each lot should be shipped in a plastic bag to a testing laboratory.

B. Laboratory selection: Most university or China Academy of Agricultural Science facilities have modern laboratories which are capable of standard forage and feed analyses. However, most agency laboratories do not necessarily function as a service for the general public with published fees, fast processing and other provisions. Many private testing laboratories have been developed which conduct chemical analyses of forages, feeds, soil, fertilizer and other agricultural products as a business. In North America, a laboratory certification process is conducted each year to standardize the processes and reporting by various public and commercial laboratories (www.foragetesting.org). With rising trade of alfalfa hay and products in China, the need for harmonization of testing procedures and commercial laboratories will likely increase.

C. Chemical analyses: Many laboratory tests have been conducted on alfalfa and other feedstuffs to predict their feeding values. Published feed analyses (Tables 5.1 to 5.5) are useful for general comparisons among roughages or feeds, but due to the inherent variability in alfalfa production systems, a laboratory test for each lot of hay is recommended. An analysis for a farmer who will feed ewes for several months during the winter may be fairly basic, with tests only requested for protein and energy, and at a cost of about $USD 15 to 20. In contrast, a detailed analysis for alfalfa to be fed to dairy cattle confined almost year-round might include protein, energy, digestible fibre and specific mineral or vitamin analyses at a cost of $USD 35 to 100 per sample. The primary laboratory tests and descriptors for forages are:

1. Moisture: All forage analyses and feeding recommendations are based on a 100% dry matter basis (100% DMB) for standardization.

2. Protein: Alfalfa is very rich in plant protein compared to other roughage resources in China. Alfalfa has high protein due to its nitrogen-fixing capability, as well as other nutrients. During flowering, the crude protein concentration of standing alfalfa declines by almost half, from 22.1% at the bud stage to 12.3% at the pod stage (Table 5.1). Besides stage of maturity, there is variation in protein and other forage quality traits due to genetic and environmental differences. For example in China, forage protein concentration at the early flowering stage ranged from 15.4% to 22.7% among 14 varieties (Table 5.2). In forages, "crude protein" is determined by the chemical analysis for nitrogen (N), and expressed in the equation: %CP = 6.25 x %N. Some further analyses include digestible protein (DP), rumen degradable (RDP) or undegradable (RUP) protein, and acid detergent insoluble N (ADIN) which is useful in detecting heat-damaged protein that is overestimated in CP. The digestibility of the protein and nutrients are generally high, depending on the stage of growth at harvest, and conditions of curing and storage. Specifically, the rapidly-digesting soluble proteins can be a problem in terms of protein loss in the rumen or the bloat hazard in alfalfa pastures. In addition to protein levels, feeds are often analyzed for the individual essential amino acids when feeding some animal species.

3. Fibre was previously reported as crude fibre (CF) in proximate analysis procedures. During flowering, the CF levels of standing alfalfa almost double (Table 5.1). Fibre is an important characteristic of roughages; however various roughage sources vary greatly in their levels of fibre digestibility. For the past three decades, intensive livestock nutrition research has focused on two fibre fractions - neutral detergent fibre and acid detergent fibre:

a. Neutral detergent fibre (NDF) is the fibre remaining after the cell wall contents are partially removed after dissolving in a standardized neutral detergent (primarily hemicellulose is removed). The NDF fraction is inversely proportional to dry matter intake by an animal: daily DM intake (DMI, as a % of live-weight) = 120/%NDF.

b. Acid detergent fibre (ADF) is the fibre remaining after the cell walls have been dissolved in a standardized acid detergent. The remaining contents are the durable cellulose, lignin and ash components. By definition, (NDF = ADF + hemicellulose). The ADF fraction is inversely related to forage digestibility; digestible DM (DDM) of alfalfa is estimated by:

DDM = 88.9 – (ADF x 0.779).

c. Relative feed value (RFV) is a calculated expression for marketing alfalfa and it is expressed by:

RFV = (DMI x DDM) x 0.775.

The RFV index has no units, and at its base calculation, alfalfa at full bloom is <100 RFV, >40% ADF and >50% NDF.

4. Energy in roughages is derived from free and digested carbohydrates, proteins and fats, and has been estimated in a variety of manners. In proximate analysis procedures, the nitrogen free extract (NFE) was calculated to determine the readily available carbohydrates such as sugars, dextrins and starches. The NFE calculation is done after the analyses for CP, CF, ash (by complete combustion) and crude fat (by extracting in ether, EE), in the form:

%NFE = 100 – (CP + CF + crude fat + ash).

At increasing maturity stages of alfalfa, crude fat and carbohydrates (NFE) decline (Tables 5.1 and 5.2).

Another estimation of energy is total digestible nutrients (TDN), the sum of all the digestible nutrients in forage: TDN = DP + digestible CF + digestible NFE + 2.25 x digestible EE. A good indicator of energy in alfalfa is digestible NDF (dNDF). A proposed refinement of the RFV index is the relative feed quality value:

RFQ = DMI x TDN x 0.813.

In balancing rations for animals, several energy calculations are utilized. First, based on detailed nutritional research, equations were developed for each animal species. Second, the required energy levels are categorized for livestock at their varying stages of production such as metabolizable energy (ME), or net energy (NE) for maintenance (NE_m), growth (NE_g) or lactation (NE_l).

5. Minerals: Fresh and conserved forages vary in their concentrations of macro- and micro-elements. For example, alfalfa is a rich source of calcium and phosphorus compared to other available roughages (Table 5.3). In some soils, forage may be deficient in one or more micro-elements (“trace nutrients”) required for normal crop growth and animal health. A detailed forage mineral analysis is often required for high-output livestock such as lactating dairy cows. Minerals are typically provided to confined animals in the form of a salt block or mineral supplement blended into a total mixed ration. In most production systems it is more economical and convenient to provide a mineral supplement to animals than to correct a livestock mineral deficiency through crop fertilization.

6. Amino acid concentrations for roughage sources are often required for feeding swine and poultry. Alfalfa contains an adequate level of most of the amino acids, except methionine, tyrosine and histidine which may often be limiting (Table 5.4). The lysine concentration in alfalfa hay is over 6 times higher than that of corn grain.

7. Vitamins: Alfalfa is a rich source of carotene (Table 5.5). Occasionally vitamin deficiencies occur in confined animals, and the forage and concentrates

are tested. Similar to mineral concentrations, vitamin levels are often monitored in forages to provide supplemental vitamins if required, and to avoid unnecessary supplementation costs when they are not.

Average nutrient concentrations for alfalfa and other common roughages grown in China are shown in Table 5.3. Alfalfa clearly differs from other roughage sources in terms of its protein, fibre characteristics and mineral concentrations. The values presented in these tables should only be used as general guidelines. Due to the inherent variability in forage quality, laboratory testing is strongly encouraged for appropriate feeding and hay marketing.

Table 5.1. Forage quality of standing alfalfa at different stages of maturity.*

	Vegetative, no buds	Bud, no flowers	Early flowering	Mid-full Flowering	Pod, post-flowering
Dry matter, %	18.0	19.9	22.5	25.3	29.3
	On a 100% dry matter basis				
Crude protein, %	26.1	22.1	20.5	18.2	12.3
Crude fibre, %	17.2	23.6	25.8	28.5	40.6
Ether extract, %	4.5	3.5	3.1	3.6	2.4
Nitrogen free extract, %	42.2	41.2	41.3	41.5	37.2
Ash, %	10.0	9.6	9.3	8.2	7.5

*Source: F.B. Morrison. 1956. *Feeds and Feeding*.

Table 5.2 Variability in hay quality among 16 alfalfa varieties tested in China.*

	Early flowering[a]	Full flowering[b]
	On a 100% dry matter basis	
Crude protein, %	19.3 (15.4-22.7)	19.1 (18.8-19.4)
Crude fibre, %	33.3 (27.5-38.5)	32.9 (29.5-36.2)
Ether extract, %	2.38 (1.46-3.67)	2.27 (2.26-2.27)
Nitrogen free extract, %	35.4 (31.3-41.2)	35.2 (32.2-38.1)
Ash, %	9.6 (6.5-13.2)	10.6 (10.5-10.7)
Calcium, %	2.02 (1.43-3.24)	1.69 (1.56-1.82)
Phosphorus, %	0.22 (0.09-0.36)	0.23 (0.21-0.24)
	[a]Mean (range) of 14 varieties	[b]Mean (range) of 2 varieties

*Source: Geng Huazhu *et al*., 1995. *China Alfalfa*. China Agricultural Press, Beijing.

Table 5.3. Average nutrient composition of alfalfa and common roughages.*

	Alfalfa			Corn		Millet	Wheat
	Early Bloom	Early bloom	Early Bloom	Well-eared	Stover no ears	Headed	Stover no grain
	Fresh Forage	Sun-cured hay	Wilted Silage	Silage	Standing dry	Sun-cured hay	Standing Dry
International Feed Identification Number:	*2.00.181*	*1.00.059*	*3.00.216*	*3.28.250*	*1.28.233*	*1.03.099*	*1.05.175*
Dry matter, %	21	90	35	33	85	87	89
	On a 100% dry matter basis						
Crude protein, %	20	18	17	8.1	6.6	8.6	3.6
Acid detergent fibre, %	29	31	33	28	39	-	54
Neutral detergent fibre, %	38	42	-	51	-	-	70
Ether extract, %	2.7	3.0	3.2	3.1	1.3	2.9	1.8
Crude fibre, %	23	23	28	23.7	34.4	29.6	41.6
Cell walls, %	38	42	43	51	67	-	70.0
Ash, %	9.8	9.5	8.2	4.5	7.2	8.6	7.8
Hemicellulose, %	7	9	9	-	-	-	-
Cellulose, %	22	24	23	-	25	-	39
Lignin, %	7	8	10	-	11	-	14
Calcium, %	2.19	1.41	-	0.23	0.57	0.33	0.18
Phosphorus, %	0.33	0.22	-	0.22	0.10	0.19	0.05
Potassium, %	2.14	2.52	-	0.96	1.45	1.94	1.42
Magnesium, %	0.27	0.33	-	0.19	0.40	0.23	0.12
Sulphur, %	0.48	0.28	-	0.15	0.17	0.16	0.19
Chlorine, %	0.44	0.38	-	-	-	0.13	0.32
Sodium, %	0.21	0.14	-	0.01	0.07	0.10	0.14
Cobalt, mg/kg	0.17	0.16	-	-	-	-	0.05
Copper, mg/kg	11	11	-	10	5	-	4
Zinc, mg/kg	-	25	-	21	-	-	6
Iron, mg/kg	111	192	-	260	210	-	157
Manganese, mg/kg	41	31	-	30	136	136	41
Selenium, mg/kg	-	0.54	-	-	-	-	-
Carotene, 1000 IU/kg	-	56.1	-	18.0	1.8	24	0.9

*Source: NRC. 1984.

Table 5.4 Amino acid concentrations of alfalfa forage in China.*

	Vegetative[a]	Early flowering[b]	Fully flowered[c]
	On a 100% dry matter basis		
Alanine	1.19	0.72 (0.49-0.85)	0.76
Arginine	1.06	0.50 (0.39-0.56)	0.64
Asparaginic acid	3.42	2.04 (1.54-3.65)	2.14
Cystine	0.43	0.26 (0.13-0.90)	0.91
Glutamic acid	2.40	1.23 (1.08-1.29)	1.53
Glycine	1.21	0.52 (0.49-0.59)	0.71
Histidine	0.56	0.22 (0.19-0.24)	0.29
Isoleucine	0.99	0.59 (0.31-0.67)	0.64
Leucine	1.66	0.92 (0.63-1.04)	1.06
Lysine	1.34	0.62 (0.56-0.80)	0.82
Methionine	0.26	0.23 (0.16-0.28)	0.16
Phenylalanine	1.31	0.73 (0.51-0.81)	0.77
Proline	2.32	0.89 (0.55-1.50)	0.96
Serine	1.30	0.62 (0.54-0.80)	0.75
Threonine	1.17	0.61 (0.46-0.66)	0.69
Tyrosine	0.87	0.31 (0.14-0.39)	0.41
Valine	1.36	0.80 (0.62-0.85)	0.81
	[a]'Guanzhong' alfalfa	[b]Mean (range) of seven varieties	[c]'Daye' alfalfa

*Source: Geng Huazhu *et al*., 1995. *China Alfalfa*. China Agricultural Press, Beijing.

Table 5.5. Vitamin concentrations of alfalfa and alfalfa products.*

	Fresh, early flowering[a]	Sun-cured meal[a]	Sun-cured leaf meal, China[a]	Sun-cured leaf meal, US[b]
Dry matter, %	25.9	90.7	91.4	-
	On as fed basis, mg/kg			
Carotene, Provitamin A	56.1	6.0	98.8	62
Choline	-	150.0	89.5	160
Thiamin, Vitamin B_1	1.6	2.8	4.4	-
Riboflavin, Vitamin B_2	2.3	8.7	15.9	15
Niacin, Vitamin B_3	6.1	35.3	53.6	55
Pantothenic acid, Provitamin B_5	9.7	15.3	28.0	33
Vitamin B_6	-	-	-	11
Folic acid, Vitamin B_9	0.64	1.30	5.93	-
Vitamin B_{12}	-	40.0	-	-

*Sources: [a]Institute of Animal Sciences. 1979. *Tables of Pig and Chicken Feed Composition and Nutrient Values*. Chinese Academy of Agricultural Science. [b]Kellems and Church, 1998.

Section 2: Forage quality grades and marketing alfalfa products

Alfalfa is widely marketed based on its forage quality characteristics. The performance of animals in a high-production status or under stress such as lactation is generally responsive to increasing levels of forage quality. The grading of different levels of forage quality is used in both open-marketing and by regulatory agencies.

2.1 Alfalfa hay

Over 90% of all hay fed to livestock is produced on-site, and most hay marketing is farmer-to-farmer trade. Five categories of alfalfa hay are recognized by the USDA Agricultural Marketing Service (Table 5.6), and these follow the maturation of dairy nutrition research. Hay is widely advertised and sold in US dairy regions by these categories, which are useful for both domestic and international trade.

Table 5.6. US alfalfa hay classification adopted for domestic purposes by the USDA Agricultural Marketing Service for the Livestock and Grain market news reports.*

Category	Crude Protein, %	Acid Detergent Fibre, %	Neutral Detergent Fibre, %	Relative Feed Value	Total Digestible Nutrients, %
Supreme	>22	<27	<34	>185	>62
Premium	20-22	27-29	34-36	170-185	60-62
Good	18-20	29-32	36-40	150-170	58-60
Fair	16-18	32-35	40-44	130-150	56-58
Utility	<16	>35	>44	<130	<56

*Source: Shewmaker. 2008.

2.2 Commercially processed alfalfa products

In contrast to hay marketing categories, there are many national and international laws governing commercially-processed alfalfa, complete feeds, and other feeds. Depending on the country and the products involved, various regulations address the labelling of products. In general, the regulations are more stringent with increasing levels of additives such as drugs and vitamins. In the case of complete feeds containing alfalfa marketed in the US for cattle, sheep, swine, poultry, equines, rabbits and fish feeds, the feed label must provide guaranteed levels of protein, fibre and most other additives. Uniform labelling is good for consumer confidence, and allows for safe and efficient commerce. The entire feed industry is largely supportive of enforcement of the labelling laws with frequent random sampling and testing. Currently, there are continual efforts to harmonize labelling standards and requirements for international marketing.

In China, three industry grades – I, II and III are recognized for alfalfa meal (Table 5.7A). Guaranteed standards are set for each category; Grade I must have a minimum of 18% crude protein, and maximum crude fibre and ash concentrations of 25% and 12.5%, respectively. These labels allow a producer to properly balance a ration for livestock with minimal laboratory testing. Over the course of time, large databases from the laboratory testing of alfalfa meal have been generated (Table 5.7B). In addition to the assurance that the industry standards are being met, additional information has been provided to the animal industries.

Table 5.7. Ministry of Agriculture, People's Republic of China feed industry standards for alfalfa meal (A) and the average nutrient and energy composition of alfalfa meal (B).

A. Industry grade standards (NY/T140-1989)			
	Grade I	Grade II	Grade III
Dry matter, DM%	On the basis of 87%		
Crude protein, %	Must be ≥ 18.0	Must be ≥ 16.0	Must be ≥ 14.0
Crude fibre, %	Must be ≤ 25.0	Must be ≤ 27.5	Must be ≤ 30.0
Ash, %	Must be ≤ 12.5	Must be ≤ 12.5	Must be ≤ 12.5
B. Average nutrient and energy composition of samples tested, flowering stage, dehydrated, adjusted to 87% DM*			
Crude protein, %	19.1	17.2	14.3
Crude fibre, %	22.7	21.6	25.6
Crude fat (ether extract), %	2.3	2.6	2.1
Ash, %	7.6	8.3	10.1
Nitrogen free extract, %	35.3	33.3	33.8
Neutral detergent fibre, %	36.7	39.0	36.8
Acid detergent fibre, %	25.0	28.6	29.0
Calcium, %	1.40	1.52	1.34
Phosphorus, %	0.51	0.22	0.19
Digestible energy, cattle Mcal/kg	2.26	2.25	1.99
Net energy, lactation, cattle Mcal/kg	1.15	1.14	1.00
Digestible energy, sheep Mcal/kg	2.36	2.29	-
Digestible energy, swine Mcal/kg	1.66	1.46	1.49

*Source: Chinese Feed Database. 2000. *Tables of Feed Composition and Nutritive Value* (11^{th} Ed.).

Section 3: Feeding alfalfa to animals

Alfalfa is consumed by a wide array of animals in the form of direct-grazed pasture, long-stem hay, chopped hay, sun-cured or dehydrated meal or leaf meal, cubes, pellets or as a processed ingredient in complete feeds. Alfalfa is used to provide the majority of the daily diets of confined or grazing livestock, or it might be used to supplement lower quality roughages during winter or lactation. Aside from the valuable biological merits of alfalfa, the economics of alfalfa in livestock feeding programs must be constantly monitored in modern animal husbandry. Depending on the livestock and crop production systems considered, alfalfa can be the most economical feed choice, or it might be the most expensive component in a ration. Thorough computer programs have been developed to balance appropriate feed combinations to meet the daily nutrient needs of all livestock on a "least-cost" basis. The following sections briefly relate alfalfa forage to the feeding systems of major food animals in China.

3.1 Animal requirements for forage quantity and quality

Not all animals or classes of livestock require the same quantity or quality of feed. In modern animal husbandry industries, the goal is to economically feed animals at the level required for their output.

A. Dry matter intake: For large animals such as cattle, sheep and horses, the general guidelines for daily dry matter intake (DMI) are: maintenance (<1.5%), growth (1.5 to 2.5%) and lactation (>2.5%) of animal body weight per day (in units of feed dry matter). The highest requirements are for dairy cattle at a high level of production, such as the Holstein cows in most modern dairies with DMI over 3.5%.

Example a: The daily feed requirement for a 600-kg dairy cow producing 40 kg of milk per day (at 4% fat) is 3.5 to 4% of body weight = 20 to 24 kg of dry matter per day. If hay (12% moisture) or haylage (50% moisture) were fed, the requirements would be 23 to 27 kg of hay or 40 to 48 kg of haylage per day.

In China, some common hay sources are "premium" alfalfa (<36% NDF), "utility" alfalfa (about 50% NDF), and sheep grass (*Leymus chinensis*) hay (>65% NDF). Based on the estimation of an animal's potential daily DMI by the equation 120/%NDF, the three hays would be expected to have >3.33, 2.40 and <1.85% DMI daily, respectively.

A 600-kg milk cow would be expected to have DMI of >20.0, 14.4 and <11.1 kg of the hay samples per day, respectively. In this example, the low-quality alfalfa or sheep grass hay do not have sufficient levels of intake (20 to 24 kg of dry matter) to support the high level of milk production. This example clearly demonstrates the utilization of high-quality alfalfa in a high-output dairy animal; even with the added expense of high concentrate levels, low quality hay cannot be utilized successfully.

B. Forage quality: Nutrient requirements vary by stage of animal development; all animals do not require the same level of nutrients in their diets.

Example b: Diets for animals on diets to support weight gain or milk production must be of a higher quality than maintenance diets. Grade III dehydrated alfalfa meal provides double the digestible energy available for a dry beef cow (1.99 Mcal/kg) compared to the net energy for lactation (1.00 Mcal/kg, Table 5.7B). By knowing the daily nutrient requirements, theoretical animal diets can be formed. For example, the nutrient requirements of a 500-kg dry beef cow can be compared to that of a 500-kg cow during heavy lactation (Table 5.8). In this example, the cows require different levels of dry matter per day (DMI), 8.8 vs. 10 kg. Based on these DMI levels, the nutrient needs of the 500-kg dry cow are met by consumption of 8.8 kg per day of the Grade III alfalfa meal. However, for the lactating cow consuming 10 kg per day, energy (NE_l) and P are deficient in the diet.

For the lactating beef cow, the energy requirement can be met by increasing the forage level to 12.64 kg of meal per day (Table 5.8, diet 2b) or by adding a high-energy supplement. The P requirement would be met by adding a mineral supplement. In this example, the DMI is not limited by a high NDF value; the 500-kg cows could consume 15.4 kg of Grade III meal per day ([120/39% NDF)] x 500).

The forage quality recommendations for various livestock can roughly be generalized (Table 5.9) based on known average intake levels. Feeding supreme-grade alfalfa hay will not injure an idle horse. However, this is inefficient if the hay cost is higher than other available hay, and it often leads to boredom and misbehaviour in confined horses that meet their nutrient requirements quickly each day.

Table 5.8. Demonstration of using alfalfa meal to meet the daily dietary nutrient requirements of a 500-kg dry beef cow vs. a 500-kg cow in high lactation with alfalfa meal.

	Forage quality of Grade III dehydrated alfalfa meal[a]				
	%DM	Net energy, Mcal/kg	CP, %	Ca, %	P, %
Grade III meal	87	NE_m = 2, NE_l = 1	14.3	1.34	0.19
	Recommended daily intake[b]				
Cow condition	DMI, kg	Net energy, Mcal	CP, g	Ca, g	P, g
1.Dry	8.8	(NE_m) 8.14	614	17	17
2. Lactating	10.0	(NE_l) 12.64	1246	40	28
Diet for	Fed, kg	Nutrients supplied in recommended DMI[c]			
1. Dry	8.8	(NE_m) 8.71	1258	118	17
2a. Lactating	10.0	(NE_l) 10.00 (-21%)	1430	134	19 (-39%)
2b. Lactating	12.64	(NE_l) 12.64	1808	169	24 (-14%)

Sources: [a] from Table 5.7B (using digestible energy as an approximation of NE_m); [b] from Kellems and Church, 1998; [c] author's calculations.

Diet 1 in Table 5.8 has double the required CP for a 500-kg dry cow; this is not necessarily harmful to the cow, but there may be less-expensive diet formulations. The livestock manager must balance the animals' nutrient requirements, while maintaining economical ingredient costs.

Table 5.9. General forage quality needs of farm animals.*

Relative feed value or relative forage quality	Animals
100 to 115	Dry cow, heifer (18 to 24 months), idle horse
110 to 125	Brood mare, working horse
115 to 130	Beef cow with calf, heifer (12 to 18 months)
120 to 135	Nursing mare, hard-working horse
125 to 145	Dairy (last 200 days), heifer (3 to 12 months), growth rations for meat animal
140 to 160	Dairy (first trimester), dairy calf

Source: Undersander *et al*., 2004.

As described in Table 5.9, the dietary requirements of animals are dynamic, with specific daily levels of dry matter, water, protein, energy, minerals, vitamins and amino acids required at each life stage. Animals' nutrient requirements can be met by balancing a daily ration from available and economical feed sources. Relative to other available feeds in China, alfalfa has high levels of protein, energy and other nutrients (Table 5.3) which make alfalfa very versatile as both a roughage and a concentrate.

3.2 Alfalfa pasture

Alfalfa is used as pasture in many regions of the world. In northern China and other temperate areas, alfalfa can be direct-grazed for four or five months during the growing season, but conserved forage (hay or haylage) is required for winter and spring feed. Livestock producers use alfalfa for season-long grazing or for periodic uses such as stockpile grazing.

“Stockpiling” is a common management practice for rainfed alfalfa in western North America beef cattle operations, where the first cutting of hay is harvested, and then all of the aftermath regrowth is deferred for grazing in autumn and winter. Alfalfa pasture can essentially provide a complete diet for most farm animals, except for certain minerals or during high-demand periods such as lactation. It is critical that the forage availability and quality meet the livestock demands throughout the entire year. Therefore in any livestock system utilizing alfalfa as pasture, hay or a combination of both, the year-round daily nutrient requirements of the animals must me known.

A. Bloat: Alfalfa poses a significant risk of bloat in ruminant animals. The highly soluble and rapidly-digested proteins form a viscous foam in the rumen, preventing the animal from eructation. Bloat symptoms range from slight abdominal swelling and discomfort to immediate acute deaths. Bloat is reduced by a number of methods: 1) using a bloat-free legume such as sainfoin (*Onobrychis viciifolia*) or trefoil (*Lotus corniculatus*) to completely avoid the problem, 2) plant gramineous plants in a mixture with the alfalfa, 3) provide mineral blocks containing anti-bloat compounds such as poloxalene, 4) allow animals into alfalfa pasture when the plants are in bloom, 5) graze only at low-risk times such as several days after a hard freeze, 6) rotate animals off of the pasture when the grazing height is down to 10 cm (or 15 cm for some gramineous species), 7) turn animals out onto lush pasture only after they have already been fed or grazed in another pasture, 8) cut the alfalfa and allow it to wilt several days before grazing (windrow grazing), and 9) provide clean water and salt at all times. Generally sheep and goats are less sensitive to bloat than cattle.

B. Grazing system: Alfalfa pasture can be continuously grazed, however pasture productivity of alfalfa and most cool-season grasses improve with a rotational grazing system. In rotational grazing, the plants are kept in a rapidly-growing stage between about 45 cm grazed down to 10 cm, and then the animals are removed for the pasture to recover. For example, a four-paddock system could provide for 10 days of grazing followed by 30 days of rest. A more intensive system with 12 cells could allow for three days of grazing followed by 33 days of rest. A rotational grazing system requires more labour and fencing, but can reduce the bloat hazard due to frequent monitoring of the animals.

3.3 Alfalfa for dairy cattle

Alfalfa is well-suited as a year-round feed for confined herds of dairy cattle, including cows at peak lactation, dry cows, replacement heifers and bulls. Numerous studies have demonstrated the benefits of high quality forage on milk yield, butterfat concentrations and long-term health. Dairy cattle provide an excellent model for the evaluation of forage quality, because milk production rapidly adjusts to slight changes in diet quality. Long-stem alfalfa hay is considered as the “gold standard” for balancing a high-quality ration for lactating cattle, therefore all other roughages and roughage forms are compared to alfalfa hay.

A. Pasture: Many dairies around the world have retained the practice of seasonal grazing for milk cows. In North America, many small and medium-sized dairies have reoriented their operations from full confinement to include summer grazing to reduce the resources devoted to year-round confined feeding. Alfalfa pasture is an excellent diet for replacement heifers and other growing animals. In many cases, the dairy herd owner eliminates the required forage harvesting equipment and labour, and relies on purchased roughages for a more efficient operation.

Alfalfa pastures can be mixed with high-quality grasses such as perennial ryegrass (*Lolium perenne*) or orchardgrass (or cocksfoot, *Dactylis glomerata*). Milk cows at a high level of milk production require a consistent supply of alfalfa and other forages in the bud stage prior to flowering. This is best accomplished with: 1) irrigated or high rainfall conditions, 2) adequate land to maintain consistently high-quality pasture for milk cows, while using the lesser-quality forage for other animals, 3) a planned grazing system to maintain high dry matter intake (DMI) and minimize waste, 4) supplementation with concentrates as needed, and 5) adequate land to allow for production of winter feed.

Many grazing experiments have been conducted in China with lactating dairy cattle on alfalfa or alfalfa-grass pastures. In digestibility experiments where chromic oxide was used as a marker for forage intake, it was determined that average daily DMI for milk cows on alfalfa was 5% of body weight from May through July, and 3.4% in August and September. High-output cows produced over 25 kg of milk per day for 84 consecutive days when grazing alfalfa-grass mixtures without supplementation. In one trial, it was determined that milk cows grazing a pasture mix of alfalfa-cocksfoot on good land and with no supplementation produced 6975 kg of milk (at 4% butterfat) per ha over a 5.5-month grazing season.

B. Greenchop is frequently fed to dairy cattle in humid areas during the growing season. A field forage chopper is used to bring a daily allotment of forage to the confined dairy cattle. This method is a good compromise between the costs, risks and losses of a stored forage system vs. the pasture waste and variable forage quality of a grazing system. One advantage of greenchop is that alfalfa maturity at harvest can be selected, and alternatives are available such as cutting high (above 15 cm) to avoid lower-quality stems. Further, greenchopping can be used in combination with grazing; following the rotation of cows from one paddock, the remaining forage can be chopped and fed to other animals. Typically 25 to 30 kg of greenchop per day is fed to lactating cows, and 10 to 15 kg to young cows (dry matter basis).

C. Hay: A considerable amount of information has recently been generated on the role of alfalfa hay in dairy cattle diets in China. As discussed throughout this manual, forage quality is significantly impacted by the stage of alfalfa maturity. For top-producing dairy cattle, high-quality alfalfa hay is obtained by cutting during the bud stage before flowering. Research in China has demonstrated that after flowering, alfalfa forage quality declines resulting in reduced milk production per unit of feed and per unit of land area (Table 5.10).

The rapid expansion in dairy cows in China has resulted in a significant deficit in the supply of high-quality alfalfa hay. For the short term, imported hay will meet this demand; however in the long-term, an increased and consistent supply of domestic hay is desirable. Despite the use of alternative feed sources such as corn silage, haylage, pellets or other forages, it will be necessary to maintain a minimum base level of dry hay (25 to 35%) within the diets of high-output dairy cattle.

Table 5.10. Effects of crop maturity on alfalfa hay quality, feed intake and milk yield.

	Early flowering	Mid-flowering	Fully flowered
	Product yield, kg/ha		
Forage dry matter	8853	8376	6819
Digestible protein	1245	1143	813
Total digestible nutrients	5243	4965	3677
Milk (at 4% fat)	6750	5910	4467
	Dry matter intake, kg/cow		
Hay consumption	18.5	18.7	18.6

D. Haylage is widely used in humid areas of cattle production where it is difficult to cure dry hay. In 1982, Jiang Zhijie compared the performance of Holstein dairy heifers (11 to 13 months of age) and milk cows when fed alfalfa hay or haylage cut at the late bud to early bloom stage. Concentrates were fed equivalently in each ration. His results were:

- Heifers gained 0.3 kg per day (ADG) more on haylage diets than hay diets
- For every 1 kg in ADG for heifers fed haylage diets, it required 2.5 kg less concentrate per day than heifers fed hay diets
- Cows on haylage diets had 8% higher milk yields than cows on hay diets
- Milk from cows on haylage diets had slightly higher butterfat contents than cows on hay diets, 3.52 vs. 3.43%
- Milk from cows on haylage diets had higher net energy than cows on hay diets, 1.38 vs. 1.20 Mcal/kg dry matter

E. Pellets are convenient for conveyance, storage and mixing as a protein or energy source in total mixed rations (TMR) for dairy cattle. The levels of bypass protein of "dehy" pellets or sun-cured alfalfa pellets are higher than that of hay. In China several feeding trials comparing alfalfa pellets to alfalfa hay have been conducted. In general pellets slightly improve milk protein and continuity of lactation above that of hay, but most other measurements of feed efficiency or milk composition are similar (Table 5.11). Therefore, depending on the costs of all feed ingredients in the TMR, alfalfa pellets may be more economical than hay in some cases.

3.4 Alfalfa for beef cattle

Alfalfa is a high-quality roughage for beef cattle, but its use is more fragmented than in modern confined dairy operations. Similar to dairy cattle, high nutrient levels are required for beef cattle during rapid growth, late gestation and lactation. In the majority of beef cattle production systems in temperate regions around the world, mother cows and their calves are maintained on grass pastures of moderate quality for most of the year. Conserved feeds are generally fed to cows in late gestation and lactation during the winter, or to heifers or steers on growth rations.

A. Pasture: Autumn and winter grazing of stockpiled alfalfa in hay fields is a common practice for beef producers in some temperate regions. Stockpiling is an economical manner of feeding cattle and reducing harvest and feeding costs. Another significant use of alfalfa for pasture is for growing yearlings ("stockers"). In Argentina and other countries, vast numbers of yearling cattle graze alfalfa-based pastures. The animals are harvested directly as "grass-fed" or fed for a brief period on a high-concentrate finishing ration. The market for grass-finished beef is a rapidly-growing segment of the beef industry, and its production system is a direct contrast to the highly-mechanized and centralized feedlot finishing in central and southwestern US. In China, it has been demonstrated that beef cattle finished (fattened) on irrigated alfalfa pastures gained over 0.9 kg per day with no supplementation, and across the entire grazing season the pasture supported animal liveweight gain of up to 900 kg per ha.

Table 5.11. Comparison of alfalfa hay and pellets in daily diets fed to lactating dairy cattle.

	Alfalfa hay 2 kg	Alfalfa pellets 2 kg	Alfalfa hay 4 kg	Alfalfa pellets 4 kg
Feed intake characteristics				
Total dry matter intake, kg/day	20.0	19.9	20.3	20.6
Dry matter intake from alfalfa, kg/day	1.9[b]	1.9[b]	3.7[a]	3.5[a]
Dry matter intake from corn silage, kg/day	9.1[a]	9.1[a]	7.4[b]	7.7[b]
Dry matter intake from roughage, kg/day	11.0	11.0	11.1	11.1
Dry matter intake from concentrate, kg/day	9.0	9.0	9.2	9.5
Animal and milk responses				
Body weight change, g/day	-110	+13	+13	+51
Milk yield, kg/day	30.8	31.1	31.1	32.5
Butterfat content, %	3.61	3.52	3.62	3.47
Butterfat yield, kg/day	1.11	1.09	1.12	1.14
Milk yield corrected to 3.5%, kg/day	31.4	31.1	31.6	32.5
Milk protein content, %	2.97[b]	3.04[a]	3.03[a]	3.07[a]
Milk protein yield, kg/day	0.91	0.93	0.93	0.99
Continuity of lactation rate, %	88.4[b]	94.9[a]	91.3[ab]	97.6[a]
Efficiency: total dry matter intake per 100 kg of milk (at 3.5% butterfat)	64.0	64.8	66.6	65.4
Blood urea nitrogen, mmol/l	7.9[a]	8.0[a]	7.1[b]	7.4[ab]

[a,b]Values within a row with different superscripts are different ($P<0.05$).

B. Greenchop can be utilized for beef cattle similarly to feeding confined dairy animals. Greenchop has been evaluated in feeding trials with confined cattle compared to cattle grazing alfalfa pastures in long (10-day) or short (1-day, "strip grazing") rotations in the same field (Table 5.12). The average weight gains were similar in all treatments; however the efficiency of the systems varied. Specifically, animals consume the greenchop with no selectivity or field losses. In addition to the biological responses shown in Table 5.12, the costs and convenience of daily greenchopping must be compared to that of the pasture systems.

C. Hay: In temperate regions, alfalfa hay is a major roughage source for winter feeding of beef cows during gestation and early lactation. Based on typical intake levels and the known requirements for dry matter and nutrients, the level of alfalfa forage required for beef cattle is generally lower than that of high-lactation dairy cows (Tables 5.8 and 5.9). In contrast, growing beef animals are responsive to high-quality alfalfa, as related to alfalfa maturity at harvest (Table 5.13). In most cases, alfalfa dry matter yield continues to increase during plant maturity, but the increased production beyond flowering does not offset the reduction in forage quality and animal response.

Table 5.12. Performance of yearling beef cattle (initial weight 250 kg) in season-long alfalfa grazing systems compared to being fed greenchop in confinement.

	Rotationally grazed, moved		Confined, fed greenchop *ad lib*
	Every 10 days	Daily	
Dry matter intake (DMI), kg/day	6.3	5.8	6.8
DMI, % body weight	2.52	2.32	2.72
Average weight gain, kg/day	0.84	0.88	0.87
<u>Feed efficiency</u>: total DMI per 100 kg of weight gain, kg	864	902	1073
<u>Land efficiency</u>: animal gain, kg/ha	472.5	652.5	792.0

Table 5.13 Influence of alfalfa maturity on the performance of beef cattle in growth rations.

	Buds, no flowers	Early flowering (10% bloom)	Fully flowered	Pod, mature
Dry hay yield, kg/ha	10,215	12,995	14,180	14,333
<u>Feed efficiency</u>: total DMI per 100 kg of weight gain, kg	1628	2086	2163	3910
<u>Land efficiency</u>: animal gain, kg/ha	627	623	656	368

D. <u>Haylage</u> is occasionally used for winter feed for beef cows, but it is more frequently used in mixed rations for growing steers and replacement heifers. As described previously, haylage has less waste in the field at and feeding, but it is only feasible for on-farm feeding.

E. <u>Meal, cubes and pellets</u> processed from alfalfa are widely used as the roughage source in mixed feeds for confined beef cattle. In cattle finishing rations in Japan, alfalfa meal comprises up to 45% of the diet until the final month when it is reduced to avoid yellow discolouration of the fat.

3.5 Alfalfa for sheep

Most of the world's sheep are located in arid and semiarid ecosystems, such as the dry grasslands of China, Australia, Africa, South America and the southwestern US. The low rainfall in these areas results in marginal feed resources that limit reproduction and lamb growth. Sheep have therefore evolved under conditions of low forage quantity and quality, and current sheep production systems are generally extensive, with minimal inputs. For example in the US, ewes can graze half of the year with no supplementation, and a diet consisting solely of forages can meet the flock's needs for 70% of the year.

The basic nutritional principles of feeding alfalfa to sheep are similar to those of feeding dairy or beef cattle. However, in many cases the unit value of output (lamb, mutton, or fleece) in a sheep enterprise may not justify the increased values of intensive inputs such as high-quality alfalfa hay or irrigated pasture. Alfalfa is most useful as a supplement for low-quality roughages at peak nutritional demands such as the conditioning period of ewes and rams before breeding, late gestation to lactation, and for finishing diets.

A. <u>Pasture</u>: In many temperate farming regions, sheep are often used to glean crop residues after harvest. In areas with late winter lambing, a common practice in the autumn is for producers to "flush" their ewes prior to breeding by feeding grain to encourage ovulation. Alfalfa aftermath grazing in the autumn is a method of flushing that is equivalent to feeding grain. In colder areas, stockpiled alfalfa is an excellent feed for sheep until snow becomes too deep or lambing begins.

Occasionally, alfalfa fields are grazed temporarily by sheep in the spring. If lambs are weaned early in the spring, a system of "creep grazing" can be used – lambs graze in strips ahead of the ewes, and can avoid being infested with high parasite loads. The high-quality alfalfa encourages good lamb growth and nutrition for the lactating ewes. During the spring, temporary grazing by sheep can be beneficial in terms of weed and insect (such as the alfalfa weevil) control in both hay and seed production systems.

During the summer, alfalfa pasture can certainly provide excellent gains for lambs, particularly in a managed rotational grazing scheme. In China, it has been demonstrated that with a good rotational grazing system, up to 1000 kg of lamb gain can be produced per ha of irrigated land. In pasture finishing diets where alfalfa intake was measured with chromic oxide, 30-kg lambs consumed 1.08 kg of alfalfa dry matter (3.6% DMI) and gained 0.16 kg per day (the feed efficiency was 100 kg of animal gain per 788 kg of alfalfa dry matter). In most cases, the operator will use a combination of grazing and haying in the early summer to capture the rapid forage growth, then solely harvest or graze the remaining cuttings.

On irrigated land, producers must be cognizant of input costs and the market values of hay and lamb. With high hay values, the best use of the land during the summer is for hay production because lamb gains are more economical on lower-quality pastures. In some intensive grazing systems with dairy cows or yearling beef animals, sheep are often used to clean up the remaining forage.

Under rainfed conditions, alfalfa-based pastures can also be used for season-long grazing. A mixed system of pasture and hay production is used at the Xunyi sheep farm in the Weibei Region of Shaanxi Province. In this area, 650 hectares of former cropland on terraces were replaced with alfalfa that was sown with Siberian wildrye (*Elymus junceus*) and Dahurian wildrye (*E. dahuricus*) with oat as a companion crop. In the year of establishment, the fields are harvested for hay once during the summer, and then grazed during the autumn and winter. In the second year, the first growth is grazed during the summer, and the regrowth is harvested as hay. Thereafter, the field follows the alternating uses of pasture or hay in subsequent years. With multiple fields there is adequate pasture for season-long grazing. The farm has compared continuous and strip grazing methods; with strip grazing there was 70% pasture utilization and lamb gains were 0.19 vs. 0.12 kg per day in continuously-grazed pastures. Additionally, the hay yields in the subsequent season are 17% higher following strip grazing than under continuous grazing.

Sheep are vulnerable to bloat, but to varying degrees depending on their condition and the seasons of use described above. For example, ewes on low-quality grass or crop residues during the summer moved rapidly to lush alfalfa can be very susceptible to bloat. In contrast, lactating ewes consuming alfalfa hay in the spring often tolerate grazing the new growth of alfalfa and grasses if it has some dry standing stubble from the previous year.

B. <u>Greenchop and haylage</u>: Sheep can efficiently utilize greenchop during the growing season with minimal waste. However, this is not a common practice due to the expense and the diet requirements of the flock during summer. In some cases where strip grazing occurs for dairy or beef cattle, the remaining forage is greenchopped and fed to confined growing lambs. Alfalfa haylage is a very efficient winter feed to supplement ewes in late gestation and early lactation. The haylage should comprise less than half of the daily diet, and can be mixed with dry feeds such as coarsely-chopped grass hay and grains.

C. Hay and meal: Alfalfa hay is a major winter feed for sheep. When hay is fed on the ground, sheep tend to waste a large amount by bedding in it, selectively eating some portions and fouling it. Hay is best fed in bunks or feeders by coarsely chopping and feeding it alone or processed with grains. Depending on roughage values, the proportion of alfalfa meal in sheep diets can comprise 50 to 80%. In feeding experiments, Zhu Xingyun and co-workers developed low-cost rations for growing lambs with late-maturity alfalfa (in seed set). The diet consisted of alfalfa hay meal (80%), oat hay meal (9.5%), flax cake (6%), corn (4%) and mineralized salt (0.5%). Over the 60-day feeding trial, the daily dry matter intake was 1.41 kg, and daily gains were 0.146 kg.

D. Pellets are a very convenient form of supplementing sheep during the winter. Compared to hay, alfalfa pellets are less dusty, the alfalfa is uniformly consumed, and the pellets can be mixed with whole or cracked grains. In general, alfalfa pellets are cost-effective for seasonal feeding or supplementation, however complete-feed pellets are generally not economical for feeding sheep in most circumstances.

3.6 Alfalfa for poultry

The modern poultry industry has created and applied many principles of nutrition, genetics, veterinary medicine and animal husbandry that have resulted in fairly consistent prices of meat and eggs over several decades. The nutritional requirements of poultry vary considerably from those of ruminant farm animals. Poultry are unable to utilize high levels of dietary fibre, so the utilization of alfalfa is restricted to processed ingredients such as meal for its contribution of specific vitamins. For caged hens or confined broilers in North America, poultry diets are typically grain-based and complex, including corn (50 to 60%), soybean meal (20 to 40%), various by-products and vegetable fats (1 to 10%), and pre-mixed vitamins, minerals and antibiotics (1%). In China, fish oil, fish meal and meat meal are often included in similar diets. Due to the ongoing protein shortages in the human food supply chain in China, there is considerable interest in utilizing more alfalfa in poultry diets to displace soybean, meat and fish products.

A. Meal and leaf meal: Due to the low fibre-digesting capability of poultry, only Grade I meal (>18% crude protein, <25% crude fibre) should be included in poultry diets. Alfalfa meal is a good source of several B vitamins, Vitamin K, carotene and xanthophyll which promotes yellow pigmentation of egg yolks, flesh, beaks and claws. Currently, Grade I alfalfa meal is used in China for standard diets of chickens (1 to 7%), ducks and quail (2 to 5%) and turkeys (2 to 25%). After processing, alfalfa leaf meal consists of about 50% crude protein, below 2% crude fibre, about 3000 kcal/kg of digestible and metabolizable energy for poultry and high vitamin and mineral concentrations. Alfalfa leaf meal has been tested experimentally to substitute for 25 to 100% of the standard meals (fish, meat, bone) in diets fed to chicks, broilers and laying hens with promising results. The cost-effectiveness of processed alfalfa leaf meal will be determined by its cost of production and the value of the displaced protein sources.

B. Pasture and greenchop: In many countries, there is an increasing demand for "free range" chicken and other poultry. The meats from these poultry are generally leaner, considered to be more natural or healthy, and are worth premium prices. Alfalfa is an excellent pasture for poultry due to its high forage quality and high populations of insects, spiders and worms which are relished by poultry. Typically, poultry are penned for security at night, and then allowed to graze freely or within fenced pastures for a portion of the day. Water and free-choice feed containing necessary vitamins, minerals and other additives are provided in the pens, which are accessible during the day. The alfalfa should not be used immediately following rain, or too intensively early during the season to avoid losses if the grazing is combined with a haying operation. Alfalfa pasture can support fast gains by broilers, and this is a very economical method of production in terms of labour and infrastructure. Greenchopped alfalfa can be fed to poultry confined in a yard, but due to the high moisture content its utilization is fairly inconsistent, and the process may not be cost-effective.

3.7 Alfalfa for swine

The modern swine production industry is highly specialized, similar to that of poultry production in terms of its large facilities with high animal concentration and use of high technology. Swine have simple stomachs, so they are unable to efficiently digest the complex carbohydrates (fibre) in alfalfa and other roughages. Intensive swine production has developed in areas with significant corn and soybean production. Standard rations for growing piglets, finishing animals and sows in reproductive phases are 60 to 80% ground corn, 10 to 15% soybean meal, 5% by-product or fats, and 5% minerals, premixed vitamins, antibiotics and other additives.

A. Alfalfa meal is often added as an ingredient in complete feeds for swine based on its vitamin, amino acid or xanthophyll content, however the maximum inclusion rate recommended in the US is only 5% of the total diet. In China, higher rates (15 to 50%) of dehydrated alfalfa meal are recommended for sows prior in late gestation and early lactation.

B. Pasture: Alfalfa-grass pastures are an efficient way to provide low-cost summer feed for gestating sows, which can utilize roughages better than young pigs. The sows are provided a grain-mineral supplement in self feeders which they can briefly access during the day. A rotational grazing system is advised, and the stocking rate should be from 15 to 25 sows per ha.

3.8 Alfalfa for horses

Horses evolved as grazing animals, so modern diets should be based on pasture and conserved forages. The stomach of the horse is small relative to its body size, so horses are better suited to small frequent meals during the day rather than one or two large feedings. The digestion of sugars, starch and fat occurs in the small intestine. Complex carbohydrates (fibre) in forages are digested in the cecum and colon by microbial populations similar to those in ruminants. Therefore, an adult horse on a maintenance diet can meet its energy demands solely from pasture or hay. The levels of forage quality needed by horses are similar to those of beef cattle, with the highest level for lactating mares and hard-working horses (Table 5.9).

A. Pasture: Ideally horses should be on pasture year-round. In temperate regions, horses can be maintained on pasture during the growing season with minimal supplementation. For pasture, alfalfa should be sown with an adapted grass such as cocksfoot or perennial ryegrass. Horses are prone to over-consumption of lush alfalfa, so the grass-alfalfa seed ratios should result in a forage canopy of about 2:1 grass to alfalfa, and grazing should commence at the late vegetative to early bloom stage. Under these conditions, the pasture would be suitable for lactating mares and their foals, young horses and work horses. However, idle mature horses are prone to over-consumption and becoming overweight, so their access to the pasture should be limited to a several brief outings per day.

A planned rotational grazing system in conjunction with haying enables the provision of good-quality horse pasture throughout the growing season. A pasture system with four paddocks of adequate size to support 10 days of grazing, rotation, and 30 days of rest rotation works effectively for horses. During the winter, horses can effectively graze decumbent grass alfalfa-grass pasture, but will need supplementation with alfalfa hay and grain.

B. Greenchop and haylage are rarely used for horses, primarily due to the lack of harvesting and feeding machinery on most farms where horses are located. In regions where alfalfa haylage is stored for livestock feed, haylage can be fed to older horses with poor teeth.

C. Hay: Alfalfa and alfalfa-grass are the preferred hay types for horses. Based on the nutritional needs and average intake levels of most adult horses, the maturity of alfalfa at harvest can be in the early to mid-flowering stage, which optimizes forage yield. The ideal hay for horses is green, soft, and free of dust and moulds, therefore the conditions of field drying, harvest and storage are very important. During winter or for horses in confinement, feeding should occur twice per day. If hay is used to supplement low-quality roughages, its access can be limited to prevent over-consumption.

D. Cubes and pellets are often used for convenience as a roughage source or complete feed. Processed feeds have less dust, and are suited for horses that sort and waste hay. For older horses, cubes can be softened by soaking in water to provide a desirable forage length.

3.9 Feeding alfalfa to other animals

Alfalfa hay and processed products are used to supply roughage or complete feeds for many animals such as pets, or in wildlife preserves, national parks, and zoos. A growing market is for pelleted feeds for numerous species of farmed fish or shrimp.

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