A PROCEDURE FOR THE DETERMINATION OF MILLFEED DEMAND

by

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INTRODUCTION

The purpose of this study is to outline a method for the determination of millfeed demand. This report is concerned with a procedure for estimating the demand schedule for a particular millfeed based on its ability to compete for inclusion in livestock rations. The technique described is basically pointed toward computing the demand for a producer's good. It has a derived demand since virtually all of the millfeeds produced are used in further production. It is expected that this procedure will be useful in future research.

Development of the report proceeds as follows: (1) a review of the general feeding practices with regard to classes of millfeeds as they may affect their demand, (2) the detailing of a mathematical technique measuring quantitatively the ability of millfeeds to economically compete in ration formulations based on nutrient and price constraints of available ingredients, and (3) a description of the process from which millfeeds are obtained.

Use of the mathematical technique will provide a method by which a firm can calculate the quantity of a millfeed which will be purchased when the price is held within a certain range and all other factors are constant. By varying price, different quantities will be sold. By using linear programming techniques, numerical quantities can be determined. With knowledge of the quantities cleared by the market at given prices, millfeed demand can be established.

Throughout this report the basic assumption is that a firm endeavors to maximize its economic well-being. The flour miller, in establishing the demand for millfeed, assumes his customers and potential customers are acting rationally in that they strive to minimize the cost of their livestock feeds. A typical linear programming problem is to find the optimum combination of resources or factors such that the final solution minimizes costs while satisfying certain given constraints. Thus, the application of linear programming methods is consistent with the assumption of rational behavior on the part of feed manufacturers. Furthermore, linear programming can be used to determine whether or not improved grades of a millfeed can command a premium price over the present ungraded millfeeds.

REVIEW OF THE DEMAND FOR THE CLASSES OF MILLFEED

A Definition of Demand

The concept of demand is among those devices of economic theory which have found frequent employment in applied economics.[1] Demand is a function of many variables including

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[1] William J. Baumol, Economic Theory and Operations Analysis (Englewood Cliffs, New Jersey: Prentice-Hall Inc., 1961), p. 139.

price, advertising, and decisions relating to competing products. The relationship which describes this entire many variable interconnection is called the demand function. Demand is defined, in the Marshallian sense, as the quantities of a given commodity which all buyers will purchase at all possible prices at a given moment of time.[2] Thus, the term demand really refers to a schedule or a list which is produced by summing the demand schedules of all individual buyers. If buyer A will purchase thirty tons of wheat bran when the price is $55 per ton and buyer B will purchase ten tons at that price, and if these two are the only buyers, the demand at that price is forty tons.

A demand schedule does not indicate what the price is; rather, it indicates what quantities would be bought at different possible prices. The lower the price, the larger the quantity that will be bought. Conversely, the higher the price, the smaller the quantity that will be purchased. The inverse relationship between price and quantity is often called the "Law of Demand."[3]

The quantity of a commodity which buyers will take is affected by the price of the good, buyers' tastes and preferences, the number of buyers, their revenue, the prices of related goods, and the range of goods available for

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[2]H. H. Liebhafsky, The Nature of Price Theory (Homewood, Illinois: The Dorsey Press, Inc., 1963), p. 60.

[3]Donald Stevenson Watson, Price Theory and Its Uses (Boston: Houghton Mifflin Company, 1963), p. 19.

purchase.[4] The definition of demand singles out for consideration the relationship between possible prices of a commodity and the quantities purchased. The other circumstances are assumed to remain constant for purposes of defining a given state of demand. If any one of these assumptions is changed, the entire demand schedule is altered. Alfred Marshall saw the businessman as always studying his production function and input prices. Marshall observed that as they change, the businessman is continually substituting one input for another, thereby keeping his costs as low as possible.[5]

The demand schedule faced by a firm for its products shows the various amounts which the firm can sell at different possible prices, other things being equal. Such a schedule could be called a "sales schedule" or a "sales curve."[6] The nature of the schedule depends upon the type of market in which the firm sells. The demand for millfeeds is derived from the demand for livestock feeds and is therefore dependent on it. By summing the demand schedules of individual rations including millfeeds, the demand for millfeeds is obtained.

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[4]Richard H. Leftwich, The Price System and Resource Allocation (New York: Holt, Rinehart and Winston, 1960), p. 27.

[5]Alfred Marshall, Principles of Economics (8th ed.; London: Macmillan and Co., Ltd., 1938), p. 341.

[6]Leftwich, loc. cit., p. 95.

A Hypothetical Demand Schedule

To study the market demand of millfeeds, or bran in particular, it is necessary to establish the quantities purchased over a range of prices. The total demand for wheat bran is derived from the component demands of bran for all purposes. Almost the entire supply of bran is fed to livestock and poultry.

Although it is known that bran is marketed for inclusion in animal rations, it is also granted that there are many ration formulations for each class of livestock. To arrive at an aggregate demand for bran, then, the amount of bran incorporated in each of the many rations must be specified, along with the price that applies in each case. With the compilation of quantities and prices, a demand schedule may be computed. From the demand schedule a graph of the demand curve can be plotted. An empirical estimate of the market demand curve is beyond the scope of this study.

It is not the intent of this report to detail prices and quantities of bran included in rations throughout the country. Nonetheless, a hypothetical example is presented here as an illustration of a demand schedule. For the sake of simplicity, five different rations are considered, denoted as A, B, C, D, and E. Recorded in Table 1 are the quantities of bran embodied in each formulation at progressively higher prices.

TABLE 1

A HYPOTHETICAL DEMAND SCHEDULE OF BRAN

Price of Bran[a] $ Per Ton	Quantity (Tons)					Total
	A	B	C	D	E	
30	100	80	65	40	15	300
35	90	75	60	30	10	265
40	80	65	50	15	--	210
45	60	45	30	5	--	140
50	45	30	15	--	--	90
55	30	10	--	--	--	40
60	5	--	--	--	--	5

[a]All other ingredient prices known and unchanged.

Because of nutrient considerations, bran is carried (at reduced levels) in rations A and B even when the ingredient is quite expensive. The table does bear out the Law of Demand inasmuch as more bran is utilized at low prices than at higher prices. The hypothetical example illustrates possible levels at which bran will be used in different rations at various prices.

Establishing the quantity of bran included in rations is a problem that can be handled mathematically. It makes little difference what type of ration is desired because the operational procedure remains the same. Over the years, dairy rations have characteristically included wheat bran. Is this happenstance, the result of good fortune, or are there sound principles supporting the inclusion of bran in dairy feeds? The following section examines this question by discussing a procedure for determining which ingredients will enter a ration and at what level (quantity) based on nutrient content and price prevailing at the time of formulation. The present discussion is concerned with the utilization of mill-feeds as based on general feeding practices in regard to the classes of millfeeds.

Classification of Millfeeds

The terms used to designate the various by-products of wheat differ somewhat in various parts of the country. Furthermore, the names of certain of the winter wheat by-products differ from those of the spring wheat by-products. The term wheat bran, often called merely bran, is used for the coarsest by-product, which consists chiefly of the bran layers. The wheat kernel is covered with brownish bran coatings which are richer than the entire grain in protein and minerals, and also much higher in fiber. Within the discussion of the flour milling process, there appears a diagram of the wheat kernel picturing the individual bran layers in cross section. Under the bran is the aleurone layer, also rich in protein. The germ, which is at the base of the kernel, is rich in oil, protein, and minerals. The remainder of the kernel consists of thin-walled cells packed with starch grains and protein. Among the starch grains are the particles of gluten that give wheat dough its unique properties. For the finer by-products from spring wheat, the terms commonly used are standard middlings, flour middlings, and wheat red dog. In the case of the by-products from winter wheat, the common names are brown shorts, gray shorts, and white middlings.

About 70 per cent of the weight of the cleaned wheat goes into flour and the remainder into the by-products. Of the total amount of by-products, bran and standard middlings each form about two-fifths of the weight, and wheat red dog slightly less than one-fifth of the aggregate amount.

Wheat bran, which consists almost entirely of the coarse outer coatings of the wheat kernel, is one of the most popular and important stock feeds. It is highly palatable to livestock, and it has a mild laxative effect. Also, it is twice as bulky as oats. Its popularity is due in no small part to these characteristics. Wheat bran averages 16.4 per cent protein and 4.5 per cent fat, and does not usually contain more than about 10 per cent fiber.[7] Wheat bran supplies 66.9 pounds of total digestible nutrients per 100 pounds, which is slightly less than oats furnish. The protein of bran is of better quality than that of corn or the entire wheat grain, but it is not as well balanced as the protein in such feeds as soybean oil meal, milk, meat by-products, and fish by-products.[8] In phosphorus content bran is one of the

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[7]See Table 2 showing average composition.

[8]Frank B. Morrison, Feeds and Feeding (22nd ed., Clinton, Iowa: Morrison Publishing Company, 1959), p. 441.

richest of all common feeds, but it is low in calcium.[9] Wheat bran has practically no vitamin A or vitamin D. It is rich in niacin and fairly high in thiamine, but rather low in riboflavin, although having more than twice as much as does the whole wheat grain.

The best grades of bran have large clean flakes and contain no screenings. Such bran is often called "pure wheat bran." When bran contains screenings, most states require that the fact be indicated on the feed tags. "Standard bran" or bran containing screenings usually sells at 50 cents to $1.00 less per ton than pure bran. Since wheat screenings have much the same chemical composition as wheat bran, there is often no significant difference in composition between bran without screenings and standard bran. Unless bran contains more screenings than usual or unless the weed seeds are of a kind that give it a bitter taste, the difference in price between the two grades probably represents the approximate difference in actual value. However, there may be danger of introducing noxious weeds on the farm when bran is fed that contains screenings. Hard wheat bran does not differ much in composition from soft wheat bran, but it is slightly higher in fat and furnishes slightly more total digestible nutrients. These relationships are indicated in Table 2.

Wheat standard middlings, usually called "standard middlings," or merely "middlings," are the by-product from

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[9] *Ibid.*, p. 442.

TABLE 2

AVERAGE COMPOSITION AND DIGESTIBLE NUTRIENTS[a]

Feeding Stuff	Total Dry Matter %	Dig Protein %	Total Dig Nutrients %	Average Total Composition				Mineral Constituents	
				Protein %	Fat %	Fiber %	N-Free Extract %	Calcium %	Phosphorus %
Wheat Bran, All Analysis	90.1	13.3	66.9	16.4	4.5	10.0	53.1	0.13	1.29
Wheat Bran, Hard Wheat	90.5	14.1	67.5	17.4	4.9	10.5	51.4	0.13	1.35
Wheat Bran, Soft Wheat	90.5	11.8	66.9	14.6	3.9	8.9	57.1	--	--
Wheat Brown Shorts	88.5	13.9	74.2	16.4	4.0	6.8	57.1	--	--
Wheat Standard Middlings	90.1	14.3	77.2	17.2	4.9	7.3	55.9	0.09	0.93
Wheat Red Dog	89.6	15.8	85.5	17.9	4.2	3.5	60.5	0.07	0.51
Wheat Feed Flour	88.4	14.2	87.1	15.4	1.9	0.5	69.7	--	--
Wheat Flour Middlings	90.1	15.4	79.2	17.5	4.5	4.3	60.0	0.09	0.71
Wheat Mixed Feed	90.7	13.1	70.1	15.8	4.3	8.3	57.1	0.11	1.09
Wheat Germ Meal	89.9	24.5	83.1	27.8	9.2	3.3	44.4	0.08	1.11

[a]Frank B. Morrison, Feeds and Feeding (22nd ed., Clinton, Iowa: Morrison Publishing Company, 1959), pp. 1066-1069. Whole table not reproduced.

spring wheat that consists mostly of fine particles of bran and germ with very little of the wheat red dog. The similar by-product from winter wheat milling is called wheat brown shorts, or sometimes "red shorts." These feeds have about the same composition, except that standard middlings are slightly higher in fiber and also higher in protein and fat than brown shorts. According to the definitions of the Association of American Feed Control Officials, standard middlings must not contain more than 9.5 per cent fiber and brown shorts not more than 7.5 per cent fiber.[10]

Standard middlings are slightly richer in protein and fat than wheat bran and contain more nitrogen-free extract. They are appreciably more digestible than wheat bran and have an average of 77.2 pounds of total digestible nutrients per 100 pounds in comparison with 66.9 pounds for bran. Standard middlings thus supply about 15 per cent more total digestible nutrients and have a correspondingly higher value, except when the more bulky nature and greater laxative effect of bran are desired. Standard middlings are rich in phosphorus, but they are low in calcium, like other wheat by-products. Middlings supply practically no carotene or vitamin D. They are high in thiamine and niacin, but low in riboflavin. Standard middlings are used chiefly for swine, calves, and poultry, but may also be fed to other stock in place of bran. For swine and poultry, middlings do not give good results when

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[10] _Ibid._, p. 442.

fed as the only supplement to the grains because their protein does not correct the deficiencies in the proteins of the grains. Standard middlings and other types of middlings are excellent swine or poultry feeds when part of the protein in the ration comes from such feeds as soybean oil meal, tankage, or dairy by-products.[11]

Wheat red dog, also called "red dog flour," is the spring wheat by-product from the "tail of the mill," consisting chiefly of the aleurone layer, together with small particles of bran, germ, and flour. The similar by-product from winter wheat is wheat white shorts, also called "white middlings." Wheat red dog is slightly higher in protein and fat than white shorts, but otherwise there is little difference in composition. These by-products are considerably lower in fiber and higher in nitrogen-free extract than standard middlings. They are highly digestible and are even richer than the entire wheat grain in total digestible nutrients. They are fed chiefly to swine, especially young pigs, but are also often used in calf meals because of their high digestibility.

Wheat feed flour consists principally of wheat flour, together with fine particles of wheat bran, wheat germ, and the material from the "tail of the mill." According to the definition of the Association of American Feed Control Officials, it should not have more than 1.5 per cent of fiber.

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[11] Ibid.

Wheat flour middlings consist of standard middlings and wheat red dog combined. The similar by-product from winter wheat is wheat gray shorts, also called "gray middlings" or "total shorts." The average fiber content of flour middlings is 4.3 per cent and of gray shorts 6.0 per cent. Flour middlings and gray shorts are used much like standard middlings, but are especially well suited to young pigs because they are slightly higher in digestible nutrients than standard middlings or brown shorts.

Wheat mixed feed consists of wheat bran and the flour middlings or gray shorts. It is often called "mill run." Since wheat mixed feed of good quality contains the middlings, it is somewhat lower than wheat bran in fiber and it is about 5 per cent higher than bran in total digestible nutrients. This is about the usual difference in feeding value, unless bran is desired for greater bulk.

Certain of the larger flour mills separate some of the wheat germ more or less completely from the middlings and sell the product as wheat germ meal. This product contains the germ together with some bran and middlings. It has an average of 27.8 per cent protein and 9.2 per cent fat, and is used chiefly in dog foods, mink feeds, and feeds for laboratory animals. Wheat germ meal is rich in oil and vitamin E.

Feeding Millfeeds to Livestock and Poultry

Dairy.--Wheat bran is one of the most popular dairy feeds, and its value for milk production seems to be somewhat greater than would be estimated from its content of protein and digestible nutrients. Bran is usually fed in combination with the grains and with feeds richer in protein, such as the oil meals. It has a higher value when forming not over one-fourth to one-third of the concentrate mixture than when more is fed. Because of its laxative effect and its bulky nature, bran is especially valuable for cows just before and after calving and for those on official test. Bran is also excellent for dairy calves and heifers. Bran and oats are often substituted for each other, wholly or partially, in making up concentrate mixtures for dairy cattle. Wheat mixed feed may be used in place of wheat bran in dairy rations and is worth about 5 per cent more than bran for this purpose.[12]

Standard wheat middlings or wheat shorts are satisfactory for dairy cows when forming not over one-third of the concentrate mixture. Though they are not so bulky as bran or quite so palatable, they are slightly higher in protein and are higher in total digestible nutrients. If standard middlings cost no more than bran, they are an economical substitute for part or all of the bran for dairy cows, unless the bulk of bran is desired to lighten the concentrate mixture. Wheat mixed feed may be used in place of wheat bran in

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[12] Ibid., p. 443.

dairy rations.

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Beef cattle.--The use of wheat bran for beef cattle is limited principally to the breeding herd and young calves, and bran is excellent as part of the concentrates for such livestock. Bran is also sometimes mixed with the grain when fattening cattle are being started on feed. After the cattle are on full feed, the bran is generally replaced by more concentrated protein supplements, such as linseed meal, cottonseed meal, or soybean oil meal. This occurs because a much larger amount of bran than of these high protein feeds must be fed to balance a ration. Since bran is bulky and relatively low in total digestible nutrients, the considerable amount needed to balance the ration will lessen the gains of fattening cattle and result in a poorer finish to the carcass. Wheat mixed feed may be used for beef cattle in the same manner as wheat bran. Wheat middlings or wheat shorts are not commonly fed to beef cattle, but may be included in the ration when economical in price.

Sheep.--Wheat bran is excellent as part of the concentrates for breeding ewes, as it is laxative and fairly rich in protein. It is often used as part of the grain mixture for young lambs, and is frequently mixed with corn and other heavy concentrates in starting fattening lambs on feed. It should form no large part of the grain allowance for fattening lambs after they are on full feed, for it is too bulky. As long as bran is cheaper in price than grain, 10 to 15 per cent can be satisfactorily included in the mixture for fattening lambs. Such combinations are commonly used in fitting sheep for show purposes. Wheat mixed feed can be used as wheat bran in sheep feeding. Wheat middlings and wheat shorts are not often fed to sheep.

Horses.--Wheat bran is one of the most useful feeds for horses, because of its bulky nature and mild laxative properties. Bran is valued as a part of the ration for brood mares, foals, and stallions. Though wheat middlings or shorts furnish more nutrients than bran, they are not so desirable for horses, because of their heavier character. When fed to horses, middlings or shorts should be mixed with bulky feeds and should not form over one-fourth the concentrates, as they may tend to produce colic if fed in too large amounts.

Swine.--Wheat standard middlings and brown shorts are popular swine feeds. They produce superior results when fed with grain and such protein supplements as dairy by-products, soybean oil meal, meat scrap, or fish meal, which balance and supplement the protein of the grains. When thus fed, standard middlings are worth fully as much or slightly more than corn per pound.[13] Middlings have the highest value for pigs when not over about one pound per head daily is added to a ration of grain and a high quality protein supplement. Middlings produce fair gains when fed to pigs on good pasture as the only supplement to grain, but it usually pays well to add a small amount of a more efficient protein supplement. Middlings should not be used as the only protein supplement to grain for pigs or breeding swine which are not on first-class pasture. On such a ration the results will be unsatisfactory, because of poor quality of protein. Even when pigs not on pasture are fed alfalfa hay in addition to grain, middlings are not very efficient as the only protein supplement. When middlings are occasionally much lower in price per ton than corn or other grain, they may be used as a grain substitute. However, as they are a less concentrated feed than corn, they produce less rapid gains and are worth only about 85 per cent as much as corn for fattening pigs.

Wheat red dog and wheat flour middlings are preferred to standard middlings and brown shorts for young pigs, because of their lower fiber content. Wheat flour middlings are worth 12 to 18 per cent more per ton than standard

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[13] Feeds and Feeding, p. 445.

middlings for growing and fattening pigs.[14] Wheat red dog is probably worth slightly more than wheat flour middlings, because of its greater digestibility. Wheat bran and wheat mixed feed are too bulky for growing and fattening pigs. They are, however, satisfactory as part of the ration for brood sows, and are especially useful when no legume hay is available for the sows because of their bulk and laxative effect.

Poultry.--The wheat by-products are popular ingredients of mashes for poultry. Because of the popularity of high energy poultry rations, wheat bran is now used to a lesser extent than formerly, but wheat middlings and red dog flour, which are higher in net energy, are used instead. Including wheat feeds in the ration tends to produce more rapid growth and development and better feathering of growing chickens. Wheat feeds help supply B-complex vitamins, including the vitamins necessary, in addition to manganese, for the prevention of perosis, or slipped tendon, in chickens.

Wheat bran is often used in poultry mashes, especially for laying hens. Usually not more than 10 per cent is included in a laying mash. Wheat standard middlings and wheat flour middlings are common ingredients of poultry mashes, both for laying hens and for chicks, the amount usually being limited to no more than 10 to 20 per cent of the mash. Wheat flour middlings are worth somewhat more than standard middlings because of their higher net energy content.

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[14] Ibid.

While studying the feeding of millfeeds to livestock and poultry, it is well to keep in mind that the composition of a particular millfeed varies. Thus millfeed nutrient coefficients range about the average composition values given in Table 2. The range of composition of millfeeds is principally due to variations in the composition of the wheat from which the millfeed is obtained. The composition ranges of selected millfeeds is presented in Table 3.

AN APPLICATION OF LINEAR PROGRAMMING TO RATION FORMULATION

In the study of the utilization of millfeeds in formula feeds it is necessary to select a technique for evaluating mill streams in the light of nutrient content and price. Such a technique would facilitate the study of the feasibility of drawing off differing grades within a mill stream and marketing the grades at differing prices. The current practice in the industry is to sack off all grades of bran and to market this bran at one price based on minimum standards. Before proceeding further with the study, some means must be devised to point out just how much an improved grade of bran, for example, is worth to a feed manufacturer. The application of linear programming techniques to a problem of this nature can point out certain answers.

Linear programming is a method of formal calculation that can be applied to the solution of a wide range of

TABLE 3

PROXIMATE COMPOSITION RANGES OF SELECTED MILLFEEDS[a]

Feeding Stuff[b]	Dry Matter Per cent		Crude Protein Per cent		Ether Extract Per cent		Crude Fiber Per cent	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Wheat Bran Unspecified	82.3	96.7	11.9	22.9	3.0	6.8	6.8	17.5
Wheat Bran Hard Wheat	88.2	92.3	16.7	21.5	4.3	6.4	10.0	14.6
Wheat Brown Shorts	88.1	89.6	12.4	20.0	3.5	5.4	4.7	7.1
Wheat Germ Oil Meal	87.5	93.7	24.9	35.6	5.4	12.8	2.1	4.0
Wheat Gray Shorts	87.3	92.6	16.3	23.9	2.6	5.9	2.0	8.4
Wheat Middlings	88.3	91.6	16.6	21.5	4.8	6.5	4.0	9.8
Wheat Mixed Feed	87.4	92.6	14.2	20.0	3.2	5.7	7.2	11.6
Wheat Red Dog	86.5	91.5	17.2	25.0	2.6	5.7	0.5	4.5
Wheat Screenings	86.5	91.3	14.7	21.4	2.4	4.6	3.7	16.5
Wheat Standard Middlings	86.3	93.3	16.7	23.1	4.1	6.2	6.0	11.6

[a]Source: National Academy of Sciences--National Research Council, Composition of Concentrate By-Product Feeding Stuffs. Publication 449 (Washington, D. C.: Printing and Publishing Office, 1956), pp. 13-14.

[b]Minimum and maximum values, other than dry matter content, are expressed on the moisture free basis.

practical problems. It has already found many important applications. Both profit maximization and cost minimization problems can be solved by linear programming. Linear means that the relationships handled are the same as those represented by straight lines. Programming simply means systematic planning or decision making. The central feature of linear programming is that it gives actual numerical solutions to problems of making optimum choices when the problems have to be solved within definite constraints.[15] A linear programming problem has three quantitative components: an objective, and resource restrictions or some other type of constraint.[16] Any problem which has these three components can be expressed as a linear programming problem. Generally, linear programming refers to the computational method used in determining a program to maximize profit, minimize cost, or related types of analysis.

Several assumptions are used in linear programming. These are the conditions of additivity and linearity, divisibility, finiteness, and single-value expectations.[17] Each will be discussed briefly.

The activities must be additive in the sense that when two or more are used, their total product must be the sum of their individual products. In other words, the total

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[15] Watson, loc. cit., p. 184.

[16] Earl O. Heady and Wilfred Chandler, Linear Programming Methods (Ames, Iowa: Iowa State College Press, 1958), p. 2.

[17] Ibid., pp. 17-18.

amount of resources used by several activities must be equal to the sum of the resources used by each individual enterprise. The term linear refers to the fact that "straight line" relationships are employed. The term linear is not as restrictive as it sounds and arises from the fact that the input-output coefficients used are assumed to be constant, and the prices paid or received are assumed to be constant.

It is assumed that factors can be used and commodities produced in quantities which are fractional units. Resources and products are considered to be continuous or infinitely divisible.

The assumption of a limit to the number of alternative activities and to the resource restrictions which need to be considered is a practical assumption. If a firm had an unlimited number of alternatives, the job of programming then could never be finished because the task of describing additional activities could not be finished.

In general, linear programming methods employ the standard assumption that resource supplies, input-output coefficients, and prices are known with certainty. This assumption may be unrealistic for certain situations. Yet this same assumption is used by conventional research techniques such as budgeting. In this regard, linear programming provides solutions which are as realistic as those from other methods which utilize the same assumptions.

The object of programming is to arrive at an optimum program consistent with the objective function. A program is a combination of activities such as enterprises or processes.[18] A feasible program is any collection of activities which meets the restrictions and which does not have any of the activities produced in negative quantities. An optimum program is one which is consistent with the constraints, and for which no improvement can be made in the objective function. That is to say, profits cannot be increased nor costs decreased, depending on which is the optimization criterion.

The primary purpose of this chapter is to test the competitiveness of bran by using a method of determining the least expensive combination of feed ingredients which meets, or surpasses, each of several stated requirements. Linear programming techniques developed by Dantzig,[19] Charnes,[20] and others are used to provide a precise solution of the problem. It is possible that the ration indicated by this analysis may be found unacceptable by practical feeders. If so, it is because the requirements used to illustrate this

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[18] Ibid., p. 16.

[19] G. B. Dantzig, "Maximization of a Linear Form Whose Variables are Subject to a System of Linear Equalities" (Headquarters: USAF Comptroller, November, 1949).

[20] A. Charnes, W. W. Cooper, and A. Henderson, An Introduction to Linear Programming (New York: John Wiley & Sons, 1953), pp. 1-18.

method do not adequately cover feed essentials. However, the method of analysis used is exact. If the prices and nutritive values of all available feeds are known, the method will indicate the least expensive combination of feeds meeting whatever requirements may be determined to be acceptable.

A Cost Minimizing Problem

The example which follows shows how linear programming can be used to find the least cost method of meeting stated requirements. The particular problem considered concerns the mixing of five ingredient sources (corn, grain sorghum, wheat bran, cottonseed meal, and soybean meal) to provide a dairy feed which meets certain protein, total digestible nutrients (TDN), calcium, phosphorus, and weight requirements. Since a feed manufacturer usually sells his formula feeds by the ton, the combination of feeds must weigh at least 2,000 pounds.

To deal with the inequalities of this feed-mix problem, slack variables are introduced. An artificial variable is used for each restriction which either has no slack activity (an equality equation) or has a slack activity with a minus coefficient.[21] To eliminate the artificial activities, the M or -M technique is utilized.[22] To ensure that an artificial activity does not enter the plan, a cost of M is used. Conversely, a cost of -M is used to ensure that some

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[21] Ibid., p. 135.

[22] Ibid., p. 131.

other activity is in the optimum plan. The symbol, M, signifies a high penalty cost associated with a factor.

The first concern is to find a plan independent of the artificial activities. Positive artificial variables in the solution mean a "too high" total cost for ingredients. Total cost can always be reduced by eliminating the M and finding another combination of ingredients.

Table 4 sets forth the basic data for the dairy ration example.

Mathematical Statement of the Problem

With Table 4 as a background, it is now possible to set forth a mathematical statement of the problem.

Let X_1 = cwt. of corn

X_2 = cwt. of grain sorghum

X_3 = cwt. of bran

X_4 = cwt. of cottonseed meal

X_5 = cwt. of soybean meal

X_6 = slack variable for excess digestible protein requirement

X_7 = slack variable for excess TDN over requirement

X_8 = slack variable for excess calcium over requirement

X_9 = slack variable for excess phosphorous over requirement

TABLE 4

BASIC DATA FOR FEED INGREDIENT EXAMPLE

Nutrient	Unit	Requirement[a]	Composition of Alternative Nutrient Sources[b]				
			Corn	Grain Sorghum	Wheat Bran	Cotton-seed Meal	Soybean Meal
		P_0	P_1	P_2	P_3	P_4	P_5
Digestible Protein	%	$\geq$14.7	6.7	8.5	13.0	34.5	42.1
TDN	%	$\geq$74.2	80.1	79.4	65.9	66.1	77.2
Calcium	%	$\geq$0.14	0.02	.03	.14	.15	.32
Phosphorus	%	$\geq$0.55	.27	.28	1.17	1.10	.67
Bulk	Cwt.	=20.0	1.0	1.0	1.0	1.0	1.0
Cost[c]	$/cwt		2.41	2.35	2.185	3.045	3.76

[a]Frank B. Morrison, Feeds and Feeding (22nd ed., Clinton, Iowa: Morrison Publishing Company, 1959), p. 1118. Based on mixtures containing approximately 18 per cent protein.

[b]National Academy of Sciences - National Research Council, Nutrient Requirements of Dairy Cattle, Publication 464, (Washington, D. C.: Printing and Publishing Office, 1958), pp. 21-23.

[c]Feedstuffs, March 8, 1965, p. 78.

X_{10} = artificial variable for digestible protein requirement

X_{11} = artificial variable for TDN requirement

X_{12} = artificial variable for calcium requirement

X_{13} = artificial variable for phosphorus requirement

X_{14} = artificial variable associated with weight requirement.

$$X_j \geq 0 \text{ for } j = 1, 2, \ldots, 14$$

Per cent Digestible Protein:

$$6.7X_1 + 8.5X_2 + 13.0\,X_3 + 34.5\,X_4 + 42.1\,X_5 - X_6 + X_{10} = 14.7$$

Per cent TDN:

$$80.1\,X_1 + 79.4\,X_2 + 65.9\,X_3 + 66.1\,X_4 + 77.2\,X_5 - X_7 + X_{11} = 74.2$$

Per cent Calcium:

$$.02\,X_1 + .03\,X_2 + .14\,X_3 + .15\,X_4 + .32\,X_5 - X_8 + X_{12} = 0.14$$

Per cent Phosphorus:

$$.27\,X_1 + .28\,X_2 + 1.17\,X_3 + 1.10\,X_4 + .67\,X_5 - X_9 + X_{13} = 0.55$$

Weight (cwt.):

$$X_1 + X_2 + X_3 + X_4 + X_5 + X_{14} = 20$$

$$X_j \geq 0 \text{ for } j = 1, 2, \ldots, 14$$

The Simplex Tableau

Table 5 is set up in the same manner as any other simplex problem and table. The first section is completed from the given data. The second section is derived from the first section, the third section from the second, and so on. The restrictions are listed in the P_0 column, and the relevant prices are written in the top row and the left column. The coefficients of the variables in the nutrient constraint equations serve as the technical "input-output" coefficients. The order of activities is arranged with the artificial

TABLE 5

PROGRAM MATRIX FOR FEED INGREDIENT MIX

C_j	Requirements Vector	M	M	M	M	M	2.41	2.35	2.185	3.045	3.76	0	0	0	0	θ_{io}
Vector	P_0	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	
M P_{10}	14.7	1					6.7	8.5	13.0	34.5	42.1	-1				.34916
M P_{11}	74.2		1				80.1	79.4	65.9	66.1	77.2		-1			.96113
M P_{12}	.14			1			.02	.03	.14	.15	.32			-1		.43750
M P_{13}	.55				1		.27	.28	1.17	1.10	.67				-1	.82089
M P_{14}	20.0					1	1.0	1.0	1.0	1.0	1.0					20.000
Z_j \$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Z_j M		1	1	1	1	1	88.09	89.21	81.21	102.85	121.29	-1	-1	-1	-1	
$Z_j - C_j$ \$		0	0	0	0	0	-2.41	-2.35	-2.185	-3.045	-3.76	0	0	0	0	
$Z_j M - C_j$		0	0	0	0	0	88.09	89.21	81.21	102.85	121.29	-1	-1	-1	-1	

activities on the left to form a unit matrix basis, the real activities in the middle, and slack variables on the right. The cost coefficients appear as the first row of Table 5. The artificial activities have M costs, the feeds have money costs, and the disposal activities have zero cost. The technical coefficients of the first five rows are taken directly from the constraint equations. Thus in both Table 4 and Table 5, the coefficient in the first row and P_1 column is 6.7, the coefficient in the second row and P_3 column is 65.9, and so on. On the left of the first five rows, Table 5, appear the activities P_{10}, P_{11}, P_{12}, P_{13}, and P_{14} that provide the first "solution" for the feed problem, and at the extreme left are the corresponding costs.

The Simplex Method

The Simplex Method[23] is a computational method of finding a set of X's that is a solution of the problem. It may be described in steps with reference to the minimum cost ration problem illustrated by Table 5.

A. Choose an initial basis.

1. In this problem, the artificial variables X_{10} through X_{14} are chosen because their coefficients form a unit matrix. Furthermore, these variables form a unit basis.

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[23]Walter D. Fisher, Notes on Linear Programming (Department of Economics, Kansas State University), pp. 18-20.

2. Set up the column and row headings for the first stage of computations. The requirements vector, P_0, is shifted into the first position followed by the artificial vectors, the structural vectors, and the slack vectors. Above each designated vector is listed its cost coefficient. In the first five rows of the section under the column headed "Vector", the basis vectors P_{10} through P_{14} are listed.

   The bottom lines are headed Z_j and $Z_j - C_j$, to be explained. The complete array, Table 5, is referred to as a "simplex tableau."[24]

B. Solve for the λ's in the basis and determine the x_{ij}'s for step C.

   1. The procedure is to copy the coefficients from Table 4 into the appropriate cells of the first section of Table 5.

   2. Let x_{ij} denote the entry in the cell formed by the intersection of row i and column j in the tableau.

C. Check whether a new basis is needed.

   1. For each column j compute $Z_j = \sum C_i x_{ij}$

   2. For each column j compute $Z_j - C_j$

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[24] Ibid., p. 18.

3. Inspect the $Z_j - C_j$ for all columns. If any are positive, a new basis should be selected because a lower value for Z is possible. If all columns are zero or negative, no improvement is possible and a solution has been found. The λ 's for the solution are in the P_0 column. The minimized Z is Z_0.

D. If a new basis is needed, change to a new basis by admitting one new variable and discarding one of the present variables.

1. Select the new variable to come in. This is the variable whose column P_j shows the most positive value $Z_j - C_j$. Call this column the "master column."
2. Select the old variable to go out. Examine the values of the x_{ik} in the master column that are positive. For each row i having a positive x_{ik}, compute $\theta_{io} = X_{io}/X_{ik}$. Find the row i having the smallest value for θ_{io}. The variable in this row goes out of the basis. In the case of two or more rows having the same value of θ_{io}, go to the next column j (to the right) and compute. $\theta_{ij} = X_{ij}/X_{ik}$ for tied rows. Then eliminate the variable i having the smallest value for θ_{ij}.
3. Make row headings for a new section of the

tableau. Call the row with the new variable the "master row."

E. Solve for a new set of λ 's and x_{ij}'s by adjustment formulas.

1. Compute new elements x'_{kj} in the master row of the new section of the tableau by the formula

$$x'_{kj} = \frac{x_{rj}}{x_{rk}}$$

where x_{rj} is an element in any column j of the corresponding row of the previous section of the tableau, and where x_{rk} is the element in the master column k of this row.

2. Compute new elements x'_{ij} in any row i and any column j of the new section of the tableau by the formula

$$x'_{ij} = x_{ij} - (x'_{kj} \times x_{ik})$$

where x_{ij} is the corresponding entry in the previous section of the tableau, x'_{kj} is the element in column j of the master row of the new section, and x_{ik} is the element in the master column of the corresponding row i of the previous section.

F. Check again whether a new basis is needed. Repeat step C for the new section of the tableau.

G. Repeat the process until no further change of basis is needed. The λ 's in the rows of the last basis represent a solution to the problem. All other λ 's are equal to zero. The value of Z_0 represents the minimized value of Z that has been attained.

Solution of the Problem

Two features to keep in mind while carrying out computations are that (1) the goal is to minimize the cost function and (2) to obtain a feasible solution, the artificial activities must be eliminated. To minimize cost, one must choose the most positive $Z_j - C_j$ rather than the most negative and introduce this activity into the basis. The selection of the most negative $Z_j - C_j$ leads to an increase in the objective function, Z.

To help distinguish the dollar and "M" components of cost, the Z, and $Z_j - C_j$ rows of Table 3 have been split in two. There is a Z_j \$ row, a Z_j M row, a $Z_j - C_j$ \$ row, and a $Z_j - C_j$ M row. The Z_j rows of the first section are obtained in the usual way by summing the product of input coefficients and the corresponding prices on the extreme left of the tableau. Dollar costs go into the Z_j \$ row, M costs into the Z_jM row. Since there are initially no dollar costs on the extreme left, the Z_j \$ row of the first section is empty. The M costs on the extreme left of the first section mean that the Z_j M row will not be empty. To conserve space, one need not repeat the M in every cell of the Z_j M or $Z_j - C_j$ M row, but consider every coefficient in the row as being multiplied by the M on the left of the row.

The $Z_j - C_j$ rows are obtained by subtracting the C_j row from the Z_j row. In particular, the $Z_j - C_j$ \$ coefficients are obtained by subtracting the dollar costs in the C_j row from the Z_j \$ row. Since the Z \$ row is empty, it follows that the $Z_j - C_j$ \$ row is the negative of the dollar costs in the C_j row. Similarly, the $Z_j - C_j$ M row is obtained by subtracting the M costs in the C_j row from the Z_j M row. Since neither the slack activities nor the real activities have M costs, their Z_j M and $Z_j - C_j$ M rows are the same. To facilitate the elimination of artificial activities, one first introduces activities with positive $Z_j - C_j$ M coefficients. This is necessary because M costs are always larger than any dollar costs in the $Z_j - C_j$ \$ row. When all $Z_j - C_j$ M coefficients have become zero or negative, one has eliminated all artificial activities from the plan, and hence here is a feasible plan. To find the optimum feasible plan, introduce the activity with the most positive $Z_j - C_j$ \$ coefficient.

Summarizing, the rules for selecting the outgoing column are enumerated below.[25]

1. As long as any activity has a positive $Z_j - C_j$ M coefficient, use the most positive $Z_j - C_j$ M to indicate the activity to bring into the basis.
2. When the $Z_j - C_j$ M row no longer contains positive

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[25] Heady, Linear Programming Methods, p. 140.

coefficients, give attention to those columns with zero in the $Z_j - C_j$ M row. Then select the outgoing column by the most positive $Z_j - C_j$ \$ column. When there are no positive quantities in the $Z_j - C_j$ M row and no column having a zero in the $Z_j - C_j$ M row has a positive coefficient in the $Z_j - C_j$ \$ row, the optimum plan has been found. After setting up the first section of the simplex tableau, it was deemed useful to convert this information to punch cards and solve the problem by computer.

Nine iterations were required to arrive at the optimum program spelled out by Table 6. The same results could have been obtained by using a desk calculator to pencil out the nine iterations although it would be a time-consuming process. As Table 6 shows, the ton cost of the ration which meets the stated nutritional requirements was \$52.87. The ration was made up of 4.97 hundredweight of soybean meal, 8.14 hundredweight of grain sorghum, and 6.89 hundredweight of wheat bran.

The indifference ranges of the ingredient cost functions for the feeds in the optimum solution are provided in the table. For the purpose of this study, the bran coefficients are noteworthy. Thus, bran would remain in the solution up to a price of \$2.885 per hundredweight, the prices of the other ingredients remaining unchanged. In other words, bran could conceivably sell for 60¢ more per hundredweight than the market price at Kansas City in early March and still be included in this formulation.

TABLE 6

LINEAR PROGRAMMING SOLUTION

Solution Column List	Solution Level	Indifference Ranges for Objective Function Coefficients		
		Lower Coefficient Limit	Original Coefficient	Upper Coefficient Limit
Objective	52.87225	--	--	--
Soybean Meal	4.97141	2.32311	3.76000	22.38558
Grain Sorghum	8.13503	1.22250	2.35000	2.41960
Bran	6.89355	.68057	2.18500	2.88483

THE FLOUR MILLING PROCESS

Wheat milling results in the production of two general classes of products, flour and millfeed. The nutrient content of a particular millfeed varies and part of the explanation lies in the flour milling process itself.

The flour milling process is divided into four main stages: (1) the reception and storage of wheat, (2) cleaning and preparing wheat for milling, (3) milling the wheat into flour and by-products, and (4) packing, storage and dispatch of the finished products.[26]

[26] Sir Joseph Lockwood, Flour Milling (4th ed., Stockport, England: Henry Simon Limited, 1960), p. 13.

Reception and Storage

According to the port or inland situation of the mill, facilities are needed for unloading wheat from ships, barges, railway cars or motor trucks. For this operation, either fixed or traveling bucket elevators or pneumatic plants are used; in traveling plants the whole of the machinery is mounted in a tower which can move along the dock, thus unloading all the holds of a vessel. The wheat discharged by the intake plant is transported by belt, chain, or pneumatic conveyors into the storage facilities.

Storage for a considerable reserve of wheat is important to keep the mill running when fresh supplies are delayed, and to enable the miller to take advantage of low wheat prices by buying in advance of his immediate needs. It is also of prime importance that the storage facilities should be so constructed and equipped that grain can be stored in them for fairly long periods without risk of deterioration.

Cleaning and Conditioning

Upon arrival at the mill the wheat will contain a certain percentage of impurities. Some wheats contain foreign seeds of every kind as well as earth, sand, stones, chaff and straw, while wheats from the more primitive countries are apt to contain, in addition to all these, an extraordinary mixture of small lost coins, chunks of wood, bits of string, and pieces of old clothes. A modern mill therefore requires an elaborate plant for removing these impurities before the wheat is ground. The methods of separation are many and ingenious, taking advantage of the differences in size, shape, specific gravity, and behavior in air currents of the wheat and the intermingled impurities. Dirt adhering to the surface of the wheat grains is removed by friction and by washing in water.

Wheats from different parts of the world vary considerably in physical condition and moisture content. Some, like Indian and Manitoba wheats, are hard and dry while others, like British wheats, are damp. Such wheats must be artificially brought into a physical state in which the separation of the endosperm from the bran can be most efficiently performed.

Hence for some wheats water must be added, whereas from others it must be removed. If the process of adding or removing moisture and distributing it throughout each separate grain of wheat is aided by the use of moderately raised temperatures, the process is called "warm conditioning"; it does not affect baking quality. The baking quality of the flour from certain kinds of wheat is improved by exposing the wheat to high temperatures as well as adding or removing moisture. The effect of this process, known as "hot conditioning," is in some ways like the natural ripening of the grain in a suitable climate.

Milling Into Flour and By-Products

The grain of wheat consists essentially of the endosperm, bran, and germ. The starchy endosperm is the portion ultimately made into flour. The germ is the embryo of the new plant. Ideally, the bran comprises all outer structures of the kernel inward to, and including, the aleurone layer.[27] Thus the bran is composed of the epidermis, hypodermis, cross cells, tube cells, testa, nucellar layer, and aleurone cell layer. A wheat kernel in cross section is pictured on the following page.

To the miller the endosperm is the most important part of the grain. Bran contains matter whose inclusion in the flour, even in small proportions, would spoil its color. Both bran and germ contain substances which would injure its baking quality. The first object of the milling process is to isolate the endosperm in as pure a state as possible. This facilitates the production of flour free of germ and bran. It is in pursuit of this aim that the old stone grinding method has been replaced by the elaborate roller milling system.

The endosperm normally represents about 85 per cent of the wheat kernel, the germ about 2.5 per cent and the bran about 12.5 per cent, although the proportions vary in

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[27] I. Hlynka, Wheat: Chemistry and Technology (St. Paul, Minnesota: American Association of Cereal Chemists, Inc., 1964), p. 67.

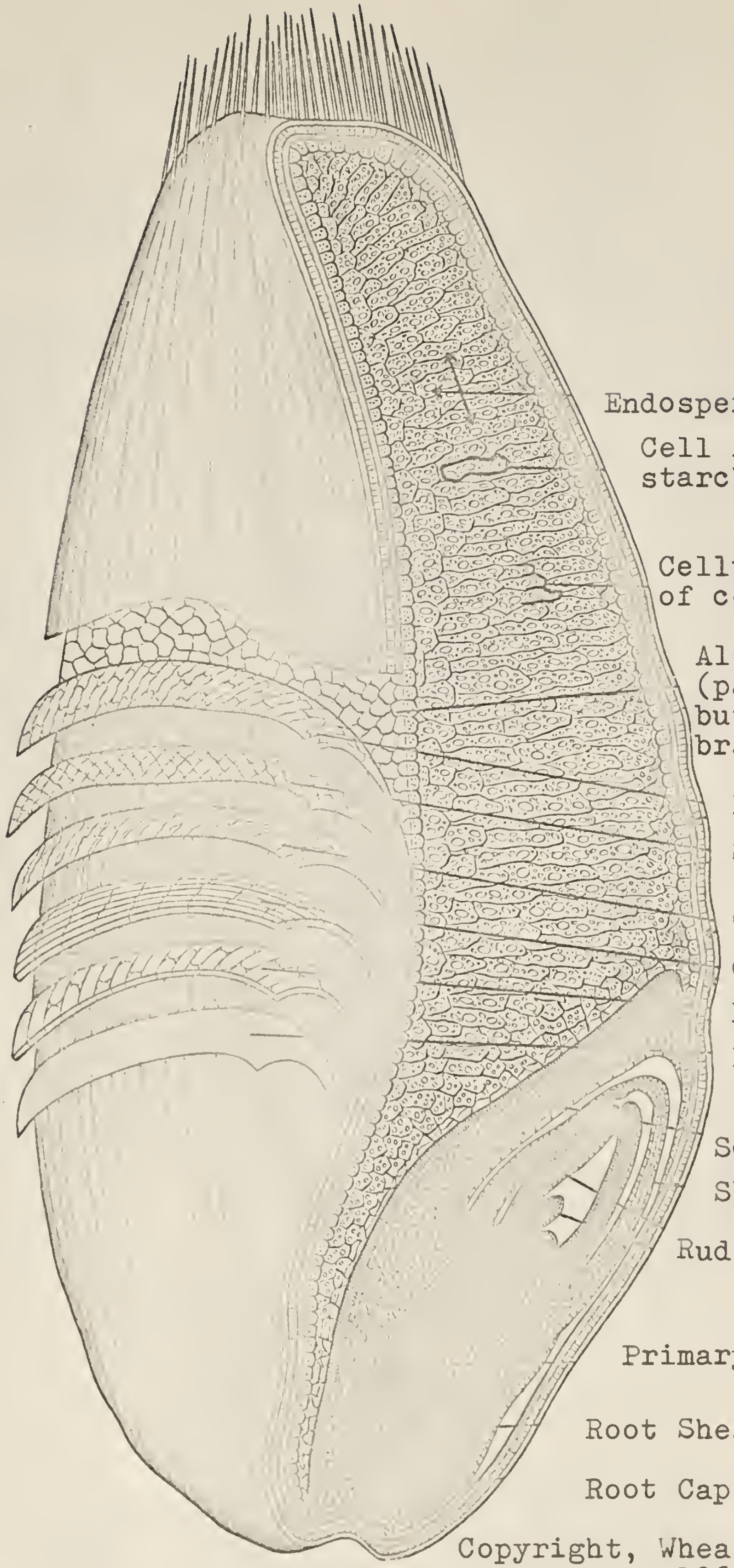

Fig. 1.--A kernel of wheat

different kinds of wheat.[28] Thus if the milling process were 100 per cent efficient it would yield about 85 per cent of pure flour free of bran and germ. This is an impossible ideal, owing chiefly to the mechanical difficulties caused by the shape of the wheat kernel, which has a crease extending its full length and sometimes reaching its middle in depth. The theoretical maximum of an 85 per cent pure flour extraction is more nearly approached by the most elaborate and best of managed mills than by plants less well equipped or managed. Even the best of mills can only extract about 72 per cent of pure flour. If the percentage of flour extraction is increased, the bran content of that flour increases rapidly.

The first part of the milling process is the break system, in which the wheat kernels are split or broken open and the endosperm scraped away from the bran. The scraping process is usually divided into six stages or breaks, after which it becomes most difficult to scrape any more endosperm from the bran without breaking down the bran into fine powder. A fine powder is undesirable because it would become inseparably mingled with the flour and would so discolor it that the flour would be unsuited for breadmaking. It is not yet possible in practice to extract all the endosperm from the bran. The last traces of endosperm are left adhering to the bran, which is then usually flaked or graded into a by-product for feeding livestock.

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[28]Lockwood, _loc_. _cit_., p. 16.

The machines used in the break system are known as rollermills. They consist essentially of chilled iron rolls working in pairs and geared together so that the upper roll runs 2 1/2 times as fast as the lower roll. The rolls are "fluted" with grooves of saw-tooth section, the flutes running at a slight spiral angle along the rolls, similar to the rifling of a rifle barrel. The rolls of the first break usually have about ten or twelve flutes per inch, the fluting of the succeeding break rolls become progressively finer.

As the wheat passes through the nip of the rolls, the individual kernels are gripped by the flutes of the slow roll, while those of the fast roll shear them open and scrape off part of the endosperm. The setting, or clearance between rolls, can be very accurately adjusted.

After each break the released endosperm is sifted from the sheared-open kernels. This process is called scalping and is usually done today by plansifters, although centrifugals or reels are occasionally used. Sometimes a plain rotary or reciprocating sieve may be employed. The sifting surfaces are clothed with woven wire covers.

Since even a small amount of wheat germ is harmful to the color and baking qualities of the flour, it is essential to remove the germ from the endosperm as early as possible in the milling process. If the separation is to be easily and efficiently made, it must be done before the particles of endosperm, germ, and bran have become too small. Once their size has been reduced beyond a point, it is only possible to separate them by flattening them between smooth rolls and then sifting them apart. Even then the sifting is imperfect, and flour quality is impaired.

For efficient germ separation, the particles of stock must not be so small that they can pass through a sifting cover of 28 meshes per inch.[29] This condition is normally fulfilled up to and including the third break. Hence germ separation should be completed before the fourth break is reached. Generally, the process consists in treating the stock lightly on finely fluted rolls, thus breaking down most of the endosperm into small particles while leaving the tougher germ and bran in relatively large pieces. The stocks are then separated on a germ separator.

The endosperm removed by the scalpers consists of particles of various sizes, ranging from those that can barely pass through a cover of 20 meshes per inch to those that are fine enough to pass 150 meshes per inch. Bran particles of varying sizes are also present. Because bran particles lower the baking quality of flour, it is important to remove them.

The removal of bran particles is done by purifiers, machines that employ the sifting principle with the addition of air currents rising through the sieves. If the purifiers are to work efficiently, the mixture of endosperm and bran must first be graded into several classes, each containing a

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[29] *Ibid.*, p. 17.

relatively narrow range of particle sizes. Before purification, the stocks are sorted out by plansifters, centrifugals, or reels into several grades.

Break flour is an undesirable but unavoidable by-product of the break system. The aim of the breaks is to scrape off the endosperm in fairly large pieces so as to facilitate the subsequent scalping, grading, and purification. At each break some of the endosperm is released in particles too fine to be purified at all. These fine particles, which will pass through a number 10 or 11 silk, are break flour. The endosperm released by the third break contains far more bran and germ than that released by the first and second breaks. It is normal practice to grade the third break products separately. Break flour is, in fact, a finished product. However, because it contains bran powder of the same size as flour particles, and as there is no known method of separating the two, break flour is of poor quality and the miller tries to produce as little of it as possible.

The graded stocks are sent to purifiers, which extract as much of the bran as possible. Purifiers consist of long, narrow, slightly sloping sieves, which oscillate rapidly, thus causing the stocks to move steadily over them from the upper to the lower end. Each sieve is divided into four sections, the first section being clothed with a silk cover of fine mesh, while the following sections are clothed with progressively coarser covers. By suitably graduating the cover meshes, the stock is further subdivided into different particle sizes. The lightest impurities are drawn away or held in suspension by air currents. In this way the lighter particles are separated from the heavier endosperm before it is sifted through the sieve covers. The graded and purified stocks, ranging from pure endosperm to endosperm with adhering germ and bran particles, are now ready to be finally ground into flour. The purifiers also separate out a certain amount of material consisting of pieces of endosperm with bran still adhering to them. This endosperm is detached from the bran by a "scratch system" consisting of rollermills, sifters and purifiers. The rollermills have finely fluted rolls, further reducing the particle size of the stock. The bran particles are finally removed by purifiers.

The graded and purified endosperm is ground into flour by another series of rollermills, which form the reduction system. The reduction rollermills are similar to the break rollermills, except that the rolls are gound dead smooth and have a differential speed of 5 to 4 instead of 2 1/2 to 1.[30]

No attempt is made to grind endosperm into flour in a single stage. After the first passage of the stock through a reduction roll, a certain amount of finished flour is sifted out. The coarser particles that remain need further grinding and are either sent to the next fine roll or are graded into coarse and fine particles. The coarse stock goes

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[30] Ibid., p. 20.

to the next coarse roll and the fine stock to the next fine roll. At the end of the reduction system, the rejected stock no longer contains enough endosperm to be worth grinding. It is then prepared and sold, like bran, as a feeding stuff for livestock.

Before the several flours are sacked off for sale, they are mixed and often bleached. They may also be improved by chemical powder or gas treatment. If all the flour grades are mixed together, the product is called straight run flour. The usual procedure, however, is to make several grades of differing quality, each grade being a mixture of several flours.

Flour milling terminology is confusing to the layman. Names such as short patent and first patent or first clear and second clear are commonly used. One needs only to remember that all of the flour coming from a mill is called straight flour. If it is further purified, it is separated into two fractions, a patent flour and a clear flour. The better of the two flours is the patent flour. The flour remaining after the removal of a patent flour from a straight flour is a clear flour. The best measure of the degree of refinement of a flour is either ash content or color.[31]

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[31]Samuel A. Matz, The Chemistry and Technology of Cereals as Food and Feed (Westport, Connecticut: Avi Publishing Co., Inc., 1959), p. 227.

Millfeed Production

Most mills obtain a 70 per cent yield of flour from a theoretical yield of about 85 per cent. The 15 per cent of flour not recovered, as such, is found in the by-products of milling. The aim of the flour milling system is to obtain as much flour as is possible from the endosperm without contaminating the flour with bran particles or with germ. The by-products of milling, the germ, the shorts, and the bran, together comprise about 30 per cent of the mill streams. About one-half of this amount is bran and about one-half shorts. Shorts are essentially pieces of finely ground bran and adherent and free endosperm mixed together. The germ, representing about 2.5 per cent of the total wheat kernel, is found in very minor amounts.

Collectively, these by-products of milling are known as millfeed and are sold as such. This name is derived from the fact that the first uses of the by-products were for animal feeding purposes.[32] The principal use of millfeeds today still is as a feeding stuff in animal rations.

SUMMARY

Although the principal aim of wheat milling is the production of flour, large quantities of by-products are produced. Most of these millfeeds find their way into animal or poultry feeds. For the most part, this report was concerned

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[32] Ibid., p. 195.

with the demand of wheat by-products by livestock for feeding purposes. A dairy ration ingredient mix problem illustrated a procedure for combining feeding stuffs in the light of nutrient content and price. It was shown that wheat bran would enter as a ration component using current prices. Furthermore, with nutrient coefficients and ration constraints unchanged, bran would enter the formulation solution at a price up to $2.88 per hundredweight. In early March, 1965, the weighted average price of wheat bran was $43.60 per ton or $2.18 per hundredweight.

Using digestible protein, total digestible nutrients, the calcium and phosphorus levels of bran, and subject to the requirements of the dairy ration problem, bran could conceivably sell for an additional 60¢ per hundredweight and remain in a ration calculated on a least cost basis.

Currently, when millfeeds are substituted in a formulation, particularly if a computer is used, they are rated at the lowest possible relative value from a nutritive standpoint. One reason for this is that the feed industry has never paid a sufficient premium for improved grades of millfeeds. Bran, for example, is sold on the basis of minimum nutrient levels. Bran is not classified by grade and marketed by grade. Yet bran is milled within a fairly wide range in both protein and fiber content. It is possible to select bran streams ranging from 11.9 to 22.9 per cent protein and 6.8 and 17.5 per cent fiber content. With bran of minimum nutrient levels being marketed at a price reflecting its low grade, surely higher grades of bran could command a premium price. Inasmuch as it is possible to market several grades of bran, and unspecified bran can feasibly enter a ration formulation at a higher price, the conclusion stated in the preceding sentence may merit further investigation.

Future research concerning millfeed demand could well incorporate linear programming procedures. Given price and nutrient levels of ingredients, ration formulation problems can be solved by linear programming for the quantities of millfeeds included. In this manner demand schedules can be computed. The prospect for this procedure appears bright.

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A PROCEDURE FOR THE DETERMINATION OF MILLFEED DEMAND

by

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AN ABSTRACT OF A MASTER'S REPORT

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Writing late in the nineteenth century, Alfred Marshall, famed English economist, observed that the businessman worked more by trained instinct than by formal calculation. Today, techniques of formal calculation have been developed to apply to a wide range of practical problems including demand determination. The purpose of this report was to outline a procedure for the determination of millfeed demand. Linear programming methods were employed to determine quantitatively the ability of millfeeds to compete for inclusion in livestock and poultry rations. Not only was the competitiveness of a millfeed tested but also the quantity desired at a given price was determined concurrently. The procedure described is basically pointed toward computing the demand for a producer's good. The term demand refers to a schedule depicting the quantities of a good purchased at all possible prices at a given time. Millfeeds have a derived demand since virtually the entire supply produced is incorporated in the production.

Considerable quantities of millfeeds are utilized in rations designed for both dairy cattle and beef cattle. Higher grade millfeeds find usage in swine feeds and poultry growing rations. A dairy ration formulation problem was detailed with ingredient sources being corn, grain sorghum, wheat bran, cottonseed meal, and soybean meal. The objective of the problem was to minimize cost while satisfying nutrient requirements. The optimum combination of ingredients had to fulfill requirements for digestible protein, total digestible nutrients, calcium, phosphorus, and net weight. A tableau was formed and iterations were calculated through use of the Simplex Method. Using ingredient price and nutrient content as criteria, the optimum formulation was determined to include grain sorghum, bran, and soybean meal.

The nutrient content of a particular millfeed varies and part of the explanation lies in the milling process itself. In the production of flour, bran streams may range from 11.9 to 22.9 per cent protein and 6.8 to 17.5 per cent fiber content. Thus, it is possible to draw off differing grades within a mill stream and market them separately. The composition of millfeeds will influence their competitiveness with other ingredients and the amounts utilized in rations. Given price and nutrient levels of ingredients, ration calculation problems can be solved by linear programming techniques for the quantities of millfeeds needed. The procedure remains unchanged regardless of what type of ration is desired or the number of available ingredients. With prices specified and knowledge of the quantities cleared by the market at those prices, the task of determining the demand for a millfeed is greatly aided.