UNITED STATES DEPARTMENT OF AGRICULTURE
MISCELLANEOUS PUBLICATION No. 363

WASHINGTON, D. C. ISSUED NOVEMBER 1939

HAY QUALITY

Relation to Production and Feed Value

By

E. O. POLLOCK
Senior Marketing Specialist
and
W. H. HOSTERMAN
Marketing Specialist
Agricultural Marketing Service

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON: 1939

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - - - - - Price 10 cents

UNITED STATES DEPARTMENT OF AGRICULTURE

MISCELLANEOUS PUBLICATION No. 363

Washington, D. C. November 1939

HAY QUALITY

Relation to Production and Feed Value

By E. O. Pollock, *senior marketing specialist* and W. H. Hosterman, *marketing specialist, Agricultural Marketing Service*

CONTENTS

INTRODUCTION

A liberal supply of the highest quality of hay obtainable can generally be used to good advantage in the efficient production of livestock and livestock products. The hay crop of the United States has an estimated farm value of some $700,000,000 a year.

There seems to be no doubt that millions of dollars are lost each year through unfamiliarity with certain important principles involved in the making of high-grade hay. The opinion appears justified that the feed value of the hay crop could be improved fully 25 percent by cutting at the right stage and by proper curing, handling, and storage to preserve the quality without materially increasing cost of production. In many instances the most economical way to increase the farm feed supply from hay would be to improve the quality rather than to increase the acreage.

Hay probably varies more in quality than any other harvested feed crop grown on American farms. In the same locality and under almost identical conditions, there is a wide difference in the quality of hay, due largely to lack of understanding of the fundamentals of good haymaking and to the tendency among farmers to give less attention to the hay crop than to cash crops like cotton, corn, wheat, and tobacco. Barring bad weather at haying time, the quality of a hay crop is largely dependent upon the farmer's knowledge of haymaking practices and the care he exercises in curing, handling, and storing the crop.

GOOD HAY PROFITABLE

On most farms a material saving in the cost of producing livestock and livestock products could be made by feeding more high-quality hay and less grain per animal unit. The quality of hay produced each

year in some sections of the country is so poor that it is idle to expect any appreciable increase in consumption per animal unit unless better hay is made. If the fullest use is to be made of an animal's capacity for utilizing forage, hay should be palatable and nutritious, for a ton of high-grade hay supplies more digestible nutrients than a ton of low-grade hay of the same kind. It is possible to satisfy an animal's appetite with low-grade hay before it gets the quantity of nutrients which should be supplied by the hay portion of the ration. It is unfortunate that the quality of roughages usually is poorest in those areas where an expansion of the acreage appears to be needed most.

There is a relationship between animal units and annual disappearance of hay. Normally the disappearance is about 1 ton per animal unit (fig. 1).[1] Unless steps are taken to improve generally the

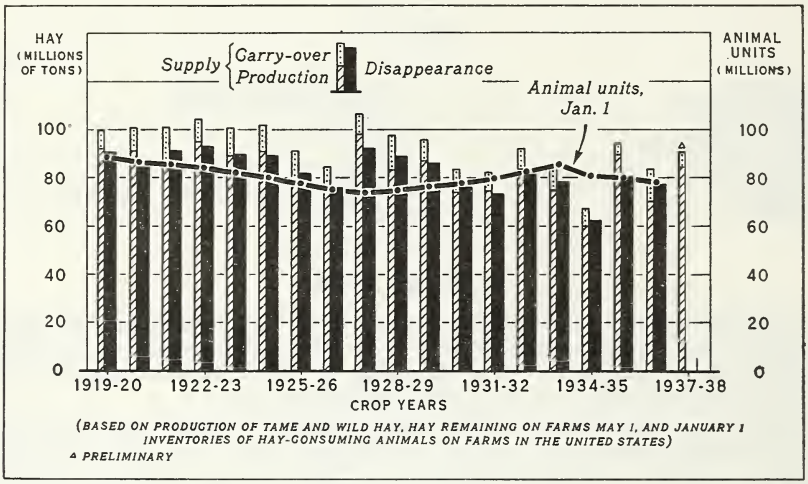


FIGURE 1.—RELATION OF LIVESTOCK TO HAY PRODUCTION AND CONSUMPTION.

During the last 7 years hay supplies per animal unit have been generally below average. This has been due both to reduced acreage and to low yields. Supplies per animal in 1937–38 were near average, as low stocks about offset above-average yields.

quality of forages there is danger of having an oversupply, especially of low-grade forages. In an effort to consume the oversupply, farm animals might be so increased as to throw animal numbers out of balance with needs. Grasses and legumes appear to be the logical buffer crops in a program designed to conserve soil fertility and to feed livestock economically, but precautionary measures should be taken so far as possible to maintain a proper balance between forage-consuming animal units and the forage supply.

QUALITY IN HAY

Quality in hay really means feed value. Thus, when the different factors of quality are measured, we are determining the feed value of the hay. High quality, of course, means hay having the physical and

[1] Specific data on which the graphs in this publication are based can be obtained in mimeograph form by application to the Agricultural Marketing Service.

chemical characteristics that are associated with a high degree of palatability and a liberal supply of essential feed constituents.

The important physical factors of quality that can be readily gaged in a practical way are: (1) Stage of maturity or ripeness when cut, (2) percentage of leaves, (3) percentage of natural green color, (4) percentage of foreign material, (5) condition as to soundness, (6) size and pliability of stems, and (7) aroma.

Generally speaking, these physical factors go along with the chemical composition of hay so that hay that is high-grade, as judged by its maturity, leafiness, color, and other physical factors, is likely to furnish the greatest quantity of nutrients.

Quality in hay, from the chemical standpoint, refers mainly to its protein, carbohydrate, mineral, and vitamin content. Protein is

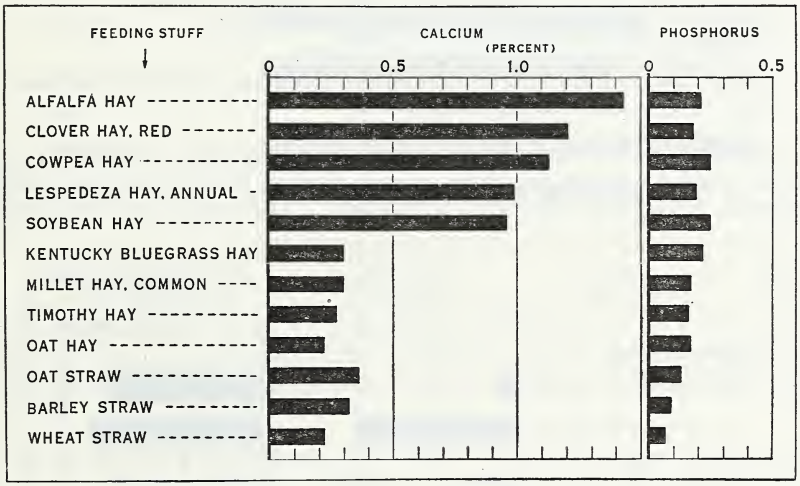


FIGURE 2.—CALCIUM AND PHOSPHORUS CONTENT OF LEGUME AND GRASS HAYS.

The legume hays contain from three to six times as much calcium as the grass hays and straws, and usually as much or more phosphorus.

necessary in the animal's ration, to build tissue. Legume hay has a higher protein content than nonlegume hay. Carbohydrates in hay supply energy. Phosphorus and calcium have an influence on the growth, production, and reproduction of livestock (fig. 2). The phosphorus and calcium requirement for most grass-eating animals is supplied largely by forage. Legume hays always contain sufficient calcium for the animal's requirements but grass hays do not always contain enough. Vitamins have a broad influence on the efficiency of the ration, and help to prevent nutritional diseases (table 1).

The quality or feed value of hay is really measured by the growth, gains in weight, and reproductive ability of the animals; and the production of meat, milk, and other products. Exact determination can be made only by feeding experiments in which the quality and the feed value of the hay are carefully measured by mechanical and chemical methods.

TABLE 1.—*Vitamin content of dry forage*

Roughage	Vitamins [1]	
	A	D
Alfalfa hay:		
Excellent quality	xxx	xx
Good quality	xx	xx
Poor quality	0 to x	--
Dehydrated	xxxx	0
Clover hay, good quality	xx	xx
Legume hay in general, good quality	xx	xx
Timothy hay and other grass hay:		
Good quality	x to xx	x
Poor quality	0 to x	--
Straw from small grains	0	--

[1] 0 indicates that the feed has none of the vitamin or only an insignificant quantity.
x indicates that the feed contains an appreciable quantity of the vitamin.
xx indicates that the feed is a good source of the vitamin.
xxx indicates that the feed is an excellent source of the vitamin.
xxxx indicates that the feed is exceptionally rich in the vitamin.
-- indicates that information concerning the quantity of the vitamin is lacking or not conclusive.

Compiled from Morrison's Feeds and Feeding, Ed. 20.

A review of the research work on livestock feeding in which hay was an important part of the ration shows that in many cases the quality or grade of the hay was not ascertained. The results of such feeding

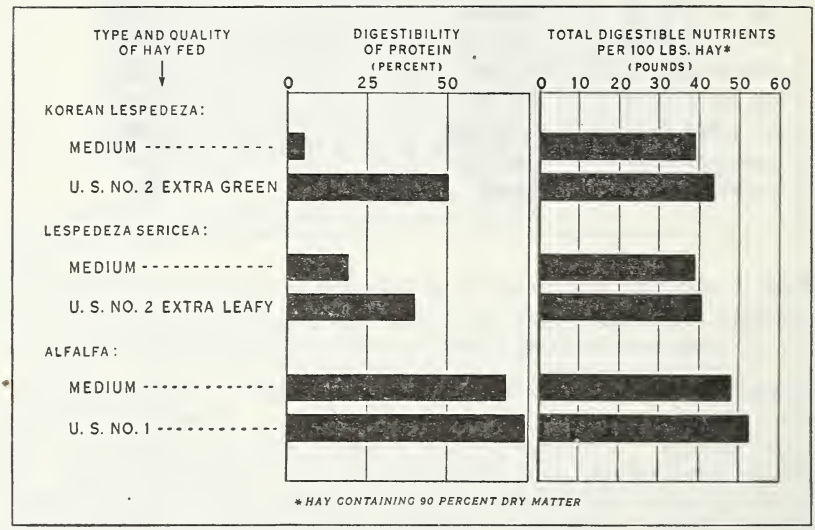


FIGURE 3.—DIGESTIBILITY OF DIFFERENT QUALITIES.

There appears to be a greater difference in the digestibility of the protein of good- and medium-quality Korean lespedeza, and *Lespedeza sericea*, than in good- and medium-quality alfalfa.

experiments cannot be used therefore in determining the relation of quality in hay to feed value. During recent years a number of the agricultural experiment stations and the Bureaus of Dairy and Animal Industry of the United States Department of Agriculture have had graded the hay used in various feeding tests. Gradually information

on the relation of quality or grade to feed value will be available. In experiments in which graded hay has been used, high-grade hay gave the best results. The value of different kinds of hay has also been determined by feeding tests (figs. 3 and 4 and table 2).

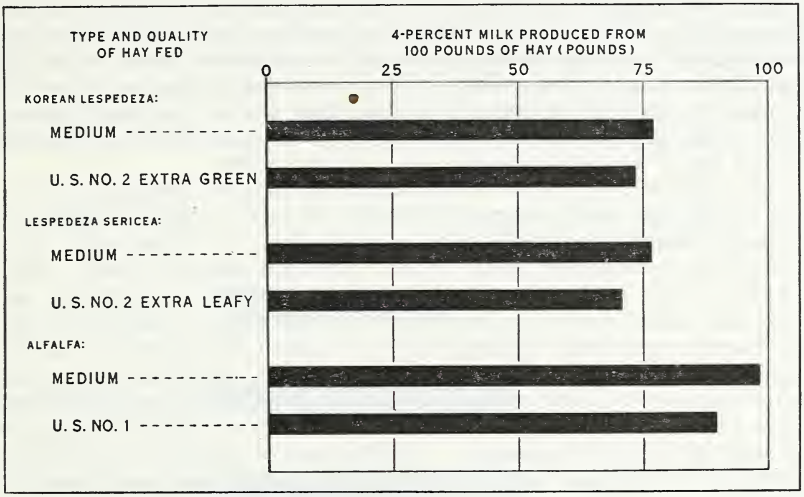


FIGURE 4.—QUANTITY OF 4-PERCENT MILK PRODUCED WITH DIFFERENT KINDS OF HAY.

Korean lespedeza and *Lespedeza sericea* of the same quality appear to be practically of equal value but only about 80 percent as valuable as alfalfa of the same quality.

TABLE 2.—*Summary of results of feeding dairy cattle lespedeza hay in comparison with alfalfa, and quantity of hay consumed*

Animals fed (number)	Kind of hay used	Live weight per head	Feed consumed per animal, daily			Daily gain in weight per head	Butterfat test of milk	Daily milk yield per cow
			Silage	Hay	Grain			
Cows:		*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Percent*	*Pounds*
18	Lespedeza		19.3	21.5	[1]14.9	0.6	3.81	45.7
18	Alfalfa		19.3	21.5	[1]14.9	.6	3.68	44.3
Heifers:								
23	Lespedeza	745		12.78	3.61	1.32		
23	Alfalfa	748		12.84	3.60	1.29		

Animals fed (number)	Kind and grade of hay consumed	Quantity fed per head daily	Quantity refused per head daily	Quantity consumed per 100 lbs. live weight
Cows:		*Pounds*	*Pounds*	*Pounds*
18	U. S. No. 1 Extra Leafy Extra Green Lespedeza	21.65	0.15	1.66
18	U. S. No. 1 Extra Green Alfalfa	21.65	.13	1.66
Heifers:				
23	U. S. No. 1 Extra Leafy Lespedeza	12.84	.06	1.72
23	U. S. No. 1 Alfalfa	12.85	.01	1.72

[1] Includes 2.2 pounds of dried beet pulp. Journal of Dairy Science 18: 593–598. 1935.

STAGE OF MATURITY

The stage of maturity at which grasses and legumes are cut for hay has a considerable influence on the yield of hay and of protein per acre, on the percentage of crude fiber in the hay, the percentage of leaves in the case of legumes (figs. 6 to 15), and the percentage of natural green color. The time of cutting also makes a great difference in the palatability and digestibility of hay. A common fault is to delay cutting too long. The quality of many excellent crops of grasses and legumes is virtually sacrificed because they are not cut early enough. Even with perfect curing weather, it is impossible to make high-quality hay from late-cut grass and legume crops.

The yield of hay per acre for most hay plants increases at a rapid rate during the early stages of growth, is fairly constant during the blooming stage, and then begins to decline. For example, alfalfa loses about as much in yield of hay from half bloom to seed stage as it gained from before bloom to half bloom (fig. 9). Soybeans, cowpeas, and alsike clover do not show the decrease in yield per acre as the plants approach maturity that is shown by some of the other important hay crops. Under favorable conditions alsike clover grows and blooms over a long period because of its continuous growth habit and soybeans and cowpeas have an abundance of relatively large seed which is fairly high in protein. At the stage of maturity at which seed varieties of soybeans are normally cut for hay, pods and seeds may make up about 40 percent of the weight of the harvested plants.

The percentage of protein in hay plants decreases and the percentage of crude fiber increases from the early stages of growth to maturity (table 3). The yield of protein per acre increases up to a certain point, then begins to decrease.

TABLE 3.—*Relation of stage of maturity of alfalfa to chemical analyses* [1]

Stage of maturity	Ash	Protein	Fiber	Fat	Nitrogen-free extract	Samples
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Number*
Bud stage	10.33	19.61	28.02	2.40	39.56	39
Initial to 1/10 bloom	10.16	18.07	30.09	2.40	39.28	45
1/5 to 1/2 bloom	9.57	16.87	32.60	2.63	38.33	10
Full bloom	9.71	15.89	33.25	2.14	38.99	52
Seeds ripe	8.52	14.57	35.29	2.10	39.54	33

[1] A compilation of analyses made on alfalfa cut at various stages of maturity and calculated to a moisture-free basis.

The proportion of leaves to stems in all kinds of legumes is usually closely correlated with the stage of maturity, early-cut hay having a relatively high percentage of leaves whereas the late-cut hay has a low percentage (fig. 7). A certain quantity of leaves will be lost in the normal curing of legume hays and hay that is cut in the later stages of maturity does not have sufficient leaves, after making allowance for this loss during curing and handling, to meet the requirements for high-grade hay under the United States standards.

The natural green color in the leaves and stems of hay plants is reduced as they approach maturity. Considerable color is lost in the normal curing of hay and early cutting assists materially in maintaining the color in cured hay.

Practical feeding work confirms what most feeders know—that the average animal will eat early-cut hay in greater quantities than late-cut hay. Early-cut hay is finer stemmed than late-cut hay, and the stems of the former are usually much softer.

The cell walls of young hay plants consist largely of cellulose, but as the plants ripen the cell walls are strengthened by the changing of some of the cellulose to lignin. Little if any of the lignin is digestible, and as its quantity increases the hay becomes less and less digestible. The cellulose, on the other hand, is a carbohydrate that is broken down and utilized to a certain extent in the animal's digestive tract. One reason why the stems of fermented hay are softer and more pliable

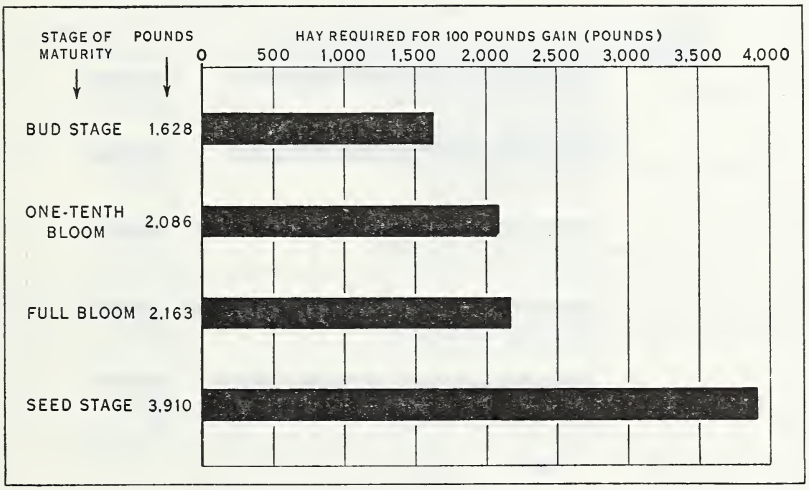


FIGURE 5.—GAINS IN WEIGHT OF STEERS AFFECTED BY THE MATURITY OF THE ALFALFA FED.

More than twice as many pounds of alfalfa hay cut in the seed stage was required to produce 100 pounds of gains in steers than alfalfa cut in the bud stage.

than unfermented hay is that some of the cellulose is broken down during the fermenting process, by bacterial action.

The cutting of grasses and legumes is usually delayed until the heaviest tonnage of hay per acre can be obtained. But usually the stage at which hay plants yield the greatest tonnage is not the stage that gives the greatest quantity of digestible nutrients per acre. These nutrients are the important thing to the feeder.

Ordinarily, grasses and legumes should be cut for hay at the stage of maturity that will give the greatest number of pounds of protein per acre. At this stage not only is there a greater quantity of nutritive elements, but the hay is more palatable and digestible than if the plants stand until they are too mature. Early-cut hay may contain as much as 20 percent more digestible nutrients than hay cut in the late-bloom or seed stages. The Kansas Agricultural Experiment Station found that it required more than twice as many pounds of alfalfa hay cut at the seed stage to produce 100 pounds of gain in steers as it did of alfalfa hay cut in the bud stage (fig. 5).

159772°—39——2

The proper stage of maturity at which the various kinds of hay should be cut varies slightly in different sections of the country. Based on research and the practical experience of farmers, alfalfa should be cut when it is about one-tenth to one-fourth in bloom (figs. 6 to 10), or about the time the basal shoots appear. In those areas in which alfalfa blooms sparingly or does not send up basal shoots it should be cut when the foliage shows a yellowish tinge indicating the slowing up or stopping of growth. Alfalfa should not be cut too early and too frequently, however, or the stands will be injured.

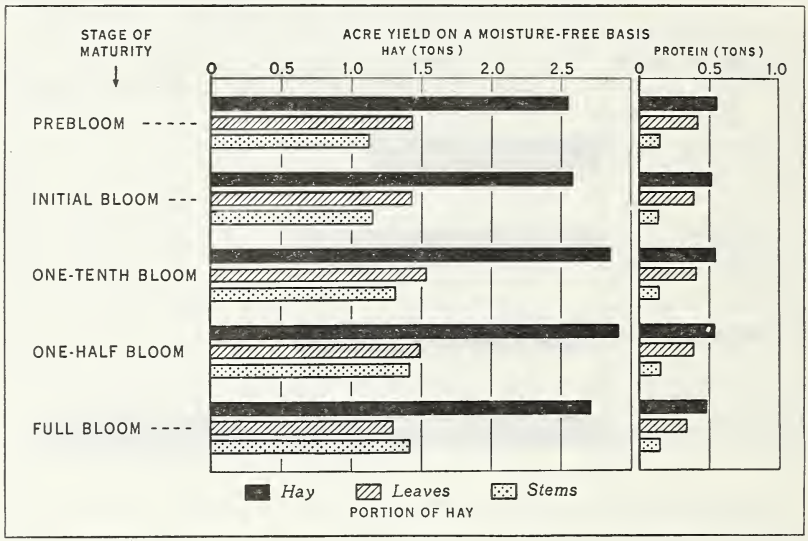


FIGURE 6.—THE YIELD OF HAY AND PROTEIN PER ACRE IS INFLUENCED BY THE STAGE OF MATURITY AT WHICH ALFALFA IS CUT.

The largest yields of high-grade hay are obtained if alfalfa is cut when one-tenth to one-half in bloom. The yield of protein per acre shows little variation during the prebloom, initial-bloom, one-tenth-bloom, and half-bloom stages. At the half-bloom stage of growth of alfalfa about half of the total hay consists of leaves but they contribute approximately three-fourths of the total protein.

Soybeans should be cut when the seeds are one-half to three-fourths developed (figs. 14 and 15); lespedeza when in full bloom; cowpeas when the first pods begin to ripen and turn yellow, but before any of the pods are mature enough to shatter their seed during handling; red clover from half- to full-bloom stage (fig. 13); vetch when the seeds in the pods on the lower half of the plants are one-half developed; timothy from the early- to full-bloom stage (figs. 11 and 12); Johnson grass when the first heads appear from the boot; oats and wheat when the grain is in the milk stage, except that oat hay that is to be fed to horses may be cut when the seed is in the dough stage; Bermuda and miscellaneous grasses not later than full bloom. The feed value of many of the grasses other than timothy declines very rapidly after full bloom and therefore makes low-grade hay if allowed to stand beyond full bloom.

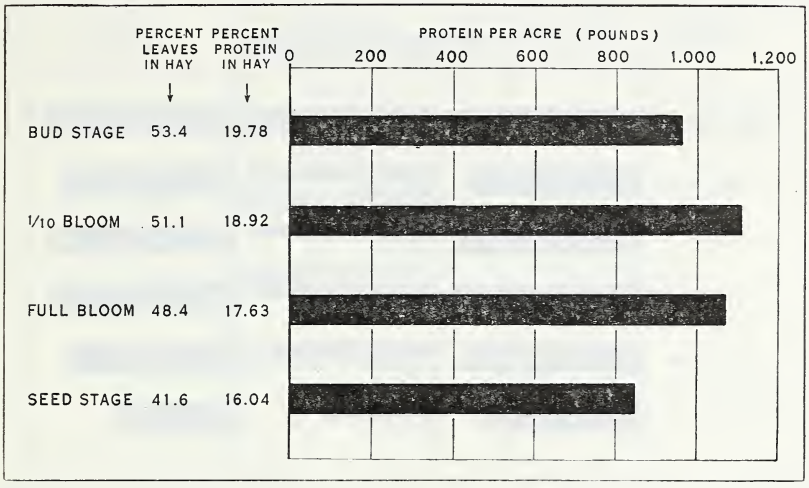


FIGURE 7.—THE MORE LEAVES IN ALFALFA THE MORE PROTEIN

There is a definite relation between the percentage of leaves in alfalfa and the percentage of protein.

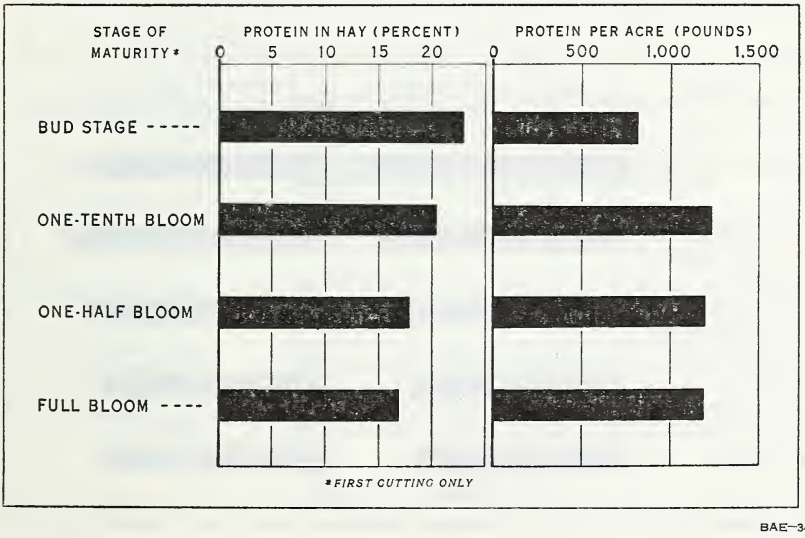


FIGURE 8.—PROTEIN IN HAY AND PROTEIN PER ACRE IN FIRST-CUTTING ALFALFA AT DIFFERENT STAGES OF MATURITY.

The percentage is greatest in early bloom. There is a gradual decrease as the plants approach maturity but the total protein per acre remains fairly constant for all but the bud stage.

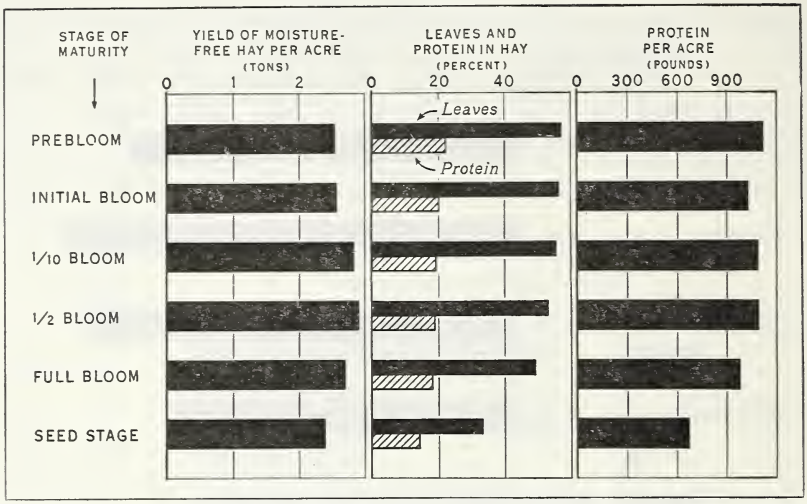


FIGURE 9.—YIELDS OF HAY AND PROTEIN PER ACRE AND PERCENTAGES OF LEAVES AND PROTEIN IN HAY FOR ALFALFA CUT AT VARIOUS STAGES OF MATURITY.

Both yields and percentage of protein decline rapidly after alfalfa reaches half bloom and are materially reduced when alfalfa is not cut until the full-bloom stage. Loss of leaves that contain the larger proportion of protein causes these lower yields.

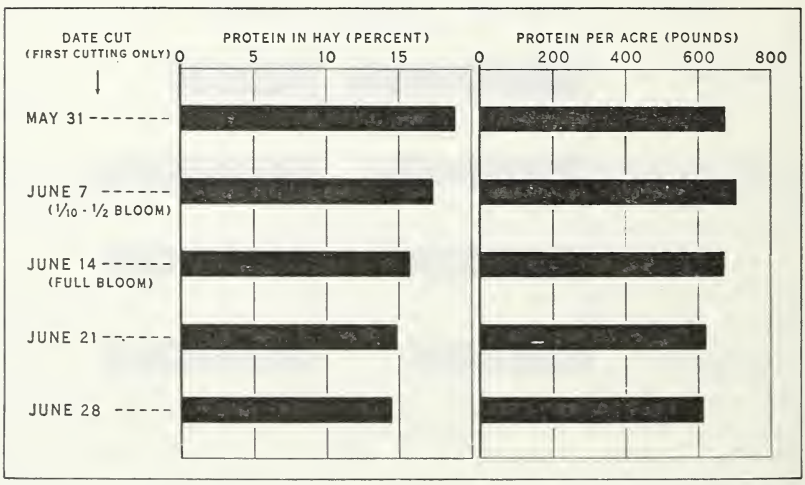


FIGURE 10.—PROTEIN IN HAY AND PROTEIN PER ACRE IN FIRST-CROP ALFALFA CUT AT DIFFERENT DATES.

In those districts in which alfalfa blooms sparingly because of seasonal conditions, dates for cutting, if established for those areas, may be used instead of blooming stage as a guide in obtaining the greatest yields of protein per acre.

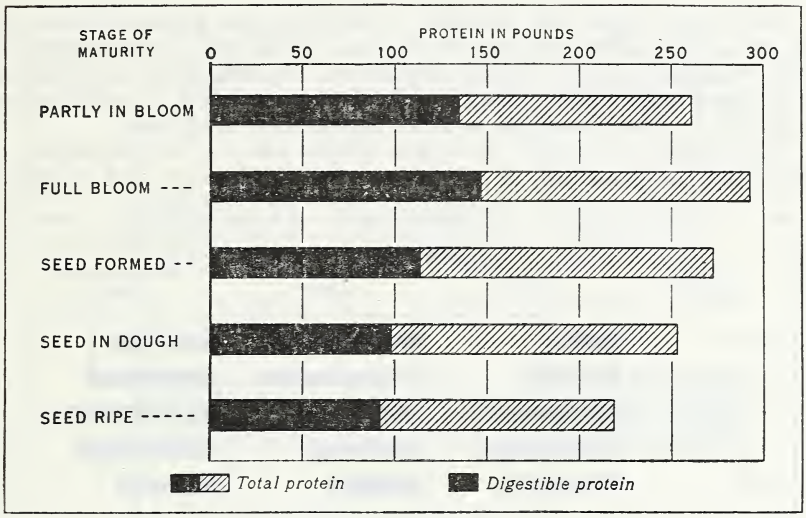


FIGURE 11.—TOTAL AND DIGESTIBLE PROTEIN IN TIMOTHY AT DIFFERENT STAGES OF MATURITY.

Timothy should be cut not later than full bloom. The maximum quantities of total and digestible protein are present in timothy hay at about the same stage of maturity. The digestible protein in relation to total protein declines rapidly after full bloom.

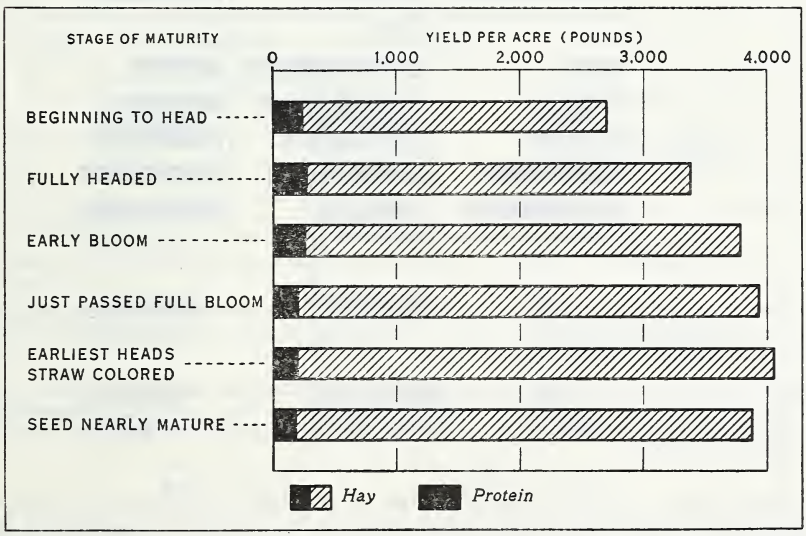
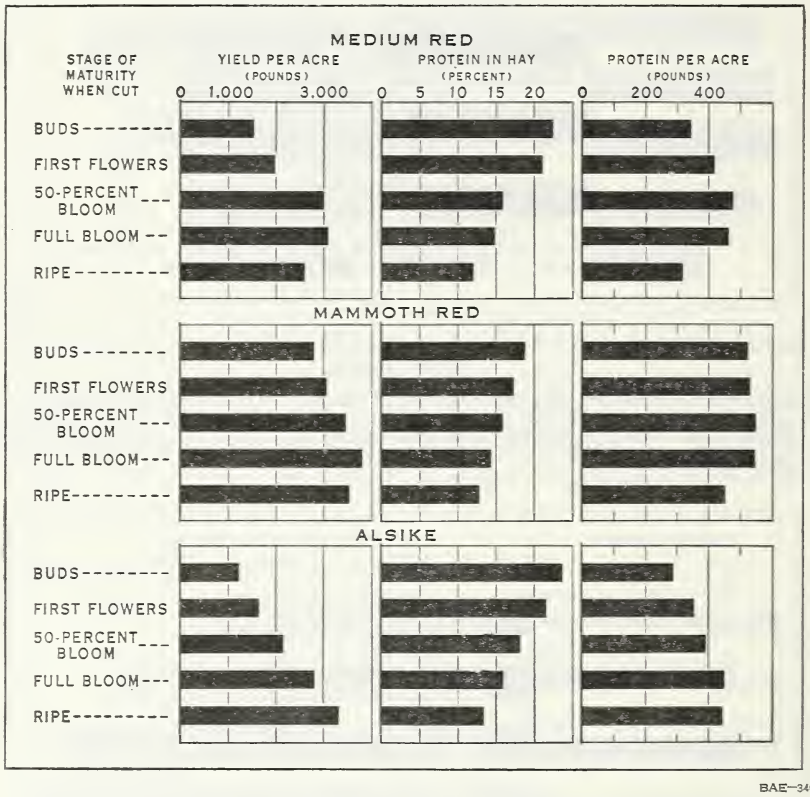


FIGURE 12.—YIELDS OF HAY AND PROTEIN PER ACRE OF TIMOTHY CUT AT DIFFERENT STAGES OF MATURITY.

Maximum yields of protein per acre for timothy are obtained at the fully headed and early-bloom stages of maturity. Very little increase in yield of hay occurs after the plants reach the early-bloom stage of growth.

It is easy to gage the maturity of legumes and grasses before they are cut. But after the hay is cut and cured this is not always so easy, especially if the hay is weathered, or distinctly sun-bleached, or if the normal development of the flowering parts of such legumes as alfalfa has been delayed because of weather conditions.

The stage of maturity at which alfalfa was cut is determined by observing the condition of the bloom and the texture and woodiness



BAE—34027

FIGURE 13.—YIELD OF HAY AND PROTEIN PER ACRE AND PERCENTAGE OF PROTEIN IN HAY FOR MEDIUM RED, MAMMOTH RED, AND ALSIKE CLOVERS, CUT AT VARIOUS STAGES OF MATURITY.

Medium and mammoth red clover should be cut at the one-half to full-bloom stage in order to obtain the maximum yields of hay and protein per acre. Alsike clover should be cut when in full bloom to obtain the greatest yields of protein per acre.

of the stems. Alfalfa that was cut in the bud stage can be told by the buds at the tips of the stems and by the complete absence of the purple flower petals. Bud-stage alfalfa also is usually very leafy and the stems are relatively fine and pliable. Alfalfa cut in the early-bloom stages is evidenced by some purple flower petals and some buds, the stems are harder than in bud-stage alfalfa but not so distinctly woody and hard as in alfalfa that is cut after it has blossomed, and by a degree of leafiness that is distinctly apparent

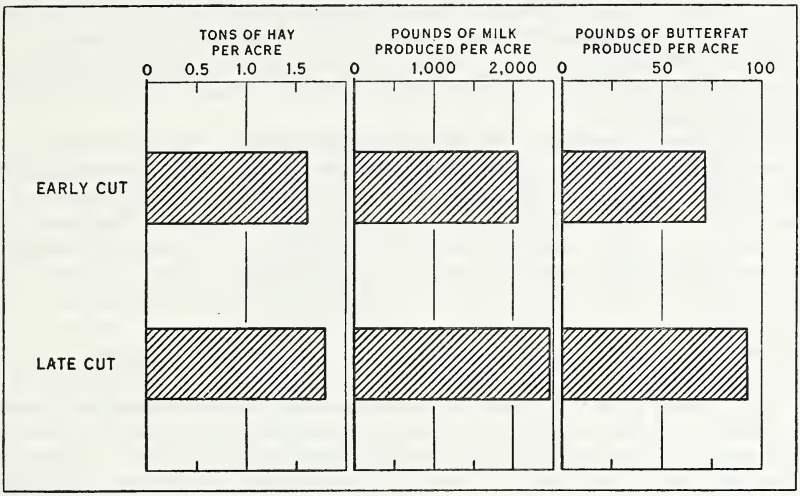


FIGURE 14.—YIELD OF HAY, MILK, AND BUTTERFAT PER ACRE FOR EARLY- AND LATE-CUT SOYBEAN HAY.

In this test relatively late-cut soybean hay gave greater yields of hay, milk, and butterfat per acre than early-cut hay.

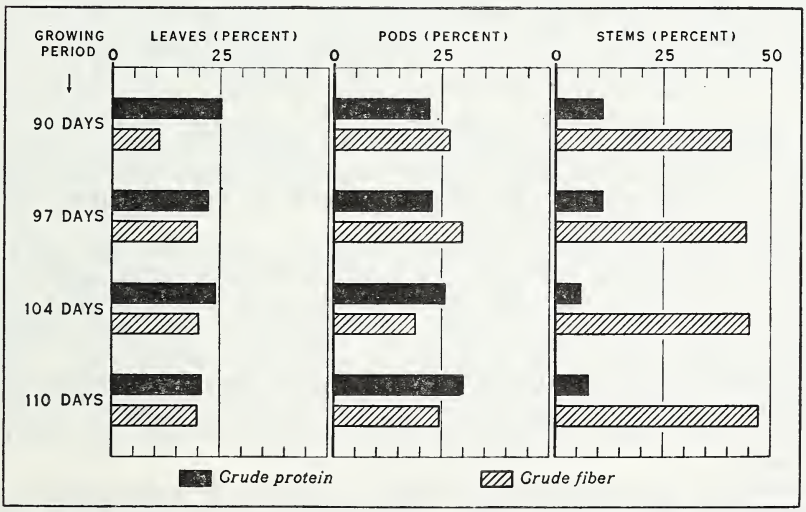


FIGURE 15.—LATE-CUT SOYBEAN HAY IS HIGH IN PROTEIN BECAUSE OF PODS AND SEED.

As the soybean plant approaches maturity the decrease in the percentage of protein in the leaves apparently is more than compensated for by the increase in the percentage of protein in the pods.

compared with the stemmy character of late-cut alfalfa. Alfalfa that was cut after the full-bloom stage usually is indicated by the hard stems, by the presence of seed pods, and by a deficiency of leaves.

Alfalfa blooms profusely under certain conditions and sparingly under others, making the determination of the exact stage of maturity somewhat difficult.

The stage of maturity at which soybean hay was cut can be ascertained by observing the development of the soybeans and of the seed pods. Early-cut soybean hay is indicated by the presence of small pods in which little or no seed has been formed. Soybean hay cut when the seeds are half developed will be indicated by well-developed pods that contain small shriveled seeds; fully matured hay will be known by its large pods, in which the seeds are plump and well developed.

There is a distinct relationship between the development of the seeds in soybean hay and the percentage of leaves. The leaves tend to turn yellow and fall from the plant as the seeds develop, and when the plant is fully mature very few leaves are left on, in the case of most varieties, especially those grown primarily for seed. Most hay varieties have a tendency to retain their leaves even when the seeds are almost mature.

The maturity of clover at time of cutting is rather difficult to ascertain under certain conditions after the hay has been cured. Sometimes it can be determined by observing the color and condition of bloom and the maturity of the seeds, if any are present. Clover that was cut not later than full bloom will have numerous heads that show the red or purplish-red blossoms of the red clover, or the pink or pinkish-white blossoms of alsike, provided the hay was not weathered while being cured. Clover cut at this stage will have no seeds, or at most only a few shrunken ones. A stage between full bloom and full maturity is indicated by the brown color of all the clover heads and the presence of yellowish-brown seeds. Full maturity is indicated by the dark-brown color of the heads and the presence of plump, mature seeds. Often the first crop of clover does not produce seed, however, which will account for the absence of seed in hay that has other appearances of being late-cut.

The stage of maturity at which timothy was cut for hay can be determined easily by rubbing a few heads in the palm of the hand. If it was cut not later than full bloom, no ripe seeds will be present and parts of the flower can be seen. Occasionally a few small, green, partly-formed seeds will be found in early-cut timothy hay. The early dough stage of maturity is revealed when there is an appreciable number of half-formed green seeds. Full maturity is shown by the plump brown seeds that shell out easily from the whitish dry glumes or chaff.

Similarly the ripeness of the seeds is related to green color and therefore to the grade of hay. Timothy with the seeds fully ripe usually has yellowish-brown stems and heads, and many brown leaves.

Studies of timothy hay have shown that the stage of maturity at which it is cut influences the physical composition of the plant as to percentage of leaf blades and sheaths, stems, and heads, as well as the protein and fiber content of the plants (table 4).

TABLE 4.—*Timothy hay: Effect of stage of maturity on percentage of different parts of the plant and on the protein and fiber content*

Stage of maturity	Part of plant	Percentage of whole hay	Protein	Fiber
		Percent	*Percent*	*Percent*
Nearly full headed	Whole hay		8.39	29.7
	Leaf blades	38.2	11.6	24.3
	Leaf sheaths	23.2	5.4	34.1
	Stems	26.6	4.4	33.8
	Heads	12.0	12.8	29.7
Nearly full bloom	Whole hay		8.4	33.1
	Leaf blades	29.3	11.6	25.1
	Leaf sheaths	19.9	5.7	36.0
	Stems	33.0	4.8	39.7
	Heads	17.8	12.5	30.7
Just past full bloom	Whole hay		6.8	34.5
	Leaf blades	20.5	11.0	25.0
	Leaf sheaths	15.7	6.2	35.6
	Stems	47.1	3.2	40.7
	Heads	16.7	12.2	28.0
About 1/10 of heads straw colored	Whole hay		7.0	33.5
	Leaf blades	11.5	9.0	25.0
	Leaf sheaths	12.9	7.4	35.8
	Stems	45.7	2.9	43.0
	Heads	29.9	12.2	21.5
Heads mature	Whole hay		7.9	28.7
	Leaf blades	10.0	6.6	25.9
	Leaf sheaths	11.2	6.1	35.3
	Stems	38.7	2.8	41.8
	Heads	40.1	13.8	15.6

The stage of maturity at which Johnson hay was cut can be told by the development of the seed heads. The seed heads of relatively early-cut hay will have just started to emerge from the boot and not more than one-fourth of the heads will be out. The seed will be straw colored and may contain tinges of reddish or purplish brown. The seed heads of late-cut hay will all be out of the boot and the seeds will vary in color from reddish brown to amber. The stems of late-cut hay are usually coarse and woody and somewhat straw colored.

Maturity in grain hay can be determined by examining the heads and shelling out the kernels. The heads of early-cut oat and barley hay cut in the dough stage will contain half-formed kernels and may contain some filled grain. The grain in the heads of late-cut oat and barley hay is usually fully matured, and for this reason will usually shatter rather badly when handled. The heads of early-cut wheat and wild-oat hay cut in the milk stage may contain small, shriveled kernels and some half-filled grain. As in the case of oat and barley hay, the grain in the heads of late-cut wheat and wild-oat hay would be fully matured. Maturity is more important in grain hay than in the other kinds of hay because it is used as a grading factor. Maturity must therefore be determined before the grade can be determined.

VALUE OF LEAVES IN HAY

The quantity of leaves, especially in the case of legumes, is probably a better gage of the actual feed value of hay than is any other physical factor. Persons trained in the application of the United States standards for hay are able to ascertain the percentage of leaves in legume hay with a fairly high degree of accuracy. Leafiness is one of the important physical factors used in determining the grade of hay.

Alfalfa leaves contain, on the average, 24 percent of crude protein and 14.4 percent of crude fiber; the stems contain, on the average,

only about 10.6 percent of crude protein and 38.3 percent of crude fiber. In other words, the leaves of alfalfa have about two and one-half times as much protein as the stems and, therefore, are very important in determining feed value. The protein in the leaves is more digestible also than that in the stems.

More calcium and phosphorus are found in alfalfa leaves than in the stems. Morrison[2] reports that alfalfa leaves contain 2.25 percent of calcium and 0.23 percent of phosphorus, whereas the stems contain only 0.79 percent of calcium and 0.14 percent of phosphorus.

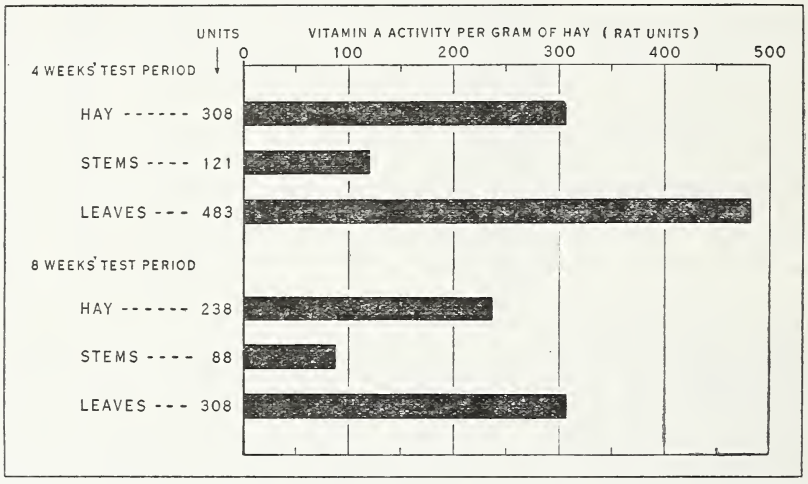


FIGURE 16.—RAT UNITS OF VITAMIN A ACTIVITY IN WHOLE ALFALFA HAY, STEMS, AND LEAVES.

Alfalfa leaves are higher in carotene than stems. This third-cutting alfalfa hay when fed to rats showed leaves to be of much greater value than stems as a source of vitamin A in alfalfa, calculated on the basis of average gain of 3 grams per week.

Little or no information is available as to the other minerals in alfalfa or the value of such minerals in feeding livestock.

Studies with alfalfa-leaf meals and alfalfa-stem meals by several of the agricultural experiment stations (fig. 16) indicate that the leaf meals are an excellent source of carotene from which animals form vitamin A, but that the stems contain only a little carotene. Probably the quantity of carotene present in these parts of the plant would vary a great deal, depending on color and length of time the the meal was in storage. But with leaves and stems from the same plant cured under similar conditions, the leaves contain a much larger quantitiy of carotene than do the stems.

Analyses of several of the other common legume hays indicate that about the same variation exists in the protein content of the leaves and of the stems of these hays as in alfalfa (table 5). Data on the protein content of leaves and stems of annual lespedeza are not available, nor are there any figures on the mineral and carotene content of the leaves and stems of legumes other than alfalfa. It is reasonable to assume, however, that the other legume crops have a

[2] Morrison, F. B., Feeds and Feeding, a handbook for the student and stockman. Ed. 20, unabridged, 1050 pp., illus., Ithaca, N. Y., 1936.

similar composition except for slight variations due to species and conditions under which they are grown.

A study made by the Agricultural Marketing Service with timothy hay showed that when timothy was cut just after full bloom the leaf blades contained 11 percent of protein, the leaf sheaths 6.2 percent, and the stems 3.2 percent (table 4). This study also indicated that the proportions of the various parts of the timothy plant changed as the plant approached maturity. The phosphorus and calcium in some of the grass hays have been determined (fig. 2). Usually the grass hays are lower in phosphorus and calcium than the legume hays. Apparently no data are available regarding the mineral content of the various parts of grass-hay plants, such as leaf blades and leaf sheaths.

TABLE 5.—*Protein in leaves and stems of different kinds of hay*

Kind of hay	Leaves	Stems	Kind of hay	Leaves	Stems
	Percent	*Percent*		*Percent*	*Percent*
Alfalfa	24.0	10.6	Alsike clover	20.7	9.5
Red clover	19.3	8.1	Soybean	22.0	10.1

The way in which hay is made and handled has a great deal to do with its leafiness. In the first place, the percentage of leaves at the time the hay is cut depends to a considerable extent on the maturity of the plant. This was discussed in detail under stage of maturity (p. 6). The methods of curing, the type of rake used, the method of handling hay from field to storage, weather conditions during curing and baling, and many other things affect the percentage of leaves in legume hays. Because the leaves are all-important in nourishing the animal, every precaution should be taken to prevent the loss of leaves in curing and handling hay.

Over and over again it must be emphasized that hay must be cut early and should be carefully cured and handled in order to save the leaves.

The Service has studied the leafiness of market alfalfa hay. Several hundred bales of hay from all parts of the country and representing all types of hay were collected, and the leafiness was ascertained by separating the leaves and stems of representative slugs taken from these bales.

The leafiness in these bales was found to vary from 68 percent for the very leafy hay to only 11 percent in the very stemmy hay. The average leafiness of all samples was 38 percent. When these data were divided on the basis of the leafiness required for the several grades for alfalfa hay, in the United States standards, it was found that 11 percent of the total number of samples fell into the No. 1 Extra Leafy grade; 33 percent into the No. 1 grade; 45 percent into the No. 2 grade; and 11 percent into the No. 3 grade.

The average leafiness of commercial hay indicates that some leaf loss occurs in the curing operations and that maturity at time of cutting and the methods of handling alfalfa in the curing and storing operations have a great deal to do with the leafiness of the cured hay. A survey of haying operations in the Platte Valley of Nebraska showed that on the average, for three cuttings, alfalfa lost 6 percent of its leaves from the time the hay was cut until it was stacked. No data were collected on loss of leaves when the hay was baled.

In much of the baled hay found on the markets the leaves have been shattered or lost during either baling or storing. When the leaves are off the stems and are loose in the bales, the hay is likely to lose part of its feed value through waste when the bales are opened for feeding. Ordinarily, hay in which the leaves are shattered considerably does not have the percentage of leaves required for the U. S. No. 1 grade. Hay that has been so cured and handled that the leaves cling to the stems usually has pliable stems, indicating that it was cut early and cured by the right methods.

While data on the leafiness of such legumes as clover, lespedeza, and soybean hay, at time of cutting are rather meager, the percentage of leaves present in commercial lots of some of these legume hays have been studied. The leafiness of lespedeza was found to range from 28 to 71 percent, with an average of 51 percent. These figures indicate that lespedeza is leafier on the average than alfalfa and for this reason the leafiness requirements for the several grades of lespedeza hay in the United States standards were set higher than for alfalfa.

Studies of soybean hay indicate that the average hay contains 39 percent of leaves, but since the pods and seeds are higher in protein than the leaves they are included as a part of the leafiness percentage in the United States standards when they are not shattered or in condition to shatter. On the average, soybean hay will have seed and pods that will constitute about 11 percent of the total hay. Under these conditions soybean hay as it is found in commerce will average about 50 percent leafiness, which is comparable with lespedeza rather than with alfalfa.

GREEN COLOR

The green color of hay is another definite indication of its feed value (table 6). A high percentage of natural green color in hay usually indicates early cutting, good curing, pleasant aroma, palatability, freedom from must or mold, and a relatively high carotene content. The quantity of carotene in hay is an indication of vitamin A potency and is dependent upon the cause and degree of discoloration of the hay and the length of time in storage.

TABLE 6.—*Steer-feeding experiment, 180 days, comparing black alfalfa with brown and green alfalfa hay*

Factors in experiment	Steers fed on shelled corn, oil meal, and—		
	Good color alfalfa hay, lot 26	Brown alfalfa hay, lot 27	Black alfalfa hay, lot 29
	Pounds	*Pounds*	*Pounds*
Total gain in weight	353. 8	350. 1	262. 1
Total feed consumed:			
Shelled corn	1, 330. 2	1, 330. 2	1, 197. 0
Oil meal	88. 2	88. 2	88. 2
Alfalfa hay	1, 407. 6	1, 407. 6	[1] 1, 663. 5
Feed required to produce 100 pounds gain:			
Shelled corn	375. 9	379. 9	456. 6
Oil meal	24. 92	23. 18	33. 65
Alfalfa hay	397. 8	402. 01	[1] 634. 6
	Dollars	*Dollars*	*Dollars*
Final cost per hundredweight gain	9. 77	9. 83	10. 18
Final value per hundredweight gain	10. 25	10. 35	9. 60
Profit or loss per steer	3. 24	3. 55	−3. 51

[1] Calculated to 8-percent moisture basis to compare with alfalfa fed to other lots.

Journal of Agricultural Research 18: 304.

The green color in hay may be lost by bleaching in the sun or by getting wet during the process of curing; by fermentation in the bale, stack, or mow; or when the plants are allowed to become too mature before being cut. The stems of hay that have bleached too long in the sun or are discolored from rain usually are harsh and brittle. As hay plants approach maturity the percentage of green color is reduced (table 7).

TABLE 7.—*Color analyses for timothy at six stages of development*

Stage of development	Date of harvest	Color reading[1]	Green color	Stage of development	Date of harvest	Color reading[1]	Green color
		Hue	*Percent*			*Hue*	*Percent*
Very early bloom	June 11	9.21Y	100+	90 percent of heads becoming straw color	July 9	4.21Y	42
Early bloom	June 14	8.92Y	100+	Mature	July 16	3.82Y	38
Full bloom	June 19	8.78Y	100+				
Past bloom	June 28	6.00Y	60				

[1] Color was measured with a colorimeter using standard Munsell color cards. For interpreting the color readings in terms of green color for timothy in the United States hay standards a hue reading of 7.40Y is considered equivalent to 100-percent green color for field-cured hay. As these samples were shade-cured they have relatively high hue readings because shade-cured hay retains the green color to a greater extent than field-cured hay. Journal of Agricultureal Research 56: 361.

Slight discolorations from sun bleach, dew, or moderate fermentation may not be serious; they do not damage hay as does the loss of green color from maturity, rain damage, or excessive fermentation. If fermentation in hay goes too far, it often results in complete loss of carotene.

In connection with hay standardization, the Service collected at random 239 samples of alfalfa hay and analyzed them for green color. The average percentage of green color for the group of samples was 54. The range in color was from zero to 100 percent. Based on grades for alfalfa hay in the United States standards, 16 percent of the samples met the color requirements of the special grade Extra Green; 28 percent met the color requirements for U. S. No. 1; 31 percent the requirements for U. S. No. 2; and 25 percent the requirements for the grade U. S. No. 3.

FOREIGN MATERIAL

The foreign material found in hay can be divided into noninjurious and injurious. The term noninjurious foreign material is used to describe all kinds of matter in hay that is commonly wasted in feeding operations but that is not harmful to livestock if eaten. Noninjurious foreign material includes weeds, so-called wire grasses, certain grasses if mature, overripe grain hay, grain straw, cornstalks, stubble, chaff; such sedges, rushes, and other plants as are coarse and woody or otherwise not suitable for feeding purposes; and other objectionable matter that occurs naturally in hay. Some of the grasses that are considered as foreign material when mature are wild-rye, annual bromegrasses like cheat, pigeon grass (sometimes called foxtail or wild millet), broomsedge, and needlegrasses from which the needles have fallen.

Material that will cause mechanical injury or that is poisonous when eaten by livestock is considered injurious foreign material. Injurious foreign material includes sandburs, poisonous plants, harsh bearded grasses like mature foxtail, wild barley, or squirreltail grass,

mature broncho grass; any grass that has a sharp-pointed callus at the base of the seed such as matured needlegrasses with needles attached and matured prairie three-awn grass; and other matter that may be injurious when fed to livestock.

Weeds are the most common noninjurious foreign material found in hay. They are usually not relished by livestock and when eaten along with the hay have little or no feed value. Hay containing weeds or other foreign material is discriminated against on the market because weeds represent waste and give the hay a bad appearance. Hay containing weeds is objected to for feeding purposes because the weed seeds that are eaten usually pass through the animal undigested and when the manure is spread on the land it becomes a source of weed infestation. Many noxious weeds are spread in this way. Occasionally bitterweed, garlic, or similar weeds may be present in hay in sufficient quantities to give milk an undesirable flavor.

Wild barley or squirreltail grass (*Hordeum jubatum*) is the most common injurious foreign material found in hay. It is found in many alfalfa meadows that have wet spots and thin stands. Wild barley has barbed awns that pierce the tissues of the mouths of animals and continue to work deeper, often causing abscesses. Broncho grass (*Bromus rigidus*) a type of injurious foreign material, commonly found in the grain and grass hays of the Western States, also has barbed awns. Stipa with the needles attached and certain aristidas with sharp-pointed callus at the base of the seeds when mature are types of injurious foreign material found in prairie hay. Stipa, when in the vegetative stage, is considered a good forage plant. Some upland prairie hay is made up almost entirely of immature stipa grasses. Aristida, when in the vegetative stage, is known as wire grass because it is wiry, stringy, and harsh. At this stage aristida is classed as foreign material. Sandburs which are also injurious foreign material, are often found in alfalfa hay produced on sandy soils or in dry climates. The burs are covered with sharp spines that may lacerate the mouths of animals. The spines are not barbed and do not work into the tissues as do the barbed awns of wild barley. Other plants, with stiff, harsh beards or spines that livestock will eat and that will lacerate their mouths, and poisonous plants such as whorled milkweed are considered injurious foreign material. Poisonous plants, however, are seldom found in hay and therefore are a minor problem from the standpoint of quality in hay.

Foreign material in hay may be materially reduced by the seeding of high-quality adapted seed on land that is not infested with weeds, by clipping weeds from meadows with a mowing machine before the weeds produce seed, and by plowing and reseeding old meadows that have become weedy.

There is considerable variation in the quantity of foreign material found in hay, depending upon whether the hay is cut from native sod or is an annual or perennial crop. Much hay, especially alfalfa, cut from land that is free from weeds, contains little or no foreign material. However, hay containing as much as 30 to 40 percent of weeds is not uncommon. Table 8 shows the distribution of foreign material in hay by grade, based on laboratory analyses of 1,109 samples made in connection with hay-standardization studies.

TABLE 8.—*Foreign material: Percentage in various classes of hay*

Classes	Samples	Percentage foreign material	Samples falling into—			
			Grade 1	Grade 2	Grade 3	Sample grade
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Alfalfa and alfalfa mixed	385	6	69	20	6	5
Timothy and clover	263	7	76	11	5	8
Prairie	213	15	42	19	17	22
Johnson and Johnson mixed	198	18	37	12	17	34
Lespedeza and lespedeza mixed	25	15	24	32	12	32
Soybean and soybean mixed	25	4	88	0	12	

VITAMINS

Vitamin A is necessary for growth and reproduction in herbivorous animals. Hay is one of the principal sources of carotene from which animals form this vitamin. The carotene content of hay decreases

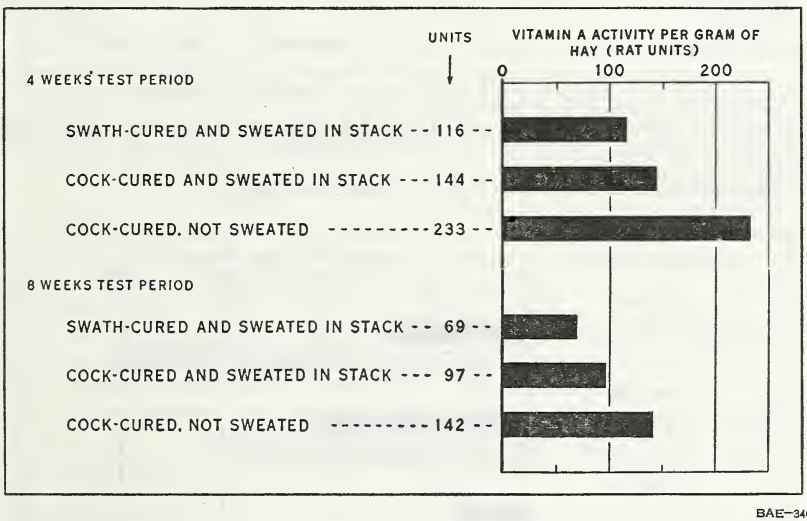


FIGURE 17.—RAT UNITS OF VITAMIN A ACTIVITY IN ALFALFA CURED BY DIFFERENT METHODS.

Methods of curing alfalfa affect vitamin A activity. This third-cutting alfalfa hay when fed to rats showed that sweating and swath curing lowered the vitamin A activity.

with maturity, so early cutting is important. Loss of green color and leaves during the curing period also reduces the carotene content of hay (figs. 16 and 17). Artificially dried hay usually has a higher carotene content than sun-cured hay (fig. 18).

There is considerable loss of carotene during field curing, regardless of the care used in handling the hay. Legumes are higher in carotene than grass hays; but low-grade alfalfa hay may contain less carotene than early cut, properly cured timothy hay (tables 1 and 9). Leaves of alfalfa hay may contain three and one-half to four times as much carotene as the stems (fig. 16).

TABLE 9.—*Carotene content of cattle feeds* [1]

Kind of feed	Carotene content per kilogram			
	Dry weight		Weight as fed	
	Range	Average	Range	Average
	Milligrams	*Milligrams*	*Milligrams*	*Milligrams*
Green growing material:				
Bluegrass	424–662	567		
Alfalfa	271–412	332		
Artificially dried material: [2]				
Grass [3]	266–479	359		
Alfalfa leaf meal			76–244	151
Silages:				
Grass, AIV [3]	381–522	427		
Alfalfa, AIV [3] [4]	Nearly same as green alfalfa			
Corn	4–156	50	1–40	14
Alfalfa hay:				
U. S. No. 1			19–121	44
U. S. No. 2			12–19	15
U. S. No. 3			1–11	4
Timothy hay:				
U. S. No. 1			[5] 8–36	21
U. S. No. 2			8–11	9
U. S. No. 3			1–11	5
Carrots, garden, yellow	268–1692	914	36–132	91

[1] The carotene content of these feeds is a practical measure of their relative vitamin-A value.
[2] Not much loss of carotene in artificial drying.
[3] Watson, S. J., Bishop, T., and Drummond, J. C. The relation of color and vitamin-A content of butter to the nature of ration fed. I. Influence of the ration on the yellow color of butter. Bio-Chemical Journal, vol. 28, No. 3, p. 1076, 1934.
[4] Nearly same as fresh material.
[5] One apparently exceptional sample of U. S. No. 1 timothy contained 8 mgs.

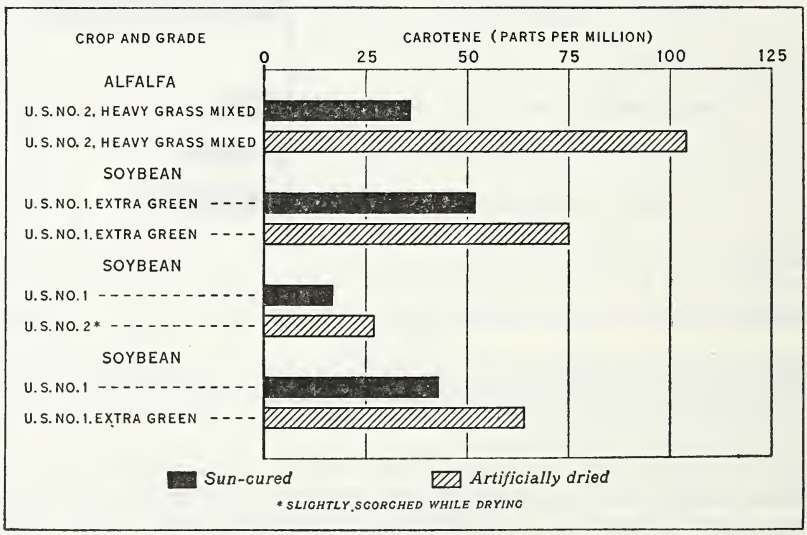


FIGURE 18.—CAROTENE CONTENT OF ARTIFICIALLY DRIED AND SUN-CURED HAYS.

The carotene content of artificially dried hay is materially greater than in sun-cured hay.

Carotene is also lost while hay is in storage. Old hay always contains less carotene than hay that has been in storage only a short time.

Temperature is another factor in determining the rate of loss of carotene in stored hay as shown by the following tabulation supplied by the Bureau of Dairy Industry, United States Department of Agriculture. Discolored hay, in addition to having a lower carotene content than green hay, may also be less palatable.

Average outdoor daily temperature during period of storage (° F.)	*Loss of carotene per month during period of storage (percent)*
45 or less (winter months)	3. 0
45 to 66 (fall and spring months)	6. 5
Above 66 (summer months)	[1] 17. 8

[1] Those hays that were stored for the first summer after they were cut lost 21 percent of their carotene per month, whereas older hays that were stored for the second summer after cutting lost only 11 percent of their carotene per month during storage.

These hays (alfalfa, timothy, and clover) were stored in bales in a rather dark, unheated barn loft at Beltsville, Md.; there was no demonstrable difference in the rate of loss of carotene with the different kinds. Meals, when ground to a ⅛-, ¼-, or ¾-inch mesh and similarly stored, lose carotene at approximately the same rate as baled hays.

The vitamin A content of milk and its products depends directly upon the quantity of carotene in the feed of the cow (table 9). Experiments conducted by the Bureau of Dairy Industry showed that when U. S. No. 1 Timothy, which is a grade of timothy with a relatively high percentage of green color, was fed to dairy cows as the only source of carotene or provitamin A, the cows remained in good health and reproduced normally. When the hay in the ration consisted of U. S. No. 3 Timothy that had lost most of its green color because it was overripe or weathered, the cows usually dropped immature, weak, or dead calves if fed this quality of hay for more than 6 months. When milk from cows that received the U. S. No. 3 Timothy was fed to calves that were normal at birth, they did not make normal growth and died within 3 months.

It was also shown that butter color varies definitely with the green color and carotene content of the roughage fed. Butter from cows fed U. S. No. 1 Timothy as the sole roughage had a color value that was approximately twice that of butter from cows that were fed U. S. No. 3 Timothy as the sole roughage.

Growing animals require vitamin D which is increased by exposure of hay to sunlight while the hay is being cured. However, animals that remain in the sunlight most of the time during the summer obtain sufficient vitamin D without depending upon feed as a source of supply.

CONDITION

Condition in hay refers to soundness or unsoundness. The factors of quality in sound hay have been discussed under maturity, leafiness, color, and foreign material.

Hay may be unsound for a number of reasons all of which are tied up with the treatment the hay receives during harvesting, curing, and storing. Ordinarily unsoundness in hay is the result of spontaneous heating. As fermentation begins in hay that contains excess moisture the temperature rises. Hay in this condition is said to be heating.

All newly harvested hay, unless overcured, will go through a light fermentation that is known as sweating. If the moisture content of the hay is less than 20 to 25 percent, the hay usually will dry out before the heat affects the green color. If the hay contains excess moisture, heating will continue until the plant tissues begin to break down and the hay gives off a strong, sour odor. When hay has reached this stage it becomes musty and moldy regardless of any attempt to salvage it.

In fact, when loose hay in a stack or barn has heated so as to be hot, it is risky to move it in an effort to prevent the hay from catching fire through spontaneous combustion, for if air gets to hay that is in this condition it may burst into flames. It should be moved only when equipment is available to extinguish any fire that might occur. In some cases, hay that is heating can be reconditioned, if fermentation has not become too severe. Slight heat may cause baled hay to become gray green or even light brown in color, yet no must or mold will develop if the hay is properly aerated during the heating process.

It has been shown that molds and other micro-organisms become inactive if hay reaches a temperature of approximately 158° F. and therefore hay in which the temperature passes beyond this point will be so-called tobacco brown. But when hay reaches this temperature the danger of spontaneous ignition is increased. Often moldy hay will be mixed with tobacco-brown hay that is not moldy because not all of the mold spores are killed by the heat around the edges of the stack or mow where the air kept the temperature down.

Must is the sour fetid odor that occurs in hay that has heated. Must is usually associated with mold. Mold is the fungus plant organism that will grow on hay when moisture and temperature conditions are favorable. Two types of molds are common on hay—the white powdery molds which are often present in the so-called stack-spotted hay of the Great Plains States and the black or brown molds which are more common in hay stored in barns.

When undercured hay is baled from the windrow the hay often heats in the bale. The slugs in bales that have heated in this manner may be set or caked and usually are musty and moldy. Sometimes the outside of the bale is green and has the appearance of good-quality hay whereas the center of the bale is discolored, musty, or moldy, caused by excessive heating after being baled.

SIZE AND PLIABILITY OF STEMS

Size and pliability of stems of hay plants, especially legumes, are influenced by thickness of stand, stage of maturity when cut, and fertility of the soil. Stems of early-cut hay are usually relatively fine, soft, and pliable. Hay of this character is relished by livestock and when it is fed, very little is wasted. Occasionally, however, hay with relatively fine stems is harsh and woody because of late cutting, drought, weathering, or overcuring.

There is a relationship between texture and the leaf content of legume hay. Legume hay with fine stems usually has a higher percentage of leaves than coarse-stemmed legume hay. Coarse-stemmed legume hay cures slowly and a large percentage of the leaves are likely to be lost in curing and handling. Occasionally the large stems of legume hay are flat and pliable, depending on the way in which

the hay was cured. But ordinarily the stems of coarse alfalfa hay are hard and round. Hay with coarse stems that are hard and round is usually unpalatable. Livestock may reject as much as 25 percent of the stems of relatively coarse soybean hay.

Texture of stems influences the purpose for which hay is used. Hay with fine, soft stems is considered preferable for the feeding of dairy cattle, sheep, and rabbits. Coarse-stemmed hay is used, to a large extent, for wintering stock cattle and for milling purposes.

AROMA

Aroma in hay refers to the sweet odor characteristic of new-mown hay or hay that has gone through a normal sweat in the bale, stack, or mow. Aroma, which influences palatability, should be typical of the particular crop from which the hay is made.

Aroma is not present in badly overripe, overcured, or weathered hay or hay that has become unsound from excess fermentation. But excessive fermentation in the absence of air may produce what is commonly called tobacco-brown hay. This kind of hay has a characteristic odor similar to silage and is considered very palatable. Aroma should not be confused with the undesirable odor in hay due to mustiness or ground odor. Occasionally hay has the odor of skunk, fertilizer, garlic, etc., which is considered objectionable because hay that has such odors is not relished by livestock.

CUTTINGS PER YEAR

The number of times certain grasses and legumes are cut for hay each year influences the quality of the hay. The length of the growing season and the kind of crop determines the number of cuttings that may be made during the growing period. Where only two or three cuttings of alfalfa were formerly made per season three and four cuttings are now made. By making the extra cutting the yields of protein per acre are increased and the hay is of higher quality. The feed value of relatively early-cut hay has already been discussed under Stage of Maturity (p. 6).

In deciding the number of times to cut alfalfa and the time at which the cuttings should be made, good meadow management requires that consideration be given to winter hardiness and insect damage, as well as to yields of high-quality hay. In southern California and Arizona, alfalfa may be cut five or six times per year. In some areas only one cutting of alfalfa is made during the summer because of the short growing season due to high altitudes or because of lack of moisture in areas where dry farming is practiced. In the Central West and the Eastern States two to four cuttings of alfalfa are usually made, depending on the length of the growing season (fig. 19).

There is a marked variation in the quality of hay from the same cuttings in different localities. Because of these variations and the inability of hay experts to consistently determine the different cuttings, no attempt was made to use "cutting" as a grading factor in Federal hay standards.

A compilation of chemical analyses of first, second, and third cuttings of alfalfa indicates that there is less variation in the chemical composition of the different cuttings than there is in hay cut at

different stages of maturity. Stage of maturity when cut is, therefore, more important in alfalfa hay from the standpoint of nutritive value than is the cutting. In fact, much of the prejudice against certain cuttings of alfalfa is due to the stage at which the particular cutting is made and the weather conditions while it was being cured. When the different cuttings are made at the proper stage of maturity and are cured without damage from weather, usually little or no prejudice is held against the hay. Chemical analyses of the different cuttings made at the same stage of maturity showed that there is very little difference in chemical composition due to the cutting.

Most of the other hay plants such as soybeans, timothy, redtop, and grasses such as bluegrass, are cut only once a year, although in favorable years two cuttings of clover, lespedeza, and upland prairie hay are sometimes made. Johnson grass is usually cut at least

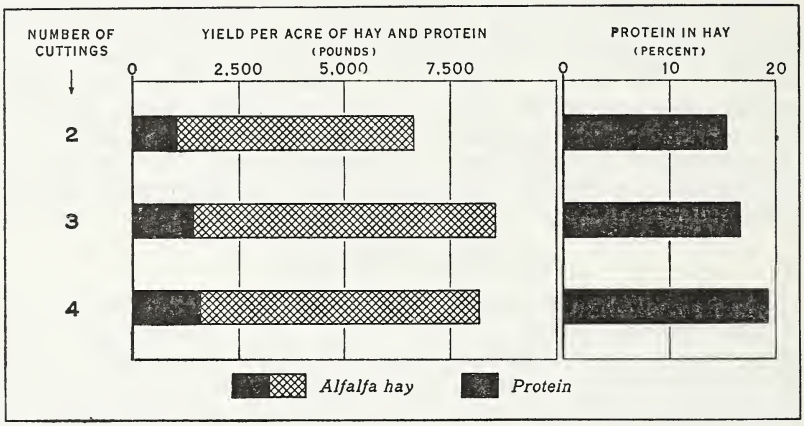


FIGURE 19.—YIELD OF HAY, PROTEIN PER ACRE, PERCENTAGE OF PROTEIN IN HAY FOR ALFALFA CUT TWO, THREE, AND FOUR TIMES PER SEASON.

The number of times alfalfa is cut per season influences the yield of hay and protein per acre. The number of times alfalfa may be cut without injury to stands in a given season depends on length of growing season.

twice during the growing season and in many areas three cuttings are made. Johnson grass grown on the more fertile soils should be cut often enough during the season to prevent the stems from becoming coarse.

CURING

No detailed discussion of haymaking practices is included in this publication, but it seems desirable to comment on certain important principles of haymaking that influence the quality of hay and, barring unfavorable weather, are largely under the farmers' control.

Hay can be no better than the meadow from which it is cut. The seeding of adequate quantities of high-quality seed of adapted varieties on soil that is good as to type, fertility, acidity, and freedom from weeds is important if good stands of hay plants are to be expected. Good yields of hay are obtained from meadows with thick stands of plants. Thick stands help to control weeds and the stems of the hay plants are generally of desirable texture.

The relationship of stage of maturity at which hay is cut to the feed value of the hay has already been discussed. If hay is cut at the stage of maturity that will give the greatest quantity of digestible nutrients per acre, the farm feed supply can be materially increased without increasing the hay acreage.

Timeliness is important in the making of high-grade hay. It is not economical to try to grow more hay than can properly be cared for

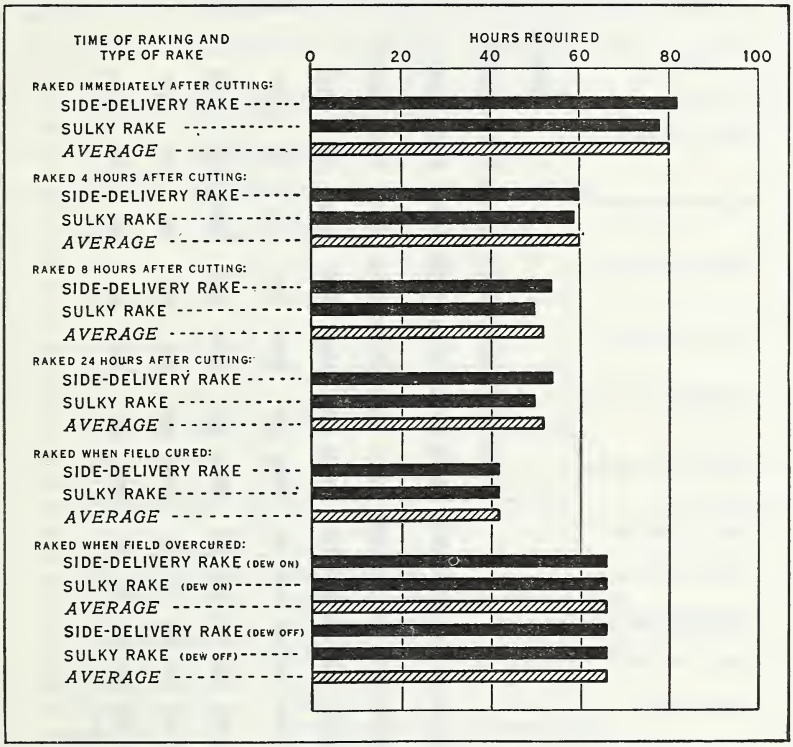


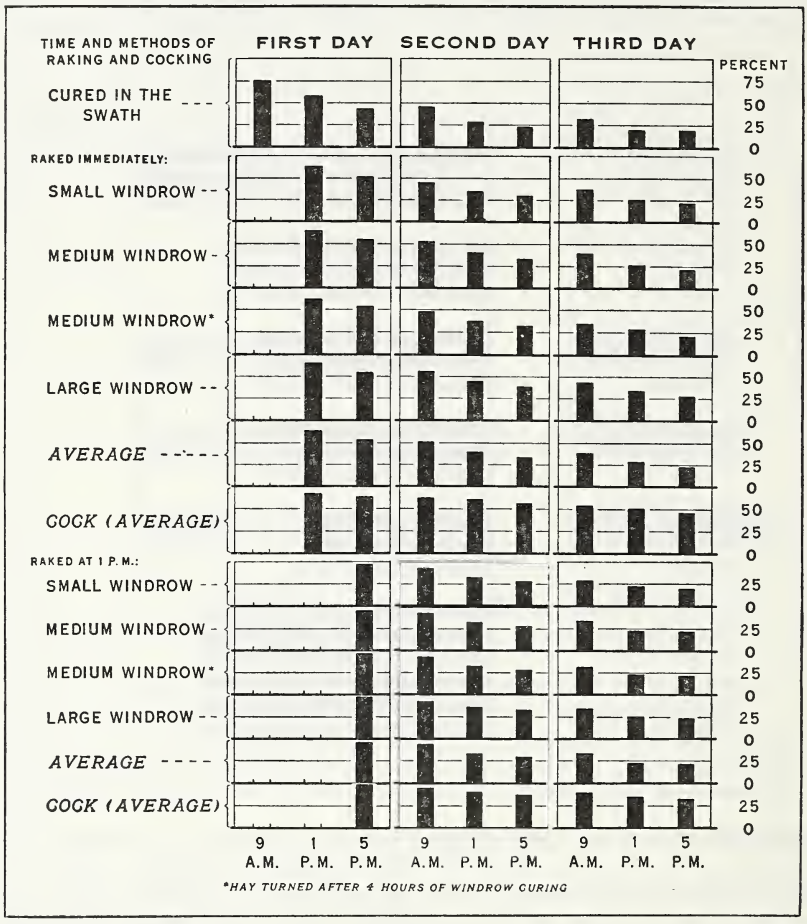
FIGURE 20.—EFFECT OF TIME OF RAKING AND TYPE OF RAKE ON HOURS REQUIRED TO CURE ALFALFA HAY.

Partial swath curing influences rate of curing of hay. Hay windrowed 4, 8, or 24 hours after cutting cured more rapidly than the hay that was raked immediately after being cut, but not so rapidly as that cured entirely in the swath. Partially swath-cured hay graded higher than the hay from either of the other methods of curing.

with the labor and equipment available. Farmers who exercise the best judgment do not cut more hay at any one time than can be cured and stored in such manner as to preserve the quality.

Rapid curing tends to minimize damage to hay from dew, rain, and sun bleach. Curing is most rapid while hay is in the swath (figs. 20 and 21). Ordinarily hay should be left in the swath until it is well wilted; then it should be windrowed with a side-delivery rake. If the hay is well wilted before it is raked into small windrows the curing will continue at a relatively rapid rate (fig. 22). If hay is raked with

a sulky rake, the windrows should be comparable in size to those made with the side-delivery rake (fig. 20). Hay should not be raked too soon after it is cut nor should it be left in the swath or windrow until it is overcured. The practice of raking hay too soon after cutting delays curing and increases the chances of the hay being damaged by



BAE—34031

FIGURE 21.—RAPIDITY OF CURING AS AFFECTED BY TIME AND METHODS OF RAKING AND COCKING.

Hay cures fastest in swath. Hay in swath was field-cured by late afternoon of the second day whereas hay in windrow required another day, and hay in cock took more than 3 days to cure.

weather (figs. 20, 21, 23). In some areas partially cured hay is raked into large windrows or bunches. This practice also delays curing and causes the hay to cure unevenly (figs. 21, 22, 23). By the time the hay on the under side of a large windrow or bunch is dry enough to store the hay on the top side is overcured.

Hay is frequently overcured because of the difficulty farmers have in deciding when hay is properly cured for baling, mowing, or stacking;

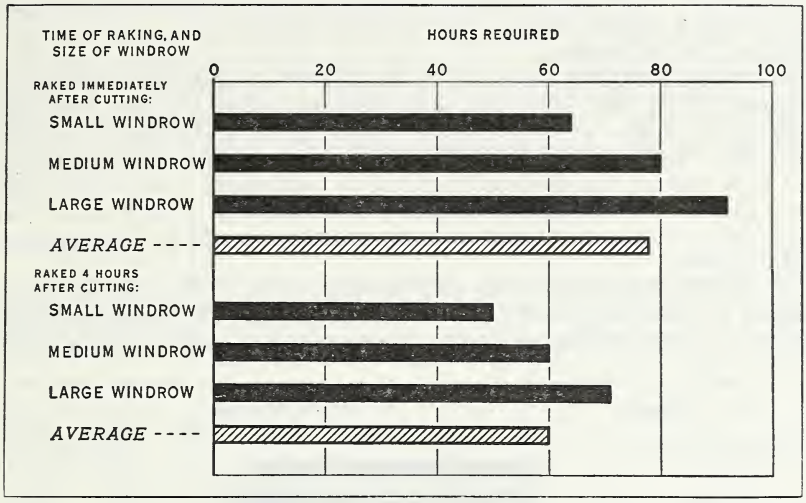


FIGURE 22.—EFFECT OF TIME OF RAKING AND SIZE OF WINDROW ON TIME REQUIRED TO CURE ALFALFA HAY.

Size of windrow affected the length of time required for hay to cure, but did not affect the quality of the resulting hay.

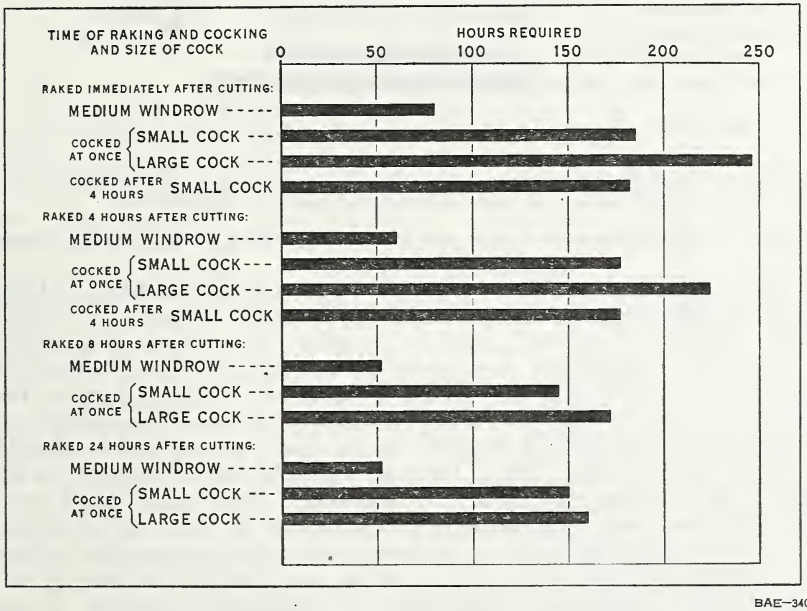


FIGURE 23.—EFFECT OF TIME OF RAKING AND COCKING AND SIZE OF COCK ON TIME REQUIRED TO CURE ALFALFA HAY.

Two and one-half to three times as many hours were required to cure hay in the cocks as in medium-sized windrows and the cocked hay was of lower grade.

also because more hay is often cut at one time than can be properly cured and handled without excess sun bleach and, in the case of legumes, loss of leaves.

In several irrigated areas of the Southwest considerable alfalfa hay is baled during the night and early morning when the hay is usually sufficiently tough to prevent the leaves from shattering. In those areas the hay is raked into windrows immediately after being cut and is not again handled until curing is completed. In more humid areas this method of windrowing hay immediately after it is cut and then baling during the night or early morning, could not be practiced without loss.

In the Southeastern States and in other parts of the country where rainfall is relatively heavy, it is sometimes difficult to complete the curing of coarse-stemmed legume hay, such as cowpea, and soybean

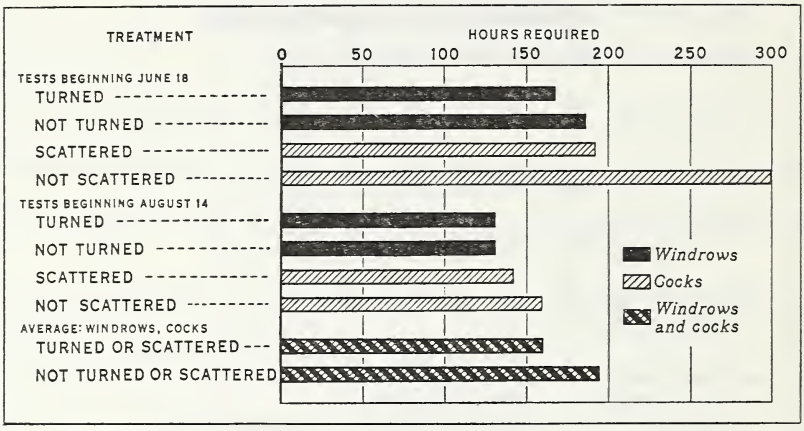


FIGURE 24.—EFFECT OF VARIOUS METHODS OF HANDLING ON TIME REQUIRED TO CURE ALFALFA HAY WHICH HAS BEEN RAINED UPON.

Turning of windrows or scattering of cocks speeds curing of hay wet by showers.

in the swath and windrow without severe weather damage. There, curing is often completed by placing the partially cured hay on tripods or by stacking it around poles in an effort to conserve the quality.

The more rapidly hay can be cured and the less it is handled, the higher the quality will be. This is especially true of legume hay. But if hay has become wet in the windrow or cock because of showers it will cure more rapidly if the cocks or windrows are scattered. (fig. 24).

In addition to field curing, the feed value of hay crops may be preserved by artificial drying and by ensiling. Artificially dried hay is hay that has been run through a dehydrator to drive off the excess moisture by artificial heat. The newly harvested grasses and legumes are usually chopped or cut before going into the dehydrator to facilitate drying. Artificially dried hay is ordinarily superior in feed value to field-cured hay as none of the leaves or green color are lost before the hay reaches the drier. Cost has limited the use of artificial drying as means of preserving the quality of hay crops up to this time.

The making of silage is one of the most recent developments in the

preservation of the quality of hay crops for home use. The practice appears to have considerable merit, especially in areas where weather conditions persistently prevent the making of high-grade hay by field curing. The economy of ensiling hay crops and the extent to which grass and legume silage may replace field-cured hay in the animal ration depend largely upon local conditions and may be difficult to ascertain definitely.

STORING TO PRESERVE QUALITY

Conditions under which hay is stored influence its quality. Hay must be cured until it does not contain more than 25 percent of moisture if it is to be stored without danger of heating in the mow or stack. Little information with reference to moisture content and its relation to curing and storage of hay is available and there is no quick method of determining moisture content of hay. Farmers have always used rule-of-thumb methods of finding out when hay is cured sufficiently for storage. Often hay is stored a little too green rather than permit it to remain in the field and become wet from rain.

One practical method used by farmers is to twist a wisp in the hands. If the twisted hay is tough and there is evidence of moisture where the stems are broken the hay is considered too sappy for safe storage. If the stems are slightly brittle when broken and there is no evidence of moisture when the stems are twisted the hay can be stored without danger of spoilage. Another method is to scrape the outside of the stems with the finger or thumb nail. If the epidermis can be peeled from the stem the hay is considered undercured. If it does not peel off, the hay is usually dry enough to stack or put in the mow.

After hay is stored, some fermentation will occur unless the hay is very dry. The intensity of this fermentation will depend on the moisture content of the hay at the time it is stored. Slight fermentation (sweating) that occurs in properly cured hay will not cause any loss of green color or nutrients but will improve the aroma of the hay and may make it more palatable. Moderate fermentation will occur when the hay is slightly undercured, causing a loss in green color and a browning of the leaves and stems. Molds will develop where the air has not been excluded. Severe fermentation will occur if the hay is stored when it is distinctly undercured. Such hay may be dark brown or black and in rare cases may be so badly charred that the plant parts are difficult to identify.

The tendency of hay to heat from natural causes is known as spontaneous heating and is one of the causes of farm fires throughout the country where hay is stored loose. It is estimated that the loss from fires on farms due to spontaneous heating and ignition is about $20,000,000 per year. The loss from spontaneous heating when ignition does not occur has never been estimated but is probably greater than the loss due to fires from spontaneous ignition.

Observations made from time to time by hay specialists seem to indicate that much loss in feed value as well as market value occurs to hay every year because of spontaneous heating. In a study covering 34,500 carlots of hay inspected at Kansas City, Mo., 15 percent of the total hay was found to be Sample grade because of being wet, heating, hot, or musty. These are the factors of quality associated with spontaneous heating of hay.

The progressive steps in the spontaneous heating of hay are about as follows: (1) Undercured, (2) heating, (3) hot, and (4) musty and moldy. Heating is the first stage of the fermentation process and when the hay is in this stage it can sometimes be salvaged, providing it is so piled and aired that heat of fermentation can be dissipated. But after hay becomes really hot, very little can be done to salvage it because at this stage decomposition has already set in and by the time the hay is cooled it is moldy. During this period the plant tissues break down and the feed value is materially reduced.

Hay that has heated has lost considerable organic substance. In experiments conducted by the Bureau of Chemistry and Soils[3] the loss of organic material in hay that was stored with high moisture content was found to range from 4 to 22 percent, with an average for all tests of 13 percent. When properly cured hay was stored, the loss in organic substance was only 3.5 percent.

The practice of salting hay has been more or less common in many sections throughout the United States. Farmers and stockmen claim that salt aids in curing the hay and reduces the danger from excessive heating. Experiments proved that the addition of 20 to 30 pounds of salt to the ton of hay at the time it is stacked or mowed will not inhibit the development and growth of mold. If sufficient salt were added to actually prevent the development of molds the hay would be unpalatable. The addition of small quantities of salt probably does make hay more palatable.

In most areas in the United States hay is stored loose but, in a few areas where it is baled directly from the windrow it is stored in the bale, except when it is shipped to market directly from the field. When hay is stored loose in barns or stacks each harpoon or sweep-rake load should be distributed evenly over the mow or stack. When large bunches of hay are thrown together in a mow or stack instead of being spread, heating may occur in such bunches and may cause serious loss in quality. No information is available on the relation of mow size to the percentage of moisture that hay can have and be safely stored. Certainly the total mass of hay is a factor in determining the percentage of moisture the hay can contain and still be stored without danger of spoilage.

Hay baled from the windrow often becomes musty and moldy while in storage or on the way to market. The danger of spoilage under these conditions can often be prevented if the bales are so piled as to permit the free circulation of air throughout the pile. In order to permit the circulation of air around the bales they should be piled on edge—that is, fold side to chaff side instead of being laid flat or wire to wire. Whenever bales are piled on edge there is always enough space between the bales for air to circulate freely. When the bales are laid flat very little air can pass between the bales. Often hay molds when stored in this way. Hay with the same moisture content will often pass through the sweat without molding if piled on edge.

When windrow-baled hay is loaded on cars for shipment to market spoilage may be prevented by piling on edge with air spaces between the bales. In some cases it may be advisable to set the bales on end in the car to reduce the danger of spoilage. Even with these precautions windrow-baled hay with excess moisture will heat in transit.

[3] Hoffman, E. J. and Bradshaw, M. A. Losses of organic substance in the spontaneous heating of hay. Journal of Agricultural Research, Vol. 54, No. 2, pp. 159-184. 1937.

CHOPPING

Considerable interest has been shown during recent years in the chopping of hay, either when the hay is stored or in the early fall after the heaviest farm work is over. Hay must be slightly drier if stored in the chopped form than if stored as long hay. Observations at the Indiana Agricultural Experiment Station [4] after a 3-year study of this method of storing hay are: That chopped hay will not heat enough to destroy the green color of the hay if it did not have more than 19 percent of moisture when it was chopped or stored. Hay with 25 to 28 percent of moisture when stored, mow-burned badly and hay with 30 percent of moisture was severely charred.

These results, as well as results at a number of other experiment stations, indicate that chopped hay must be slightly drier than long hay in order to be stored without danger of spoilage. In Idaho it is a common practice to store the hay in long form in stacks and in the fall or early winter to run this hay through a cutter and blow it into a conical stack. It has been found there that the moisture from rains or snows will not penetrate more than a few inches into this chopped hay.

There is a much smaller percentage of waste when chopped hay is fed to cattle or sheep. Sheep will waste about 20 percent of the alfalfa hay fed to them in this area because of its relatively coarse texture. But if the hay is chopped, this waste is reduced to less than 5 percent.

About 200 cubic feet of mow space is required for a ton of chopped hay while for a ton of long hay 450 to 600 cubic feet is needed. Under these conditions two to three times as much chopped hay can be stored in the same space. When chopped hay is stored in barns built for long hay the mows should be well supported in order to carry the additional weight.

The cost of storing chopped and long hay is about the same, the cost of power to run the chopper being offset to a certain extent by the fact that no one is needed in the mow to scatter the chopped hay. When it is blown into a barn it should be distributed in the mow by readjusting the blower pipe frequently; under no condition should the hay be packed or tramped. Chopped hay can be fed from the mow much easier and with less manual labor than long hay because it can be taken out in vertical instead of horizontal sections.

RELATIONSHIP BETWEEN GRADE AND PRICE OF ALFALFA

For grades to be useful in the marketing of hay they should reflect feed value and should be associated with market prices. Information compiled on average monthly price per ton for alfalfa hay at Kansas City, Mo., for the 7 years 1930 to 1936, inclusive, show a definite relationship between price and grade (table 10). Average monthly prices for the numerical grades of alfalfa, including the special grades U. S. No. 1 Extra Leafy Alfalfa and U. S. No. 2 Leafy Alfalfa, ranged from $12.65 to $25.15 per ton in 1930–31 and from $6.10 to $13 per ton, respectively, in 1932–33, according to grade. During the 7-year period, U. S. No. 1 Extra Leafy Alfalfa sold for $2 to $4 per ton more than U. S. No. 1 Alfalfa. U. S. Sample grade alfalfa sold for $1 to $2 per ton less than U. S. No. 3 Alfalfa.

[4] Hienton, T. E. and Hilton, J. H. CHOPPING AND STORING ALFALFA HAY. Ind. Agri. Exp. Sta. Cir. 221, 4 pp., illus. 1936.

TABLE 10.—*Alfalfa hay: Average price, per ton, by United States grades, at Kansas City, Mo., by months, 1930–36* [1]

Year beginning June 1 and United States grade.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Average
1930	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*	*Dol.*
No. 1 Extra Leafy	------	20.80	25.15	26.00	26.25	27.35	27.25	27.00	26.65	25.65	24.25	20.50	[2]25.15
No. 1	------	17.50	21.40	22.00	22.25	23.15	22.50	21.45	19.55	19.65	19.25	17.25	[2]20.55
No. 2 Leafy	------	15.95	19.50	20.00	20.20	21.70	20.65	18.45	16.40	17.20	16.65	15.50	[2]18.40
No. 2	------	14.25	17.55	18.00	18.05	19.40	18.05	16.00	14.65	15.65	14.75	13.90	[2]16.40
No. 3	------	11.55	13.95	14.00	13.75	14.30	13.30	12.25	11.55	12.45	11.50	10.60	[2]12.65
1931													
No. 1 Extra Leafy	14.75	14.95	15.45	15.90	16.30	15.75	16.50	16.55	17.20	19.25	19.50	16.95	16.60
No. 1	12.90	13.20	13.20	12.90	13.10	13.15	14.25	14.00	14.50	16.00	15.90	13.55	13.90
No. 2 Leafy	11.65	11.95	11.90	11.75	11.75	11.65	12.40	12.25	12.80	14.50	14.50	12.45	12.45
No. 2	10.50	10.65	10.80	10.55	10.40	10.00	10.15	10.25	10.80	12.50	12.50	10.95	10.85
No. 3	8.45	8.40	8.75	8.75	8.55	7.75	7.80	7.75	8.20	9.50	9.50	8.45	8.50
1932													
No. 1 Extra Leafy	12.50	12.50	12.50	12.50	13.00	12.50	13.50	13.25	12.55	13.30	13.50	14.25	13.00
No. 1	9.70	9.75	9.75	9.75	10.50	10.50	11.05	10.50	10.25	10.80	11.00	11.20	10.50
No. 2 Leafy	9.25	9.25	9.25	9.25	9.60	9.50	9.50	9.25	9.25	9.50	9.50	9.50	9.40
No. 2	8.75	8.75	8.50	8.25	8.25	8.25	8.25	8.15	8.25	8.50	8.50	8.50	8.40
No. 3	6.55	6.25	6.05	6.00	6.00	6.00	6.00	5.90	6.00	6.25	6.25	6.25	6.10
1933													
No. 1 Extra Leafy	11.20	11.00	13.15	13.50	13.40	13.50	14.10	14.25	14.30	15.25	16.80	15.80	13.85
No. 1	9.65	9.90	11.45	11.75	11.75	11.75	12.70	12.50	12.35	12.75	13.95	13.50	12.00
No. 2 Leafy	8.70	8.95	10.50	10.75	10.75	10.75	11.75	11.55	11.35	11.75	12.75	12.45	11.00
No. 2	7.70	7.95	9.50	9.75	9.75	9.75	10.75	10.55	10.35	10.75	11.60	11.50	10.00
No. 3	5.45	6 90	7.75	7.90	7.75	7.95	8.75	8.75	8.85	9.25	10 05	9.75	8.25
1934													
No. 1 Extra Leafy	16.55	20.10	25.50	25.50	25.10	24.50	26.50	26.65	26.25	26.30	25.50	23.50	24.35
No. 1	14.10	17.60	22.50	22.50	21.70	21.50	23.25	23.50	23.10	22.75	22.00	20.10	21.20
No. 2 Leafy	13.50	16.75	21.50	21.50	21.10	20.50	22.25	22.50	22.10	21.75	21.25	19.25	20.35
No. 2	12.75	15.95	20.50	20.50	20.10	19.50	21.25	21.50	21.25	21.00	20.50	18.75	19.45
No. 3	11.25	13.80	17.25	17.25	17.05	16.75	18.75	18.75	18.75	18.75	18.50	16.75	16.95
1935													
No. 1 Extra Leafy	17.50	13.65	15.65	16.10	17.00	17.00	16.70	16.50	17.25	18.00	21.50	18.80	17.15
No. 1	14.80	11.20	13.00	13.40	14.00	14.00	13.50	13.50	13.75	13.60	15.80	14.25	13.75
No. 2 Leafy	14.05	10.40	12.00	12.40	12.95	13.00	12.70	12.50	12.75	12.50	13.10	12.25	12.55
No. 2	13.35	9.80	11.00	11.40	12.00	12.00	11.70	11.25	11.25	11.85	10.80	10.30	11.40
No. 3	11.70	8.25	9.00	9.55	10.25	10.25	9.65	9.15	9.25	8.90	8.00	7.50	9.30
1936													
No. 1 Extra Leafy	12.45	18.25	21.40	21.45	21.95	23.00	23.50	24.00	24.50	25.50	28.40	22.10	22.20
No. 1	11.30	16.50	18.80	19.10	19.70	20.20	20.00	20.70	20.90	20.35	21.45	18.50	18.95
No. 2 Leafy	10.15	15.50	17.80	18.10	18.10	18.50	18.50	19.25	19.40	18.80	19.70	17.20	17.60
No. 2	9.25	15.00	17.00	17.10	17.00	17.00	17.00	17.55	17.60	16.40	17.30	16.10	16.20
No. 3	7.50	13.70	15.20	15.10	15.00	15.00	15.00	15.00	14.90	13.20	14.00	13.50	13.90

[1] Average of bulk of sales price for 1 day each week.
[2] 11-month average.

Prejudice of buyers, descriptive buying and selling of hay under such terms as "pea-green leafy dairy alfalfa" and "sound brown alfalfa" which do not reflect feed value, and lack of knowledge among buyers and sellers of hay as to what constitutes quality in hay, prevent market prices from reflecting the feed value of hay in many cases. Although the price range for different grades of alfalfa and other hay varies from year to year and during different seasons, premiums are always paid for high-grade hay. Dairymen and other buyers do not usually find it profitable to purchase low-grade hay that has been shipped long distances, because of transportation costs.

U. S. GOVERNMENT PRINTING OFFICE: 1939

For sale by the Superintendent of Documents, Washington, D. C. - - - - Price 10 cents