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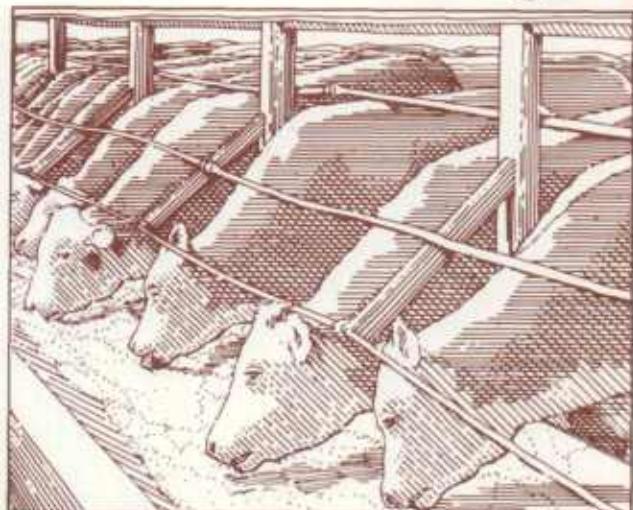
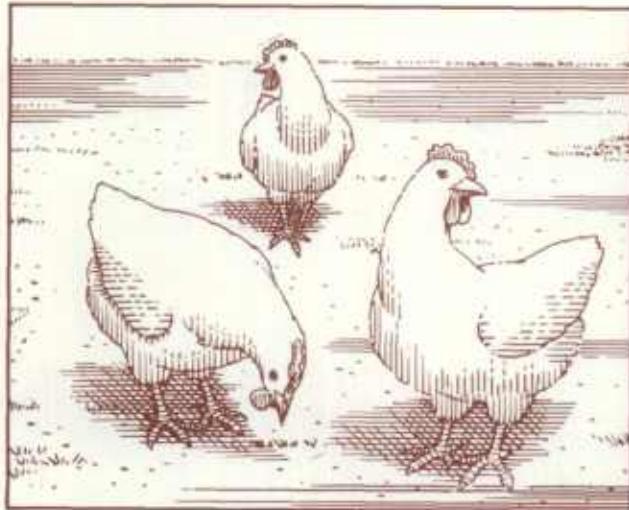
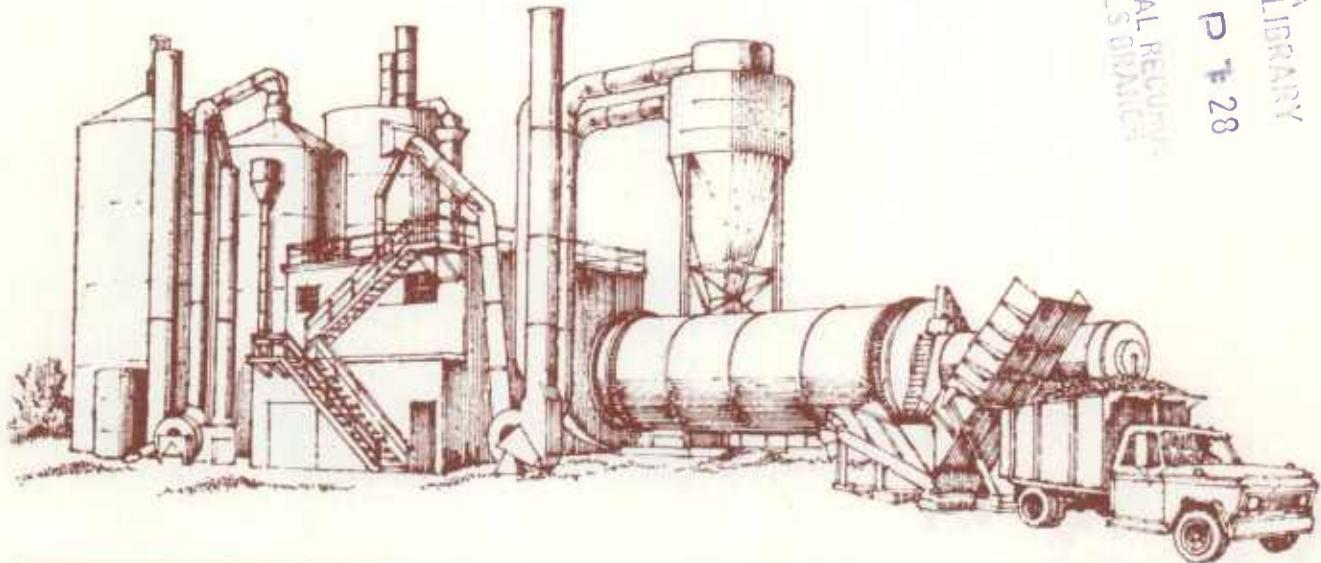
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# Producing Pro-Xan (Leaf Protein Concentrate) from Alfalfa:

## Economics of an Emerging Technology

Robert V. Enochian, George O. Kohler,  
Richard H. Edwards, Donald D. Kuzmicky,  
and Carl J. Vosloh, Jr.

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## ABSTRACT

Modifications in the process of separating alfalfa into a low-fiber leaf protein concentrate (Pro-Xan) and high-fiber press cake have increased Pro-Xan yields and reduced natural gas use. Since completion of a 1975 USDA economic evaluation of Pro-Xan processing, these modifications and changes in input prices have altered the returns on investment. This report updates the earlier study, reevaluating the economic effects of these input price changes and estimating the market potential for Pro-Xan in the United States.

KEYWORDS: Alfalfa, dehy, leaf protein, Pro-Xan, feed ingredients, poultry feeds, xanthophyll, feed prices, processing costs, energy savings, market potential.

This publication supersedes Leaf Protein Concentrate (Pro-Xan) from Alfalfa: An Economic Evaluation, AER-346, Sept. 1976.

## SUMMARY

Modifications in the process of separating alfalfa into a low-fiber leaf protein concentrate (Pro-Xan) and high-fiber press cake have increased Pro-Xan yields and reduced natural gas use. The process for wet fractionation of alfalfa into two components, developed by the Western Regional Research Center of the Science and Education Administration, U.S. Department of Agriculture (USDA), better utilizes nutrients than does the feeding of whole alfalfa.

The component that is high in protein and xanthophyll and low in fiber is suitable for feeding poultry and other nonruminants; the other component, which contains most of the fiber, may be fed to cattle and other ruminants. This process, called Pro-Xan, derives from the high Protein and Xanthophyll fraction.

Since completion of a 1975 USDA economic evaluation of Pro-Xan processing, changes in input prices and modifications in the engineering system have made potential returns on investment more favorable. The 1975 study evaluated the effects of different systems for producing Pro-Xan and the effect of several processing variables on annual returns on investment for "model" Pro-Xan plants. This report updates the earlier study, reevaluating the economic effects of input price changes and estimating the market potential for Pro-Xan in the United States.

In this study, we base estimates of the market value of Pro-Xan on three assumed levels of xanthophyll in Pro-Xan of 0, 450, and 765 mg. per pound. We estimate returns on investment for model Pro-Xan plants with Pro-Xan yields of 12, 15, and 18 percent, on a dry weight basis of the fresh alfalfa (green-chop) used in the process. We make initial estimates for plants operating 130 days per season with a capacity of 40-tons green-chop input per hour. Annual returns on investment for such a plant, with a xanthophyll content in the Pro-Xan of 450 mg. per pound, are estimated as 28.7, 37.0, and 45.4 percent before income taxes when yielding 12, 15, and 18 percent Pro-Xan, respectively. Subsequent changes in plant capacity, season length, and natural gas prices caused wide differences in the annual returns on investment. Each potential investor would have to evaluate the profitability of a projected Pro-Xan operation based on his own situation.

The modifications in the Pro-Xan process since the 1975 study include introduction of a waste heat evaporator. A new method for extracting the Pro-Xan containing green juice from the alfalfa is another modification. This method recovers more Pro-Xan than was possible with the systems analyzed in the 1975 study. Subsequent feeding trials with broilers and laying hens have shown that in poultry rations the xanthophyll in Pro-Xan is utilized 1.7 times more efficiently than the xanthophyll in dehydrated alfalfa. Finally, changes in

the prices of feed ingredients, equipment, utilities, and other inputs required for the Pro-Xan process have significantly affected returns on investment. Therefore, we have updated our earlier economic evaluation.

Some plants now producing dehydrated alfalfa may find it profitable to convert to Pro-Xan processing. The estimated return on the investment required to convert an alfalfa dehydration plant with an input capacity of 20 tons per hour was 42.8 percent when using 1976 prices for competing feed ingredients and 1977 costs for inputs. This assumes an operating schedule of 130 days per season and a 15-percent Pro-Xan yield.

The returns on investment in a Pro-Xan plant, or a dehy plant converted to Pro-Xan processing, are what the initial adopters of this new technology might expect. As more firms enter into Pro-Xan production, competition with other feed ingredients would tend to lower prices for Pro-Xan and, thus, the returns on investment might be lower than those indicated in this report.

The annual U.S. demand for Pro-Xan is estimated at 300,000 tons, provided only Pro-Xan were used to supply all supplemental xanthophyll required for broiler and laying hen rations.

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# PRODUCING PRO-XAN (LEAF PROTEIN CONCENTRATE) FROM ALFALFA

## Economics of an Emerging Technology

*Robert V. Enochian, George O. Kohler, Richard H. Edwards,  
Donald D. Kuzmicky, and Carl J. Vosloh, Jr.<sup>1/</sup>*

### INTRODUCTION

The separation of alfalfa into leaf protein concentrate and the remaining fibrous press cake results in a better utilization of alfalfa when these fractions are fed to different classes of livestock. The process for making this separation, developed at the Western Regional Research Center (WRRC), Science and Education Administration (SEA), U.S. Department of Agriculture (USDA), Albany, Calif., has been named the Pro-Xan process. The leaf protein concentrate is called Pro-Xan. An economic analysis of the Pro-Xan process made in 1975 estimated the annual returns on investment for different systems of extracting Pro-Xan in plants of different size, operating for different lengths of season (29). <sup>2/</sup> Since completion of that study, modifications in the process have resulted in greater yields of Pro-Xan with higher xanthophyll content and in reduced use of natural gas. Since the 1975 study, prices of equipment, utilities, and other inputs have increased, and the prices of competing feed ingredients have changed. Together, these changes affect the returns on investment in a Pro-Xan processing plant.

The purpose of this report is to update the earlier study by evaluating the economic impact of these changes. It will estimate the returns on investment for a Pro-Xan plant, two sizes of alfalfa dehydration (dehy) plants, and a dehy plant converted to a Pro-Xan plant. It will also include estimates of the market potential for Pro-Xan in the United States.

Alfalfa contains nutrients that are important in many kinds of livestock feeds. However, the alfalfa plant is not by nature a feed ingredient that both ruminant and nonruminant animals can utilize with equal efficiency. Rich in

<sup>1/</sup> Respectively: Agricultural Economist, National Economics Division (NED), Economics, Statistics, and Cooperatives Service (ESCS), Albany, Calif.; Research Leader, Western Regional Research Center (WRRC), Science and Education Administration (SEA), Albany, Calif.; Research Engineer, WRRC, SEA; Research Chemist, WRRC, SEA; Agricultural Economist, NED, ESCS, Washington, D.C. The authors appreciatively acknowledge the many helpful comments on earlier drafts of this report from Donald de Fremery and Joseph Chrisman, WRRC, SEA, and from William Arnold and Mel Vinci of the alfalfa dehydration industry.

<sup>2/</sup> Underscored numbers in parentheses refer to items listed in references.

protein and xanthophyll 3/, alfalfa also contains high levels of fiber. Most broiler and laying hen diets specify both protein and xanthophyll, and turkey and swine diets also require protein, but the use of alfalfa in such diets is restricted to low levels because these animals cannot digest fiber. Ruminant animals, on the other hand, can effectively utilize the fiber portion of the plant, and although protein is required in their diets, xanthophyll is not. Thus, when whole alfalfa is fed to ruminants, the xanthophyll is essentially wasted.

For many years, researchers have attempted to develop products from alfalfa and other forage crops that would improve the utilization of and increase the value of these crops. Initial work in this field was reported over 25 years ago, and numerous approaches and techniques for obtaining high-protein fractions (which also contain xanthophyll) from green leaves have been tried (23). WRRC has been active in this research and several years ago developed a process for air separation of dehydrated alfalfa (dehy) into high and low protein fractions. An economic evaluation of this process showed commercial possibilities (3, 31).

In recent years, processes for the wet extraction of leaf protein concentrate from alfalfa have been receiving considerable attention, and five or six plants both in the United States and abroad are now producing leaf protein concentrate from alfalfa. This process results in a better separation of the fiber from the high protein-high xanthophyll fraction than does the air separation process of dehy. In 1975, pilot plant data on material balances and processing variables served as a basis for an economic evaluation of the Pro-Xan process. That evaluation showed potentially favorable returns on capital investment (29).

Several developments since the 1975 study could affect returns on investment:

1. Process modifications make possible the extraction of up to 18 percent of the total solids in alfalfa, in the form of Pro-Xan, instead of only 12 percent as in the 1975 study 4/.
2. Process modifications have also resulted in a xanthophyll content of 450 mg. per pound of Pro-Xan rather than 350 mg. as in the 1975 study.
3. A waste-heat evaporator which saves on natural gas usage has been introduced into the process 5/.

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3/ Xanthophyll is a naturally occurring pigment present in several feed ingredients which, when ingested by chickens, results in yellow skin and yellow egg yolks.

4/ Pro-Xan yields of over 20 percent have been obtained in pilot plant operations, but 18 percent Pro-Xan yield is the maximum considered here.

5/ Waste heat evaporators have been used for a number of years for the concentration of liquids, especially orange juice (24). Recently a patent was issued to a French firm for concentration of alfalfa solubles by waste heat evaporation (4).

4. Broiler and layer feeding trials have shown that the xanthophyll in Pro-Xan is utilized 1.7 times more efficiently than is the xanthophyll in dehydrated alfalfa (20) 6/.
5. Changes in the prices of feed ingredients as well as increases in the prices of equipment, utilities, and other inputs have made Pro-Xan economically competitive.

The effect of these developments on return on investment has been presented in two unpublished speeches (10, 30), on which this report is partially based.

### The Pro-Xan Process

Although several possible variations exist, the basic Pro-Xan process starts with fresh alfalfa (green-chop) being fed into a machine which grinds or macerates it. Next, the ground alfalfa is pressed to separate a protein-rich green juice from the partially dewatered press cake. The Pro-Xan is extracted from this green juice by subsequent processing steps. To reduce the fiber content of Pro-Xan, a defibering screen removes fiber suspended in the green juice. The green juice is then heated by direct steam injection to 80° to 95°C to precipitate most of the protein. The chlorophyll, carotene, and xanthophyll present in the original juice remain complexed with, or attached to, the heat-precipitated protein. So that processing behavior is improved, the expressed green juice is ammoniated to a level of pH 8.0 to 8.5. This step reduces proteolytic activity, stabilizes the carotene and xanthophyll during processing, preserves the green color of the product, and increases the firmness of the Pro-Xan curd. Ammoniation also adds nonprotein nitrogen to the alfalfa solubles which remain after the Pro-Xan curd is removed from the green juice.

The heat-precipitated protein forms distinct curds which are separated from the alfalfa solubles by centrifugation, then granulated or extruded and dried in a hot-air drying system. The resulting product is called Pro-Xan or leaf protein concentrate. Other products from the process are the press cake fraction, containing most of the fiber, and the alfalfa solubles. A portion of the dilute alfalfa solubles is recycled to the green-chop to improve protein extraction. Research has shown that the alfalfa solubles have potential as an ingredient in liquid feed supplements. The composition of concentrated solubles and their potential uses are reported elsewhere (16, 22). For our purposes, we assumed that the solubles would be concentrated and added to the wet press cake which would then be dehydrated for feeding to ruminant animals. Figure 1 shows the system for producing Pro-Xan from alfalfa analyzed in this study. A more complete description of the Pro-Xan process appears in several other sources (5-9, 14, 15, 17).

### Study Procedure

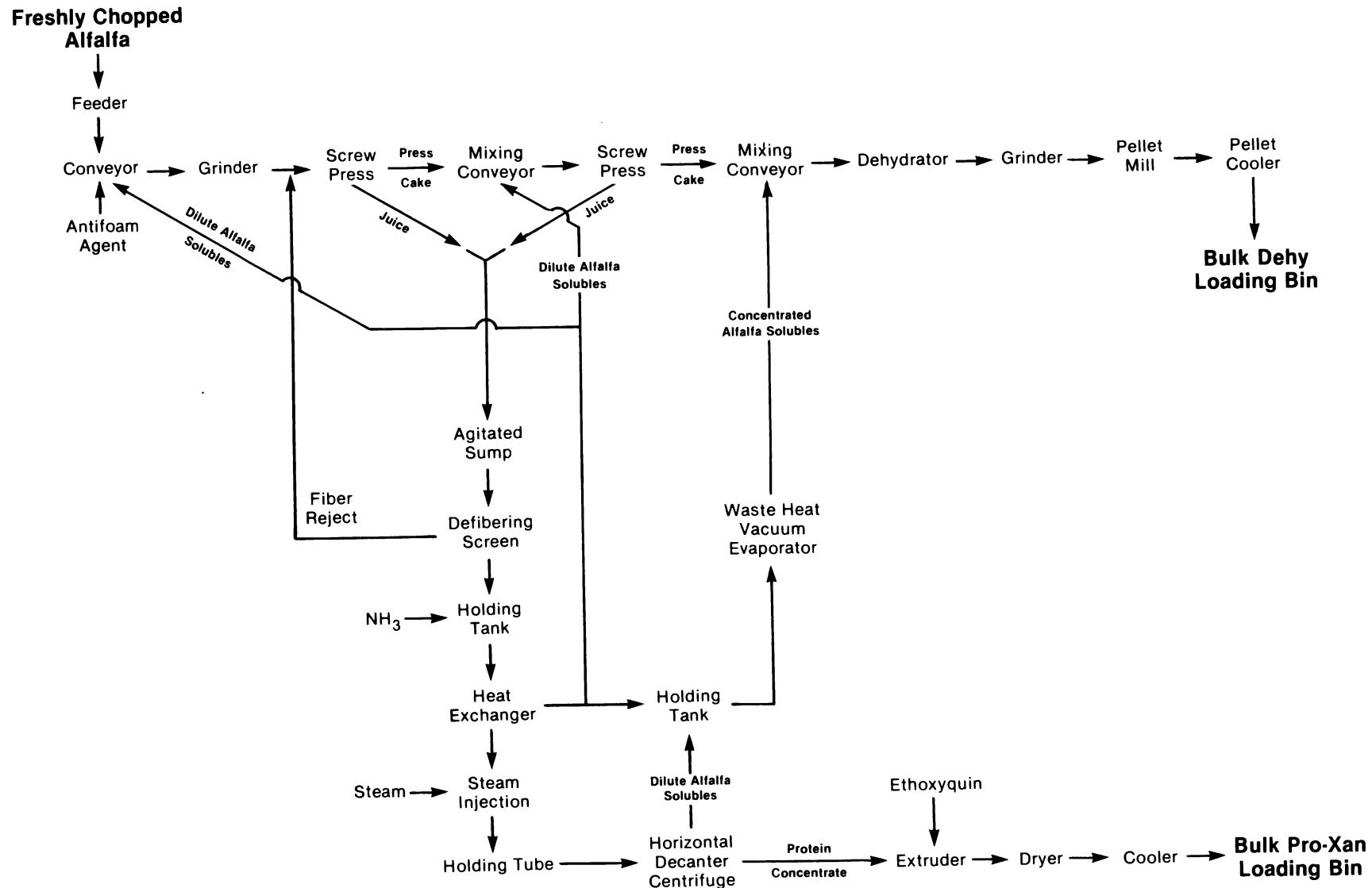
In our 1975 study, we analyzed the potential costs and earnings of four systems for producing Pro-Xan. The basic differences among these four systems

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6/ These feeding trials were made with rations containing from 0 to 10 mg. of xanthophyll per pound.

Figure 1

## Production of Pro-Xan from Alfalfa



occurred in the way the juice was expressed from the alfalfa and in the yield of Pro-Xan, which ranged from 8.5 to 12.0 percent of the total dry weight of the original alfalfa. We also evaluated the effect of four important processing variables on costs and earnings: the method of disposition of the alfalfa solubles, the method of handling the press cake, the length of operating season, and the size or capacity of the processing plant. We analyzed four different lengths of season--130, 180, 230, and 280 days--and three plant capacities in tons of green-chop input per hour--20, 40, and 80 tons <sup>7/</sup>. Table 1 shows the principal differences in the four systems analyzed in the 1975 study in comparison with the system analyzed in this (1977) study.

In the 1975 study, as might be expected, the system with the greatest yield of Pro-Xan, operating for the longest season and with the largest capacity had the highest return on investment. Regarding the method of disposition of the solubles and the method of handling the press cake, the highest return accrued to those plants in which the dilute solubles were assumed added to the press cake and the press cake was dehydrated in a dehydration drum. Returns were highest even though the quantity of gas used for this method of water removal was nearly double that required when the dilute solubles were assumed concentrated in a triple effect vacuum evaporator before being added to the press cake for final drying. The increasing price of gas, however, means that the concentration approach will become the more profitable method. This effect was illustrated in the 1975 study (29).

As the price of natural gas has increased rapidly since the 1975 study and is expected to continue to increase, we considered in the current study only the concentration approach to water removal from the dilute solubles. The concentrated solubles are then added to the press cake prior to final dehydration.

Alfalfa is grown in many areas of the United States and the production season varies widely, ranging from about 130 to 280 days. Emphasis here is on plants operating for 130 days per season, which is typical in the Kansas-Nebraska area where the alfalfa dehydration industry is concentrated <sup>8/</sup>. Length of season has a significant effect on costs per unit of output in a given size of plant. The reason is that annual fixed costs remain the same but are spread over a greater output the longer the plant operates. In this report, we evaluate the effect of several variables, including length of season, on annual return on investment.

The following analysis computes rates of return on investment for a "synthesized" or "model" plant producing Pro-Xan yields of 12, 15, or 18 percent. To compute these rates of return, we estimate requirements and costs for equipment, buildings, and land; annual fixed and operating costs; and sales values for Pro-Xan and dehydrated press cake. The basis for these estimates are discussed below.

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<sup>7/</sup> Tons refer to U.S. short tons (2,000 pounds).

<sup>8/</sup> The actual harvest season lasts for about 150 days, but 20 days are allowed for nonproductive time.

Table 1--Principal differences in Pro-Xan systems analyzed, 1975 and 1977

System and year	Method of extracting juice from green-chop	Recycling of dilute solubles	Pro-Xan yield	Final treatment of solubles and press cake (p.c.)
:	:	:	:	
:	:			<u>Percent</u>
:	:			
:	:			<u>A, B, C, below used with systems I-IV</u>
:	:			
I (1975)	No grinder Twin screw press	Not recycled	8.5	A. Dilute solubles added to p.c. and p.c. dehydrated
:	:			
II (1975)	No grinder Twin screw press	Recycled to green-chop prior to pressing	9.0	B. Dilute solubles pumped to field 1. p.c. fed wet 2. p.c. dehydrated
:	:			
III (1975)	No grinder Double twin screw press	Recycled to green-chop between presses	12.0	C. Solubles concentrated with triple-effect evaporator 1. Added to p.c. a. p.c. fed wet b. p.c. dehydrated
:	:			
IV (1975)	Grinder plus twin screw press	Not recycled	12.0	2. Used as a liquid feed supplement
:	:			
V (1977)	Grinder plus four single screw presses	Recycled	12-18 <u>1/</u>	Solubles concentrated with waste heat evaporator, added to p.c.; p.c. dehydrated
:	:			
:	:			

1/ Pro-Xan yields of over 20 percent have been obtained in pilot plant operations, but here 18 percent Pro-Xan yield is the maximum considered.

## EQUIPMENT, BUILDING, AND LAND REQUIREMENTS AND COSTS

Requirements

Harvesting, hauling, and processing equipment requirements were determined for the model Pro-Xan plant with a green-chop input of 40 tons per hour. This model plant was based on manufacturers' equipment specifications and material balance determinations. The same plant is used for recovering all levels of Pro-Xan. Material balances were based on pilot scale experimental work done at the Western Regional Research Center (6, 8, 9, 17) and are given for 12-, 15-, and 18-percent Pro-Xan recovery (table 2).

Table 2--Material balance description of model Pro-Xan plant with green-chop input of 40 tons per hour 1/

Item <u>2/</u>	: Pro-Xan yield <u>3/</u> at percentage levels of		
	: 12	: 15	: 18
	:	:	:
	<u>Pounds per hour</u>		
Green-chop input	: 80,000	80,000	80,000
Green juice <u>4/</u>	: 120,047	121,600	123,153
Wet press cake	: 36,753	35,200	33,647
Heating steam used	: 8,334	8,433	8,522
Wet Pro-Xan cake	: 5,280	6,600	7,920
	:		
Dilute alfalfa solubles to evaporator	: 46,301	46,633	46,955
Concentrated alfalfa solubles	: 5,089	5,812	6,532
Alfalfa solubles (dry basis)	: 2,992	2,992	2,992
Water evaporated from dilute solubles	: 41,212	40,821	40,423
Press cake drier input	: 41,842	41,012	40,179
	:		
Water evaporated from--Press cake in drier	: 24,242	24,012	23,779
Water evaporated from--Press cake in grinder	: 765	739	713
Water evaporated from--Pro-Xan	: 2,933	3,667	4,400
Pro-Xan (10-percent water)	: 2,347	2,933	3,520
Dehy press cake (8-percent water)	: 16,835	16,261	15,687
	:		

1/ Green-chop contains 22 percent dry matter which is 20 percent protein.

2/ Does not include 80 pounds of anhydrous ammonia per hour which is added to enhance processing behavior.

3/ Pro-Xan yield is the percent of dry matter recovered as Pro-Xan.

4/ Includes 76,800 pounds of recycled dilute alfalfa solubles.

Green-chop input rates were determined by a least-cost matching of the capacities of the screw presses and the press cake dehydration drum. At different Pro-Xan yields, all equipment may not be fully utilized, but the model plant was designed with the best balance of available equipment capacities.

All driers in the model plant are assumed to be equipped with exhaust gas recycling systems. Recent experience suggests that Environmental Protection Agency (EPA) emission standards for the drying operation can be met by using recycling systems and by carefully controlling the drying cycle.

The model plant contains equipment, not shown in figure 1, to permit conversion of the Pro-Xan operation into a straight dehydration operation in case of mechanical failure or other emergency. In this event, the green-chop input per hour would have to be reduced from 40 to 20 tons.

Estimates of equipment requirements for harvesting and hauling green-chop were based on an earlier study of alfalfa harvesting costs (28) and confirmed by alfalfa dehydration industry experience. Table 3 lists all harvesting and processing equipment, with specifications.

Building space requirements for the model plant were based on estimates of the space required for the equipment layout. Construction was assumed to be a combination of masonry and steel sheeting having reinforced concrete roofs with beam supports and concrete floors and foundations. Building construction varied depending upon whether or not space was to be used for the processing operation, office space, maintenance shop, or boiler room. Total space required for the model plant was estimated at 8,300 square feet.

Land requirements for the model plant--4 acres-- were based on the space required for the building and on the area required for truck movement.

#### Investment Costs

Costs for the model plant were based on those prevailing in Kansas and Nebraska. Harvesting and hauling equipment and processing plant equipment costs were based on manufacturers' estimates. Equipment costs represent delivered costs to the Kansas-Nebraska area. For the harvesting and hauling equipment and some processing plant equipment, we updated costs from the 1975 study to 1977 by using the net increases in the wholesale price index for equipment, reported by the Bureau of Labor Statistics (27). The increases were 17, 15, and 14 percent for harvesters, trucks, and plant equipment, respectively.

We estimated that installation of processing plant equipment and plant engineering costs by firms involved in this type of construction would be 35 percent of the total delivered costs of equipment in 1975 and 40 percent in 1977. These estimates include all electrical wiring, piping, valves, and controls.

Table 3--Harvesting and processing equipment requirements for a Pro-Xan processing system with a capacity of 40 tons green-chop per hour

Item	Number required	Specifications	Connected horsepower (electric motors)
Harvester	4	Self-propelled, 14-ft. header	1/
Truck	5	15-ton, tandem axle 24-ft. bed, diesel powered	1/
Truck	2	3/4-ton pickup	1/
Truck scale	1	60 tons	0
Hydraulic truck lift	1	35 ft. long	10
Feeder	1	40 tons/hr.	20
Grinders (green-chop)	4	10 tons/hr.	400
Single screw press	4	20 tons/hr.	400
Hydrasieve	1	72 in. wide	0
Steam injector	2	3 in. diameter	0
Centrifuge	2	130 gal. feed/min.	330
Heat exchanger, plate type	1	147 sq. ft. plate surface	0
Extruder (Pro-Xan)	1	8,000 lb. wet curd/hr.	20
Drier (Pro-Xan) with recycle system	1	9,000 lb. H <sub>2</sub> O evap./hr.	60
Waste heat evaporator with cooling tower (4-stage, 3-effect)	1	51,000 lb./hr.	352
Pneumatic conveyor (Pro-Xan)	1	5 tons/hr.	25
Drier (press cake) with recycle system; 185°F wet bulb	1	30,000 lb. H <sub>2</sub> O evap./hr.	164
Pneumatic conveyor (press cake)	1	12 tons/hr.	50
Grinder (press cake)	2	6 tons/hr.	400
Pellet mill	2	6 tons/hr.	420
Transfer system (hot press cake pellets)	2	6 tons/hr.	10
Pellet cooler	2	6 tons/hr.	80
Transfer system (cold pellets)	2	6 tons/hr.	100
Automatic weigh scale (100 lb. bags)	1	5 bags/min.	1
Boiler	1	400 boiler h.p.	55
Air compressors	1	36 SCFM	10
Pumps	6	1 to 275 gal./min.	48.25
Conveyors	14	4 to 45 tons/hr.	50.5
Tanks (with agitators)	4	1,000 to 10,000 gal.	2
Well	1	250 gal./min.	20
Total horsepower			3,027.75

1/ Not applicable.

Estimated building costs in 1975 ranged from \$16.86 to \$25.70 per square foot, depending on intended use. In 1977, these costs had increased 20 percent (1).

Land costs were assumed to be \$4,000 per acre in 1975 with an estimated increase of 30 percent in 1977 (26).

The total 1977 investment costs for a Pro-Xan operation with a capacity of 40 tons of green-chop input per hour is given in table 4. Total investment is over \$3.3 million with over 80 percent in the cost of plant equipment.

Table 4--Investment costs for Pro-Xan system with capacity of 40 tons green-chop input per hour, 1977

Item	Investment cost
Harvesting and hauling equipment	395,790
Processing plant equipment	1,941,405
Installation 1/	776,562
Subtotal	2,717,967
Buildings 2/:	
Dehydration and pelletizing	44,400
Pro-Xan processing	70,800
Office	43,200
Maintenance shop	26,040
Boiler room	15,480
Total buildings	199,920
Land 3/	20,800
Total	3,334,477

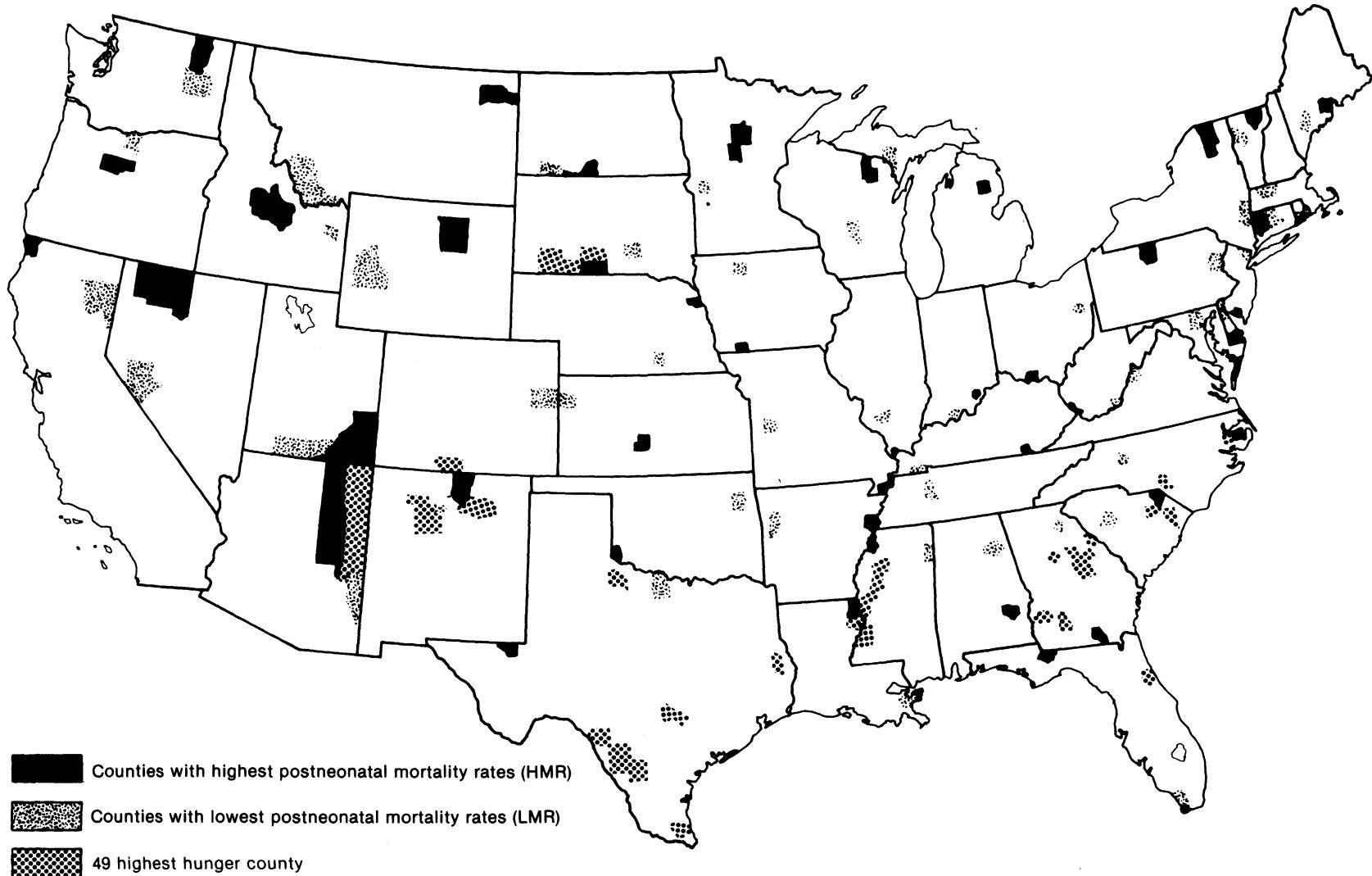
1/ Based on 40 percent of equipment cost and includes plant design and engineering.

2/ Buildings include space for all operations except for product storage which is treated as a separate cost item.

3/ Land area is 4 acres.

Figure 3

## U.S. Postneonatal Mortality County Sets



location of the facility with regard to local fire protection. The rate used in this study was based on these factors.

#### Fuel, Utilities, and Chemicals

Motor fuel and oil requirements for harvesters and trucks were based on estimates provided by operators of alfalfa dehydration plants in Kansas and Nebraska.

Utilities include electricity, natural gas, and water. An operating electrical load of 80 percent of total connected horsepower was assumed except for power required to run the green-chop grinder and the screw presses. The energy requirement for the grinder was assumed to be 7.46 kilowatt-hours per ton of green-chop and 5.97 kilowatt-hours per ton for the double pressing operation (8). Electric motor efficiency was assumed to be 88 percent. Total electricity consumption for the model plant when operating for a 130-day season was estimated to be 5,857,280 kilowatt-hours whether recovering 12, 15, or 18 percent Pro-Xan.

Natural gas was regarded as the fuel source for the boiler, the press cake drier, and the Pro-Xan drier. High-temperature rotary driers with an exhaust recycling system were used to dry the press cake and the Pro-Xan products. The exhaust-gas recycle system in the press cake drier is capable of recycling 50 to 75 percent of the normal exhaust gases. Such recycling raises the wet bulb temperature of the final drier exhaust gases to approximately 185°F. These exhaust gases provide the primary heat source for the waste-heat vacuum evaporator. For each pound of water evaporated from the press cake by the press cake drier, 1.7 pounds of water are evaporated from the dilute alfalfa solubles in the evaporator. The energy requirement for dehydrating press cake with concentrated solubles added was assumed to be 1,500 Btu's per pound of water evaporated. Energy consumption by the Pro-Xan drier was set at 1,600 Btu's per pound of water evaporated.

Steam is required for juice heating, for pelleting, and for the vacuum steam ejector system on the waste heat evaporator. The boiler, equipped with an economizer, was assumed to have an efficiency of 86 percent.

Total annual gas consumption for the model plant when yielding 12 percent Pro-Xan was estimated to be 154,133,770 cubic feet; for 15 percent Pro-Xan yield, it was 156,776,380 cubic feet; and for 18 percent yield, it was 159,370,600 cubic feet. For a comparable plant using a triple effect evaporator with recompression (5 pounds of water evaporated per pound of steam consumed) instead of a waste-heat evaporation system, as in the 1975 study, gas usage would be about 30,587,554 cubic feet greater for 15-percent Pro-Xan recovery, and a comparable amount for 12- and 18-percent recovery, with no offsetting savings in capital costs. An alfalfa dehydration plant of the same capacity, operating for the same number of hours per year, would consume about 277,820,100 cubic feet of gas annually. Thus, for a Pro-Xan plant yielding 15 percent Pro-Xan, gas reduction would be about 44 percent over that for dehydration of chopped alfalfa.

Chemicals added to the process include anhydrous ammonia, a food-grade silicone anti-foaming agent, and ethoxyquin as a Pro-Xan antioxidant.

The model Pro-Xan plant uses water at the rate of 100 gallons per minute, assumed to be pumped from a well, for which costs are included in the estimate of plant investment.

#### Maintenance and Repairs

Although building maintenance cost is usually quite small compared with that of equipment, the average annual cost for maintenance and repairs for both plant equipment and buildings was estimated to be 7 percent of the total investment. This rate is based on Internal Revenue Service (IRS) allowances and does not include inplant maintenance labor, which was discussed earlier.

Maintenance and repair costs for harvesters and trucks were estimated by equipment manufacturers.

#### Administration and Supervision

Administrative costs include the manager's salary, office workers' wages, and miscellaneous office expenses. In an actual operation, the total costs would vary with the length of season and might involve other enterprises, such as farming. For our study, we based estimates of annual administrative costs on information supplied by operators of commercial alfalfa dehydration plants. One-third of the overall administrative costs were charged against the harvesting and hauling operation, 40 percent for the processing plant operation, and the remainder for storage and marketing, which we treated as custom charges.

We assumed that one supervisor was required for the entire operation and 45 percent of his salary was charged to the harvesting and hauling operations and 55 percent to processing plant operations.

#### Storage, Marketing, Transportation, and Working Capital

After alfalfa has been processed into Pro-Xan and dehydrated press cake, these products must be transported to market and sold. Part of the production is stored for disposal throughout the year. Either alfalfa dehydrators perform these functions themselves or a group of plants do them cooperatively, each paying for its use of the service. In this analysis, we assumed these services would be purchased on a custom basis. Expenses would vary depending upon distance to market, length of time the product is stored, and payment arrangements. Alfalfa dehydrator operators in Kansas and Nebraska provided estimates that might be considered representative.

We assumed that, for a plant operating 130 days per season, half the production of both dehydrated press cake and Pro-Xan would have to be stored for an average of 6 months. To preserve its quality, Pro-Xan would have to be held in inert gas storage, the monthly cost for which was also assumed to

apply to stored press cake. We assumed selling charges for dehydrated press cake and Pro-Xan would cover quality control costs.

Transportation charges to market would vary depending upon size of shipment and distance hauled. Carlot charge per ton to ship dehy from Alfalfa Center, Nebr., to Kansas City, Mo.--the location used to estimate product values--was assumed to represent transportation charges for both Pro-Xan and dehydrated press cake.

The amount of working capital required in any business depends upon the rate of inventory movement and credit arrangements between suppliers and customers. Here we assumed that, for a plant operating 130 days per season, the working capital requirement would be equal to a fourth of all annual operating costs and would be needed for the entire year. The cost of this working capital would be the interest at 9 percent.

#### Annual Operating Costs

Annual operating costs are based on operational specifications and the rates or costs of inputs. The 1975 and 1977 rates or costs for these factor inputs and their allocations appear in table 5.

The annual cost for harvesting and hauling green-chop is the same for all levels of Pro-Xan recovery. For 1977, this annual cost amounted to \$401,796, with the major portion being the variable costs of labor, fuel, and maintenance and repairs (table 6).

The effects of 12-, 15-, and 18-percent Pro-Xan yields on annual plant operating costs are shown in table 7. As the same plant is used to achieve all levels of Pro-Xan recovery, the only cost items affected by the higher Pro-Xan yields are those for natural gas and chemicals, with relatively minor differences. The major cost items are the variable costs of utilities and maintenance and the fixed costs of depreciation and repairs.

#### PRO-XAN PRODUCTS AND THEIR SALES VALUES

As has been indicated, the Pro-Xan process results in the recovery of Pro-Xan and dehydrated press cake, the latter containing the alfalfa solubles. Table 8 shows the nutrient composition of Pro-Xan is independent of Pro-Xan yield.

The amount and composition of press cake recovered from the Pro-Xan process depends upon the Pro-Xan yield. The more Pro-Xan extracted from the green-chop, the lower the recovery and protein content of the press cake. The protein content of dehydrated press cake (8 percent moisture) ranges from 14.4 percent, when the yield of Pro-Xan is 12 percent, to 11.6 percent, when the Pro-Xan yield is 18 percent.

Pro-Xan and dehydrated press cake are not currently being marketed in the United States; therefore, their sales values had to be estimated

Table 5--Factor inputs and their rates or costs per unit, 1975 and 1977

Item	Rate or cost	
	1975	1977
Green-chop (standing in field)	\$5.15/ton	\$6.70/ton
Labor (includes fringe benefits and overtime for two 12-hour shifts):		
Harvest and haul (8 workers/shift)	\$3.30/hour	\$4.30/hour
Processing plant (5 workers/shift)	\$3.75-\$4.00/hour	\$4.75/hour
Fuel and oil (for harvesters and trucks)	\$0.75/ton of green-chop	Same
Maintenance and repairs:		
Harvesters and trucks	\$1.00/ton of green-chop	Same
Processing equipment and buildings	7.0 pct. of investment cost/year	Same
Administrative costs (management, office expenses, and others)		
	\$23,000/year allocated 33.3 pct.	\$26,680/year; same
	for field operations, 40 pct. for allocation	
	plant operations, and 26.7 pct.	
	for storage operations	
Supervisor's salary		
	\$20,000/year allocated 45 pct.	\$23,000/year; same
	for field operations and 55 pct. allocation	
	for plant operations	
Depreciation:		
Harvesters	10 pct. of cost/year	Same
Trucks	16.67 pct. of cost/year	Same
Plant equipment	6.67 pct. of cost/year	Same
Buildings	4.0 pct. of cost/year	Same
Insurance:		
All equipment	1.0 pct. of cost/year	Same
Buildings	0.5 pct. of cost/year	Same
Property taxes		
	1.0 pct. of assessed value which is assumed to be 35 pct. of cost	Same
Working capital		
	Annual interest on 25 pct. of all annual costs	Same
Interest on investment		
	9.0 pct./year (4.5 pct. of cost for depreciable property)	Same
Natural gas	\$0.66/1,000 cubic feet	\$0.97/1,000 cu. ft.
Electricity	\$0.021 KwH	\$0.027 KwH
Anhydrous ammonia (2 lbs./ton of green-chop)	\$150/ton	Same
Silicone, anti-foam agent (21bs./40 tons of green-chop)	Not considered	\$0.85/lb.
Ethoxyquin, antioxidant (added to Pro-Xan at rate of 0.015 percent)	Not considered	\$12.95/gal. (6 lbs./gal.)
Inert gas storage (half annual production stored for 6 months)	\$1.50/ton/month	\$1.75/ton/month
Marketing costs	\$1.50/ton	\$1.75/ton
Transport to market (Alfalfa Center, Nebr. to Kansas City, Mo.)	\$10.00/ton	\$11.30/ton

Table 6--Annual harvesting and hauling costs for Pro-Xan system, 1977\*

Item	:	Annual costs
	:	<u>Dollars</u>
Fixed costs:	:	
Depreciation	:	51,775
Administration <u>1/</u>	:	8,900
Taxes	:	1,385
Insurance	:	3,958
Interest	:	17,810
Supervisor <u>2/</u>	:	10,440
Subtotal	:	94,268
Variable costs:	:	
Labor	:	107,328
Gasoline and oil	:	85,800
Maintenance and repairs	:	114,400
Subtotal	:	307,528
Total	:	401,796

\* Processing 40 tons green-chop per hour and operating for 130-day season.

1/ One-third of total cost.

2/ 45 percent of total cost.

so that potential earnings and returns on investment from the Pro-Xan model plant could be computed. These values were based on market prices of commercially available feed ingredients that would provide comparable nutrients; they were calculated separately for press cake and for Pro-Xan as will be described.

#### Press Cake Value

In the 1975 study, the sales value for dehydrated press cake was based on the average price received for 17-percent protein dehy in Kansas City during 1974. This price was discounted 10 cents per ton for each 0.1-percent reduction in protein content below 17 percent.

Since the 1975 study, discussions with dehy industry representatives have led to the conclusion that dehydrated press cake from a Pro-Xan operation would be more comparable in value to suncured alfalfa pellets. Suncured pellets are available at protein contents of either 13 or 15 percent; the price difference between them is small but the price level of both is generally lower than for dehy 17.

Table 7--Annual processing plant costs for model Pro-Xan plant, 1977\*

Item	Annual costs with Pro-Xan percentage yield of--		
	12	15	18
:	<u>Dollars</u>		
Fixed costs:	:		
Depreciation	:	190,101	190,101
Administration <u>1/</u>	:	10,672	10,672
Taxes	:	10,285	10,285
Insurance	:	28,179	28,179
Interest	:	133,177	133,177
Supervisor <u>2/</u>	:	12,760	12,760
:			
Subtotal	:	385,174	385,174
:			
Variable costs:	:		
Labor	:	74,100	74,100
Utilities	:	307,656	310,220
Maintenance and repairs	:	204,252	204,252
Chemicals <u>3/</u>	:	24,195	25,063
:			
Subtotal	:	610,203	613,635
:			
Total	:	995,377	998,809
:			1,001,543

\* Processing 40 tons of green-chop per hour and operating for 130-day season.

1/ Administration costs for plant operations are assumed to be 40 percent of the total costs of administration.

2/ 55 percent of the supervisor's salary is charged to plant operations.

3/ Includes anhydrous ammonia, silicone anti-foaming agent, and ethoxyquin antioxidant.

Feed ingredient prices are reported once a week for major markets by the Market News Service of the U.S. Department of Agriculture and by Feedstuffs, a weekly journal reporting developments in the feed industry. Upon examining feed prices reported by these two sources, we found that there were only small random differences in these prices. As it appeared that Feedstuffs reported the prices of more ingredients used in broiler finisher rations than the Market News Service, we selected the former as the primary source of ingredient prices used in our analysis. To reduce research costs and to keep the analysis of returns on investment manageable, we decided to use prices for only 1 week of each month to compute annual average sales values for press cake and Pro-Xan. A random selection resulted in the third week of each month being chosen for these prices. Using reported prices in Kansas City for the third week of each month, we computed an average annual value for suncured pellets of 13 and 15-percent protein content for 1974 through 1977. These prices appear in table 9 which, for comparative purposes, also gives the average prices for dehydrated alfalfa pellets of 17-percent protein content and for alfalfa hay.

Table 8--Nutrient composition of Pro-Xan

Nutrient	:	Unit	:	Content in Pro-Xan
Dry matter	:	Pct.		90.00
Metabolizable energy	:	Kcal./lb.		1,175.00
Protein	:	Pct.		51.70
Arginine	:	do.		3.34
Glycine	:	do.		2.86
Isoleucine	:	do.		2.90
Lysine	:	do.		3.06
Methionine	:	do.		1.19
Methionine plus cystine	:	do.		1.80
Threonine	:	do.		2.64
Tryptophan	:	do.		.77
Phosphorous	:	do.		.54
Calcium	:	do.		1.39
Fiber	:	do.		1.83
Fat	:	do.		8.47
Xanthophyll 1/	:	Mg./lb.		450.00
	:			

1/ Pigmentation-type xanthophyll as measured by a method developed by Livingston, and others (21). In the 1975 study the xanthophyll content was assumed to be 350 mg./lb. Process modifications since that study have resulted in the higher content.

Sources: (2, 19, 20).

The prices of sun-cured pellets of 13- and 15-percent protein content were interpolated and extrapolated to obtain estimated prices for press cake when Pro-Xan yields were 12, 15, and 18 percent (table 10). These estimated prices are probably conservative as, research studies have shown that the fiber in dehydrated press cake from the Pro-Xan process is more digestible than that in the unprocessed alfalfa from which it was made (18).

#### Pro-Xan Value

We determined the estimated sales value of Pro-Xan by computer, using parametric linear programming (PLP). The following three elements are needed to make this determination for a new feed ingredient: (1) the nutritional specifications of the ration in which the ingredient is to be used; (2) the nutrient values of all ingredients that might be used to satisfy the nutritional specifications of the ration, including nutrient values for the new ingredient; and (3) the market prices of all feed ingredients that might enter a

Table 9--Average annual prices for dehy, suncured alfalfa pellets, and alfalfa hay, Kansas City, 1974-77

Item	Average annual prices			
	1974	1975	1976	1977
Dollars per ton				
:				
Dehy pellets, 17 percent <u>1/</u>	86.80	80.87	106.19	<u>2/</u> 91.74
Suncured pellets, 15 percent <u>1/</u>	77.92	74.15	92.67	<u>2/</u> 82.38
Suncured pellets, 13 percent <u>1/</u>	77.83	74.07	92.42	<u>2/</u> 82.25
Alfalfa hay <u>3/</u>	47.50	49.50	54.00	51.50
:				

1/ Based on prices reported by Feedstuffs.

2/ Based on the first 8 months of 1977.

3/ Based on average prices received by Kansas farmers for baled alfalfa hay as reported in Agricultural Prices, U.S. Department of Agriculture, ESCS. Does not include costs for pelleting and transportation to Kansas City, both of which are included in the prices for the other ingredients.

Table 10--Protein content and estimated value of dehydrated press cake from a model plant with three different yields of Pro-Xan, 1974-77

Yield	Protein content <u>1/</u>	Estimated annual values <u>2/</u>			
		1974	1975	1976	1977 <u>3/</u>
		:	:	:	:
Percent	Percent	---Dollars per ton---			
12	14.4	77.91	74.13	92.60	82.34
15	13.0	77.83	74.07	92.42	82.25
18	11.6	77.77	74.01	92.24	82.16

1/ Assumes green-chop contains 18.4 percent protein on an 8-percent moisture basis and that dehydrated press cake contains 8 percent moisture.

2/ Based on Kansas City prices.

3/ Based on the first 8 months of 1977.

least cost ration. These three inputs are programmed to determine the combination of ingredients that would supply all the required nutrients in a ration at least cost.

The initial least cost formulation through PLP contains none of the new ingredient because it is intentionally priced too high to be accepted. The computer then continuously reduces the price of the new ingredient until it is low enough to replace some other ingredients that supply the same nutrients. This procedure results in a series of prices at which the new ingredient is accepted into the ration in successively larger quantities. A more complete description of this use of parametric linear programming can be found in other reports (11, 12, 13, 25).

Requirements for a broiler-finisher ration were considered the most appropriate for valuing a high-energy, high-protein, high-xanthophyll ingredient such as Pro-Xan. Using Kansas City feed ingredient prices for the third week of each month, we calculated three different PLP sales values, based on different assumptions, for each month of 1974, 1975, and 1976 and the first 8 months of 1977 <sup>9/</sup>. We then averaged these monthly values to arrive at average annual sales values for Pro-Xan. The three different sales values were based on the following assumptions:

- o No xanthophyll was specified in the ration; thus, the value of Pro-Xan would be based on the value of its protein, energy, and other nutrients, excluding xanthophyll.
- o The ration specification for xanthophyll was 13 mg. per pound of ration, and the xanthophyll content of the Pro-Xan was 450 mg. per pound as measured by a chemical analysis method (21).
- o The ration specification for xanthophyll was 13 mg. per pound of ration, and the xanthophyll in Pro-Xan was 765 mg. per pound (1.7 times the analytical content) based on pigmentation results when Pro-Xan was used in broiler and laying hen feeding trials (20).

When no xanthophyll was specified in the ration, the PLP price selected for Pro-Xan was the first point at which it entered the least-cost ration in an amount of 4 percent or more. In most cases this resulted in over 10 percent Pro-Xan in the ration. At levels of usage in the 4 to 15-percent range, there were only slight differences in the PLP price of Pro-Xan. Because of the high xanthophyll content of Pro-Xan, its use in broiler rations would have to be restricted to a maximum to prevent excessive coloration of the skin and flesh. This maximum would depend on buyer preference and on the

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<sup>9/</sup> All ingredients which could be used in broiler finisher rations for which prices were reported were used in the PLP analysis. The major sources of xanthophyll for satisfying the requirements in broiler finisher rations are corn, corn gluten meal, dehy, and marigold meal. Marigold meal prices were not reported; therefore, it was not included in the analysis. However, the prices of marigold meal are generally too high for it to be competitive in rations with the specifications of those used in this study.

amount of xanthophyll in the Pro-Xan. Annual averages of the monthly PLP prices computed for Pro-Xan in rations with a zero specification for xanthophyll are given in table 11.

When Pro-Xan is used in a least-cost broiler-finisher ration with different xanthophyll specifications, use of other ingredients in the ration shifts. Pro-Xan enters the ration primarily as a source of protein and energy, when the xanthophyll specification is low, and the amount of other high-protein and high-energy ingredients, such as soybean meal and animal fat, is reduced. In addition, either milo or corn increases slightly, depending on their comparative prices, so that ration specifications for protein and energy are balanced.

When the ration specification for xanthophyll was set at 13 mg. per pound of ration, the PLP price selected for Pro-Xan was the closest point at which Pro-Xan supplied 7 mg. of the ration xanthophyll. This amount of Pro-Xan xanthophyll was generally what was not supplied by corn. As corn contains about 9 mg. of xanthophyll per pound, the maximum amount of corn that would enter a least-cost broiler finisher ration would supply about 6 mg. of xanthophyll per pound of ration. When the price of corn was sufficiently greater than that of milo, the computer selected milo instead of corn, plus a combination of Pro-Xan and corn gluten meal, or dehy 17, to satisfy the ration xanthophyll requirement at the selected PLP point. The average annual PLP prices computed for Pro-Xan, with xanthophyll contents of 450 and 765 mg. per pound, are given in table 11.

Table 11--Average annual PLP values for Pro-Xan, used in broiler-finisher rations, Kansas City, 1974-77

Year	:	No xanthophyll in ration	:	13 mg. xanthophyll per pound of ration with xanthophyll content of Pro-Xan at--
	:		:	450 mg./lb. 1/ : 765 mg./lb. 2/
	:			
	:			<u>Dollars per ton</u>
1974	:	184.02		344.74 457.15
	:			
1975	:	163.06		349.97 480.64
	:			
1976	:	211.15		432.65 587.28
	:			
1977 <u>3/</u>	:	277.99		524.25 712.80
	:			

1/ Analytical content of xanthophyll. See Livingston, and others (21).

2/ Apparent content of xanthophyll (1.7 times the analytical content) based on broiler and laying hen feeding trials. See Kuzmicky, and others (20).

3/ Based on the first 8 months of 1977.

To illustrate the effect on the value of Pro-Xan of rations with different xanthophyll specifications, we also made PLP computations for Pro-Xan using specifications of 10 and 4 mg. per pound of ration for March, July, and October 1976. Computations based on 10 mg. per pound showed the same PLP values for Pro-Xan as when the ration specification was 13 mg. but the use levels were lower. Computations using 4 mg. per pound of ration resulted in Pro-Xan receiving no value for its xanthophyll in March, but in July and October receiving 98 and 75 percent, respectively, of its value when the xanthophyll specification was 13 mg. In March, corn was only \$3.80 per ton higher than milo, whereas in July and October it was \$10.80 and \$11.80 per ton higher. Thus, at a xanthophyll specification as low as 4 mg. per pound, Pro-Xan can compete as a xanthophyll source when the price of corn is sufficiently higher than that of milo.

The 1975 study contains data on nutritional requirements for a broiler-finisher ration and the nutritional values of the ingredients used in poultry rations (29).

#### EFFECT OF PROCESSING VARIABLES ON ANNUAL RETURNS ON INVESTMENT

Without a supply of a product to sell, it is difficult to determine how the market will value it. Prices determined by PLP cannot substitute for prices determined in the market where supply and demand forces operate. Our PLP prices for Pro-Xan are what might have been received by initial processors whose production would be too small to affect the demand for competing feed ingredients significantly. We would also anticipate that considerable sales effort and independent feeding trials would be required before poultry feeders would accept the research finding that xanthophyll in Pro-Xan is utilized up to 1.7 times more efficiently than the xanthophyll in dehydrated alfalfa. We assumed, therefore, that initially Pro-Xan would sell near the PLP price based on its analytical content of xanthophyll (450 mg. per pound). We selected this value to estimate total annual earnings and returns on investment for the model plant.

Table 12 summarizes total annual sales values, costs, earnings, and returns on investment for the model Pro-Xan plant. The estimated annual returns on investment, before income taxes, using 1976 product sales values and 1977 costs, are 28.7, 37.0, and 45.4 percent for 12-, 15-, and 18-percent Pro-Xan recovery, respectively. These returns on investment not only illustrate what initial processors might have received in that year but also the sensitivity of returns on investment to different yields of Pro-Xan.

It may be difficult to achieve an 18-percent yield of Pro-Xan regularly in a commercial operation. Furthermore, as the protein content of the press cake from this high a Pro-Xan yield is lower than any pelleted alfalfa products now on the market--either dehydrated or suncured--it is uncertain how the market would value such a product. On the other hand, a 15-percent Pro-Xan yield could be achieved readily under most commercial conditions; therefore, the return on this yield is considered the most realistic for most situations.

Table 12--Estimated annual returns on investment for a Pro-Xan plant, 1977\*

Item	: Unit :	Pro-Xan percentage yield of--		
		12	15	18
	:			
Dehydrated press cake:	:			
Production per hour	: Pounds	16,835	16,261	15,687
Annual production	: Tons	24,074	23,253	22,452
Price per ton	: Dollars	92.60	92.42	92.24
Annual sales value	: do.	2,229,252	2,149,042	2,069,128
	:			
Pro-Xan:	:			
Production per hour	: Pounds	2,347	2,933	3,520
Annual production	: Tons	3,356	4,194	5,034
Price per ton	: Dollars	432.65	432.65	432.65
Annual sales value	: do.	1,451,973	1,814,534	2,177,960
	:			
Annual sales value of all products	: do.	3,681,225	3,963,756	4,247,088
	:			
Annual costs (fixed and variable):	:			
Green-chop	: do.	766,480	766,480	766,480
Harvesting and hauling:	: do.	401,796	401,796	401,796
Processing	: do.	995,377	998,809	1,001,543
Storage	: do.	143,992	144,098	144,197
Marketing	: do.	47,997	48,033	48,066
Transport to market	: do.	309,927	310,155	310,367
Interest for working capital	: do.	59,975	60,061	60,130
	:			
Total costs	: do.	2,725,544	2,729,432	2,732,579
	:			
Annual earnings	: do.	955,681	1,234,324	1,514,509
	:			
Total investment	: do.	3,334,477	3,334,477	3,334,477
	:			
Annual return on investment	: Percent	28.7	37.0	45.4
	:			

\*Processing 40 tons of green-chop per hour and operating for 130-day season. All product sales values based on 1976 estimates; all costs based on 1977 estimates.

The wide variation in the estimated annual prices for press cake pellets (table 10) and Pro-Xan (table 11) means that the annual return on investment would fluctuate, being higher in some years and lower in others. Table 13 illustrates the sensitivity (discussed later) of returns on investment to these price variations. These estimated returns can be assumed to represent the range of returns on investment in a Pro-Xan process that might be expected in the future.

The return on investment from a Pro-Xan operation would depend not only on variations in prices of Pro-Xan and press cake but also on the size or capacity of the plant, the length of operating season, the yield of Pro-Xan and its xanthophyll content, and the prices of processing inputs, especially natural gas.

We computed the effects of plant capacity and length of operating season for plants yielding 15 percent Pro-Xan, with a xanthophyll content of 450 mg. per pound. Our computations were based on constant prices for all ingredients and production inputs. The annual return on investment ranges from about 30 percent for a plant processing 20 tons of green-chop per hour and operating for 130 days a year to about 110 percent for a plant processing 80 tons of green-chop per hour and operating for 230 days (fig. 2).

The different lengths of season represent what would be experienced in different geographic regions: the short season (130 days), the Midwest; the medium season (180 days), the Texas high plains; and the long season (230 days), the far western United States. All returns are before income taxes.

Table 13--Estimated annual returns on investment for a Pro-Xan plant recovering 15 percent Pro-Xan, 1974-77\*

Year	:	Return on investment
	:	<u>Percent</u>
	:	
1974	:	16.1
1975	:	14.0
1976	:	37.0
1977 <u>1/</u>	:	41.4
	:	

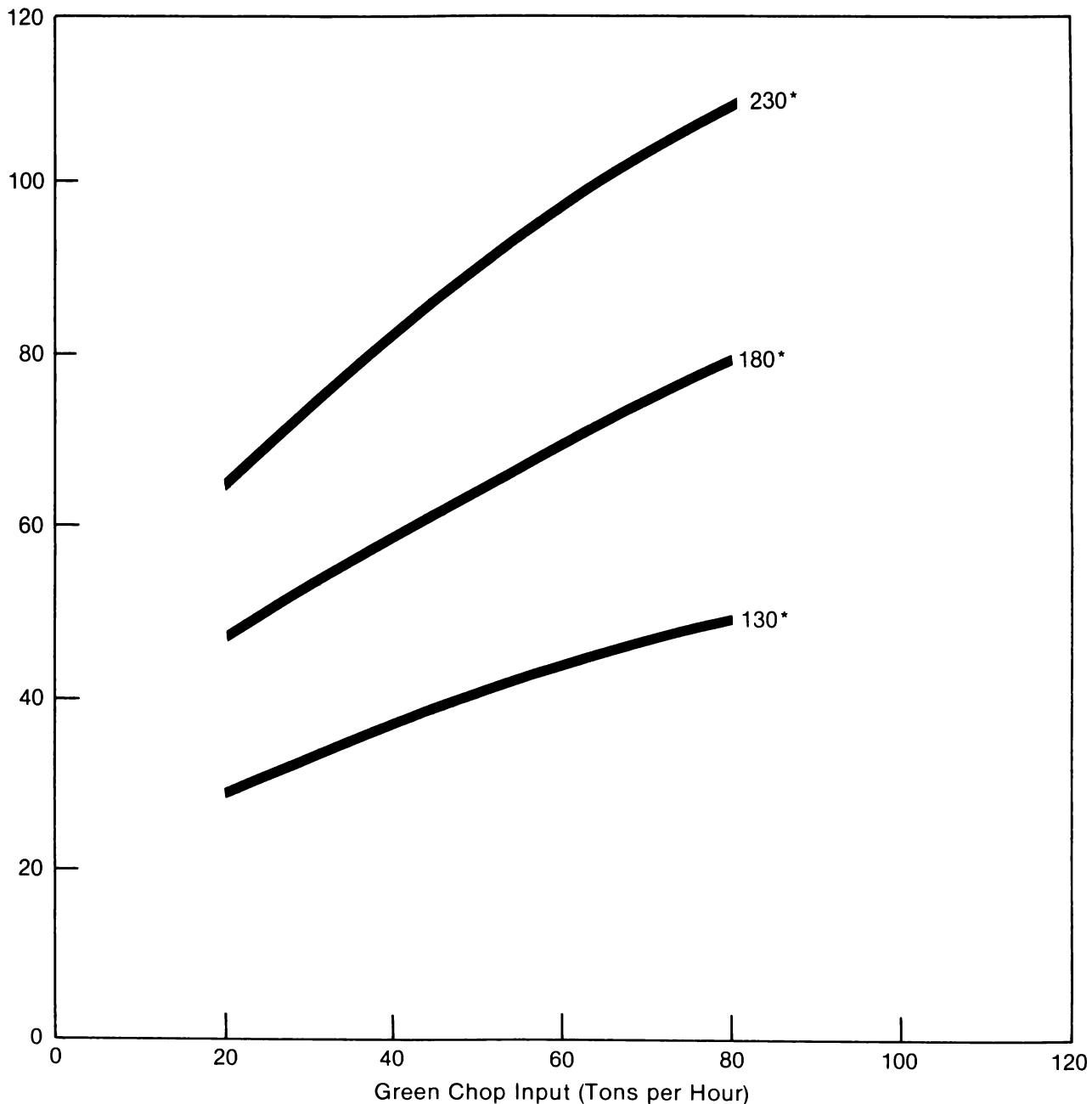
\* Processing 40 tons of green-chop per hour and operating for 130-day season. See tables 10 and 11 for press cake and Pro-Xan prices. See table 12 for press cake and Pro-Xan yields and for processing costs for plants yielding 15 percent Pro-Xan. Estimated prices here for Pro-Xan and press cake pellets in 1974-77 are used in conjunction with 1977 cost estimates to calculate return on investment.

1/ Based on the first 8 months of 1977.

Figure 2

## Effect of Pro-Xan Plant Capacity and Length of Operating Season on Return on Investment, 1977

Annual Return on Investment (Percent)



\* Length of Season (Days)

Assumptions:

Alfalfa solubles concentrated and added to partially dewatered press cake; press cake dehydrated; Pro-Xan recovery 15% of dry matter; and xanthophyll content in Pro-Xan of 450 mg. per pound.

Figure 3 shows the effects of Pro-Xan yield and xanthophyll content of Pro-Xan on return on investment at constant prices for plants processing 40 tons of green-chop per hour and operating 130 days per year. The annual return on investment ranges from about 6 percent for a plant yielding 12 percent Pro-Xan, with zero xanthophyll content, to about 70 percent for a plant yielding 18 percent Pro-Xan containing 765 mg. of xanthophyll per pound.

With different prices for ingredients and production inputs, the rates of return on investment would be different. For example, changes in the price of natural gas, a major cost factor in a Pro-Xan operation, would have a significant effect on return on investment. The Pro-Xan plant data in table 12 show the annual return on investment as 37 percent, when natural gas is 97 cents per 1,000 cubic feet--as it was in the Kansas-Nebraska area in 1977. If natural gas had cost 50 cents per 1,000 cubic feet, the annual return on investment would have been about 40 percent. As the price of natural gas increases, the annual return on investment decreases, until at \$2.00 per 1,000 cubic feet, it would be about 30 percent. Thus, because natural gas prices are rapidly escalating methods to reduce gas usage for Pro-Xan processing are of great importance.

Variations in prices of feed ingredients and production inputs mean that each potential investor in a Pro-Xan system would have to evaluate the projected profitability based on his own particular situation. This can be done with the engineering data and physical relationships used in this study.

#### COMPARATIVE RETURNS TO PRO-XAN AND DEHY OPERATIONS

Dehydrators of alfalfa who are potential investors in a Pro-Xan system will want to compare the relative profitability of dehy and Pro-Xan operations.

Table 14 shows the annual production, sales value, costs, earnings, and return on investment for synthesized dehy plants with 20 and 40 tons of green-chop input per hour, operating for 130 days per season. The annual returns on investment indicated are 22.4 and 27.2 percent, respectively, compared with 37 percent for the 40-ton per hour model Pro-Xan plant with 15 percent Pro-Xan recovery (table 12).

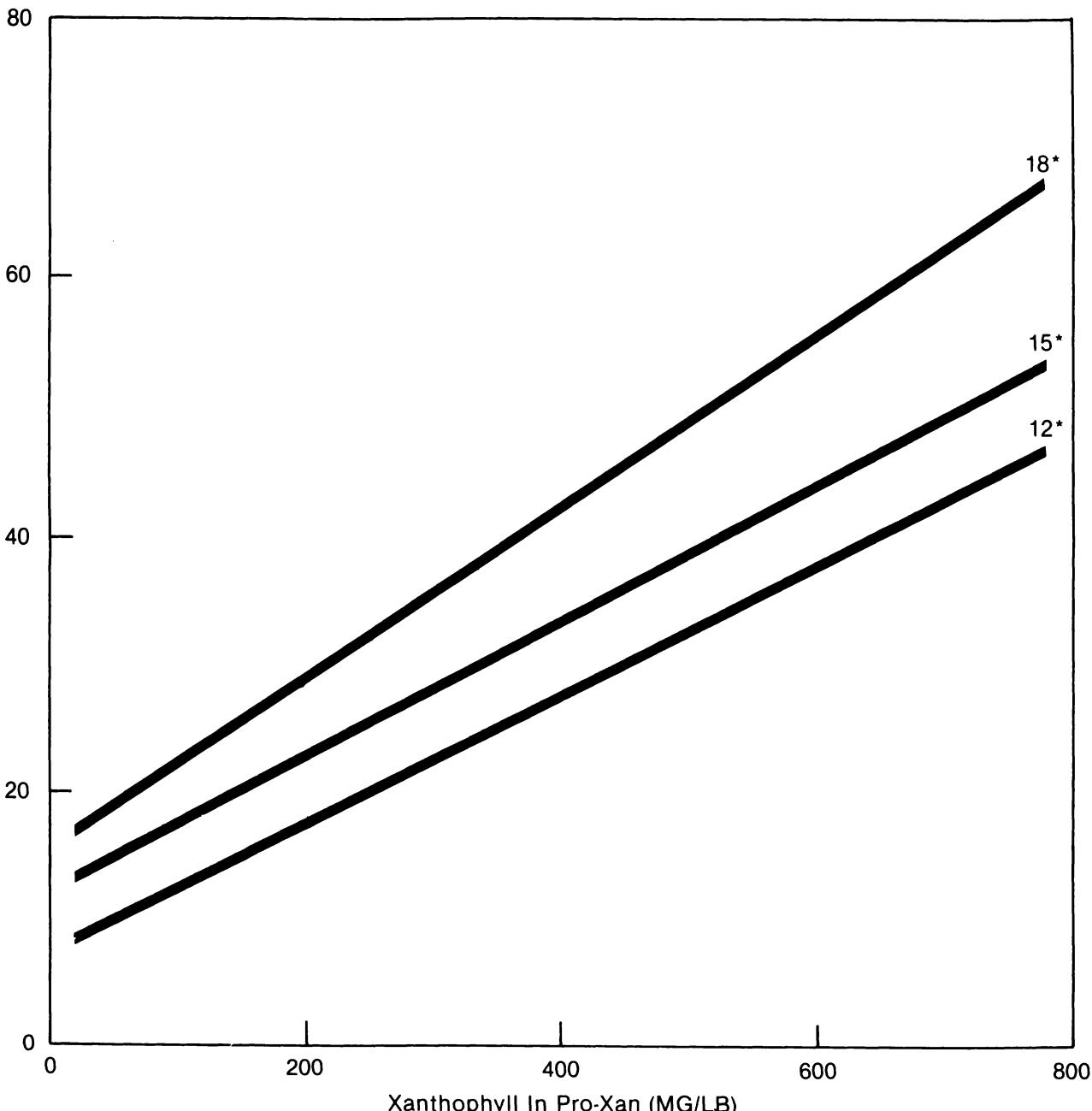
An estimated 25 percent of the approximately 250 plants that produce dehydrated alfalfa also pellet sun-cured alfalfa during the winter season. The same plants do not necessarily engage in this practice every year, nor do they do so for the same reasons. Some plants follow this practice to keep their permanent crews occupied over the winter months, thus reducing the problems of recruiting a new crew each year. Other plants use alfalfa that exceeded their dehydration capacity during the seasonal peak and, therefore, had to be sun-cured.

For those dehydration plants that also produce sun-cured alfalfa pellets, fixed costs would be spread over a greater output than has been indicated; therefore, returns on investment would tend to be greater than indicated. Pro-Xan plants could also produce sun-cured alfalfa pellets during the winter

Figure 3

### Effect of Pro-Xan Yield and Its Xanthophyll Content on Return on Investment, 1977

Annual Return on Investment (Percent)



\* Pro-Xan Yield (Percent of Dry Weight)

*Assumptions:*

Plant processes 40 tons of green-chop per hour and operates for 130 days per season.

Table 14-- Production, costs, and returns for dehy plants, 1977\*

Item	Production, costs, and returns with green-chop input per hour of--		
	Unit	20 tons	40 tons
	:	:	:
Dehydrated alfalfa:	:		
Production per hour	: Pounds	9,565	19,130
Annual production	: Tons	13,678	27,356
Price per ton	: Dollars	106.19	106.19
Annual sales value	: do.	1,452,467	2,904,934
	:		
Annual costs:	:		
Green-chop	: do.	383,240	766,480
Harvesting and hauling	: do.	208,130	401,796
Processing	: do.	375,255	697,744
Storage	: do.	71,809	143,617
Marketing	: do.	23,937	47,875
Transport to market	: do.	154,555	309,109
Interest for working capital	: do.	27,381	53,249
	:		
Total costs	: do.	1,244,307	2,419,870
	:		
Annual earnings	: do.	208,160	484,564
	:		
Total investment	: do.	928,388	1,784,000
	:		
Return on investment	: Percent	22.4	27.2
	:		

\*Processing 20 and 40 tons of green-chop per hour and operating for 130 days per season. All product values based on 1976 prices; all costs based on 1977 estimates.

season, but because the fixed costs for these plants are larger than for dehydration plants, the increase in returns on investment would tend to be smaller. Thus, a comparison between dehydration and Pro-Xan plants also producing suncured alfalfa pellets would tend to show a somewhat smaller differential in return on investment than indicated.

The comparative returns to dehy and Pro-Xan operations are based on the investment in new plants with all new equipment. Plants and equipment of various ages would have lower book values so that returns based on these book values would be higher than those based on investments in new plants. As dehy plants of various ages already exist, the book values of these plants would be relatively lower than for most Pro-Xan plants which would probably have to be built primarily with mostly new equipment. The actual return on existing investment for individual dehy plants, therefore, might be higher than for most Pro-Xan plants.

Some existing dehy plants might find it profitable to convert to Pro-Xan processing. Its feasibility can be illustrated by estimating the costs of converting an existing dehy plant with a green-chop input of 20 tons per hour to a Pro-Xan plant with a green-chop input of 40 tons per hour and estimating the annual additional costs and sales for such a conversion. The major item of investment in a 20-ton dehy plant--the dehydration drum--would be large enough to accommodate the input of a 40-ton per hour Pro-Xan plant. Table 15 lists the equipment or modifications required for conversion.

Additional building space would be required for the Pro-Xan part of the operation and for a boiler room. Total investment cost for making this conversion amounts to nearly \$2.4 million (table 16).

The additional annual costs of operating this converted plant are based on operational specifications and rates or costs for factor inputs (table 5). These annual costs totaled \$193,518 for harvesting and hauling (table 17) and \$631,715 for processing (table 18).

Table 19 summarizes the estimated annual sales values, costs, earnings, and returns on the investment required to convert a particular alfalfa dehydration plant to a particular Pro-Xan plant. The estimated annual return on the investment required to convert such a plant is 42.8 percent.

In a recent study of the economics of green-crop fractionation in the United Kingdom, the authors concluded that except in special circumstances, the fractionation of alfalfa would not be any more attractive economically than dehydration (32). They based this conclusion on the assumption that leaf protein concentrate would be valued only for its crude protein and energy content, not its pigmenting (xanthophyll) value. Their assumption stems from the apparently small demand for supplemental pigmenting materials in poultry feeds in the United Kingdom. When a value was included for the xanthophyll, estimates of the return on investment were considerably higher and, according to the authors, were comparable to the returns in our 1975 study (29).

In contrast to the situation in the United Kingdom, the United States has a sizable market for xanthophyll. Apparently, U.S. consumers prefer yellow-skinned broilers and yellow-colored egg yolks. The consequent additional cost per ton of feed--\$5.32, with 13 mg. xanthophyll--is illustrated in table 20.

Assuming that about half of all broiler rations contain a specification for xanthophyll averaging 13 mg. per pound, we estimated total costs for including xanthophyll in broiler rations in the United States in 1976 to be \$48.5 million 10/. Yet, the estimated cost per pound of ready-to-cook broilers amounts to only slightly more than 0.5 cent per pound. Therefore, we assume such use of xanthophyll in the United States will continue for the foreseeable future. Pro-Xan should be able to share in this demand for xanthophyll.

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10/ 18.24 million tons of broiler feed used in the United States divided by 2, times \$5.32.

Table 15--Equipment requirements for converting an existing alfalfa dehydration plant to a Pro-Xan plant\*

Equipment	Number in existing 20-ton dehy plant	Additional requirements for 40-ton Pro-Xan plant
	<u>Number</u>	
Harvester	2	2
Truck (tandem axle)	3	2
Truck (pickup)	2	0
Truck scale	1	0
Hydraulic truck lift	1	0
Feeder (forage)	1	modify
Grinders (green-chop)	0	4
Single screw press	0	4
Hydrasieve	0	1
Steam injector	0	2
Centrifuge	0	2
Heat exchanger, plate type	0	1
Extruder (Pro-Xan)	0	1
Drier (Pro-Xan)	0	1
Waste heat evaporator	0	1
Pneumatic conveyor (Pro-Xan)	0	1
Drier (press cake)	1	modify
Pneumatic conveyor (press cake):	1	modify
Grinder (press cake)	1	1
Pellet mill	1	1
Transfer system (hot pellets)	1	1
Pellet cooler	1	1
Transfer system (cold pellets)	1	1
Automatic weigh scale (100 lb. bags)	1	0
Boiler (400 boiler h.p.)	0	1
Air compressor	1	0
Pumps	0	6
Conveyors	0	14
Tanks (with agitators)	0	4
Well	0	1

\*Assumes an alfalfa dehydration plant with an input capacity of 20 tons green-chop per hour, and assumes a Pro-Xan plant with an input capacity of 40 tons green-chop per hour.

Table 16--Investment costs for converting a dehy plant to  
a Pro-Xan plant 1977\*

Item	:	Investment cost
	:	
	:	<u>Dollars</u>
	:	
Harvesting and hauling equipment	:	175,470
	:	
Processing plant equipment <u>1/</u>	:	1,427,877
Installation <u>2/</u>	:	571,151
Redesign <u>3/</u>	:	99,951
Subtotal	:	2,098,979
	:	
Buildings:	:	
Pro-Xan processing	:	70,800
Boiler room	:	15,480
Redesign <u>3/</u>	:	21,570
Subtotal	:	107,850
	:	
Total	:	2,382,299
	:	

\*/ Assumes a dehy plant with a capacity of 20 tons green-chop per hour and a Pro-Xan plant with a capacity of 40 tons green-chop per hour. Total investment cost for a Pro-Xan plant with a capacity of 40 tons of green-chop input per hour is given in table 4.

1/ Includes delivery to the Kansas-Nebraska area and estimates of modifications specified in table 15.

2/ Based on 40 percent of equipment costs including plant design and engineering.

3/ Based on 5 percent of estimated installed cost for add-on equipment and on 25 percent of cost for add-on buildings to allow for unforeseen costs in redesigning an existing plant.

#### U.S. MARKET POTENTIAL FOR PRO-XAN

In the United States only broiler and laying hen rations have a xanthophyll specification. The specification varies widely depending on the specific ration, the use of the end product, and the market demand.

Broiler-starter and broiler-grower rations generally specify less than 6 mg. of xanthophyll per pound of ration. As indicated earlier, in rations in which corn is an important ingredient, this specification for xanthophyll can be satisfied without another (supplemental) source of xanthophyll 11/. Broiler-finisher rations, those used in the last 2 or 3 weeks of the 8- to 9-week growth period of most broilers, generally have more xanthophyll. An exception is broilers grown under contract for food processors and restaurants where the consumer does not see the product until after it is cooked. Finisher

11/ These sources are corn gluten meal, dehy, marigold meal, and Pro-Xan.

Table 17--Annual additional harvesting and hauling costs for a Pro-Xan plant converted from a dehy plant, 1977\*

Item	:	Annual additional costs
	:	
	:	<u>Dollars</u>
Fixed costs:	:	
Depreciation	:	22,149
Administration <u>1/</u>	:	3,400
Taxes	:	614
Insurance	:	1,755
Interest	:	7,896
Supervisor <u>1/</u>	:	3,940
	:	
Subtotal	:	39,754
	:	
Variable costs:	:	
Labor	:	53,664
Gasoline and oil	:	42,900
Maintenance and repairs	:	57,200
	:	
Subtotal	:	153,764
	:	
Total	:	193,518
	:	

\*/ Assumes a Pro-Xan plant with a capacity of 40 tons green-chop per hour and a dehy plant with a capacity of 20 tons green-chop per hour, both operating 130 days per season.

1/ Difference between estimated cost for a 40-ton Pro-Xan plant and a dehy plant with an input capacity of 20 tons green-chop per hour.

rations for these broilers may have no specification for xanthophyll. For ready-to-cook retail broilers, the xanthophyll specification in broiler-finisher rations ranges from about 9 mg. per pound of ration to over 25 mg. for some specialized markets.

As about half of all feed requirements for producing broilers is for broiler-finisher rations, only this half would require a supplemental source of xanthophyll. If we assume that the average specification for xanthophyll in this half of the feed is 13 mg. per pound and that half of this specification must be satisfied by a supplemental source of xanthophyll, we can estimate the amount of Pro-Xan that would be required in U.S. broiler rations if it were the only source of this supplemental xanthophyll.

In 1976 an estimated 18.24 million tons of feed were required for producing broilers in the United States. Based on the above assumptions and a xanthophyll content in Pro-Xan of 450 mg. per pound, about 131,735 tons of Pro-Xan would be required to satisfy the supplemental xanthophyll in broiler rations.

Table 18--Annual additional processing costs for a Pro-Xan plant converted from a dehy plant, 1977\*

Item	:	Annual additional costs
	:	<u>Dollars</u>
Fixed costs:	:	
Depreciation	:	144,316
Administration <u>1/</u>	:	3,672
Taxes	:	7,724
Insurance	:	21,529
Interest	:	99,307
Supervisor <u>1/</u>	:	3,760
	:	
Subtotal	:	280,308
	:	
Variable costs:	:	
Labor <u>2/</u>	:	29,640
Utilities	:	142,226
Maintenance and repairs	:	154,478
Chemicals <u>3/</u>	:	25,063
	:	
Subtotal	:	351,407
	:	
Total	:	631,715
	:	

\*/ Assumes a Pro-Xan plant with a capacity of 40 tons green-chop per hour recovering 15-percent Pro-Xan and a dehy plant with a capacity of 20 tons green-chop per hour, both operating 130 days per season.

1/ Difference between estimated cost for a 40-ton dehy plant and a 20-ton dehy plant.

2/ Two additional workers are required on each shift.

3/ Includes anhydrous ammonia, silicone anti-foaming agent, and ethoxyquin antioxidant, none of which is required for a dehy operation.

For most laying hen rations, the xanthophyll specifications range between 3 and 10 mg. per pound of ration. Eggs produced specifically for commercial egg breaking plants which manufacture egg products for use in bakery and other food products are an exception. The manufacturers of these products want highly colored egg yolks requiring a higher xanthophyll specification in laying hen rations. In 1976, eggs used by commercial egg breakers represented about 10 percent of the Nation's total egg production. Some eggs going to egg breakers are produced specifically for them and come from hens which have been fed rations high in xanthophyll (in some cases reportedly as high as 40 mg. per pound). Most, however, are eggs produced for the shell egg market but which, because of heavy supplies or checked or cracked shells, are diverted to egg breakers.

Table 19--Annual returns on the investment required for converting a dehy plant to a Pro-Xan plant, 1977\*

Item	:	Value
	:	<u>Dollars</u>
Annual sales:	:	
40-ton Pro-Xan plant	:	3,963,756
20-ton Dehy plant	:	1,452,467
Difference (additional sales value)	:	2,511,289
	:	
Annual additional costs:	:	
Green-chop	:	383,240
Harvesting and hauling	:	193,518
Processing	:	631,715
Storage	:	72,049
Marketing	:	24,017
Transport to market	:	155,078
Interest for working capital	:	32,034
Total additional costs	:	1,491,651
	:	
Annual additional earnings	:	1,019,638
Additional investment	:	2,382,299
	:	<u>Percent</u>
Annual return on additional investment	:	42.8
	:	

\*/ Assumes a dehy plant with a capacity of 20 tons of green-chop per hour and a Pro-Xan plant of 40 tons of green-chop per hour yielding 15 percent Pro-Xan, both operating 130 days per season.

1/ See table 12.

2/ See table 14.

In 1976, an estimated 18.8 million tons of feed were required for egg production in the United States. If we assume that the xanthophyll specification for all laying hen rations averages 8 mg. per pound of ration, with half this amount coming from a supplemental xanthophyll source, about 167,000 tons of Pro-Xan would be required to satisfy the entire supplemental xanthophyll requirement in U.S. laying hen rations. Therefore, the combined annual requirement for all supplemental xanthophyll in U.S. broiler and laying hen rations could be satisfied by about 300,000 tons of Pro-Xan.

As production of Pro-Xan increases to satisfy the potential demand, the return on investment in a Pro-Xan plant may not be as high as that realized by initial investors because of possible competition from other ingredients that supply xanthophyll. Therefore, firms considering entry into Pro-Xan production should monitor production growth and Pro-Xan's market prices to help them decide whether or not producing Pro-Xan would be profitable.

Table 20--Comparative costs of broiler finisher rations  
with and without xanthophyll, Kansas City, 1976

Month	Cost of least-cost ration :			Cost difference	
	with 0 and 13 mg. xanthophyll :				
	per pound of ration		0 : 13		
<u>Dollars per ton</u>					
January	123.01	127.87		4.96	
February	122.29	128.37		6.08	
March	123.71	129.28		5.57	
April	126.00	132.23		6.23	
May	133.82	136.49		2.67	
June	148.57	150.91		2.34	
July	154.95	160.30		5.35	
August	140.65	146.23		5.58	
September	140.55	147.88		7.33	
October	134.10	141.27		7.17	
November	130.17	135.52		5.35	
December	139.67	145.01		5.34	
Average	134.79	140.11		5.32	

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