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PROTEIN SOURCES FOR LIVESTOCK

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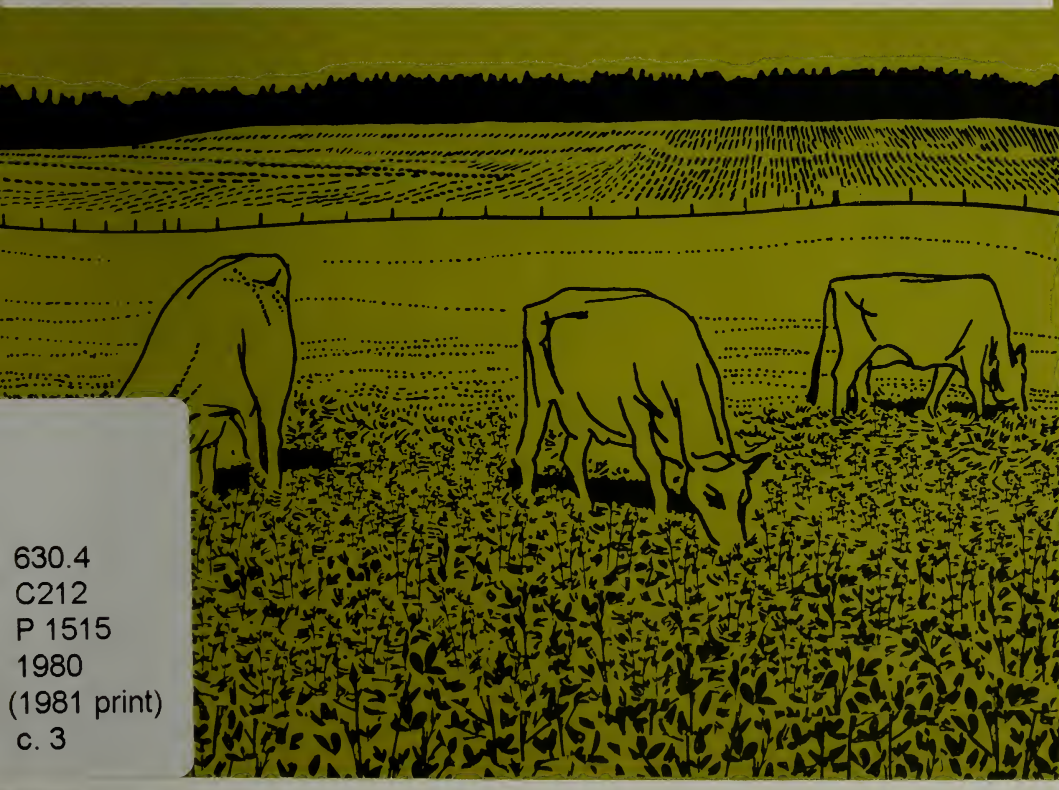

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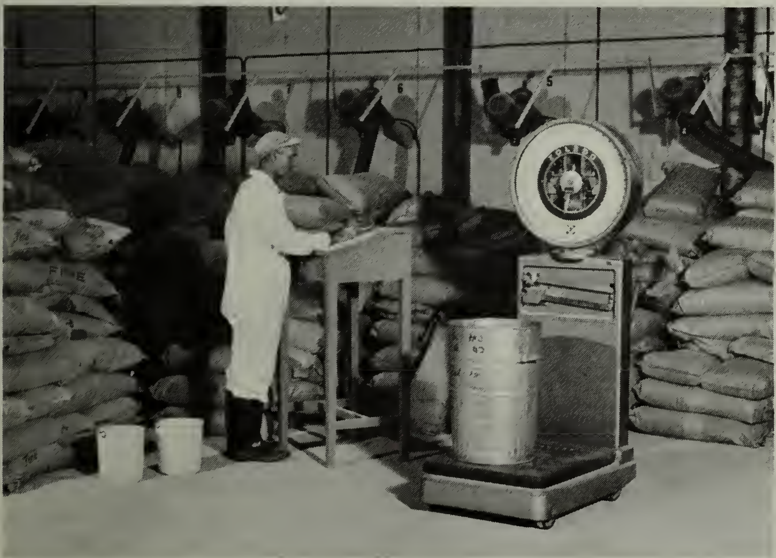
PROTEIN SOURCES FOR LIVESTOCK

No single feed grain, and few forages, will supply all the nutrients and energy required for livestock production. Feeds vary in quality and quantity of nutrients (protein, fats, carbohydrates, minerals and vitamins), as well as in cost. A livestock producer, therefore, must know something about the nutritional values of feeds if he is to select the least expensive combination that will give the performance he wants.

Protein is a major cost item in a feeding operation, and its price will likely remain high because of the widespread demand. To ensure best use of protein, it is important that energy (from fats and carbohydrates), minerals and vitamins be supplied in adequate quantities. Failure to provide a balanced ration limits the full utilization of protein by the animal.



Weighing ingredients is an essential part of formulating high performance rations.

It is also important to appreciate the major difference between ruminants (cattle and sheep) and nonruminants (pigs and poultry) in their dependence on quality protein sources. For top performance, pigs and poultry must be fed a proper balance of the essential amino acids (components of proteins) as well as an adequate level of proteins. To attain this, it is often more economical to increase the protein level of the diet by using an inexpensive protein source rather than a smaller quantity of expensive, high-quality protein. Cattle and sheep on the other hand, are able to upgrade low-quality proteins and even convert nonprotein nitrogen (urea) to protein. So, it is generally wasteful to feed high-quality proteins to ruminants.

Following are suggestions on feeding protein to different classes of livestock, with a view to reducing the cost of the overall ration.

PROTEINS FOR PIGS AND POULTRY

PROCESSED PLANT PROTEINS

Soybean Meal

Soybean meal is generally accepted as the standard of quality for protein supplements around the world. It may be replaced by many other protein sources, depending on price, but it is still one of the best plant protein sources we have today because of its lysine content and general amino acid balance and the uniformity of the processed meal. The amino acid methionine is a limiting factor in soybean meal but this material is available as an inexpensive synthetic product.

Generally speaking, lysine is the most important amino acid in a protein supplement because it is the one most commonly deficient in cereal grains. An approximate evaluation of protein sources for pigs and poultry can be made on the basis of lysine content. Table 1 shows the protein and lysine values of some of these protein supplements compared with soybean meal.

Although the actual values shown should not be interpreted too literally, they help indicate the best alternatives to soybean meal. Values over 100 mean that, for a given feed, protein and/or lysine are at higher levels than in soybean meal. Where a protein value is higher than a lysine value for a given feed, then the protein is of generally poorer quality as a cereal supplement than is soybean meal. A high lysine figure relative to that for protein indicates a supplement of high potential value. However, some other factors, such as yield, energy value and cost, must be considered.

Rapeseed Meal

Rapeseed meal (35-40% protein) has a good biological value for its proteins, but it can contain excessive amounts of undesirable goitrogens and tannins.

Since progressively higher energy rations are being fed to chicken and turkey broilers and to market hogs, more rapeseed will likely be fed, as such, in the future. The relatively low cost of shipping concentrated energy in the form of rapeseed oil will assist in making this supplement competitive on an energy basis. Further development is required.

Sunflower Seed Meal

Sunflower seed meal would appear to be the best alternative to soybean as a protein source, if obtainable at not more than three quarters the price. However, its lower energy value (because of higher fiber level) must be taken into consideration when it is used in formulations.

Sunflower seed meal contains as much (or more) of the amino acids methionine and cystine as soybean meal, but a somewhat lower level of lysine. It may be used as the only protein source in dairy and beef rations. It is a good protein for poultry except for its deficiency in lysine.

Corn Gluten Meal

Corn gluten meal has no toxic problems but the amino acid balance is not as good as that of soybean meal. The deficient amino acids are lysine, arginine and tryptophan, but these can often be adjusted by balancing with other protein sources.

Peanut Meal

Peanut meal is very deficient in methionine and slightly deficient in lysine, but it is relatively simple to balance the amino acids with synthetic methionine and a good lysine source. Since this product is manufactured and stored in the tropics, the feed industry has encountered very severe problems of toxic mold growth. A very reliable source is required if peanut meal is to be used.

Brewers' Grains, Dry

Dried brewers' grains and distillers' solubles or grains are fairly good proteins but, unfortunately, they contain only 25-28% protein. If the price is advantageous they can be used to reduce the amount of soybean meal required.

Coconut Oil Meal

Coconut oil meal is deficient in both lysine and methionine and, like sunflower seed meal, is high in fiber. Toxic materials have been reported in some samples but not in others. As the occurrence of a toxic factor is probably due to mold growth in the stored meal, a reliable source of supply is needed.

PROCESSED ANIMAL PROTEINS

All animal protein sources (Table 1) except dried skim milk are rich sources of protein and lysine. In reality, however, they can be of very low value through poor processing.

Fish Meal

Fish meal, provided it has a low oil content, is probably the best animal protein source, but it costs about one-and-a-half times as much as soybean meal.

Blood Meal

Blood meal has the highest protein and lysine levels of any feed ingredient; but it is relatively indigestible, poorly balanced with regard to other amino acids and generally of lower value than meat meal. Isoleucine is the only deficient amino acid in blood meal.

TABLE 1. VALUE OF PROTEIN SUPPLEMENTS FOR SWINE AND POULTRY RELATIVE TO SOYBEAN MEAL

	Protein content	Lysine content
Plant proteins		
Soybean meal	100	100
Linseed meal	77	37
Sunflower meal	98	63
Rapeseed meal	82	66
Peanut meal	102	57
Animal proteins		
Blood meal	182	237
Meat meal	125	123
Fish meal	145	189
Dried skim milk	75	73
Homegrown proteins		
Alfalfa meal	40	28
Bean meal	57	60
Pea meal	61	70

Meat Meal

The quality of meat meal is variable depending on processing methods. For that reason, it is not advisable to use it as a total substitute for soybean meal. It is high in ash (from the bones included in the meal) and provides calcium and phosphorus. It is a good source of lysine but can be low in methionine and cystine.

Dried Skim Milk

Dried skim milk is a high-quality protein source but not economical for any use other than in milk replacers.

Poultry By-product Meal

Made from heads, feet and internal organs, poultry by-product meal is a good protein source for layers and broilers. It may be used in considerable quantities if readily available.

Hydrolyzed Poultry Feathers and Hog Hair

Feather meal is deficient in methionine, lysine, tryptophan and histidine, and usually is used only in small quantities (up to 3%). Its high protein content (85%) allows high-energy grains to be added to the diet.

The properties of hydrolyzed hog hair are similar to those of feather meal.

HOMEGROWN PROTEINS

Alfalfa

Of the homegrown protein sources (Table 1) alfalfa meal is too fibrous to be of much value in any swine feeds other than for dry sows, for which up to 25% may be given as a supplement to corn.

Cereal Grains

Using percentage lysine as the standard of quality, home-grown grains compare as follows in value as protein supplements:

Grain	% lysine
Buckwheat	.62
Oats	.50
Barley	.53
Wheat	.45
Corn	.18

Buckwheat is the best cereal source of protein for livestock feed. However, not much is grown for this purpose because of its low yield and low energy. Corn is a relatively poor source of protein.

Homegrown barley contains about .53% lysine, making it a useful protein feed for livestock.

Fababeans

When supplemented with methionine, fababean meal is a fairly good protein source.

Fababeans are new to most of North America and have been grown only to a limited extent in Canada. European varieties produce from 23 to 32% protein, depending on variety. At the Morden Research Station in Manitoba, yields of four varieties ranged from 3558 lb per acre to 4472 lb in 1972. Fababeans appear to be adaptable to cool, humid areas such as the parklands and lake regions of Canada.

Peas and Navy Beans

Peas and beans provide protein of very similar quality to that of soybean meal but at only about half the concentration. They can be stored and shipped like other grains and, because of their low fat level (about 1%) rancidity or heating problems should be no more pronounced than in cereals.

Apart from being deficient in the sulfur amino acids (methionine and cystine) and tryptophan, dried peas provide a fairly good quality protein. The quantity of protein present in the meal is lower (24%) than in most other supplements and the energy content is low. Peas contain no known toxic materials or enzyme inhibitors and should require no processing other than grinding for use in feeds. The characteristic flavor is not unpalatable to animals.

Navy beans provide about the same amount of energy as soybean meal but only about half as much lysine.

Soybeans

Raw soybeans grown on the farm can be used as feed for livestock. They should be heat-treated and ground to improve nutritive value and feed efficiency.

Rapeseed

Full-fat rapeseed, properly heat-treated on the farm, can be fed to pigs and poultry. Used in this way, rapeseed becomes a relatively economical source of fat and can compete with conventional sources of fat for feed (e.g., tallow).

POULTRY REQUIREMENTS

To avoid waste, poultrymen can formulate rations for specific needs. For example, instead of using a single laying ration containing 17% of protein, a feeder may change his diets from 17 to 15 to 13% protein as the birds progress through the laying period. The use of phase feeding could be extended to other classes of animals thus reducing the demand for, and subsequently the cost of, feed proteins. These requirements are based on the use of soybean meal as the main protein supplement. Higher levels of protein or supplemental amino acids may be required if other sources are used.

It is important to remember that the age of the bird and demand to produce additional body tissue (protein) may greatly influence the ability of another protein source to replace soybean meal in the ration. This is because the requirement for a specific amino acid, when expressed as a percentage of the protein, varies with age.

To avoid waste, poultrymen can formulate rations for specific needs.

Rapeseed meal is limited in broiler rations to 10% and in laying rations to 5% of the diet. At levels higher than these, an increase in mortality is observed.

SWINE REQUIREMENTS

Like poultry, the performance of swine is influenced by the quality of protein they receive. For maximum growth, pigs require higher levels of protein, or proteins of better quality, than those in cereal grains. Usually, 20% protein is recommended in the diet for pigs on creep feed, 16% for pigs from weaning to 100 lb liveweight, and 14% for pigs from 100 lb to slaughter weight. Suckling sows require 16% protein, but dry sows may manage on as little as 12% for at least the first three quarters of pregnancy.

These allowances are based on the assumption that soybean meal is the main source of protein in the diet. Total protein level has to be increased if soybean meal is replaced, to compensate for the poorer quality of other sources.

Up to 6% rapeseed meal has been included in the diets of brood sows and gilts without adverse effects. Rapeseed meal, may readily replace 25-50% of the soybean meal; but can only be

The performance of swine is influenced by the quality of protein they receive.

substituted entirely, because of its lower price, if a 15% reduction in growth rate and efficiency of feed utilization can be tolerated.

PROTEINS FOR RUMINANTS

Protein sources are evaluated on the basis of both content and quality (amino acid proportions). However, since protein quality is of little or no importance to ruminant animals, it is wasteful to feed them the kind of high-cost, high-quality protein sources needed by swine and poultry. All protein supplements (except urea and other non-protein-nitrogen sources) contain energy as well as protein; and the energy has a value depending on the cost of the grains it replaces. So, in evaluating two different protein sources, the value of the energy of the feed sources should be considered. Table 2 gives the relative values for ruminant animals of several feeds when corn and soybean meal are priced as indicated.

FEED ANALYSIS

Protein costs money, whether it is overfed or underfed. Overfeeding adds to the cost of production, while underfeeding protein may lead to a decline in performance. First step in achieving the right balance is to have an analysis of the grains and forages used in the ration. A protein analysis of feeds can be obtained from university laboratories or feed manufacturers, depending on the area. When he has the facts and figures on

TABLE 2. RELATIVE VALUES OF FEEDS FOR RUMINANTS[1]
(Based on corn at $70/ton, and soybean meal at $240/ton)[2]

	$/ton
Alfalfa hay (immature)	82
Alfalfa meal (17%)	81
Barley	81
Beet pulp	53
Brewers' grains (dried)	135
Brewers' yeast	217
Corn gluten feed	135
Corn gluten meal	215
Corn silage (29% DM)	14
Cottonseed meal	193
Distillers' grains (dried)	132
Fish meal	292
Linseed meal	183
Malt sprouts	128
Meat meal	228
Molasses	26
Oats	83
Rye	81
Sorghum grain	79
Sunflower seed meal (dehulled)	247
Wheat	91
Wheat bran	91
Wheat shorts	99
Wheat middlings	101

[1]From Morrison.

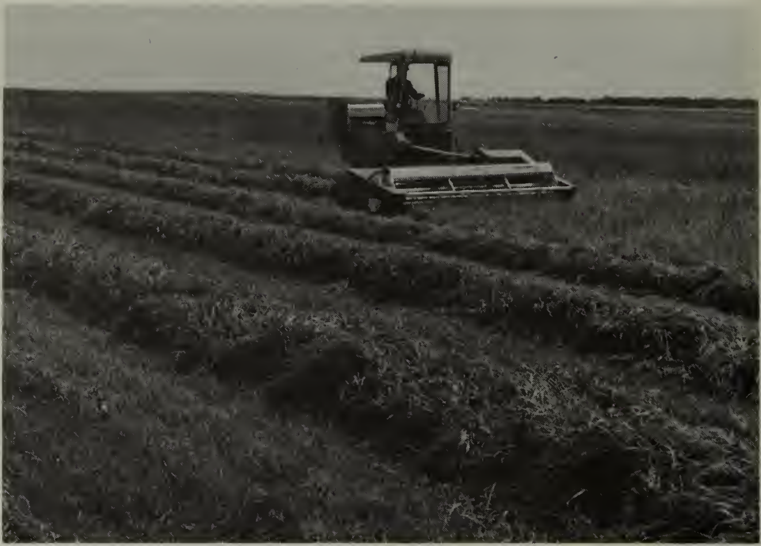
[2]At more normal prices for soybean meal the values of the other cereal grains are closer to that of corn.

levels of ingredients, a feeder can adjust rations more accurately in line with production.

PROTEIN SOURCES

Feed-Grade Urea

Feed-grade urea and other non-protein-nitrogen sources are possible alternatives to natural protein sources. Problems sometimes associated with feeding urea can be avoided if proper precautions are taken. Considering the high cost of other protein



Good hay or grass silage can be the cheapest form of feed energy and protein.

sources, it is worth taking the time and effort to utilize urea properly. The main precautions are:

1. Do not use urea in the grain mix if urea has been added to corn silage at ensiling time.
2. Make sure urea is well mixed with other feeds, to avoid potential danger of getting too much urea all at once.
3. Introduce urea into the ration slowly. Animals require 10 to 15 days to adjust to the taste. Rumen microorganisms also have to adapt to urea.
4. A safe maximum limit of urea is ¼ lb daily per cow, or about 20 lb per ton of grain mix.

High-Protein Roughages

Producers are reminded of the value of alfalfa as a protein source. Early cut alfalfa (bud stage to 10% bloom) has a protein content of 18% or higher and can do much to satisfy the protein requirements of cows. Nitrogen-fertilized grasses can also produce forage containing in excess of 15% protein if cut before bloom. Weather might not permit harvesting those forages as hay, but direct-cut forage with formic acid as a preservative can be readily stored in horizontal silos. The value of alfalfa relative to corn and soybean meal (Table 2) indicates that it is worth taking the time and effort necessary for proper harvesting and storage.

Forage

Under normal conditions, good hay or grass silage can be the cheapest form of feed energy and protein. Grass and clover mixtures have all the nutrients required for maintenance of ruminants, as well as for much of production in the form of milk or weight gains.

However, forage quality or intake is often too low for satisfactory performance and feeders have to add supplement. Forage intake and protein content can be improved by early (1/10 bloom) cutting to ensure high digestibility (65%) and utilization of the protein. Forage intake is also greater when dry hay or wilted silage is fed without a preservative.

Preservatives—To make best use of forage, farmers must have the equipment to harvest and store the required volume at the peak of condition. Any delay means loss of feed value. CDA researchers have found that formic acid applied as a preservative to ensiled, direct-cut forage eliminates much of the effect of poor harvest weather. If formic acid treatment continues to be successful and economical, many farmers will be able to save much of the protein usually lost due to harvest delays.

Corn Silage

Because of the variability of forage quality and intake, many dairymen and beef producers have swung to corn silage for their roughage. The quality and yield of corn are more reliable—but it is low in protein. Adding up to 10 lb of urea per ton of corn ensiled will partly correct this deficiency. High-energy grain corn lacks the protein required to balance corn silage. Because of its low protein, grain corn can be a relatively wasteful supplement, compared with higher-protein grains such as barley, oats or wheat.

DAIRY CATTLE REQUIREMENTS

It is a growing practice among dairy farmers to feed the same ration to all cows except the highest milk producers. Although this saves labor, it is wasteful of protein, since dry cows and low producers receive excess protein in their ration. When the cost of protein supplement is high compared with the cost of grains, it may be too high a price to pay for the convenience.

Protein cost can be reduced by grouping cows according to production. For example, you might feed three or four different complete feeds to satisfy different groups. Mix only the minimum quantity of protein for each group. Protein then becomes the limiting factor in production and, if desired, extra protein can be hand fed to the highest producers in the group.

According to National Research Council standards, growing heifers require a minimum of 10% protein in their *total* ration, and dry cows require only 8.5%. Also dairy cows producing less than 30 lb of milk a day require 13% but the requirement increases to 14% if they produce from 30 to 45 lb. Fifteen percent protein is required in total rations of cows producing 45 to 65 lb of milk, and 16% protein for those producing above 65 lb.

BEEF CATTLE REQUIREMENTS

The protein requirements for beef cattle vary widely depending on age, growth and function. Mature pregnant beef cows need only 6.0% crude protein (2.5% digestible crude protein) in their diet dry matter. Young rapidly growing finishing calves (330 lb) require 13% crude protein (8.5% digestible protein) in their dietary dry matter.

Mature pregnant cows are usually wintered on low-quality roughages because of low cost, whereas young growing animals should receive high-energy rations if they are to grow rapidly. In times of high protein and energy costs, producers should reassess their feeding programs and reformulate rations to minimize costs. In terms of energy, a lower energy content in the ration (that is, a higher roughage content) reduces both rate of gain and feed efficiency (feed per pound of gain) and this must be considered together with the price difference between roughages and grains to determine if this course of action would be economical. Lower rates of gain require lower protein levels. Also, in terms of protein, feeding standards generally have a safety factor included. In times of high protein costs, therefore, protein levels in rations should be reduced to barely meet the stated protein requirements and the cheapest source of protein should be used.

Mature Pregnant Cows

The low protein requirements of mature pregnant cows can be met by most roughages. However, cereal straws, mature corn stover and prairie hay are too low in protein to meet even these low requirements. Since these feedstuffs are also short of readily available carbohydrates, non-protein nitrogen sources (urea) should not be used unless combined with a readily fermentable material such as molasses or grain. Liquid supplements containing urea and molasses and fed through a mechanism to limit rate of intake should be suitable. It is difficult to justify using costly protein supplements for wintering mature pregnant cows, but supplementing low-quality roughage with approximately 10% dry matter from good quality alfalfa hay or silage should prove economical as well as nutritionally sound. Spring calving beef cows in good condition in the fall can lose weight during the winter without adverse effects, provided pasture or range grass is plentiful the following summer for them to recover.

Suckling Cows

When suckling their calves, beef cow requirements for energy increase by 50%, and for protein levels by 2½ times over pre-calving. Thus they need about 50% more feed containing a higher protein level (9.0%). Therefore, the low-quality forages

Protein requirements for beef cattle vary widely depending on age, growth and function of animal.

used to winter pregnant cows are not suitable when cows are lactating. This is not normally a problem since most beef cows calve in spring and go on good pasture or range when their requirements are greatest.

For those farmers or ranchers practicing early winter or fall calving, good-quality feeds have to be available so that intake will be high enough to prevent severe weight loss and maintain reproduction function. If roughage is fed alone, good quality is required to obtain a high intake. Corn silage supplemented with proteins and minerals should be adequate. This can be done by protein-mineral supplements based heavily on urea or by using alfalfa hay or silage. Alternatively, lactating beef cows can receive lower-quality forage if it is supplemented with grain. Cereal grains contain higher levels of proteins than low-quality roughages and cut down on need for additional protein supplements. They also provide a readily fermentable carbohydrate source which will make urea utilization more efficient.

Stocker Calves

Stocker calves gaining about 1 lb/day require good quality rations containing 10 to 12% protein. Younger calves will need supplemental grains but over 400 lb they will gain satisfactorily on good quality forage. For calves on forage alone, a combination of 50% of dry matter from corn silage and 50% from alfalfa or alfalfa silage will provide the required protein and energy for a rate of gain in excess of 1 lb/day. As calves become older, the proportion of corn silage can be increased. Grass silage, wilted or preserved with formic acid, will provide sufficient protein and energy for growth of stocker calves if the forage is harvested early in the season.

In areas where roughages are expensive and of low quality, calves for market can be grown on high energy, all- or nearly all-concentrate diets if grains are more readily available. Bloat and digestive upsets can occur if too much grain is introduced too quickly and aggressive animals in a group are allowed to gorge themselves.

All-concentrate rations for growing finishing calves need little supplemental protein if cereal grains are used. Urea can readily supply all the supplemental nitrogen needed but it must be well mixed. If corn grain is used for all-concentrate feeding, only about 70 to 90% of the animal's protein needs are met. Urea, well mixed, should be satisfactory to supply the remainder.

TABLE 3. ANALYSIS OF CERTAIN ANIMAL FEEDS USED AS PROTEIN SOURCES

Feedstuff	Protein %	Amino acids (protein) Lysine %	Methionine %	Cystine %	Energy Ruminant TDN %	Poultry ME cal/lb
Alfalfa meal (dehydrated)	17	.73	.28	.18	54	750
Barley	11.5	.42	.17	.19	72	1,200
Beans (navy cull)	21	1.6	.25	.2	74	1.060
Beet pulp, dried	8	.6	0	0	65	275
Brewers' dried grains	25	.72	.57	.39	62	960
Buckwheat	11	.6	.2	.2	69	1,185
Corn (yellow)	8.6	.24	.18	.16	80	1,550
Corn & cob meal (yellow)	7.5	.20	.14	.14	73	1,290
Distillers' dried grains (corn)	27	.8	.4	.30	79	740
Fish meal, herring	73	5.7	2.06	.68	73	1,350
Fish meal, white	60	4.3	1.65	.75	72	1,170
Linseed meal (solvent)	33	1.2	.6	.66	70	640
Meat meal	54	3.0	.76	.68	66	910
Oats	11.5	.32	.18	.18	66	1,130
Poultry by-product meal	60	2.70	1.2	1.0	74	1,365
Soybean meal (solvent)	45	3.0	.65	.67	78	1,020
Sunflower seed meal	46.0	1.7	.8	.75	69	1,000
Wheat, hard	12.5	.34	.24	.26	79	1,360

Yearling Cattle

These animals require about 11% protein in their high-energy diet. This can usually be met by feeding a substantial proportion of cereal grains. However, if low-protein roughage is fed as well, it must be balanced by feeding a high-protein forage, or providing corn silage with ammonia or urea added at time of ensiling, or supplementing the grain ration with urea. If corn grain is used as the high-energy source with low-protien roughage, some natural supplemental protein source will be required.

SHEEP REQUIREMENTS

The general discussion in the beef cattle section regarding protein sources, alternatives, use of urea, ration formulation, etc. applies equally well to sheep. The protein requirements are, however, somewhat different for sheep than for beef cattle. Thus, mature ewes and rams require about 9% crude protein (5% digestible crude protein) in their dietary dry matter. This level of protein is adequate for older ewes during gestation and lactation as well. For younger ewes (100 to 120 lb liveweight) that are still growing, the protein levels should be increased to about 9.4% crude protein (5.2% digestible crude protein) during the last 6 weeks of gestation and lactation.

The protein requirements for rapid growing and fattening lambs, and for slower growing replacement lambs and yearlings, decrease as liveweight increases.

Fattening lambs:	Liveweight	%CP
	60 lb	13.3
	70 lb	12.2
	80 lb	11.9
	90 lb	10.6
	100 lb & up	10.3

Replacement lambs and yearlings:	Liveweight	%CP
	60 lb	12.2
	80 lb	9.7
	100 lb	8.4
	120 lb	7.7

TABLE 4. USE OF PROTEIN MATERIALS IN LIVESTOCK FEEDS

	Beef	Dairy	Eggs	Broilers	Turkey	Hogs	Slaughter calves
Soybean oil meal	x	x	x	x	x	x	x
Rapeseed oil meal	x	x	x	x	x	x	x
Linseed oil meal	x	x	–	–	–	x	x
Fish meal	–	x	x	x	x	x	–
Meat meal	x	x	x	x	x	x	x
Blood meal	–	–	x	x	x	x	some
Buttermilk powder	–	–	–	–	–	–	x
Skim milk powder	–	–	–	–	–	–	x
Whey powder	–	–	–	–	–	–	x
Brewers' and distillers' grains	x	x	small amount used			–	–
Gluten feed	x	x	x	x	x	x	–
Gluten meal	x	x	small amount used			x	–
Urea	x	x	–	–	–	–	–

X indicates the use of the ingredient as a protein source.

CONCLUSIONS

The availability, cost, nutrient content and quality of protein sources determine the extent to which any or all can be used to advantage. Farmers need all the information they can get to make the right decisions on protein sources at this time.

Some savings may be obtained by substituting ingredients during periods of rising feed costs. However, this approach is not always a solution to the problem. As the price of one ingredient rises demands for alternative materials rise and this tends to lead to across-the-board increases. It is suggested that greater emphasis be placed on formulating diets for particular needs.

METRIC EQUIVALENTS

LENGTH

inch	= 2.54 cm	millimetre	= 0.039 in.
foot	= 0.3048 m	centimetre	= 0.394 in.
yard	= 0.914 m	decimetre	= 3.937 in.
mile	= 1.609 km	metre	= 3.28 ft
		kilometre	= 0.621 mile

AREA

square inch	= 6.452 cm^2	cm^2	= 0.155 sq in.
square foot	= 0.093 m^2	m^2	= 1.196 sq yd
square yard	= 0.836 m^2	km^2	= 0.386 sq mile
square mile	= 2.59 km^2	ha	= 2.471 ac
acre	= 0.405 ha		

VOLUME (DRY)

cubic inch	= 16.387 cm^3	cm^3	= 0.061 cu in.
cubic foot	= 0.028 m^3	m^3	= 31.338 cu ft
cubic yard	= 0.765 m^3	hectolitre	= 2.8 bu
bushel	= 36.368 litres	m^3	= 1.308 cu yd
board foot	= 0.0024 m^3		

VOLUME (LIQUID)

fluid ounce (Imp)	= 28.412 ml	litre	= 35.2 fluid oz
pint	= 0.568 litre	hectolitre	= 26.418 gal
gallon	= 4.546 litres		

WEIGHT

ounce	= 28.349 g	gram	= 0.035 oz avdp
pound	= 453.592 g	kilogram	= 2.205 lb avdp
hundredweight (Imp)	= 45.359 kg	tonne	= 1.102 short ton
ton	= 0.907 tonne		

PROPORTION

1 gal/acre	= 11.232 litres/ha	1 litre/ha	= 14.24 fluid oz/acre
1 lb/acre	= 1.120 kg/ha	1 kg/ha	= 14.5 oz avdp/acre
1 lb/sq in.	= 0.0702 kg/cm^2	1 kg/cm^2	= 14.227 lb/sq in.
1 bu/acre	= 0.898 hl/ha	1 hl/ha	= 1.112 bu/acre