A SURVEY OF DEHYDRATION OF FORAGE CROPS IN OKLAHOMA WITH SPECIAL EMPHASIS ON ALFALFA

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REASONS FOR STUDY

Interest in artificial dehydration of hay and other forage crops has increased considerably in Oklahoma during the past few years. The possibilities of dehydration apparently have stimulated the interest of individuals with surplus capital to invest in new industries. Livestock feeders are interested in the possibilities of getting a high quality feed through dehydration.

The Oklahoma Agricultural Experiment Station has received many letters and visits from persons seeking information concerning dehydration of hay and other forages. Some of the questions asked by these individuals concern:

1. Types of dehydration units available.
2. Initial cost and operating expenses.
3. Installation.
4. Principles and methods of dehydration.
5. Feeding value of dehydrated alfalfa meal in comparison with sun-cured hay for various types of livestock.
6. Proper meadow management when alfalfa is cut for dehydration.

Since very little information has been compiled in regard to dehydration of hay and other forage crops, the author was assigned the task of bringing together available information which could be used in answering inquiries. This information was obtained by:

1. Reviewing research data on dehydration.
2. Personal correspondence with owners of dehydrators in Oklahoma and elsewhere.

3. Contacting manufacturers of various dehydrating units.

4. Personal visits to locations in Oklahoma where dehydrators were in operation.

HISTORY AND GENERAL DESCRIPTION OF DEHYDRATION

More people are dependent, fully or in part, upon forage crop production than upon any other class of crops. Forage is the very basis for a large part of our livestock and allied industries. The hay crop alone has an estimated annual farm value of approximately $700,000,000 (18). It also has been estimated that the United States farmer recovers not more than 75 percent of the value of the hay crop produced, due to difficulties and lack of efficiency in harvesting, curing, handling, and storage practice. Proper curing is necessary if losses are to be reduced to a minimum.

Several methods of artificial drying of forage crops have been in use for a number of years. In 1909 alfalfa was dried in Missouri by machine, and in 1910 native Louisiana grasses were dehydrated. From these areas the practice spread elsewhere. Many systems were tried and discarded. One of the earlier machines carried the green forage on a wire apron conveyor through a drying chamber where hot air or furnace gases were circulated by fans. Crops like alfalfa and the grasses were dried whole, but the coarser crops were crushed or chopped for proper drying. Various drum types of dehydrators were considered experimentally. In these dehydrators the chopped or shredded material was exposed to high temperatures for a short period of time.

The same principles are involved in our dehydrators today. The progress made by commercial, federal and state agencies has been rather slow until recent years. Commercial concerns have become interested in artificial dehydration of forage crops and have improved the equipment in many respects. The purpose of dehydration is to convert the raw material, at its best stage of growth, into the highest priced finished product, and at the same time minimize the risk of crop loss at harvest time.

In general, artificial drying, when properly carried out, will eliminate the numerous hazards present under ordinary hay making procedures. These hazards that normally occur may reduce the quality of forage. This artificial drying process helps retain the plant nutrients, a large number of the vitamins, and, in some forages, unknown nutrients that are important in the diet of animals. By dehydration, excellent forage in large quantities can be produced in some sections where climatic conditions may be a problem in hay making. It is quite evident that dehydration would be of much more value in areas of high rainfall than in the drier areas. In areas where farmers have access to a dehydration plant, the gamble in hay making can be reduced to a minimum. Less storage space is needed for the finished product and the ease in feeding dehydrated forage is an added convenience.

The average farmer is interested in the home made kind of feed; the forage and hay crops which he can process for his own profit and advantage. Hay and other forage crops can be dried artificially, independent of sun and weather, and in this way feed of a superior quality can be assured. This is especially true in the more humid areas, where rain and dew often play havoc with hay, sometimes ruining it completely. The main object of dehydration is to preserve the feeding value of forage crops.

Interest in artificial drying of forage crops in Oklahoma has increased considerably during the past few years, mainly due to the increased acreage and the possibility for further expanding the acreage of alfalfa. The reduction of cotton acreage, which has limited the supply of high protein feeds, also has stimulated dehydration. In the higher rainfall section of Oklahoma, hay making is a gamble with the weather, especially along streams and rivers where rich, fertile fields are subject to overflow. High rainfall and humid conditions cause losses of food nutrients in alfalfa hay due to exposure. Farmers in those sections are interested in new methods of curing hay to avoid losses that normally occur under regular hay making processes.

Although dehydration has numerous advantages, some of the disadvantages which are listed should not be overlooked.

1. The expense involved in dehydration. The studies that have been made are not sufficient to fix definitely the cost of drying.

2. At the present cost of dehydration, it appears that when field losses are greater than 25 to 30 percent, and if at the same time the prices of hay are relatively high, then artificial drying may pay.

3. Morrison (25) reports that if the temperature gets too high during the process of dehydration, and the hay is charred or burned, digestibility may be decreased considerably, especially that of the protein; some of the unidentified nutrients are destroyed.

4. Vitamin D is generally much lower in dehydrated hay than in sun cured hay.

Some progress is being made toward a plan for sun curing hay between 40 and 50 percent moisture and then placing the hay in a barn so equipped that air, heated if necessary, can be forced through it to complete the drying. Since less expense is involved, this method of mow-curing is worthy of consideration in storing hay on the farm in Oklahoma.

PROBLEMS IN CURING HAY AND OTHER FORAGE CROPS

For many years farmers have been concerned with losses in hay which ordinarily occur by the regular field curing method, which until recently was practically the only method ever used in preparing hay for storage. Losses usually are due to:

1. Loss of leaves (that portion of the crop richest in dry matter, proteins, vitamins and minerals) which usually occurs under ordinary conditions of field curing of hay.

2. Loss of valuable constituents of the hay as the result of leaching and over-drying, which may at times in certain localities account for as much as half the value of the crop.

Loss of Leaves

Leafiness and color are correlated with carotene and protein content, as the leaves contain a much higher percentage of these important nutrients than do the stems. The retention of leaves and green color are the two things most important to the producer. Since the leaf color and percentage of leaves are important in hay quality, the best method of haying will be the one that saves the most leaves and then retains the green color.

Loss of leaves is reported by several investigators (8,20,25). They found that for average conditions of drying and handling hay in good weather the loss is approximately 20 percent of the total quantity of leaves. When it is considered that 65 to 80 percent of the total protein of the alfalfa plant is in the leaves, and that the leaves also represent one-half of the dry matter of the plant and the major portion of the minerals and carotene, the loss of 20 percent of the leaves represents a loss of approximately 20 percent of the total nutrients in the hay.

It has been reported by Kiesselbach (21) and others that the change in the leaf percentage of alfalfa ranges from 57.3 in early stages to 33.3 with advancing maturity. The leaf losses which appear in full bloom stage probably can be attributed to disease, insect injury, adverse weather conditions, lodging and natural leaf shedding with maturity. It has been shown that alfalfa leaves are roughly twice as high in percentage of protein as are the stems of the same plant, while the stems have a crude fiber content about three times that of the leaves.

The composition of the leaves and stems changes with age as is indicated in Table 1. The change in the stem is much more rapid.

Table 1. Percentage of leaves of alfalfa and timothy and their change in composition at different stages of growth.

	Proportion	Leaf		Stem	
Stage of growth	of total weight, percent	Protein, percent	Crude Fiber, percent	Protein, percent	Crude Fiber, percent
		Alfalfa (39)			
Prebudding stage	58.5	32.83	12.47	19.46	30.94
Budding Stage	48.4	28.38	13.19	13.57	42.88
Early Flowering Stage	42.1	24.57	13.94	11.03	46.49
		Timothy (16)			
Headed	38.22	11.6	24.3	4.4	33.8
Early bloom	29.3	11.6	25.1	4.8	39.7
Just past full bloom	20.5	11.0	25.0	3.2	40.7
10 percent of heads straw colored	11.5	9.0	25.0	2.9	43.0
Heads mature	10.0	6.6	25.9	2.8	41.6

Studies in Kansas (10) report leaf losses during curing varied from 2.3 to 34.0 percent. This loss is 1.2 to 17.4 percent of the total crop and a proportionally larger part of its nutrient content. These data compare well with those of many other investigators, who report 30 percent or more loss of leaves in alfalfa during the curing process.

Data reported by Grandfield and Throckmorton (10), shows the percentage of leaves in alfalfa hay varies from 41.6 to 53.4, depending on the stage of maturity at time of harvesting (Table 2).

Table 2. — Effect of stage of maturity of alfalfa on yields of hay, percent of leaves and protein, and total protein produced per acre. (Average for 8 years.)

Stage of Maturity	Yield of Moisture free hay per acre	Leaves in hay	Protein in hay	Total Protein Per Acre
	Tons	Percent	Percent	Pounds
Bud Stage	2,427	53.4	19.78	960
One-tenth bloom	2,931	51.1	18.92	1,109
Full bloom	3,037	48.4	17.63	1,071
Seed Stage	2,647	41.6	16.04	849

From these data, it is evident that the highest percentage of leaves is obtained in the early stage of growth, but that the largest amount of protein is obtained when alfalfa is cut in the one-tenth to the full bloom stage. Since 65 to 80 percent of the protein in the alfalfa is in the leaves, it is important that the alfalfa be cured in a manner so that the leaves will be retained. Alfalfa can be dehydrated immediately after cutting. New-mown hay contains from 70 to 80 percent moisture, depending on the atmospheric conditions and stage of growth when cut. Handling hay at a high moisture content avoids shattering of the leaves.

Overdrying alfalfa hay in the field is probably the most common cause for the loss of hay quality. If hay is too dry when handled, the leaves shatter and a high percentage of nutrients is lost.

Loss by Exposure

The exposure of forage to the sun and weather in field curing should be as brief as possible, as these are the chief factors in the destruction of carotene, a source of vitamin A, in a feed. It was reported by Wall (38) that in order to secure a high carotene content, hay should be removed from exposure to sunlight and weather as rapidly as possible. However, there are a number of other factors causing the carotene content to vary in dried feeds.

The average carotene values which may be expected in Oklahoma feeds are summarized by Wall (38) in Table 3. High values were found with young,

Table 3. -- Range in Carotene Value of Oklahoma Feeds. (Effect of drying and storage on carotene.)

	(p.p.m. Dry Basis)					
	Carotene Green		Carotene Dried		Carotene 6 mo. storage	
Kind of Feed	High	Low	High	Low	High	Low
Bermuda	375	225	185	100	85	30
Alfalfa	390	200	200	80	90	20
Sorghum	165	75	90	35	40	10
Johnson grass	90	60	50	20	20	7
Soybeans	250	100	140	65	120	25
Mungbeans	200	100	100	45	70	25
Wheat	300	180	140	70	80	25
White clover	185	90	65	45	25	15
Sweet clover	100	80	55	35	30	15
Big Blue Stem	120	70	60	30	20	7
Little Blue Stem	100	65	55	30	20	7
Switch grass	80	50	45	25	15	5
Rye grass	320	200	160	105	70	35

green, fast growing plants, grown in the spring or fall when soil moisture was plentiful. Low values in general are for more mature plants, and for plants grown during the summer when rainfall was slight and the temperature high. These values were in all cases for plants that were still green and had not been seriously wilted by exposure to sunlight or drought.

Keim, Hathaway and Davis (13) working on the carotene content of twenty-four grasses native to Nebraska found that the carotene concentration of most of the grasses was moderately high during the growing season and declined to a rather low point by late November. The carotene values observed during the periods of greatest concentration varied from 511.6 p.p.m. (Sandhill Bluestem) to 122.6 p.p.m. (Northern Reedgrass). These values ranged from 60.7 p.p.m. (June grass) to 1.6 p.p.m. (Little Bluestem) during the period of lowest concentration.

Sun curing and artificial drying both cause losses of carotene, but the artificially dried plants contain approximately seven times as much pro-vitamin A as the brownish-green field cured plants (8,15,30). Freshly cut alfalfa contains about 390 parts of carotene per million parts of dry matter in the hay (38). Approximately 90 percent of the carotene may be saved by proper drying.

Bleached hay contains little or no carotene. As much as 65 percent of the carotene may be lost in as little as 30 hours of normal field exposure; it is necessary to bring hay to an air-dry condition in the shortest possible time to retain the carotene content.

The necessity and importance of carotene in the well-being of farm animals has frequently been discussed in the literature. The vitamin A content of milk and eggs increases as the carotene in the diet of the producing animals is increased. Unfortunately, carotene is lost by oxidation during storage of dried alfalfa meal. Smith (32) found that only one-fourth of the pro-vitamin A remained after hay was in bales for 12 months. Wall (38) reported a loss of approximately 50 percent of carotene might be expected under average conditions between the newly made dehydrated hays and those that had been stored during the winter months until May. The loss can be lessened by packing in good, reasonably air-tight bags and proper storing, but this is not practical for farm storage.

The vitamin D content is higher in sun-cured hay, while vitamin E is present in larger quantities in artificially dried hay.

Exposure to weather for 96 hours without rain did not affect the vitamin G content, but 0.68 inches of rain removed as much as 50 percent of this vitamin (17).

Guilbert, Mead and Jackson (23) showed that losses from leaching may be as high as 67 percent of the minerals, 35 percent of the carbohydrates (nitrogen-free extract), and 18 percent of the protein. Only a slight loss of fat was noted. Hay stored with high moisture content undergoes very serious deterioration, and often its feeding value is destroyed completely. These losses are probably due to the respiration process of the living plant cell and to the activity of micro-organisms. Respiration continues for some time after the green plants are cut unless the plants are dried immediately. The losses due to normal respiration in the field are largely controlled by the rate and efficiency of drying. Since the plant cell lives for several hours after cutting, respiration continues and loss of dry matter due to this process is reported to range from 3 to 13 percent of the total dry weight. Bacteria and enzymes also begin action immediately, tending to destroy the plant.

TYPES OF DEHYDRATORS

Since designs of dehydrators vary widely; the initial cost, fuel requirements, operating temperatures, and operating conditions also vary considerably. Prospective buyers should investigate very thoroughly the different types of units available before buying. Detailed specifications and recommendations based on the buyer's requirements will be furnished by manufacturers.

Several types of machines have been developed for the rapid artificial drying of hay by using heat from fuel oil, gas or coal furnace. They may be classified as (1) conveyor type (2) rotary drum and (3) pneumatic drier. There are many variations within each type. Driers are made in capacities usually ranging from 3/4 tons to 3 tons per hour. The dehydrated forage may be blown directly to a storage structure, or it may be pulverized with a hammer mill for the purpose of sacking or pelleting.

Apron-conveyor Drier 1/

In the apron-conveyor type of drier the green forage is loaded on an endless screen-wire apron and conveyed through a drying chamber where hot air or furnace gases are circulated through the layer of forage by means of fans. Figure 1 shows the drying process and how the moisture-laden air is allowed to escape into the atmosphere. In general the drying of whole plants of grasses, clovers, and alfalfa is satisfactory in this type of drier; therefore the usual farm haying equipment may be used for harvesting. The apron-conveyor drier operates at a relatively low temperature, 250° to 350° F.,

1/ In all instances where the word "drier" appears in this thesis, it has reference to a dehydrator.

making it necessary that the forage be exposed to the furnace gases from 15 to 45 minutes, according to the moisture content. The temperature of the hay remains much lower than that of the surrounding gases, due to the cooling effect of evaporation.

Drum Driers

Drum driers in general consist of large cylindrical steel shells mounted on rollers so they can be rotated. Baffles or flights are usually fastened to the interior of the shell so that the material is picked up and falls back as the shell rotates. The chopped green forage is fed into the drum at the furnace and is drawn through the shell by an exhaust fan as indicated in figure 2.

The drum drier, when used for forage, is usually classed as a high temperature machine, which necessitates a short period of exposure to prevent charring or burning the hay. Furnace gases enter the machine at 1000 to 1500° F. and leave at 150 to 250° F. The time of drying is about 1 to 5 minutes, depending on the initial moisture content of the forage. The high exhaust temperature represents a considerable loss of heat, which tends to reduce the thermal efficiency.

For the drum type units, the crop is usually harvested with a pickup type cutter which mows, conveys, cuts the material into one inch lengths, and blows it into a truck or trailer following alongside the machine. However, the forage may be cut, windrowed, and picked up with hayloaders, and then hauled to the plant and chopped with a stationary chopper before it is dehydrated.

This type of drier may have one, two, or three drums; but the principle of operation is the same in all of them.

In the single-drum drier the chopped hay passes directly from the furnace end to the discharge end. These driers are usually from 40 to 60 feet in length and from 7 to 9 feet in diameter.

The double drum drier has one drying chamber inside the other. This unit may be shorter than the single drum unit because the use of multiple drums increases the length of the drying chamber as compared to the length of the unit.

In triple drum units, as shown in Figure 2, the material moves through the center shell, back through the second and out through the third, thus traveling approximately three times the length of the drier before it passes to the exhaust fan.

Drum driers occasionally are placed on especially equipped railroad cars so they can be moved to different locations and set up for operations on a siding or spur. One manufacturer makes a portable drum type unit mounted on a rubber-tired chassis for field use.

Pneumatic Driers

The pneumatic drier has no moving parts, the chopped material being carried through the unit by moving air. An upward current of furnace gases dries the hay in suspension. The forage is carried in suspension on a cushion of air from the time it enters the drying chamber until it is discharged. The lighter portions of the forage are carried upward into the zones of lower temperature and velocity more rapidly than the heavier, undried portions. The rate of movement of the particles is governed both by the rate of gas admission to the drying tower and also by the positions of a set of bailers which converge the stream at various points and thereby increase the gas velocity. The green material is exposed to a maximum temperature of 850° F. in the first cycle of the process. In the second cycle the temperature is decreased considerably to avoid burning the hay.

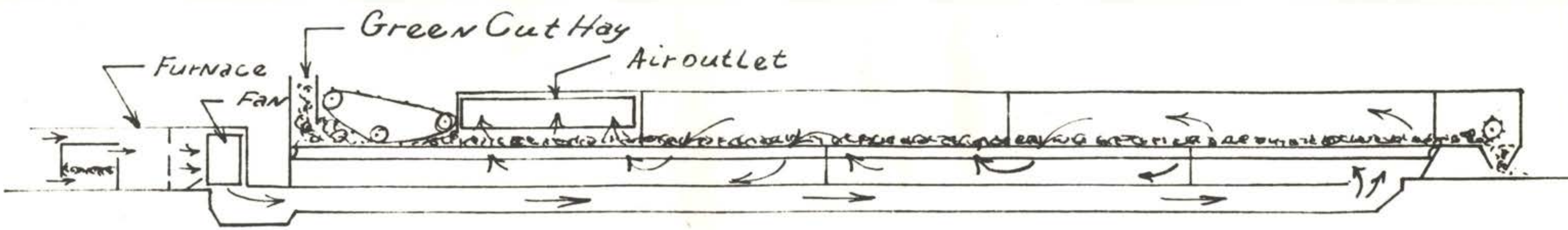

Fig. 1. Interior arrangement of the Conveyor-type drier.

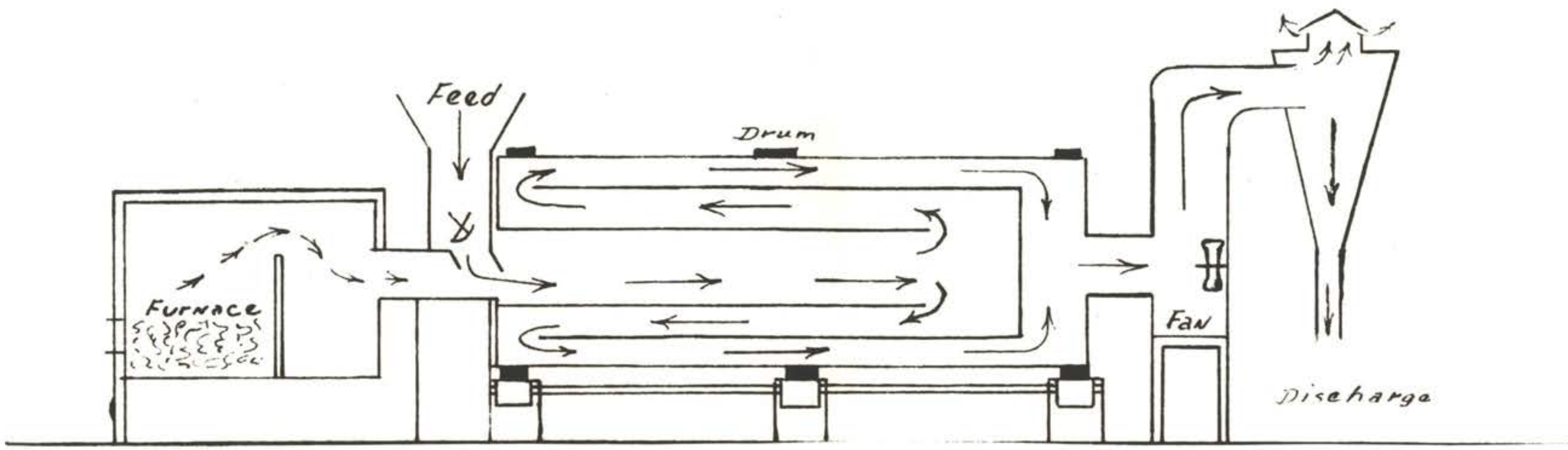

Fig. 2. Revolving-drum type of forage drier, triple-drum design.

COST AND PLANT REQUIREMENTS

Location

It is essential to locate dehydration units (1) adjacent to a railroad and (2) in an area where sufficient alfalfa is available.

By locating the unit and warehouse alongside a railroad, it is very convenient to unload drying equipment at the point where it is to be installed. Also, it is convenient to ship direct from the drier without requiring storage prior to shipment. The operator can eliminate extra handling of meal by having the sacking floor and the warehouse floor on a level with the railroad car floor. Buildings, including warehouses, should not only be planned for convenience, but also be well constructed with fireproof material, since fire is a constant hazard when dust accumulates. Smoldering meal, started by burning forage or a spark from metal, has caused fires several days after the material was stored.

Some locations may be objectionable to nearby residents, because of the odor and dust given off when the plant is in operation.

Also, since it is essential to avoid long hauls, the plant should be located in an area where a sufficient amount of hay is grown. Approximately 1,000 to 1,600 acres are required. A dry or wet season will have an important bearing on the acreage. In dry years a much larger acreage will be required. Adjustments must be made to allow for cuttings retained by the farmer.

Adequate reserve field equipment must be available at all times, since breakdowns occur frequently. This is understandable considering that stationary and mobile equipment is in operation from 18 to 24 hours each day. A well-equipped repair and service shop is necessary to keep machinery in good condition.

Cost

In general, some of the best dehydration ovens will cost approximately $15,000. Mobile equipment such as trucks, trailers, field choppers, mowers, and tractors will cost in excess of $10,000. A good high-capacity set of grinders able to operate continuously will cost approximately $5,000. Dust collectors, which are a necessity, probably will cost $5,000 or more depending on the design desired. A total investment for bare necessities to properly construct and install a complete drum type dehydration unit would be approximately $50,000. Most plants, installed and with all necessary equipment purchased, will cost from $30,000 to $75,000.

Although the equipment for dehydration is expensive, as a rule the best obtainable is the cheapest. This is obvious since efficiency depends upon quality and total production. If any part fails during operation or does not have sufficient capacity, the entire plant is affected.

The following outline shows the requirements and approximate cost of a typical alfalfa dehydration mill. (Acknowledgment is made to the Arnold Drier Company for most of this information.)

Operating Costs

Total Costs - Dry ton basis Approximately____$30.00

Fuel - 9,000 cubic feet natural gas: 1,000 B.T.U./cubic feet
65 gallons fuel oil: 148,000 B.T.U./cubic feet.
0.25¢ per 1,000 cu. ft.______________________________ 2.25

Power- 2,900 cubic feet natural gas: 1,000 B.T.U./cubic feet
254 Elec. h.p. 746 watts = 1 h.p.
1 kilowatt = 1,000 watts
254 h.p. = 189 kilowatt
189 kilowatt at .02 = ______________ 3.78

Bags 20-100# alfalfa meal bags ______________________________ 2.00

Labor-	1 Operation for plant	.75
	1 Tractor driver for harvester	.75
	1 Man leveling load on trailer	.75
	2 Truck drivers bringing alfalfa to drier	1.50
	1 Man feeding cutter	.75
	1 Man sacking meal	.75
	2 Warehouse men	1.50

Miscellaneous - Gasoline, oil, lubrication, insurance depreciation,
repairs, etc.____$ 3.00

Initial Cost of Equipment

Field Equipment

2 Field harvesters @ $1,275.	$ 2,550.00
2 Tractors @ $944.	1,888.00
5 4-Wheel trailers @ $199.	995.00
5 Trailer bodies @ $200.	1,000.00
3 $1\frac{1}{2}$ ton pick-up trucks @ $1,110.	3,330.00

Drying Equipment

2 Cutters	
1 Dryer $12,000.	22,500.00
2 Hammermills	
2 Sifters	

Miscellaneous

Freight	$ 700.00
Unloading - Installation	800.00
Firebrick for furnace	450.00
Installation of firebrick	125.00
Foundation & building for drier	3,500.00
Warehouse	3,500.00
Electric Wiring, etc.	1,500.00
Fuel oil tank	900.00
Total	43,738.00

Fuel And Power Requirements

Fuel - Fuel Oil - Approx. 60-65 gallons per hour base on
140,000-148,000 B.T.U. per gallon.
Natural Gas - approx. 9,000 cubic feet per hour based on
1,000 B.T.U. per cubic feet
Coal - Approx. 900 to 1,000 pounds per hour.

Power - Electric - 25 h.p. for the chopper
40 h.p. for the drier
125 h.p. for the breakdown hammermill
100 h.p. for the regrind hammermill
2 h.p. for sifter

Natural Gas -340 cubic feet per hour for chopper engine
440 cubic feet per hour for drier engine
1220 cubic feet per hour for breakdown hammermill engine
900 cubic feet per hour for regrind hammermill engine

The following information was taken from a preliminary report on commercial dehydration of livestock feed. This report was prepared by the personnel of the industrial division of the Georgia Power Company at Atlanta, Georgia.

Capital Investment:

Real Estate for plant site (2 acres @ $100 per acre)	$ 200.00	
Cleaver - Brooks dehydrator	19,000.00	
Freight on equipment	700.00	
Foundations for equipment	2,000.00	
Unloading and installing	700.00	
Power Wiring and water supply	1,500.00	
Frame shed over dehydrator and warehouse	2,000.00	
	$26,100.00	$ 26,100.00

Field Equipment:

2 Tractors @ $1,200	$ 2,400.00	
1 Tractor @ $800	800.00	
6 4-Wheel trailers, with bodies	900.00	
2 Mowing attachments	300.00	
1 Hay chopper with drive	1,000.00	
2 Hay pickups	650.00	
	$ 6,050.00	$ 6,050.00
		$ 32,150.00
Miscellaneous 10%		3,215.00
Total Investment		$ 35,365.00

Based on processing 3500 tons dry product per year - 234 days operation.
(When plant does harvesting and hauling)

Operating Expenses:

Labor - two 8-hour shifts - Plant 8 men
Field 8 men
Total 16 men

12 men at $5 per day and 4 men at $6 per day	$ 19,656.00	
Fuel 3500 tons @ $2 per ton	7,000.00	
Electric Power - 3500 tons @ $1.25 per ton	4,375.00	
Bagging - 3500 tons @ $2.70 per ton	9,450.00	
Water and repairs - 3500 tons @ 25¢ per ton	875.00	
Total	$ 41,356.00	$ 41,356.00
Per Ton	11.80	

Fixed Expenses:

Labor - 1 Supervisor	$ 3,600.00	
Interest on $35,365 @ 5%	1,768.00	
Depreciation $26,100 @ 10%	2,610.00	
Depreciation $ 6,050 @ 20%	1,210.00	
Taxes - 3% on $10,000	300.00	
Insurance 4% on $20,000	800.00	
Total	$ 10,288.00	$10,288.00
Per Ton	2.95	
Total Expenses		$51,644.00
Total cost per ton	$ 14.75	

If bagging is omitted, deduct $2.70 per ton.

When farmer harvests and hauls green product to plant. (Based on processing 3500 tons dry product per year; 234 days operation.)

Operating Expenses:

Labor - Two 8 hour shifts at plant; 8 men 2 men @ $6 per day and 6 men @ $5 per day	$ 9,828.00	
Fuel - 3500 tons @ $1.50 per ton	5,250.00	
Electric Power - 3500 tons @ $1.50	5,250.00	
Bagging - 3500 tons @ $2.70	9,450.00	
Water and Repairs - 3500 tons @ 25¢	875.00	
	$ 30,653.00	$30,653.00
Per ton	8.75	

Fixed Expenses:

Labor - Supervisor	$ 3,600.00	
Interest on $35,365 @ 5%	1,768.00	
Depreciation $26,100 @ 10%	2,610.00	
Taxes 3% on $8,000	240.00	
Insurance 4% on $20,000	800.00	
	$ 9,018.00	$ 9,018.00
Per ton	2.57	
		$39,317.00
Total cost per ton	$ 11.32	

If bagging is omitted, deduct $2.70 per ton.

MANAGEMENT AND OPERATIONAL PROCEDURE

Plants may be owned and managed several different ways. The owner of a dehydrating unit might be a private individual whose profit would come from the fee that he would charge farmers on a per-ton basis. The farmer would retain the meal for feed or sell it on the market. A farmer who operates on a large scale might purchase a plant to process the hay and other forages grown on his own acreage. The processed feed would be fed to his own livestock or sold on the open market. A farmers' co-operative might purchase a machine to dehydrate the products grown by its members. A milling company might install a dehydrator and purchase hay and other forages from local farmers. The company could dehydrate such products and sell them on the open market or incorporate them into their mixed feed.

The conventional type driers of a common size ordinarily produce 2,000 tons of alfalfa meal during a four-month season. On the basis of three or four cuttings, it will be necessary for the operator to have access to 1,000 to 1,600 acres of alfalfa in order that a sufficient amount of green hay will be supplied. A plant of this type, which has a production output of three-quarters of a ton per hour, 20 hours a day, would produce from 1,500 to 2,000 tons of dried hay in 100 to 120 days, which would be a normal season.

Normally, dehydration plants are operated on two 8 or 10 hour shifts during the haying season to produce the largest possible output per unit of investment. Almost all companies in Oklahoma have their own facilities for handling the entire crop. The acreage is leased prior to harvest and the contractors take the responsibility of the entire crop. The producer is paid on dry weight basis. It is necessary that the contractor schedule cutting and other field work to provide a constant supply of forage at the dehydrator. Weather conditions causing impassable roads, soggy fields, and other contingencies account for a number of undesired shutdowns.

It is the desire of the plant operator to cut the alfalfa in the pre-bud stage, as it has the highest percentage nutritional content at that stage and a higher leaf content is obtained. Modern field equipment should be used so that the material is elevated from the mower direct to a trailer and transported at once to the drier for processing. Another method might be used; that is to cut the hay in the field and haul it in loose and then chop it with a stationary chopper which is set up alongside the dehydrating unit.

In most of the modern plants it is necessary that the hay be chopped into a desirable length, which varies from one-fourth inch to one and one-half inches. For most drum type driers, hay chopped to a one-fourth inch length is desired.

The green hay is elevated directly from the chopper to the feed hopper near the top of the drum, just in front of the furnace. The furnace gases, plus a small amount of excess air, are led into the inner drum (in the case of a triple rotary drum) together with the hay cut to one-fourth inch. The hay and gases pass through the inner drum, back through the second, and through the outer drum to the exhaust fan, directly into a collector where the moisture-laden air escapes to the atmosphere. After the dried material cools, foreign material, such as metal or stone should be removed by a special device before the hay enters the hammermill. The hay may be transferred to storage or hammer-milled into meal and sacked. The "rejects", or material that does not pass through a 3/64 screen, is reground in a second hammermill and screened to second and third grade meal. To obtain leaf meal, it is necessary to pass this material over a sifter to separate the stems from the leaves.

Ordinarily, baled hay can be stored with 25 percent moisture or less. When finely chopped hay or meal is stored in sack or bulk the air circulation is reduced and to avoid spoilage in storage the moisture content must be reduced to 12 percent or less.

Several precautions are necessary to obtain fair speed of drying and to secure quality, fuel economy, and thermal efficiency above 60 percent. Bechdel, Clyde, Cramer and Williams (4), experimenting with a rotary-drum, high-temperature drier, obtained the best results by adjusting the burner for full fire. A temperature of 1,450° to 1,500° F. was necessary to evaporate one ton of water per hour. Evaporation prevented the hay from reaching any such temperature. Feeding to full capacity was necessary to utilize the full capacity of the furnace. It was found very important to dry the material properly, since over-drying destroyed quality and under-drying caused the material to change color in storage and a musty odor developed. It also is important, these authors report, to avoid excessive speed of gases in the drier; the operator could obtain this control by regulating the speed of the exhaust fan. In this experiment, best results were obtained when the exhaust fan was operated a little below 1,100 revolutions per minute instead of 1,350 recommended by the manufacturer. The air current was still sufficient to move hay steadily through the drier.

To reduce the cost of handling and the cost of dehydrating a ton of alfalfa with fuel oil, Bechdel, Clyde, Cramer and Williams (4) believe field wilting should be investigated more extensively. Freshly cut alfalfa usually has 75 percent moisture or more. Seventy-five percent moisture requires the removal of 5,240 pounds of water at the drier to produce one ton of hay having 10 percent moisture. If the crop is allowed to dry to 60 percent moisture in the field, the drier must then remove only 2,500 pounds of water, or less than half as much as in the case of the freshly cut hay. With this reduction in moisture the cost of dehydration is cut in half as shown in Table 4.

Table 4. -- Results in dehydration of freshly cut alfalfa and alfalfa wilted in the field.

	Alfalfa freshly cut	Alfalfa wilted
Moisture as received, percent	74.5	59.5
Thermal efficiency of drier, percent	58.9	58.2
Fuel oil per ton of dried hay, gallons	64.8	31.6
Time required per ton dried hay, minutes	176.	87.

These authors report there seemed to be little loss in feeding value after a few hours of field drying. Probably the moisture could go below 60 percent before the loss of value in the hay would approach the large saving in processing. However, the crushing of hay did not lower the cost of dehydration, although it aided field curing immensely and might be valuable in connection with artificial drying.

Green alfalfa hay that contains 75 to 80 percent moisture requires much expense in handling. The bulky forage contains an excessive amount of water which requires extra trips to be made in hauling the product to the dehydrators. If alfalfa hay is allowed to wilt in the field to 60 percent moisture or less, the total weight is reduced considerably. (Table 5).

Table 5. -- The approximate weight of hay to be handled at various moisture contents.

Moisture Content %	Green weight plus moisture	Pounds of water to be removed	One ton of hay 10% Moisture
85	12,000	10,000	2,000
80	9,000	7,000	2,000
75	7,240	5,240	2,000
70	6,000	4,000	2,000
65	5,140	3,140	2,000
60	4,500	2,500	2,000
55	4,000	2,000	2,000
50	3,600	1,600	2,000
45	3,200	1,200	2,000
40	3,000	1,000	2,000

The weight of green material to be handled is an important factor. Strong sturdy equipment and good roads are necessary in transporting the heavy loads of hay. Dirt roads and soggy fields during rainy weather are also factors that should be considered.

DEHYDRATION ACTIVITIES IN OKLAHOMA

Several dehydration plants in Oklahoma were visited to determine the method of handling the hay, how the hay was purchased, and the cost of dehydration. The units and their location are shown in Table 6.

All of the plants visited have their own equipment to harvest and dehydrate the alfalfa hay. The hay is usually contracted from the farmer in the field, and the farmer is paid on dry weight basis depending on the quality of the hay. The quality is usually based on the protein content.

There is only one dehydration plant in Oklahoma that dehydrates alfalfa before it is chopped to short lengths. This unit is a conveyor type located at Pauls Valley, Oklahoma, which was owned and operated by the Pecos Valley Milling Company for over 10 years.

Most of the dehydration units in Oklahoma are the drum type and are used to dehydrate alfalfa hay after it is harvested and the material has been cut or chopped. Most of the units are used to dehydrate both green alfalfa and sun-cured hay. Few or no advantages are gained in the dehydration of sun-cured alfalfa hay.

Table 7 gives the average price received by farmers for loose alfalfa hay by years as reported by K. D. Blood, Agricultural Statistician in Charge, Bureau of Agricultural Economics, U. S. D. A., Oklahoma City, Oklahoma. Prices received by farmers for baled-hay, sun-cured alfalfa meal or dehydrated alfalfa meal were not available. Prices in Oklahoma, as elsewhere, vary with the quality and supply of hay. Weather condition is the main factor causing the supply to vary.

Table 6. — Location of Alfalfa Dehydration Plants in Oklahoma.

Name of County	Name and Location of plant	Manufacturer's of Equipment	Type of Dehydrator
Alfalfa	Waldo Alfalfa Milling Company Cherokee, Oklahoma (Two units)	Heil Company Milwaukee, Wisconsin	Drum
	Ingersoll Alfalfa Mill Ingersoll, Oklahoma	A. Edward Smith 818 Midwest Building Oklahoma City, Oklahoma	Drum
	Schoeb Alfalfa Milling Company near Burlington, Oklahoma	Heil Company Milwaukee, Wisconsin	Drum
Blaine	Greenfield Alfalfa Mill Greenfield, Oklahoma	A. Edward Smith 818 Midwest Building Oklahoma City, Oklahoma	Drum
Caddo	Anadarko Alfalfa Mill Anadarko, Oklahoma	A. Edward Smith 818 Midwest Building Oklahoma City, Oklahoma	Drum
Canadian	Waldo Alfalfa Milling Company El Reno, Oklahoma	Heil Company Milwaukee, Wisconsin	Drum
Cleveland	Alfalfa Dehydrating Mill Moore, Oklahoma	Borden Steel Company Oklahoma City, Oklahoma	Drum
Garvin	Pecos Valley Alfalfa Milling Co. Pauls Valley, Oklahoma		Conveyor
	Lindsey Alfalfa Mill Lindsey, Oklahoma	A. Edward Smith 818 Midwest Building Oklahoma City, Oklahoma	Drum
Grady	Alfalfa Mill Verdon, Oklahoma	A. Edward Smith 818 Midwest Building Oklahoma City, Oklahoma	Drum
Grant	Tonkawa Dehydrating and Product Company Lamont, Oklahoma	Heil Company Milwaukee, Wisconsin	Drum
	Consumers Cooperative Pond Creek, Oklahoma	Howard Company	Drum
Kay	Elk Valley Dehydration Mill Tonkawa, Oklahoma (North of Tonkawa)	Howard Company	Drum

Table 6. (Continued)

	Chickasha Valley Mill Sumpter, Oklahoma (North of Blackwell)	A. Edward Smith 818 Midwest Building Oklahoma City, Oklahoma	Drum
	Tonkawa Dehydrating and Products Company Tonkawa, Oklahoma	Heil Company Milwaukee, Wisconsin	Drum
Kingfisher	Hennessey Alfalfa Mill Hennessey, Oklahoma	Cleaver-Brook Milwaukee 9, Wisconsin	Drum
Muskogee	Coal Grain Company South Cherokee Muskogee, Oklahoma	Heil Company Milwaukee, Wisconsin	Drum
Osage	Fairfax Mill Fairfax, Oklahoma	McGehee Company Board of Trade Building Kansas City 6, Missouri	Drum
Payne	Agronomy Farm Near Perkins, Oklahoma	J. B. Beaird Company, Inc.	Drum
Pottawatomie	W.J. Small and Company Shawnee, Oklahoma	W. J. Small Mfg. Co. Neodosha, Kansas	Drum
Sequoyah	Lee Kelly Dehydrating Mill West Fort Smith, Arkansas and Moffet, Oklahoma		Drum
Wagoner	Choska Alfalfa Mill Coweta, Oklahoma (9 miles south)	Heil Dryer Milwaukee, Wisconsin	Drum
Washington	W. A. Kent Alfalfa Mill Dewey, Oklahoma	Heil Dryer Milwaukee, Wisconsin	Drum

Table 7. -- The Season Average Price Received for Alfalfa Hay by Farmers from 1935 to 1947, inclusive.

YEAR	SEASON AVERAGE PRICE
1935	$ 10.60
1936	16.20
1937	13.20
1938	9.10
1939	11.00
1940	8.60
1941	8.90
1942	11.10
1943	19.50
1944	16.60
1945	16.70
1946	Not Available
1947	Not Available

Most of the owners of the dehydrating plants believe that the cost of hay plus the costs of dehydration in 1947 actually ranged from $35 to $45 per ton. The market for the finished product has ranged between $30 and $70 per ton in 1945, 1946, and 1947. Price is determined by the quality and demand.

Table 8 shows the production and the average wholesale price received for sun-cured and dehydrated alfalfa meal for the years from 1943 through 1947, inclusive. This report was released June, 1947, by the U. S. Department of Agriculture, Production and Marketing Administration, Grain Branch, Washington 25, D. C.

Table 8. — Tons of Sun-cured and Dehydrated Meal Produced in the United States and the Average Wholesale Price for Sun-cured and Dehydrated Meal in Dollars per ton, bagged at Kansas City.

Date	Sun-cured meal		Dehydrated meal 17% Protein		Sun-cured meal 20% Protein	
	Tons	Average wholesale price per ton, finely ground	Tons	Average wholesale price per ton	Tons	Average Wholesale price per ton
1943-44	421,600	$ 39.50	245,400	$ 55.15	Not	$ 51.58
1944-45	491,100	43.65	377,100	60.30	Avail-	56.62
1945-46	604,600	44.05	497,100	60.40	able	56.33
1946-47	481,500	43.35	563,500	59.30		55.33

(Source) Report released June, 1947 by the U. S. D. A. Production and Marketing Administration, Grain Branch, Washington, D. C.

There have been a large number of forage dehydration plants placed in operation the past two years in the United States. As the number increases, competition will become greater and the market for the final product will probably decrease.

The bulk of the alfalfa that is dried is made into meal. The chief markets for alfalfa meal at present are the manufacturers of mixed feed. During the period from June, 1945, to May, 1946, about 1,100,000 tons of alfalfa meal were produced, of which about 45 percent were from dehydrated meal. It was estimated that 1,300,000 tons of alfalfa meal were produced from June, 1946 to May, 1947. The average output of alfalfa meal before the war was about 300,000 to 400,000 tons per year.

Individuals who are interested in establishing dehydration units in Oklahoma are concerned with the return on their investment. It is estimated that an average season for the dehydrating of alfalfa in Oklahoma would be approximately 120 to 200 days. The production for the average unit in Oklahoma is approximately 2,000 tons of alfalfa meal per season. Table 9 indicates what the return on the investment would be at various margins of profit, at different market levels.

Table 9. — The Return on Investment for Processing 2,000 tons of alfalfa at various margins of profit at different market levels.

Percent Profit on 2,000 Tons	Market Price	Dollar Profit	Return on Investment
4%	$ 30.00	$ 2,400.00	6.8%
8	"	4,800.00	13.6
10	"	6,000.00	17.
15	"	9,000.00	25.4
20	"	12,000.00	33.9
25	"	15,000.00	42.4
4%	40.00	3,200.00	9.
8	"	6,400.00	18.
10	"	8,000.00	22.6
15	"	12,000.00	33.9
20	"	16,000.00	45.2
25	"	20,000.00	56.5
4	50.00	4,000.00	11.3
8	"	8,000.00	22.6
10	"	10,000.00	28.2
15	"	15,000.00	42.
20	"	20,000.00	56.5
25	"	25,000.00	70.7
4	60.00	4,800.00	13.6
8	"	9,600.00	27.1
10	"	12,000.00	33.9
15	"	18,000.00	50.9
20	"	24,000.00	67.9
25	"	30,000.00	84.8
4	70.00	5,600.00	15.8
8	"	11,200.00	31.7
10	"	14,000.00	39.6
15	"	21,000.00	59.4
20	"	28,000.00	79.2
25	"	35,000.00	99.

The market price for dehydrated feeds in the future will doubtless range between a low of $30 to a high of $70 per dry ton. The market price the last few years has ranged from $50 to $72 per dry ton. A net profit of 10 percent on the prevailing market price of dehydrated meal should give a satisfactory return on the investment, and at the same time will leave enough margin of profit to the farm operator to interest him in having his green product processed.

FEEDING VALUE OF DEHYDRATED FORAGE AND ALFALFA MEAL

Dehydrated Forage

One of the main questions concerning dehydrated forage is, how does the machine-dried product compare with field-cured hay as feed? The fact that alfalfa as a dehydrated or sun-cured meal, is so widely used in the manufacture of mixed feeds shows that the high value of this crop in terms of animal nutrition is highly appreciated by both manufacturer and purchaser.

The feeding value of forage is influenced by a number of factors. Investigators are well aware that a very significant loss of carotene occurs in alfalfa when exposed in field curing or left in storage six to eight months. Little information is available concerning the deterioration of other qualities of alfalfa during storage. Carotene and some of the other factors that influence the feeding value are discussed in the following paragraphs.

It is evident that the nutritional value of hay is affected by a number of factors. In the grading of hay, the physical factors of quality included in addition to the hay class are: (a) stage of maturity when cut, (b) percentage of leaves, (c) percentage of green color, (d) percentage of foreign material, (e) condition as to soundness, (f) coarseness of stems, and (g) aroma. While these physical factors are related to, and generally go along with, the nutritional value of the hay, they can be used only as a general guide.

As hay plants advance toward maturity, the percentage of protein decreases while the percentage of fiber increases. There is a decline in the percentage of ash and its constituents. The trend and relative magnitude of these changes are presented in Table 10.

Table 10. — Effect of time of cutting upon the chemical composition of alfalfa hay (21).

Stage of Maturity	Protein Percent	Fat, Percent	N-free Extract Percent	Fiber, Percent	Ash Percent
Prebloom	21.98	2.93	38.72	25.13	11.24
Initial bloom	20.03	3.03	40.67	25.75	10.52
1/10 bloom	19.24	3.02	40.38	27.09	10.27
1/2 bloom	18.84	2.90	39.45	28.12	10.69
Full bloom	18.13	2.99	38.70	30.82	9.36
Seedstage	14.06	2.39	39.61	36.61	7.33

Similar results have been reported for Red clover, Alsike clover, and many other forage plants.

Nutritional value from a feeding point of view is best measured by the digestibility of the forage and its protein, carbohydrate, mineral and vitamin content.

Table 11, compiled from data by Morrison (25), shows a comparison of the nutrient composition of some of the most important hay grasses and legumes.

Table 11. — Average composition and digestible nutrients of some common forage crops for hay (25).

Forage Material	Protein	Fat	Fiber	N-free extract	Ash	Digest-ible protein percent	Total digest-ible nutrients percent
Alfalfa in bloom	14.0	2.0	30.3	35.8	8.3	9.9	49.7
Red Clover in bloom	12.6	3.6	26.2	39.6	6.2	7.2	53.4
Alsike in bloom	16.4	3.2	26.9	37.7	7.8	8.6	52.7
Timothy in bloom	6.2	2.6	30.3	44.8	4.8	3.2	48.0
Bromegrass	9.9	2.1	38.4	35.5	8.2	5.0	48.9
Oat hay	6.3	2.7	28.4	41.7	6.9	4.5	46.3

In general, the stage of growth or development of the herbage when cut and the method of curing have more influence upon the feeding value of the resulting hay than do the species or varieties of crops contained in the hay. The stage of growth has a very marked influence on the yield of hay and its nutritive composition. The palatability and digestibility of the forage is also greatly influenced by the time of cutting. The yield of most perennial herbage plants increases rapidly during the early stage of growth, is fairly constant during the flowering period, and declines thereafter. In the case of annual and biennial plants the decline following flowering is much less marked.

Feeding Tests

The following experimental tests were conducted at the Pennsylvania State College (4):

1. Dehydrated versus sun-cured oat and pea hay.
2. Dehydrated versus sun-cured oat hay.
3. Sun-cured versus dehydrated milled hay (Timothy and clover hay).
4. Silage versus dehydrated green corn.
5. Dehydrated versus sun-cured red clover.
6. Dehydrated versus sun-cured alfalfa for milk production.

It was reported (4) that in each of the six feeding tests, except number three, there was evidence of superior feeding value in the product that was dehydrated as compared with that of the same hay field-cured in the sun. The sun-cured hay was of excellent quality when cured without rain. The results obtained were significant.

In test number 3 of the experiments mentioned above, the results were contrary to the other tests. The twenty-four Holstein yearling heifers, twelve for each kind of hay, were fed for a period of 121 days. A concentrate ration low in carotene was chosen purposely to afford a real opportunity for the content of carotene in either hay to show up in the feeding test. The heifers on dehydrated hay made an average gain of 1,433 pounds, whereas the corresponding figure for those on sun-cured hay was 1,544 pounds. The unfavorable results probably were due to overheating of the hay and oxidation of the carotene to the extent that there was not enough vitamin A for best growth and well-being of the heifers. The protein content of the various dehydrated hays ranged from 2 to 2.2 percent higher than the corresponding sun-cured hay. However this difference alone was not enough to account for the superior quality indicated by the feeding test.

It was reported from the results obtained at the Pennsylvania State College that the most plausible explanation of the improved quality of artificially dehydrated hay was the higher carotene (mother substance of vitamin A) content.

Snell (34) also proved that both calves and steers gained faster on machine-dried soybean hay than on chopped soybean hay. A 10 percent gain was in favor of the machine-dried meal. The value of machine-dried soybean hay was 59 to 71 percent more than chopped soybean hay. Calves getting unchopped hay either consumed or wasted about 47 percent more hay than calves getting chopped hay. Machine-dried hay was more palatable than field cured hay and a 40 percent saving was in favor of the machine-dried product.

Research workers (24) at the western Washington Experimental Station fed chickens in two groups of 60 birds each a ration of dehydrated alfalfa in their mash for 336 days. Laying production averaged 68.2 percent, mortality was but 20.8 percent, and feed consumption totaled 79.43 pounds. An equal number of birds in the same experiment, getting dehydrated alfalfa in their mash plus succulent greens, averaged 65.6 percent laying production, 21.7 percent mortality, and consumed 83.19 pounds of feed. Another group, fed a ration of succulent greens and no dehydrated alfalfa in the mash, had 65.8 percent production, 21.7 mortality, and consumed 80.11 pounds of feed. Egg quality also was better with the ration of dehydrated alfalfa in the mash and no succulent greens, due to more uniform yolk color. High quality dehydrated alfalfa is a valuable addition to feed because it supplies carotene as a source of vitamin A and also contains vitamins of the B complex.

Newlander (27) substituted dried young grass for all of the concentrates in the rations of dairy cows and fed full amounts of hay and silage. This substitution of dried grass for the hay in the ration resulted in an increased milk flow. Camburn (7) fed machine-dried young grass to two groups of milch cows, together with two-thirds of the usual allowance of hay and silage, in comparison with grain and the usual allowance of hay and silage. The milk production, butter fat, and solids-not-fat produced by the two rations were essentially the same. On the basis of total digestible nutrients consumed, the machine-dried grass ration was at least equal to or possibly more efficient than the grain ration.

Feeding experiments at the Illinois Station (22) showed that a basal ration composed of ground yellow corn, wheat flour middlings, soybean meal, tankage, fish meal, fortified cod-liver, and minerals was nutritionally inadequate for weaned pigs that had been continuously in dry lot. The addition of alfalfa meal increased survival and proved to be the most adequate vitamin supplement fed. The pigs fed the basal ration had abnormal development of feet, legs and gaits; and also showed dermatitis and some loss of hair. The abnormalities were much more apparent before the pigs reached 75 pounds in weight. In one test, the six required B vitamins (B_1, B_2, niacin, pantothenic acid, B_6, and choline) were added in excess of the pigs' requirements to this basal diet. It was significant that the pigs fed alfalfa meal gained about as rapidly and were more nearly normal in thrift, feet, legs, gaits, and skin, than pigs fed the six B vitamins in the crystalline form. The alfalfa meal was apparently supplying material in addition to the B vitamins known to be required by pigs.

Chopping, chaffing, cutting, or grinding benefits hays (6) by reducing wastes and by increasing the amount of stems consumed. The coarse stemmed hays were benefited most. Soybean hay for dairy cattle was benefited as much as 20 percent by chopping, whereas chopping did not improve alfalfa hay for dairy or beef cows. Chopping hay for horses was unprofitable. Grinding had the disadvantage of making the feed dusty.

Chemical Analysis

Russell (30) reported that alfalfa dehydrated by the Mason drying process contained seven times as much vitamin A as hay from the same field cured under conditions that resulted in the loss of most of the color. The hay artificially dried contained only a small amount of the antirachitic vitamin. Drying alfalfa leaves in the sun without exposure to dew or rain increased the antirachitic value.

Hauge and Aitkenhead (15) found enzymes play an important role in the destruction of vitamin A. Mechanical drying with either hot fuel gases or hot air was equally effective in preserving the vitamin A content of alfalfa. High temperatures and sunshine were shown not to be destructive to vitamin A. Conditions favoring enzymatic activity lowered the vitamin A content of alfalfa. Hathaway, Davis, and Graves (12) found alfalfa hay dried in an Airdrier to have twice as much vitamin A as alfalfa hay cured in the field in shocks for eight days. Machine drying tended to preserve the vitamin E content to a greater degree than field curing. These authors reported that the dry matter, calcium and phosphorus of artificially-dried alfalfa hay was as available as that of field cured hay or hay partly dried in the field and dried in the machine drier. The high temperature, from 480°C. to 535°C., for forty seconds to which hay was submitted in the drying process apparently did not affect the digestibility of the nutrients studied.

Smith and Briggs (33) of the Arizona Experiment Station cured alfalfa in the dark and spread it out in the field for varying lengths of time. As compared with that cured in the dark, alfalfa hay spread out for two and three-fourths hours in the sun lost from 20 to 33 percent more of the vitamin A content. Alfalfa left on the field over night had lost 75 percent of its vitamin A.

Alfalfa left in the field from 11:15 A. M. to 12:00 Noon the next day had lost 84 percent of its vitamin A. The alfalfa cured in the dark was deficient in vitamin D, but that exposed to the sunlight from 11:15 A. M. one day until 12:00 Noon the next day had mild calcifying powers.

A series of studies (4) revealed that dehydrated alfalfa produced at the Pennsylvania State College possessed carotene ranging from 70 to 106 micrograms per gram, whereas the corresponding figures on sun-cured alfalfa from the same source ranged from 11 to 84. In these studies very little carotene was lost in storage during the winter months but it was reduced as much as 50 percent during the summer. Alfalfa hay, mow-burned as a result of high moisture, was found to contain only 1.3 micrograms of carotene per gram.

Some experimental work has been done on the value of the grass juice factor. E. B. Hart (14) of the Wisconsin station reported that this factor can be preserved by quick drying, as in the Heil drier. The grass juice factor in dehydrated forage may play an important role in the superior nutritional value.

Digestion Trials

Newlander and Jones (28) dried lawn clippings in a machine drier (Airdrier), and compared the digestibilities of these with fresh lawn clippings as feed to dairy cows. They state: "Digestion trials with dairy cows fed solely on artificially-dried young grass and on fresh green grass indicated that both are highly digestible and essentially equally digestible. On a basis of 90.17 percent dry matter, the total digestible nutrient contents of the dried grass was 64.37 percent, of the green grass 63.36 percent".

Digestion trials with cattle (6) showed rather conclusively that chaffing, cutting, or grinding of hays has little affect upon the digestibility of the nutrients. Some of these trials showed a depressing affect upon digestibility, probably due to the fact that a considerable portion of the finely ground material may find its way direct into the true stomach and hence may not be regurgitated for rumination. Henry and Morrison (25) quote Ladd as finding that cooking decreased the digestibility of the protein of corn meal, clover, and cottonseed meal.

Metabolism trials conducted by Snell (34) at the Louisiana Agricultural Experiment Station with steers which were fed machine-dried soybean forage and field cured soybean hay indicated that the machine drying apparently caused the hay to retain the protein, ether extract and nitrogen free extract, but caused a decrease in the crude fiber and ash of soybean hay. Although machine-dried hay was higher in crude protein than field-cured soybean hay, the nutritive value of its protein seemed slightly less than the nutritive value of the proteins of cut soybean hay. Machine drying reduced the digestibility of the crude fiber, but apparently had no affect on the digestibility or nutritive properties of the ether extract, the nitrogen free extract, or ash.

Alfalfa Meal

Commercial grades of alfalfa meal are based on the grades of hay from which they are made. Color, leafiness, soundness, and freedom from foreign material are important factors of the highest grades of commercial alfalfa hay and meal. Grading by the above factors is not enough when the nutritional values are considered.

Alfalfa meal may be a product from field cured or dehydrated alfalfa. The quality of the meal depends entirely on the hay used. If made from high quality hay, the meal will be a high protein feed which is used largely in the making of mixed feed.

Alfalfa leaf meal is defined by the association of American Feed Control Officials as the ground product consisting chiefly of leafy material separated from alfalfa hay. It is made by separating the leaves from the stems. It must be reasonably free from other crop plants and weeds and must not contain over 18 percent of crude fiber.

Early studies made by Steenbock and reported by Aries, Lester and Othmer (3) showed that carotenes are intimately related to vitamin A_1 and are therefore called pro-vitamin A. Certain forms of carotene are transformed to vitamin A in the human organism. Because of their highly unsaturated nature, carotenes are easily oxidized by atmospheric oxygen. Since carotenes are subject to oxidation, the keeping qualities are therefore limited. Taylor and Russell (35) determined the stability of carotenes in plant tissues, by storing chopped and artificially dried alfalfa hay in bags. After three months in storage (in the late summer) 50 percent of the carotenes originally present were lost. No further loss occurred during the winter, but an additional 25 percent was lost during the following summer season. The carotenes in a sample of ball-milled, artificially dried alfalfa hay, were preserved for a period of twenty months when the hay was stored in vacuo in the dark at 0 to 5°C.

Fraps and Kemmerer (19) reported the effect of storage on carotenoid constituents in alfalfa. A sample kept at 5 degrees Centigrade for 8 months lost 33 percent of the crude carotene. Another sample stored at 37 degrees Centigrade for the same length of time lost 78 percent carotene.

Some of the important vitamins and vitamin-like compounds known to be present (36) in alfalfa meal are:

Vitamin A: Dehydrated alfalfa meal is one of our richest sources of vitamin A among feedstuffs used in feeding poultry. The best grades contain about 60 times as much as new yellow corn.

Vitamin B_1 (or thiamin): Dehydrated alfalfa meal contains more vitamin B_1 than corn, milo, barley, or wheat, and almost as much as oats.

<u>Vitamin B_2 (or riboflavin)</u>: Dehydrated alfalfa meal is one of our richer sources of riboflavin. The best grades contain about as much as dried skim milk.

<u>Vitamin C (or ascorbic acid)</u>: Fresh alfalfa contains four times as much ascorbic acid as citrus juice. Dehydrated alfalfa meal is not so rich in ascorbic acid as is fresh alfalfa.

<u>Vitamin E (or alpha-tocopherol)</u>: Among the common feedstuffs, dehydrated alfalfa meal is one of our richest sources of alpha-tocopherol; it contains about one-fifth as much as an equal weight of wheat-germ oil.

<u>Vitamin K</u>: Dehydrated meal is an unusually rich source of vitamin K.

<u>Choline</u>: Dehydrated alfalfa meal contains as much or more choline as the common grains.

<u>Niacin</u>: Dehydrated alfalfa meal contains about as much niacin as barley and wheat and much more than any other grain cereal.

<u>Pantothenic acid</u>: Dehydrated meal is among the richer sources of pantothenic acid. It contains from three to five times as much as the common grains, somewhat more than dried skim milk, and about as much as dried buttermilk.

Dehydrated alfalfa meal contains many mineral elements, including calcium, phosphorus, magnesium, sodium, chlorine, potassium, sulphur, silicon, and many essential trace mineral elements; manganese, iodine, iron, copper, cobalt, and zinc. It contains more calcium than any of the other common feedstuffs of either plant or animal origin except soybean meal.

Titus reported (36) that in addition to supplying vitamins and minerals essential for normal nutrition, high quality alfalfa meal makes a worthwhile contribution to the total digestible nutrients and protein of the feed. It supplies from 30 to 40 percent as much total digestible nutrients, and from

35 to 70 percent more protein as the cereal grains. It also contains nearly as much arginine as dried skim milk, almost as much lysine as dried whey, nearly twice as much methionine and cystine as any of the cereal grains, and only slightly less tryptophane than dried skim milk or linseed meal.

Table 12 gives the percentage and composition of ash in different grades of alfalfa meal. The quantity of mineral elements in the tissue of plants is

Table 12. -- Ash content and composition of ash from alfalfa meal (5).

	Percent Ash	Pounds Per Ton
Leaf-meal	11.5	230
Standard meal	9.1	180
Stem meal	7.8	156
	Composition of Ash	
Potash K_2O	23.5%	54
Lime CaO	40.7	93.6
Soda Na_2O	1.7	3.9
Magnesia MgO	4.9	11.3
Phosphoric Acid P_2O5	8.5	19.5
Sulfuric Acid H_2SO_4	5.7	13.1
Silica Si_2O_3	9.5	21.8
Chlorine Cl	3.0	6.9

not uniform. Different species of plants and different organs of the same plant vary greatly in the content and composition of their mineral matter. The mineral elements are shown in the table as oxides, although in the original plant material these elements existed in other forms as organic and inorganic compounds of unknown composition.

Table 13 gives the average composition of the two grades of dehydrated alfalfa meal: standard meal, which contains 15 to 17 percent protein, and leaf meal, which contains 20 to 24 percent protein and less than 18 percent fiber (11).

Table 13. -- Composition of Alfalfa Meal.

	Dehydrated meal	
	Leaf meal	Standard meal (Leaf-stem)
Crude Protein	22.72%	15.72%
Nitrogen-free Extract	39.17	37.96
Crude Fiber	16.30	26.77
Crude Fat	2.86	1.99
Moisture	7.40	8.39
Crude Ash	11.55	9.17

A partial list of the minor constituents of alfalfa is shown in Table 14. Alfalfa seems to be an excellent source of these constituents, however, extraction method at present is a costly item. Griffith, Antonsom, Darwin, and Edmister (11) reported that if these minor constituents in alfalfa could be extracted and purified economically, their value at ten cents per gram would exceed several times the present market value of dehydrated alfalfa meal.

Table 14. -- A partial list of the minor constituents of alfalfa (11).

Fat Solubles	p.p.m.	Grams/Ton
Chlorophyll	3,000	2,700
Xanthophyll	425	382
Carotene	300	270
Phytol	1,000	900
Vitamin E	250	225
Sterols, waxes, fats		25,000
Water Solubles		
Vitamin C	Riboflavin	Thiamin
Choline	Pantothenic Acid	Niacin
Folic Acid	Amino Acids	

MEADOW MANAGEMENT

Proper meadow management for alfalfa is essential for the production of high quality hay.

Soil fertility is an important factor in meadow management for alfalfa production in Oklahoma. The fertility of the soil is a major factor in making alfalfa the excellent feed that it is for growing young animals.

Alfalfa acreage as well as the tonnage could be increased in central and eastern Oklahoma by proper soil management. The proportion of calcium declines as one goes from soils of the west to those in eastern Oklahoma where alfalfa is grown with difficulty. Not only is this true with legumes, but crops in general decline in calcium in this traverse from west to east. The contents of calcium, phosphorus, and potassium in soils go down, with the calcium content declining most rapidly. Normally, soils in eastern Oklahoma are deficient in the three elements mentioned; however, this condition can be corrected by the addition of limestone and commercial fertilizers. Soil tests should be made early enough so that one can apply the necessary fertilizers. With proper soil treatment, alfalfa will grow on well-drained soil that has sufficient calcium, phosphorus, and potassium for normal plant development. According to Albrecht (2), one of the controlling forces in determining whether legume crops like alfalfa are highly proteinaceous or more nearly only carbonaceous is the ratio of calcium to potassium in the soil.

The soil intended for alfalfa should not be contaminated with weeds and grasses. Better stands and meadows with less weed competition are usually obtained in Oklahoma from fall sowing. Where alfalfa is sown in the spring, weeds usually appear in abundance. Attempts to improve poor stands by reseeding generally have been unsuccessful. Normally, it is better to plow up unsatisfactory stands, grow a cultivated crop on the land for a year or two, and then reseed to alfalfa. It is difficult to produce a good crop of high-grade alfalfa hay on meadows with thin stands. Invariably such meadows are invaded by weeds and grass, and the hay produced is coarse and of low leaf percent. Alfalfa plants produced in a thin stand are relatively coarse, and the percentage of leaves is relatively low. For high quality alfalfa hay, meadows should be kept free of trash, grass, weeds, and old hay.

Dehydration contractors prefer to cut alfalfa in the prebud or bud stage. Stage of cutting has an important bearing on the longevity of the meadows and the quality of hay harvested. In most instances for dehydration of hay alfalfa should be cut when one-tenth to one-fourth in bloom, or when the growth starts from the crown irrespective of the bloom. Parker reported (29) that the grower will gain little if any increase in tonnage by allowing the crop to stand to maturity. He stated that in the early stage of maturity the leaves usually constitute 45 to 55 percent of the total weight of the plants, and the stem is not objectionably hard and woody. Usually the highest quality hay is obtained when it is cut in the pre-bud or bud stage. However the yearly tonnage is usually greater when the cutting is done at one-tenth to one-quarter bloom. A continuous practice of pre-bud and bud-stage cutting often weakens the vitality of the crowns and roots, shortens the life of the meadow, and causes an increase of grasses and weeds in the meadow. Alfalfa cut in full-bloom stage and pod-stage usually is much lower in the percentage of leaves and the stems are more woody than when harvested earlier. The carotene content is also much lower in alfalfa hay cut at late stages than in that which is harvested in earlier stages and cured properly.

Nelson (26) indicates that frequent cutting of alfalfa in premature stages results in depleted root-reserves. The yields of hay for a three year average from different stages of cutting were as follows:

Bud stage	1.8 Ton
1/10 bloom.	2.7 Ton
Full bloom.	3.5 Ton
Seed pod.	3.1 Ton

Depleted root reserve caused slow recovery of the plant growth after cutting, low yield of hay, increased weed infestations, and retarded root growth. Chemical analysis of alfalfa roots has shown that the nitrogen and carbohydrate reserves of the roots were decreased when the crop was cut early.

The results of experiments conducted over a period of eight years at Kansas by Salmon and Swanson (31) indicated an important relation of reserves to cutting treatment. They found that when alfalfa was cut at stages less mature than full bloom, the longevity of the stand and the yield were appreciably reduced. Plants cut at the full-bloom and seed pod stages were capable of maintaining themselves over a considerable period of years. Cutting at immature stages thinned the stand and lowered the yield. It was also pointed out that alfalfa should be cut when one-tenth to one-fourth of the crop is in bloom in order to produce good hay. Alfalfa that has put forth new shoots from the crown should be cut without regard to bloom. Alfalfa that is allowed to stand in the field until after full bloom loses many leaves and the stems become hard and woody, lowering the feeding value and the palability of the hay. This statement is supported by the results of experiments made at the Kansas Stage Experiment Station (31) in feeding steers, and reported below:

Time of Cutting	Feed Required to Produce 100 Pound Gain on Steers
Bud stage	1,628
1/10 bloom.	2,086
Full bloom.	2,163
Seed stage.	3,910

Albert (1) found that in the first year of cutting the largest yields of hay were obtained from plants cut at one-tenth bloom and at flower bud stages. In the second year of cutting the largest yields of hay were obtained from plants cut at relatively mature or full bloom stages. Also cutting the top growth of plants at relatively immature stages retarded root development to a marked degree. The percentages of total nitrogen and reserve carbohydrates tended to be lower in roots of plants cut at immature stages, in contrast to the roots of plants cut at more mature stages. A high content of root reserves and the initiation of new root growth seem to be correlated with a relatively slow rate of top growth. Small amounts of late fall top growth have a pronounced influence on winter killing of the plants and slows down early spring growth. Also, Leukel, Graber, Nelson, and Albert (9) reported that cutting alfalfa plants frequently or immaturely late in the season caused a continuous reduction of the organic root reserve without its replenishment for subsequent growth, retarded the increase in the size and weight of roots, and decreases the vigor and production of the new top growth. The plants also go into winter dormancy low in organic root reserve and high in moisture, which may cause them to suffer severe winter injury.

Lower crude fiber and higher protein content of alfalfa hay have been correlated closely with the percentage of leaves. In a recent investigation at the Nebraska Station (37) it was found that plants differ remarkably in leafiness even though in the same stage of growth. In one test, in which the leaves were removed from the stem, dried, and weighed; the leafiness varied from 40 to above 70 percent in different plants. In a test run in 1940, similar results were obtained. This study was made to determine the percentage of leaves at three different stages of cutting. The results obtained showed the percentage of leaves averaged 40.6 for the first cutting, 53.2 for the second, and 46.0 for the third. The total leaf percentage averaged from 43.3 to 49.3 percent. Some of the strains showed a uniformly high percentage of leaves for all cuttings, while others were uniformly low.

To help maintain a meadow free of weeds and grass and to protect the life of the stand, alfalfa should not be pastured until after the first year. It should never be pastured closely as grazing of the crowns often results in killing the plants. Cattle should never be allowed access to a field when the ground is wet or frozen.

If alfalfa is cultivated, a sharp cutting tool such as a disc should not be used because the disc has a tendency to split and destroy the crown. The spring tooth harrow or the alfalfa harrow, which is a modified form of the spring tooth, is the best type of implement to use, especially on fine textured soils. The spike tooth harrow does equally as well on coarser textured soils. The main object of this operation is to destroy weeds and grass early in the spring just before the alfalfa starts spring growth. While this procedure has been tested under controlled experiments, it is doubtful whether the practice will pay in areas where the meadow is used for hay. In the drier areas cultivation may increase the seed yield.

Cultivating alfalfa early in the spring is a common practice in western Oklahoma. A number of farmers in this area who practice renovating their alfalfa meadows early in the spring were contacted relative to their opinion of the practice. All were of the opinion that renovating alfalfa meadows early in the spring, at the proper time, destroyed a lot of winter annual grasses and weeds without injuring the meadow. They were of the opinion that the quality of hay was increased by following this practice.

PARTIAL LIST OF MANUFACTURERS OF DEHYDRATING UNITS

Dehydration drums can be purchased for various amounts. A one drum plant, if correctly constructed throughout, will require an investment of at least $30,000 for bare necessities including essential auxiliary equipment. Plants cost between $30,000 and $75,000 after they are finally established and fully equipped. The prices listed below for different units are subject to change. To this equipment must be added the harvesting implements, trucks, tractors, foundation, building to house the drier, warehouse, bulk fuel oil storage tanks, electric power, and firebrick for furnace.

Some of the manufacturers of dehydration units can furnish all auxiliary equipment necessary. Others can furnish the information in regard to the best type of equipment necessary for the unit.

The following is a partial list of manufacturers, together with some descriptive material from literature provided by the companies. The mention of these firms does not imply any particular endorsement.

Pneumatic Types

L. R. Christie Company
17 East 42nd Street
New York 17, N. Y.

The pneumatic unit manufactured by the Christie Company has a capacity of one and one-half dry tons per hour. The price of this unit is $9,750 f.o.b. Hagerstown, Maryland, complete with structural supports, driving motors, feed conveyors, automatic temperature controls, and oil burning apparatus.

This price does not include cost of field equipment, foundations or brick work for the combustion chamber, for which complete plans and specifications are furnished on receipt of an order. Drying costs depend principally on moisture conditions. Assuming 75 percent initial moisture, the fuel oil consumption is 60 gallons per ton of dry product, or its equivalent if another fuel is used. The company does not manufacture any of the auxiliaries necessary for field operations, such as chopping machinery, pulverizers, and bagging machinery.

The Formith Corporation
Wichita, Kansas

The Formith Airflow Dehydrator will produce 2,500 to 3,000 pounds of dry material per hour. The material travels approximately 274 linear feet through the unit, suspended in heated air. Materials are in contact with more than 30,000 cubic feet of heated air per minute. This long travel permits each particle sufficient time to give up its moisture to the surrounding air. The large volume of air is more than sufficient to absorb and carry away the moisture contained within the materials being dehydrated. The Formith Dehydrator has no moving parts. The process is simple in operation. The unit is self-contained and offers low operating temperatures, which should tend to preserve the vitamin and pigment properties of the alfalfa. The capacity of this unit is one and one-half to two tons of dry forage per hour.

This unit complete with burners, 440-volt electric motors for power, electric controls and other necessary equipment to make a complete installation sells at $18,500 f.o.b. factory at Wichita. This price does not include field equipment.

A Forster # 8 Heavy Duty Hammer Mill direct connected to a 150 h.p., 440-volt electric motor sells at $5,200 f.o.b. factory at Wichita.

O. W. Randolph Company
Toledo, Ohio

The Randolph Company manufactures two units, the Randolph Junior and the Randolph Senior. In the Junior model, the material to be dried is elevated to one end of the unit and passes through a feeder which is equipped with a metal trap to eliminate any metal from the material being dehydrated. From the feeder the material is forced into the dehydrator by a fan supplying hot air direct from the furnace. After entering the dehydrator, the material is picked up by a specially designed impeller which keeps the material in complete suspension as it passes from one section of the dehydrator to the other during the drying process.

The Randolph unit is capable of dehydrating one ton of meal per hour from freshly cut alfalfa hay with 75 percent moisture content. The furnace is equipped with a stoker for using soft coal. It may be fired with oil or gas if desired.

The Randolph Senior is of the same principle as that described for the Junior, except for a greater capacity which is obtained with a larger furnace and the addition of one section to the dehydrator body.

The writer was unable to obtain the cost for the dehydrators described above.

Rotary Drum Types

American Process Company
Lebanon, Pa.

The American Process Company manufactures a conventional type of direct heat, single-drum, rotary drier for drying hay. This unit is similar to the other rotary driers. The drum is encircled by heavy steel tires on which the drum is supported and rotated by rollers mounted on bases beneath. The cost of this unit could not be obtained.

Arnold Dryer Company
3000 W. Montana St.
Milwaukee 1, Wisconsin

The Airdrier, a stationary Model SD-8-24 alfalfa dehydrator, is manufactured by the Heil Company of which the Arnold Company is a subsidiary. This unit is a triple rotary drum type. The mixture of furnace gases and tempering air enters the drier at a temperature around 1400° F. and leaves, with the moisture, between 200° and 250° F. Three sizes of machines are made, having evaporating capacities of one, two, and three tons of water per hour.

In round figures a dehydrating plant completely equipped would amount to $21,000 f.o.b. Milwaukee, Wisconsin. The total price of necessary equipment will run between $50,000 and $80,000 depending upon the type of building erected, etc.

A portable dehydration unit, which is a rotary multipass direct fired drum type mounted on a rubber-tired steel frame chassis, is also manufactured by the Arnold Drier Company. The price of this unit is $7,500 f.o.b. Milwaukee, Wisconsin. This price does not include field equipment.

Cleaver-Brooks Company
Milwaukee 9, Wisconsin

Cleaver-Brooks Company manufactures a triple rotary drum type which has a capacity of approximately one ton of finished product per hour. Heat is applied to the drying drums by a direct fired Dutch oven type furnace. A special designed oil burner is used.

The capital investment, including real estate for plant site, a Cleaver-Brook dehydrator, freight on equipment, foundations for equipment, unloading and installing, power wiring and water supply, frame shed over dehydrator and warehouse, would be approximately $26,100. The price of field equipment is not included.

J. B. Beaird Company, Inc.
Shreveport, La.

The Model D-700 Challenger, manufactured by the Beaird Company, is a machine primarily designed for operation on forage crops. It is a compact unit, completely assembled on one steel skid, and includes all necessary motors, blowers, cooler, cyclone, and sacking devices which are necessary for operation on this type product.

Provided there is adequate electric power (220-volt, 3-phase, 60-cycle), the Model D-700 CHALLENGER Dehydrator, complete with electric drive and burner equipment for natural gas, butane or propane for processing alfalfa and other forage crops is priced at $5,634 f.o.b. Shreveport, Louisiana.

A fuel oil burner is available for $206 additional. In the absence of sufficient electric power, the machine may be equipped with an internal combustion engine at additional cost.

The above cost does not include the necessary equipment for field harvesting.

McGehee Company
Board of Trade Building
Kansas City 6, Missouri

The McGehee Company manufactures two sizes of drum dehydrators. The large one, P-1036, was the original piece of equipment and is for "professional users" such as feed mills or cooperative organizations. It has a very high capacity and requires a sizeable investment in auxiliary equipment such as field harvesters, trucks for transporting the green material to the plant, grinding, sacking, and storage facilities. The large plant sells for $22,839. The total investment for installation of the large plant would be close to $70,000. This would include the necessary equipment required for the operation of a dehydration plant.

The P-1036 was designed as a 12,000 pound evaporation (or a two-ton per hour) dehydrator. The company claims reports of three tons and more per-hour average for a long period of operation.

The P-828, which is a small plant, sells for $15,960 f.o.b. Kansas City, Missouri, with a total investment of approximately $40,000 for complete installation, which includes the necessary equipment required for operation of a dehydration plant.

General American Transportation Corporation
Louisville Drying Machinery Company Unit
National Theatre Bldg., 5th & Walnut St.
Louisville 2, Kentucky

This company can furnish a complete plant or the drier alone. The drier can use either gas or oil as a fuel. The interior construction is such that the drying gases are in contact with the hay at all times. This allows the use of low temperature gases which stands for high carotene content and low operating costs. The drier comes complete with combustion chamber, gas or oil burners (refractory for the combustion is not included), drier drive unit, exhaust fan with drive motor, ductwork, and cyclone.

This company manufactures plants with three different capacities, as follows: The small type, which is 54 inches in diameter and 40 feet long; the medium type, which is 6 feet in diameter and 60 feet long; and the large type, which is 8 feet in diameter and 60 feet long. (Prices are f.o.b. cars, Sharon, Pa.)

The small drier has a capacity of 800 to 1,200 pounds per hour of dry meal at about 10 percent moisture. The price on this size plant complete, using gas a fuel, is $16,475, or using oil is $17,680.

The medium size drier has a capacity of 1,800 to 2,500 pounds per hour of dry meal at about 10 percent moisture content. The price on this size plant complete, using gas as a fuel, is $21,900, or using oil is $23,100.

The large drier has a capacity of 3,000 to 4,000 pounds per hour of dry meal about 10 percent moisture. The price on this size plant complete, using gas as a fuel, is $28,940, or using oil is $29,940.

Prices quoted above do not include freight, unloading, rigging, foundations, building site, or field equipment. These items would amount to 30 or 40 percent of the total investment.

Conveyor Belt Types

Proctor & Swartz, Inc.
Seventh Street and Tabor Road
Philadelphia 20, Pa.

The Proctor & Swartz Company manufactures a conveyor belt drier which, when fully equipped, represents an investment between $50,000 to $100,000. H. G. Black, a representative of the Proctor & Swartz Company, reports that the company installed a number of conveyor type driers several years ago and that they operated very satisfactorily. However, their recent experience indicates that a rotary drum drier is considerably less expensive than the conveyor type drier.

Fuller Drier Company
Nazareth, Penn.

Conveyor-belt driers manufactured by Fuller Drier Company are made in capacities up to ten or twelve tons of dried material per hour. The cost of this equipment, complete and ready for operation, would be approximately $50,000 to $100,000.

Pellet Mills

Craig Espy
California Pellet Mills
2nd Unit Santa Fe Building
Dallas 2, Texas

Some interest has been devoted to pressing dehydrated meal into pellets. The California Pellet Mills have designed a machine for this purpose.

The California Pellet Mill Company makes two sizes of machines; the Master Model California Pellet Mill, the smaller machine in the California Line, and the heavy-duty California Pellet Mill.

The rated capacity of the Master Model California Pellet Mill is 30 to 40 bags an hour on 3/16 inch pellets, and somewhat greater capacity on larger sizes. Some users report an hourly capacity of 45 to 50 bags an hour in the larger sheep and cattle size pellets. Materials being pelleted, consistency of mash, and local operating conditions govern to a large extent the capacity of the machine.

The price of the California Master Model Pellet Mill equipped with feeder, mixer, 30 h.p. built-in open motor and open starter with push button ammeter unit for 3-phase, 60-cycle, 220/440 volt current is approximately $2,956.

The heavy-duty California Pellet Mill, furnished for 50 h.p. operation, has about twice the capacity of the master model. The rated capacity of this machine is 70 to 90 bags an hour in the 3/15 inch pellets, but higher capacity is possible, depending upon the above listed governing factors.

The price of the California heavy-duty Pellet Mill with a feeder, mixer, base, v-belt drive, motor base plate, of new construction including open gear-head drive for mixer and feeder with starter is approximately $5,548.

SUMMARY AND CONCLUSION

Interest in artificial dehydration of hay and other forage crops in Oklahoma has increased during the past few years. The Oklahoma Agricultural Experiment Station has received numerous inquiries concerning various phases of dehydration of forage crops. This paper reports a survey made to bring together information which could be used in answering inquiries.

Although dehydration of forage crops is relatively new in Oklahoma, it has been going on in the United States since about 1909. Experiments were first conducted in areas where hay-making was a tremendous gamble with the weather. Later these experiments spread elsewhere. Dehydration plants have been installed in the western irrigated areas where an abundance of alfalfa hay is produced. Before the dehydrator came into use, hay produced in this area was usually sold commercially in the bale.

In general the purpose of dehydration is to convert the raw material, at its best stage of growth, into the highest priced finished product and at the same time minimize the risk of crop loss at harvest time. When cut hay is exposed to the weather for a great length of time, important nutrients are lost.

The most common method of curing hay is by curing it in the sun. The disadvantage of this method is the uncertainty of the weather for curing. Overdrying in the field causes many of the leaves to shatter when the hay is handled. In order to retain a high carotene content and other valuable nutrients lost by leaching, hay should be removed from exposure to sunlight and weather as rapidly as possible. Several investigators report that green alfalfa contained twice the carotene content of dried alfalfa.

To overcome the difficulties in curing of hay and to produce a better product, new machinery has been developed to cure alfalfa and other forage by dehydrating the freshly cut hay in a current of heated air. This method eliminates the adverse effects of weather after cutting.

The three common types of dehydrators are (1) apron-conveyor, (2) drum and, (3) pneumatic. Principles of three dehydrators are described previously. There are many varieties of each type.

Location of the dehydrator is important. A dehydrator located near a railroad makes it convenient for shipping meal direct from the drier without requiring storage prior to shipment. The plant should be located in an area where a sufficient amount of hay is grown to avoid long hauls. Approximately 1,000 to 1,600 acres are usually required. The weather condition will have an important bearing on the acreage needed.

The cost of dehydration ovens will vary but may cost approximately $15,000. Field equipment such as trucks, trailers, field choppers, mowers and tractors will cost in excess of $10,000. Most plants installed and with all necessary equipment purchased will cost from $30,000 to $75,000. Dehydration equipment is expensive, but as a rule the best obtainable is the cheapest. Failure of equipment during the operating season is expensive.

Dehydrators may be owned and operated by private individuals or firms or by a group of farmers as a cooperative. The dehydrated meal may be utilized for private feeding or sold on the open market. The chief market for alfalfa meal at present is the mixed feed industry. During the period from June, 1945 to May, 1946 about 1,100,000 tons of alfalfa meal was made in the United States of which about 45 percent was from artificially dehydrated hay. Production of alfalfa meal for the same period in 1946 and 1947 was estimated at 1,300,000 tons. The average output of alfalfa meal before the war was about 300,000 to 400,000 tons per year.

Alfalfa hay for dehydration in Oklahoma is usually contracted for in the stand and the producer is paid on the dry weight basis. The owners of the dehydration plants prefer to do the harvesting since it is very important to provide a constant supply of forage at the dehydrator for maximum efficiency. Dehydration plants are usually operated day and night if weather and supply of forage permit, in order to produce the largest possible output per unit of investment.

The green forage may be dried whole or chopped to one-fourth inch to one and one-half inches in length, depending on the type of unit used. The green material is elevated to the drying chamber where it is mixed with furnace gases for dehydration. Although the dried material may be stored whole or in the chopped form, it is usually hammer-milled into a meal and sacked.

All of the plants visited in Oklahoma have their own equipment to harvest and dehydrate the alfalfa hay. The alfalfa hay is contracted from the producer and is paid for on dry basis depending on the quality. The quality is usually based on the protein content.

Most of the dehydrators in Oklahoma are the drum type and are used to dehydrate alfalfa hay after it is harvested and the material has been chopped. The type of units and the area where they are located are shown in Table 6.

Experiments with artificially dehydrated forage crops generally indicate that if directions are properly followed a feed of very good quality and high nutritive value will result. This process enables the producer to remove the hay from the field immediately, before any appreciable loss occurs. On the other hand, a number of experiments prove that if drying is done at extremely high temperatures it may have an adverse effect on the feed.

High quality alfalfa meal is an excellent feed and is especially valuable for swine and poultry. Poultry and swine consume only a small amount of roughage, which makes alfalfa meal economical to feed. The ruminant animals can utilize lower quality feed more economically since they require a large volume.

It has been pointed out by many experimenters that the feeding value of properly dehydrated alfalfa hay is superior to corresponding sun-cured hay even when the latter is cured under favorable conditions. When alfalfa is properly dehydrated it is a rich source of protein, calcium and vitamin A, and a fair source of phosphorus. For the production of high quality meal it is necessary that the unit used be designed and operated properly. Improper design or operation can destroy the quality of the product. For detailed information concerning cost installation and design of various units, it is suggested that the manufacturers be contacted. A partial list of dehydration manufacturers is given in the text.

Dehydration is a process to retain the maximum food nutrients. So, to obtain high quality dehydrated meal, the raw product must be of high quality. In order to produce high quality alfalfa hay, a good stand, free from trash, weeds and grass is necessary. The producer should keep in mind that repeatedly cutting alfalfa in the pre-bud or bud stage has a tendency to deplete the root reserve. This causes a very slow recovery and a reduction in yield. Removing the vegetative growth late in the summer before the root reserve has time to build up weakens the plant and makes it more susceptible to winter-killing. The plants are also slow to recover in the spring. The proper time to cut alfalfa, for maximum yield of good quality hay and to avoid the above mentioned factors, appears to be one-tenth to one-fourth bloomstage.

It is concluded from this study that dehydration units for drying alfalfa have a very limited use in the dry sections of Oklahoma except where irrigation is available. High quality alfalfa hay usually can be made by ordinary methods in this area. Furthermore, weather conditions normally are favorable for alfalfa seed production during late July, August and early September. Occasionally weather conditions in certain areas of Oklahoma cause serious damage to hay when it is cured in the field. In some instances the entire crop is lost and in many cases the value of the hay is reduced considerably. Under such conditions the dehydration unit may be profitable provided it is properly managed.

The large investment required for dehydration and field equipment limits its ownership to those who have access to a large capital. The cost of drying hay artificially is much higher than that of cutting it in the field and allowing it to field cure. The initial cost of a dehydration unit plus the fuel and power required to process a ton of hay has more or less limited the use of the unit. Also, keen competition with other proteinaceous feed is a factor.

It appears from this study that dehydrators are impractical for use on average farms in Oklahoma because the investment is large and the period for dehydration is short. When portable driers or smaller stationary units are proven satisfactory and supplied at a reasonable cost, alfalfa meal can be produced at much lower cost. In order for the operator to obtain the maximum profit, it will be necessary for him to have access to material to dehydrate most of the year.

Farmers in some sections of Oklahoma can, without dehydrating, produce high quality pea-green alfalfa hay which is in direct competition on the market with dehydrated alfalfa meal. Although the cost of drying is at present too high for dehydrated hay to compete with sun-cured hay in dairy feeding the dehydrated alfalfa, at a cost much higher than sun-cured alfalfa hay, is much in demand for poultry and swine rations.

In general the main cause for the slow development in artificial drying is the extremely high cost of equipment, the high cost of drying, and the fact that large driers are rather unadaptable to local farm condition.

It is the writer's opinion that if dehydration of alfalfa and other forage is to be profitable a low cost unit must be designed. Furthermore, the overhead might be reduced by using the unit to lower the moisture content of grain and other crops for proper storage. It is reasonable to assume that if dehydration were highly profitable dehydrators would be more widely distributed than they are in areas where hay-making is a gamble with the weather each season.

Those who are considering the possibility of installing a dehydration plant should give careful consideration to the investment involved, capacity of such a plant, the amount of hay available, and the possibility of operating the plant a sufficiently long period to justify the high overhead involved. The quality of product is a very important factor because buyers are not paying premium prices for an inferior quality meal. There is much difference in the quality of meal produced by the various dehydration mills. In Oklahoma the season for dehydration of alfalfa is very short; therefore consideration should be given to sweet potatoes and to other forages to extend the dehydration period.

It would not be wise to let a sales promoter sell a lot of machinery without making very careful investigation. Before planning too far ahead, it would be advisable to visit some other sections of the country where dehydrators are established and find out more about methods and problems involved in the dehydration of alfalfa hay. First hand information is very valuable.

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