AN ABSTRACT OF THE THESIS OF

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Title: ECONOMIC EVALUATION OF POTATO WASTE AS A FEED INGREDIENT FOR BEEF FINISHING RATIONS

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Potato waste is processing residue generated as a byproduct from the production of frozen and dehydrated potatoes. Although feedlots have fed potato waste to cattle for years, very little information is available to provide guidance to potential buyers and sellers for determining prices. The value of potato waste in beef finishing rations can be estimated to provide an indication of the maximum prices which feedlots should offer, and which processors can expect to receive for the waste.

The objectives of this thesis are: (1) to estimate the value of potato waste to the feedlot when fed in beef cattle finishing rations, (2) to compare the methods for evaluating the feedlot value of potato waste for reliability purposes, and (3) to estimate the value of potato waste at the processing plant and at the feedlot when there is competition among spatially separated feedlots of different size and location.

Objective (1) was met by determining the shadow price values of potato waste from the linear programming models. Model 1 evaluated potato waste in least cost ration formulations based on various nutrient specifications. Models 2 and 3 evaluated potato waste in optimal feeding programs using cost minimization and profit maximization per animal as the model objectives (Model 2), and using profit maximization per year as the model objective with full feedlot capacity (Model 3). The results of the models were compared to satisfy objective (2), whereupon it was verified that Model 1 is as reliable a method of evaluation as Model 2, since both models produce similar results. For most rations, potato waste values differed by 7 percent or less, but differed by 25 percent for rations exceeding 50 percent potato waste content.

Objective (3) was met by modifying Model 2 to include potato waste shipment activities between a potato processing plant and three feedlots. This allowed potato waste to be evaluated on the basis of its value to feedlots and processors. A processor price for potato waste was determined as the size of processors and feedlots varied, and as the quantity of potato waste changed. The evaluative and allocative methodology was examined, and implications for allowing processors to estimate approximate potato waste prices were discussed.

ECONOMIC EVALUATION OF POTATO WASTE AS A FEED INGREDIENT FOR BEEF CATTLE FINISHING RATIONS

by

Paul S. Turek

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Head of Department of Agricultural and Resource Economics

Redacted for privacy

Dean of Graduate School

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ECONOMIC VALUATION OF POTATO WASTE AS A FEED INGREDIENT FOR BEEF CATTLE FINISHING RATIONS

Introduction

The production of processed potatoes in the form of frozen and dehydrated potatoes has flourished in the last decade, due, in large part, to the increase in consumer demand for convenience food items and to the growing trend in food consumed away from home. It is estimated that approximately half of all fall crop potatoes produced in the United States are processed, and that roughly 35 to 50 percent of the incoming raw potato weight is wasted after processing. This potato process waste material may be used as cattle feed, which alleviates a disposal problem for processors and provides cattle feeders with a good source of feed energy. However, the slurry consistency of the waste product and high water content make it costly to transport long distances. Therefore, the feeding of potato waste to cattle normally takes place within reasonably close proximities to processing plants.

The intrinsic value of potato waste as a cattle feed ingredient is an important factor for determining exchange arrangements for the potato waste between processors and feedlots. The value provides an indication of the maximum prices a feedlot might be willing to pay for various quantities of potato waste, and establishes the maximum prices an individual processor can expect to receive from the sale of the waste. As competition develops between feedlots for a given supply of potato waste produced by a potato processor, the feed value of potato waste for feedlots can be used by processors as a guideline for establishing a single price for potato waste. This price will generate a maximum return to the processor, and allocate the potato waste to the feedlots in the most economically efficient manner for producing weight gains in cattle. The major purpose of this research is to evaluate potato waste as a feed ingredient for cattle.

The initial phase of the evaluation process involves analyzing the simple case of a single feedlot which feeds potato waste to cattle. Competition for the potato waste by other feedlots is assumed to be nonexistent, and the transportation cost of shipping the waste from the processor to the feedlot is assumed to be zero. The analysis is presented in Manuscript 1. Two alternative feeding models which use potato waste are employed to estimate the value of potato waste at the feedlot. One is the least cost feed blend model which formulates feed rations containing potato waste under varying nutrient specifications and varying ingredient prices. The other is the optimal feeding program model which selects optimal feed rations for feeding cattle from specified alternative rations as the availability of potato waste for formulating the rations changes. The optimal feeding program model incorporates information on beef productivity by relating the dry matter intake of potato waste to the weight gains achieved by cattle per feed ration. Since the water content of potato waste may vary slightly between processing plants, the potato waste value is estimated on a dry matter basis in both models. The results of the models are compared to one another, and their reliability as value estimators is discussed.

The addendum to Manuscript 1 outlines an approach for developing a number of simplified methods for approximating potato waste values. The analysis used in the least cost feed blend model provides results which suggest that potato waste may be evaluated solely upon the basis of one or two major ingredients or nutrients. Formulas are developed for use when computer equipment is not readily available. Estimates of potato waste values are derived from the formulas and compared to the values obtained in Manuscript 1 to determine their accuracy for predictive purposes.

Manuscript 2 estimates the value of potato as a cattle feed ingredient when transportation costs for hauling potato waste are a significant factor and competition for potato waste exists among spatially separated feedlots. The analysis used in Manuscript 2 builds upon the foundations developed in Manuscript 1, and is designed to incorporate changes in hauling distances and relative sizes of processing plants and feedlots. The model used for evaluation considers the total supply of potato waste at the processing plant in relation to the total feedlot demand for potato waste, and generates maximum prices for potato waste based upon its value to processors and feedlots. Based upon the results of the analysis and the addendum, a simplified procedure for evaluating potato waste is suggested in lieu of computer analysis.

Review of Literature

Potato wastes have been fed to cattle for many years in various forms. One of the first feeding trial experiments using potato waste in cattle feed was conducted by Lindsey (1913), in which cattle consumed up to 50 pounds of cull potatoes daily during the feeding period. Morrison (1949) mentions several studies in which cattle were fed cull potatoes and potato meal with favorable results.

More recent research on potato waste as a cattle feed ingredient involves the nutritional analysis of filter cake, which is a residue of potato processing plants. Filter cake is a high moisture byproduct containing suspended particles of potato matter, which generally gives it the consistency of wet mashed potatoes. Laboratory studies of the filter cake have revealed that 60 to 75 percent of the dry matter is starch, portions of which can be lost when potato waste is allowed to ferment in the storage process (Howes and Sauter, 1974; Sauter et al., 1979). One solution to this problem was proposed by Sauter and Hinman (1979) which recommended storing the potato wastes as silage. A feeding trial experiment conducted by Heinemann and Dyer (1972) indicated that potato processing slurry was 73.5 percent digestible and contained 3.3 and 2.8 Mcal/kg of metabolizable energy when fed at 19.2 to 37.5 percent of the diet dry matter. Digestion experiments were conducted by Stanhope et al. (1980) to determine the effect of various levels of potato processing residue in feedlot diets on the digestion of dry matter, gross energy, crude protein, and starch. When fed at 15 percent of the diet dry matter, potato processing residue was found to be superior to barley as an energy source for beef cattle diets.

Economic Considerations

Much of the early research aimed at estimating the nutritional composition of feedstuffs in cattle feeding produced results which could be further analyzed to provide economic information for beef producers. Pioneering efforts were made by researchers in the 1950's in using linear programming models to minimize the ingredient cost of formulating feed rations under certain nutrient specifications (Waugh, 1951; Fisher and Shruben, 1953; Hutton and Allison, 1957; Hutton and Alexander, 1957; Hutton et al., 1958). The evaluation of ingredients is implicit in the cost minimization method, which allows an ingredient to be evaluated relative to the prices of other ingredients in the ration, even when the purchase price of the ingredient in question may be unknown. As Dorfman et al. (1958) and others have pointed out, the procedure involves establishing marginal costs for the separate nutritive elements based upon the possibility that ingredients of different nutritive composition may be able to substitute for one another in the ration. The imputed value of any ingredient included in the optimal diet ration must then be equivalent to the sum of the marginal costs of its constituent nutrients.

The linear programming method of formulating least cost rations provides a simple method to evaluate prospective feed ingredients. With the advent of high speed computers and calculators, its popularity has increased over the years. In 1971, for instance, it was estimated that nearly 70 percent of the mixed feeds in the U.S. were formulated this way (Enochian et al., 1971). However, it is important to note that the marginal costs of the nutrients in the formulated feed ration depend not only on the prices of the ingredients and their nutritional contents, but also on the nutrient levels specified for the diet. It has been traditionally assumed by most economists that "recommended" levels of protein, energy, minerals, etc., are economically optimum for the linear programming least cost ration problem. It has been argued, instead, that the determination of optimum nutrient levels is an economic problem, as well as a biological one, and minimizing feed costs is only part of the problem (Brown and Arscott, 1959). Alternative sets of nutritional specifications usually will produce differences in the biological performance of the animals fed and also change the cost of the animals' diet. The returns for the livestock feeding enterprise should also be considered if the most profitable combination of feed ingredients for the ration are to be found (Brown and Arscott, 1959).

Several studies have also been done which use the linear programming technique as a method for evaluating productive inputs by maximizing the returns to certain limiting factors. Given the objective of profit maximization in a perfectly competitive framework, the price of the productive factor is equal to its marginal value product (MVP). For potato waste in cattle feeding, its price or use value is determined by its MVP, which is what it is worth at the margin in producing livestock and livestock products. Hardin and Johnson (1955) set out the essentials of the evaluation problem under these circumstances in a paper dealing with forage evaluation. Smith (1955) demonstrated that a nonmarketable factor (e.g., pasture) can be evaluated by maximizing profits for a beef-cattle feeding enterprise under different market assumptions using linear programming analysis. Nelson et al. (1959) used linear programming to analyze input-output data and estimate the most profitable level of nitrogen fertilizer use in producing wild hay and pasture. In the process, the values of hay, pasture, and rangeland were obtained.

Of the potato waste studies previously discussed, the paper by Heinemann and Dyer (1972) also provides some information on ingredient costs and beef cattle performance which could be analyzed in an economic framework. Five feed rations containing different proportions of potato slurry were fed to cattle in the 154-day finishing experiment. The initial and final average weights of cattle were documented as well as the rate of gain and feed conversion each ration produced. Feed cost per pound of gain declined as the proportion of potato slurry increased between rations.

Costs Versus Revenues

The review of past literature has revealed there are two ways in which linear programming analysis may be used to evaluate potato waste as a feed ingredient in cattle. The least cost feed blend method offers a simple and direct approach, but fails to consider returns generated in the form of beef production or revenues. The optimal feeding program based on costs and returns often suffers from data problems. The valuation problem assumes both economical and biological characteristics. The method that produces the most suitable solution could well depend on the primary objectives of feedlots and beef producers. Brokken et al. (1976) and Melton et al. (1978) noted that objectives may differ between various beef producing enterprises, and it may be inappropriate to label any one objective as good and another as bad. As a result, Melton et al. (1978) analyzed the impact of alternative objectives upon beef production strategies. An interesting finding was that the objectives of ration cost (feed ingredient cost) minimization, total feed cost (feed ingredient cost plus nonfeed variable cost per day) minimization, and profit per day maximization with full capacity utilization and replacement, produced results similar in ration, profit per animal, and response to relative price changes, over one feeding period for fixed prices. This result, and the results of the previous relevant literature, warrant the consideration of both linear programming methods and alternative objectives for evaluating potato waste in cattle feeding. The papers by Brokken et al. (1976) and Melton et al. (1978) also raise the empirical question whether potato waste values would differ between models which minimize ration cost and total feed cost, and models which maximize profit if the beef production strategies selected are the same.

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ESTIMATING THE VALUE OF POTATO WASTE IN CATTLE FEEDING WITH LEAST COST FEED BLENDS AND OPTIMAL FEEDING PROGRAMS

The feeding of potato waste to cattle has become a common practice for many feedlots located near potato processing plants. The nutritive benefits of potato waste when used as a feed ingredient have been previously estimated (Heinemann and Dyer, 1972; Stanhope et al., 1980) but the economic implications of the practice have not been well defined. The feed value of potato waste is generally established through arrangements that award the potato waste to the highest bidder.

Methods for the evaluation of potato waste could be useful for establishing guidelines enabling feedlot operators to determine what they would be willing to pay for potato waste. This information becomes important if it becomes necessary for beef producers to submit bid prices for the opportunity to purchase the available potato waste.

The primary purpose of this paper is to estimate the value of potato waste as a cattle feed ingredient. Three linear programming formulations, based upon two alternative feeding models, are employed to derive the potato waste value. The feeding models used are a simple, least cost feed blending model and an optimal feeding program model, both of which use potato waste. The least cost feed blend model (Model 1) formulates minimum cost feed rations including potato waste and other ingredients. Each ration is formulated so that specific nutritional requirements (e.g., energy, protein, vitamins, minerals) for cattle, expressed as a proportion of the total ration, are satisfied. The value of potato waste is determined in relation to the set of specified nutrients and ingredient prices. The potato waste is assigned a zero price so that its value as feed ingredient is represented by its opportunity cost value (shadow price) within the model.

The optimal feeding program model considers the effect that different ingredient combinations have upon the performance of cattle to gain weight. Different combinations of potato waste and other feed ingredients are formulated into five separate feed rations so that each ration produces the same total amount of weight gain per head of cattle. The average daily rate of gain differs for each ration, however. This results in different periods of time which an animal must remain on feed in order to attain a fixed amount of weight gain. Two linear programming formulations are used to evaluate potato waste through the selection of optimal feed rations for different feeding programs. The first formulation (Model 2) chooses the optimal ration or combination of the five rations which produce the desired amount of weight gain per head of cattle at the lowest cost, given the set of ingredient requirements and fixed ingredient prices.

The second formulation (Model 3) chooses the optimal ration or combination of the same five rations which produces the desired amount of weight gain per head of cattle and maximizes annual profit for a feedlot of limited capacity given a set of specific ingredient requirements, ingredient prices, and alternative slaughter steer and feeder calf prices. Potato waste is assigned a zero price in both formulations of the optimal feeding programs model so that its feed ingredient value is represented by its opportunity cost (shadow price) value. This value establishes the marginal value of potato waste for producing weight gains in cattle, and can be compared to the opportunity cost value of potato estimated in the least cost feed blend model. Consequently, it is conceivable that the two models could produce very different results for the value of potato waste. However, if the results are similar, the least cost feed blend model offers a more simple and direct approach to evaluating potato waste as a feed ingredient for cattle, making it the more preferable method for evaluation. Therefore, the secondary objective of the research is to compare the different approaches to evaluating potato waste for reliability purposes.

The analysis is conducted using several scenarios of feed prices and feed programs. Prices of feedstuffs used in the study represent prices paid by beef producers for feedstuffs which are generally fed throughout the Pacific Northwest area. Since the potato waste value is predicated in part upon the market for these feedstuffs, the applicability of the results is somewhat confined by the regional nature of the ingredient prices. It is further assumed that the market for the prices of barley, corn, or other feedstuffs is not directly affected by any changes in the availability of potato waste to beef producers.

Methods

The prices of barley and hay used in the linear programming models were derived from the price of corn by using regression analysis to analyze average monthly cash grain prices for barley and corn at Portland, and average monthly alfalfa hay prices in Oregon, for 1972-82 (USDA, various issues). The regression analysis constructs a relative price series for barley and hay based upon the price of corn, and corrects for any short term disturbances inherent within monthly prices. The use of the relative price series in the models allows potato waste to be evaluated based upon long term price relationships between the feedstuffs. It also permits the model to be analyzed with current relative prices of corn, barley, and hay (based upon the corn price in the fall of 1982), and can be used to represent changes in the prices of barley and hay as the price of corn changes. The prices of other ingredients were obtained in fall of 1982 by contacting Oregon feed purveyors and selected feedlots in Oregon and Washington.[1/]

Model 1: Least Cost Feed Blend Model

Model 1 formulates least cost rations by blending feed ingredients, including potato waste, into one kilogram of dry matter while satisfying specific nutrient requirements (Table 1.1). All nutrient requirements used in the model are consistant with levels recommended by the National Research Council (1970) for finishing steers. Constraints were provided for minimum requirements of digestible protein, vitamin A, calcium, and phosphorus. Limits were imposed upon the amounts of ether extract and urea that could be permitted in the diet. The requirement for the amount of energy in the diet can be formulated in terms of either net energy for gain (NEg) or metabolizable energy (ME). For the purposes of this model, the NEg requirement was used. The tradeoffs involved with using the NEg requirement versus the ME requirement are worthy of discussion. Two sets of sample solutions were obtained for Model 1 for the sake of comparison. The model was first analyzed using the NEg requirement to produce two

Table 1.1. Tableau Representation of Least Cost Feed Blend Model Based on NEg Restriction (Model 1).

Objective: Minimize Costs												
Activities[a/]										Constraints		
X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	B_1	Type	Value	Name
.128	.133	.077	0	.300	.498	.286	.110	.332	0	-	-	Costs ($/kg)
1	1	1	1	1	1	1	1	1		=	1	Ingredient Mass (kg)
1.29	1.48	.49	1.39	1.29						≥	1.36	NEg Requirement (Mcal/kg)
2.96	3.29	2.06	3.13	2.93					-1	=	0	ME Accounting (Mcal/kg)
.082	.075	.127	.032	.438				2.62		≥	.071	Protein Requirement (kg)
.0145	.0357	.0220	.0090	.0130						≤	.05	Ether Extract Restriction (kg)
.0007	.0002	.0125	.0023	.0036	.2313					≥	.0025	Calcium Requirement (kg)
.0045	.0035	.0023	.0024	.0075	.1865					≥	.0035	Phosphorus Requirement (kg)
-.005	-.005		-.005					1		≤	.005	Urea Restriction (kg)
	.06	3.816		.006		3000				≥	.22	Vitamin A (IU's/kg)
		1								≥	.10	Roughage Requirement (kg)
							1			≥	.015	Salt Requirement (kg)

a/ X_i are feed ingredients where X_1 is barley, X_2 is corn, X_3 is alfalfa hay, X_4 is potato waste, X_5 is soybean meal, X_6 is dicalcium phosphate, X_7 is vitamin A, X_8 is salt, and X_9 is urea; B_1 is an accounting activity.

solutions. The energy requirement was then reformulated in terms of an equivalent ME energy base, and analyzed again to produce two comparable solutions. These results are presented and discussed in a later section. Net energy for maintenance (NEm), which together with NEg make up the net energy measure of the food energy present in a feed ration, was not included in Model 1 as part of the overall energy requirement. The portion of net energy in feed rations utilized by cattle as NEm becomes important if the intention of the research is to formulate the least cost of gain ration (McDonough, 1971), or to compute a daily rate of gain for each least cost ration based upon some assumed starting weight per animal and daily feed intake level. Both cases are primarily concerned with the weight gain performance of cattle as the ingredients in the least cost ration change. The least cost of gain ration goes one step farther by formulating the least cost ration which produces the lowest feed cost per pound of weight gain. In either case, it is necessary for all feed ingredient prices to be non-zero.

The major purpose of Model 1 is to evaluate potato waste, which is priced at zero in the model, over a range of least cost rations that differ slightly in NEg content. The capacity of the simple blend rations to produce daily weight gains in cattle is not expressly considered by Model 1. As a result, the importance of the NEm content of the rations is discounted, and it becomes unnecessary to include NEm as part of the energy constraint.

Model 2: Optimal Feeding Program with Cost Minimization

The optimal feeding program estimates the value of potato waste using information about beef productivity, and determines how this value changes as the ingredient composition of the rations changes. The major difference between Models 1 and 2 is the ability of Model 2 to recognize changes in weight gains of cattle when feed rations change so that the value of potato waste is estimated accordingly. If these potato waste values are comparable to the values estimated with Model 1, it will have been established that Model 1 is just as reliable and appropriate a methodology for evaluating potato waste as Model 2. However, it is quite possible for Model 2 to generate very different values for potato waste from Model 1.

The data used in Model 2 were taken from the feeding trail experiments conducted by Heinemann and Dyer (1972). In this 154-day finishing experiment, potato slurry was fed to cattle at 0, 15.4, 27.8, 42.5, and 51.9 percent of the ration dry matter. Table 1.2 lists the proportions of potato slurry and other ingredients contained in the experimental rations along with the average weight gain produced by each ration. The daily rate of gain was similar in four of the rations, but was lower in the ration containing the highest percentage of potato slurry. Animals entered the feeding trials at an average starting weight of 610 pounds, and gained an average of 440 pounds each to finish at an average weight of 1050 pounds. Feed cost per pound of gain declined as the level of potato slurry was increased. The experiment also showed that the digestible energy of potato waste decreased when the percentage of potato waste increased. This result is consistent with the performance parameters used in Model 2 which further distinguishes Model 2 from Model 1, since the nutrient composition of potato waste was assumed to remain unchanged

Table 1.2. Proportions of Ingredients Contained in Experimental Rations and Average Daily Gain Produced

Item	Rations 1	2	3	4	5
Ingredient					
Alfalfa Hay	23.2	22.4	23.7	22.9	24.5
Potato Slurry	0.0	15.4	27.8	42.5	51.9
Barley	68.0	55.0	42.9	30.6	20.8
Beet Pulp	7.7	6.2	4.9	3.5	2.4
Urea	0.6	0.4	0.3	0.1	0.0
Salt	0.5	0.5	0.5	0.5	0.5
Vitamin A	a/	a/	a/	a/	a/
			Beef Pounds		
Average Daily Gain	2.93	2.86	2.91	2.89	2.69

a/ Less than .01 percent

Source: W.W. Heinemann and I.A. Dyer, "Nutritive Value of Potato Slurry for Steers," Washington Agricultural Experiment Station, 1972.

in Model 1 as the percentage of potato waste changed between rations.

The objective function used in Model 2 minimizes feed costs and feedlot expenses associated with the feeding of the ingredients contained in five separate feed rations, which may be fed to cattle to promote a fixed amount of total weight gain per head. The daily rations used in Model 2 are identical to the experimental feed rations formulated by Heinemann and Dyer (1972). Model 2 selects the ration or combination of rations that produce the total weight gain at minimum cost (Table 1.3). As the rations are selected, the amounts of feed ingredients comprising the optimal ration mix are also provided, simultaneously.

A starting weight of 610 pounds was assumed for a feeder calf. Each of the rations contains the total amounts of dry matter ingredient pounds needed to finish the calf to 1,050 pounds live weight. The prices of feed ingredients for Model 2 were taken from Model 1, except for the price of dried molasses beet pulp, which was not included as an ingredient in Model 1. Its price was obtained from price quotes given by several Northwest feedlots who purchased the ingredient in fall of 1982.

Model 2 estimated the value of potato waste as (a) feed costs alone were minimized and (b) feed costs plus feedlot expenses were minimized. The feedlot expenses consisted of itemized costs per head of cattle and daily expenses associated with normal feedlot operations. The daily expenses serve to charge the different rations that produce a lower rate of gain. The breakdown of these expenses is shown in Table 1.4. The results of (a) and (b) were compared to determine if any significant changes in potato waste values occurred

Table 1.3 Tableau Representation of Optimal Feeding Program Model for 440 lb. Weight Gain in Cattle: Cost Minimization (Model 2a)

Objective: Minimize Costs														
Activities[a]														
Rations					Ingredients							Constraints		
R_1	R_2	R_3	R_4	R_5	X_1	X_2	X_3	X_4	X_5	X_6	X_7	Type	Value	Name
61.4	62.52	61.72	62.04	65.49	.035	0	.058	.092	.151	.049	.130	-	-	Costs[b]
1	1	1	1	1								=	1	Ration Selection (percent)
687.0	704.7	693.5	699.3	760.0	-1							=	0	Alfalfa Hay Requirement (pounds)
0	484.5	813.4	1297.8	1609.9		-1						=	0	Potato Slurry Requirement (pounds)
2013.6	1730.3	1255.3	934.4	645.2			-1					=	0	Barley Requirement (pounds)
228.0	195.0	143.4	106.9	74.5				-1				=	0	Beet Pulp Requirement (pounds)
18.1	13.8	7.9	3.4	0					-1			=	0	Urea Requirement (pounds)
15.1	15.4	14.0	13.7	14.3						-1		=	0	Salt Requirement (pounds)
.3	.3	.3	.3	.3							-1	=	0	Vitamin A Requirement (pounds)

[a] R_i are respective feed rations, each of which produce a 440 lb. weight gain in cattle at a starting weight of 610 pounds; X_i are feed ingredients where X_1 is alfalfa hay, X_2 is potato slurry, X_3 is barley, X_4 is beet pulp, X_5 is urea, X_6 is salt, and X_7 is vitamin A.

[b] Cost of R_i measured in \$/unit, cost of X_i measured in \$/pound.

Source: W.W. Heinemann and I.A. Dyer, "Nutritive Value of Potato Slurry for Steers," Washington Agricultural Experiment Station, 1972.

Table 1.4. Selected Cattle Feedlot Expenses

Items	Dollars Per Head	Dollars Per Day
Expenses		
Transportation to Feedlot (300 miles)	3.96	----
Commission	3.00	----
Vet Medicine	3.00	----
Death Loss	5.64	----
Interest on Feeder and one-half feed	----	.188
Feed Handling	----	.117
TOTAL EXPENSES	15.60	.305

Source: "Livestock and Poultry Outlook and Situation." Economic Research Service, USDA, Washington, D.C., February, 1983.

when feedlot expenses were added to feed costs. Values of potato waste were estimated as the amount of available potato waste was varied in both cost scenarios. This provided a means for determining how potato waste value changes as optimal rations change and, hence, as ingredient combinations change.

Model 3: Optimal Feeding Program Model With Profit Maximization Per Year

This model maximizes the annual profit of a feedlot which can replace animals as they are slaughtered. Feedlot turnover may become a major consideration for producers feeding at or near the capacity level of the feedlot since performance rates can be affected by the level of potato waste feeding. The feeding scenario changes between Model 2 and Model 3 from the minimization of feed costs per head of cattle to the maximization of profit per unit of feedlot capacity for one year (Table 1.5). The five feed rations represented in Model 3 are identical to the rations used in Model 1. Each ration contains the total amounts of dry matter ingredients needed to produce a total weight gain of 440 beef equivalent pounds. The rations which produce a lower rate of gain and cause animals to spend additional days in the feedlot are appropriately charged in the formulation of Model 3. Optimal combinations of the five feed rations were chosen by the model, and estimates for the value of potato waste were produced as the availability of potato waste was decreased and as the price of choice beef changed. The prices for feed ingredients in Model 3 were the same as in Model 2. The choice steer and feeder calf prices used in Model 3 were established by the Omaha Livestock Auction in May 1982.

Table 1.5. Tableau Representation of Optimal Feeding Program Model for 440 lb. Weight Gain in Cattle: Profit Maximization (Model 3)

Objective: Maximize Profit (Revenues - Costs)																
Activities[a]																
		Rations					Ingredients							Constraints		
S_1	P_1	R_1	R_2	R_3	R_4	R_5	X_1	X_2	X_3	X_4	X_5	X_6	X_7	Type	Value	Name
782.25	-422.43	-61.40	-62.52	-61.72	-62.04	-65.49	-.035	0	-.058	-.092	-.151	-.049	-.130			Revenues ($/head) - Costs[b]
1		-1	-1	-1	-1	-1								=	0	Feed-Sell Choice Steer
	1	-1	-1	-1	-1	-1								=	0	Buy-Feed Choice Steer
		687.0	704.7	693.5	699.3	760.0	-1							=	0	Alfalfa Hay (pounds)
		0	484.5	813.4	1297.8	1609.9		-1						=	0	Potato Slurry (pounds)
		2013.6	1730.3	1255.3	934.4	645.2			-1					=	0	Barley (pounds)
		228.0	195.0	143.4	106.9	74.5				-1				=	0	Beet Pulp (pounds)
		18.1	13.8	7.9	3.4	0					-1			=	0	Urea (pounds)
		15.1	15.4	14.0	13.7	14.3						-1		=	0	Salt (pounds)
		.3	.3	.3	.3	.3							-1	=	0	Vitamin A (pounds)
		150.17	153.85	151.2	152.25	163.57								≤	365	Total Rations (animals) Fed Per Year

a/ S_1 is choice beef selling activity; P_1 is feeder calf purchase activity; R_i are respective feed rations, each of which produce a 440 lb. weight gain in cattle at a starting weight of 610 pounds; X_i are feed ingredients where X_1 is alfalfa hay, X_2 is potato slurry, X_3 is barley, X_4 is beet pulp, X_5 is urea, X_6 is salt, and X_7 is vitamin A.

b/ Cost of P_1 measured in $/head; cost of R_i measured in $/unit; cost of X_i measured in $/pound.

Results

The prices of barley, corn, and alfalfa hay in Model 1 were represented by a relative price series constructed with regression analysis. Prices of barley and alfalfa hay were derived from the price of corn. The prices of barley and alfalfa hay were found to be highly proportional to the price of corn. The estimated equations displayed high coefficients of determination, and the intercept values did not differ significantly from zero (Appendix). Current prices of barley, corn, and alfalfa hay that were used in the analysis of Model 1 were based upon the Portland price of corn for fall of 1982.

Model 1: Least Cost Feed Blend Model

Model 1 was analyzed using the NEg requirement rather than the ME requirement for a set of ingredient prices. Since the model can be analyzed using either energy requirement, it was necessary to generate two sample sets of solution results using the alternative energy bases for comparison. Because a nonlinear functional relationship exists between the NEg and ME measures, Model 1 will generate a formulation of ration ingredients using the ME base that is different from the ration formulated with the NEg base, even though the energy values expressed by both forms in the model may be largely equivalent. However, if the energy requirement in the model is weighted by the energy level (ME or NEg) contained by the ingredients in the ration mix, identical rations will be formulated regardless of the energy base used (ME or NEg). This is demonstrated in Table 1.6. The solution obtained in (1a) when Model 1 was formulated with an NEg

Table 1.6. Potato Waste Value and Ration Content for Corresponding NEg and ME Energy Bases (Units per kilogram, 100 percent dry)

Solution	Energy Value Used		Value of Potato Waste[b]	Slurry Content of Ration[c]
	NEg[a]	ME[a]		
1a	1.000	---	12.79	13.67
1b	---	2.665	12.57	13.67
2a	1.348	---	12.99	11
2b	---	3.098	12.70	11

a/ Mcal

b/ Cents

c/ Percentage

requirement of 1.00 Mcal per kilogram consisted of an ingredient mix composing one kilogram of feed ration. The amount of ME contained in this ration was 2.665 Mcal. The model was subsequently reformulated using the ME requirement of 2.665 Mcal instead of the NEg requirement. The same mix of ingredients was obtained with the ME base (Solution 1b) as was obtained using the NEg base (Solution 1a). The similar result occurred for Solutions 2a and 2b using NEg at 1.348 Mcal and ME at 3.098 Mcal. The values of potato waste in the corresponding rations differed only slightly between energy bases. Additional formulations based upon DE, TDN, or ME requirements yield equivalent values for potato waste since all are linearly related to one another.

The validity of Model 1 as a technique for evaluating feedstuffs was tested by comparing the shadow price values of barley and corn produced by the model to the monthly average corn and barley prices in Portland of May 1983, and to the relative corn and barley prices of September 1982 obtained from the regression results (Table 1.7).[2/] The shadow price values helped provide an indication of what the feed ingredients were worth in the model, given the respective set of ingredient prices. When the relative prices for barley, corn, and alfalfa hay were used in the model, a shadow price value (12.5¢/kg) was estimated for barley. This value did not differ significantly from the relative barley price (12.8¢/kg), used in the objective function. The exercise suggests that the shadow price value generated for a feedstuff in Model 1 may be representative of the long term price of the feedstuff, which lends credibility to the evaluation process of Model 1 using long term price relationships. Portland and Oregon market prices for May 1983 were then substituted for the relative

Table 1.7. Grain Valuation by Model 1 With Relative Prices of Corn and Barley and Portland Monthly Prices of Corn and Barley (cents per kilogram, 100 percent dry)

Relative Prices, September, 1982					
Corn	Barley	Alfalfa Hay	Shadow Price of Barley[c/]	Barley-Corn Ratio of Relative Prices	Barley-Corn Ratio Using Barley Shadow Price
13.3	12.8	7.7	12.5	.962	.940

May, 1983, Portland Prices and Oregon Prices					
Corn[a/]	Barley[a/]	Alfalfa Hay[b/]	Shadow Price of Corn[c/]	Barley-Corn Ratio of Portland Prices	Barley-Corn Ratio Using Corn Shadow Price
17.6	13.5	11.5	14.4	.767	.938

a/ Portland price.

b/ Oregon price.

c/ NEg = 1.20 Mcal in least cost ration.

barley, corn, and alfalfa hay prices. The least cost ration model formulated a ration using barley, and a shadow value was calculated for corn (14.4¢/kg). The shadow price was somewhat lower than the Portland market price of corn (17.6¢/kg), reflecting the greater price volatility associated with short term prices. However, the barley-corn price ratio (.940) obtained from the barley shadow price value and corn relative price in September 1982 was quite comparable to the barley-corn price ratio (.938) of the barley market price and corn shadow price value in May, 1983. These results establish some validity for the valuation of feed ingredients with opportunity cost values using relative ingredient prices based upon long term price relationships. It can therefore be assumed that the same type of long term price relationship can be established for potato waste using Model 1 to estimate opportunity cost values, even when a price series for potato waste is unavailable.

Feed blend rations were formulated with Model 1 using relative ingredient prices based upon nutritional requirements. The least cost rations were separated into two groups: rations formulated with corn where barley is not considered by the model as a potential ingredient (corn based rations); and rations formulated with barley where corn is not considered a potential feed ingredient (barley based rations). When the relative ingredient prices are used in the analysis with both corn and barley, the least cost ration that is formulated satisfies the nutrient requirements of the model by using corn rather than barley exclusively in the ingredient mix. Barley can be considered a feed substitute for corn, and is sometimes used by feedlot operators in the ration instead of, or in combination with, corn. Therefore, the value of potato waste in cattle feeding needed to be estimated for both rations where either barley or corn was fed in conjunction with potato waste and other ingredients.

Numerous sets of least cost feed rations were formulated as corn or barley based rations using Model 1. To help understand the physical ranges and tradeoffs involved between feed ingredients and energy levels in the ration, Figures 1.1 and 1.2 were developed to illustrate the sensitivity of the results. Viewed in this context, it is possible to also examine how potato waste value varies between rations as the ingredient formulation changes and/or energy levels changes.

The values for potato waste were relatively constant as the ration composition varied for corn and barley based rations with fixed relative ingredient prices. Potato waste values ranged from 10.163¢/kg (a, Figure 1.1) to 12.998¢/kg (b, Figure 1.1) dry matter in the corn based rations. The value of potato waste declined slightly as the percentage of potato waste in the corn based rations increased with a fixed NEg level or with a constant hay proportion (Figure 1.3). This was a result of the addition of urea to the ration, which was required to offset the loss in digestible protein as potato waste substituted for corn. For barley based rations, the value of potato waste ranged from 12.316¢/kg (a, Figure 1.2) to 15.738¢/kg (b, Figure 1.2) dry matter. The potato waste value also declined slightly whenever the percentage of potato waste in the barley based rations increased with a constant level of NEg or constant proportion of hay due to the addition of urea to the ration (Figure 1.3).

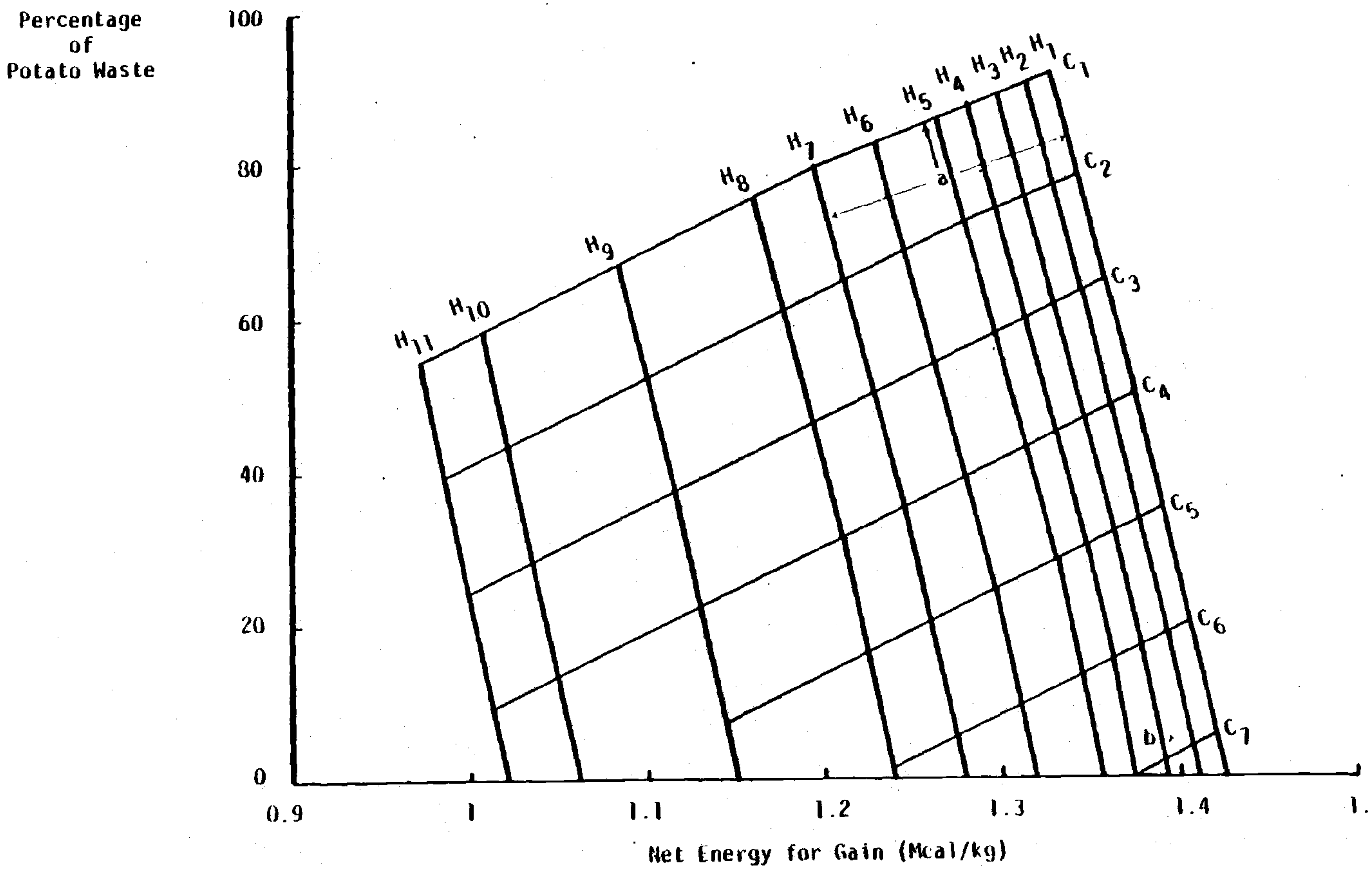

Figure 1.1. Potato Waste, Corn, and Alfalfa Hay Percentage Contained in Least Cost Rations Formulated at Selected NEg Levels[1/]

[1/] H_i are iso-alfalfa hay lines where H_1 equals 2 percent hay, H_2 equals 4 percent hay, H_3 equals 14 percent hay, H_7 equals 18 percent hay, H_8 equals 22 percent hay, H_9 equals 31 percent hay, H_{10} equals 40 percent hay, and H_{11} equals 44 percent hay; C_i are iso-corn lines where C_1 equals 0 percent corn, C_2 equals 15 percent corn, C_3 equals 30 percent corn, C_4 equals 45 percent corn, C_5 equals 60 percent corn, C_6 equals 75 percent corn, and C_7 equals 90 percent corn.

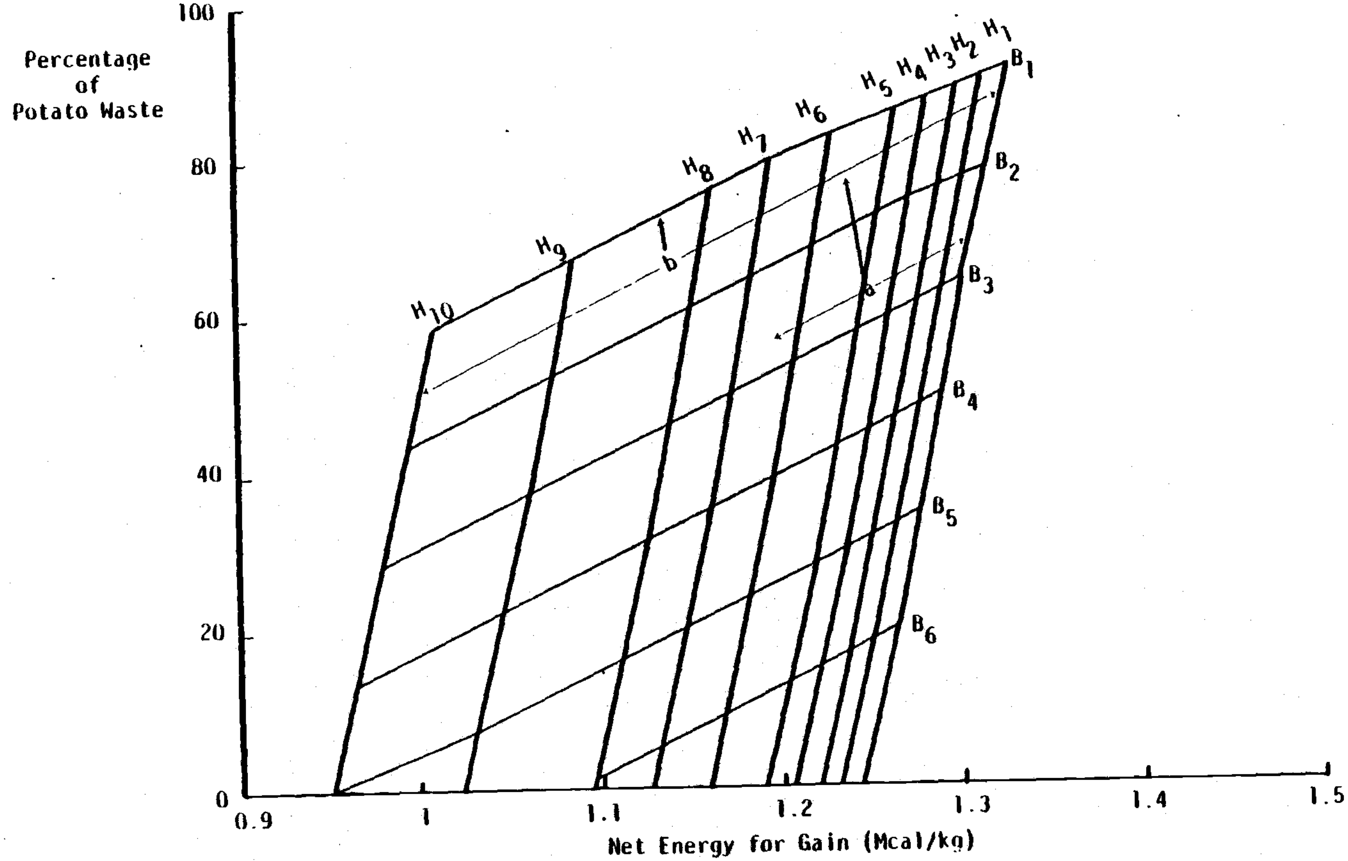

Figure 1.2. Potato Waste, Barley, and Alfalfa Hay Percentage Contained in Least Cost Rations Formulated at Selected NEg Levels[1/]

1/ H_i are iso-alfalfa hay lines where H_1 equals 2 percent hay, H_2 equals 4 percent hay, H_3 equals 6 percent hay, H_4 equals 8 percent hay, H_5 equals 10 percent hay, H_6 equals 14 percent hay, H_7 equals 18 percent hay, H_8 equals 22 percent hay, H_9 equals 30 percent hay, and H_{10} equals 40 percent hay; B_i are iso-barley lines where B_1 equals 0 percent barley, B_2 equals 15 percent barley, B_3 equals 30 percent barley, B_4 equals 45 percent barley, B_5 equals 60 percent barley, and B_6 equals 75 percent barley.

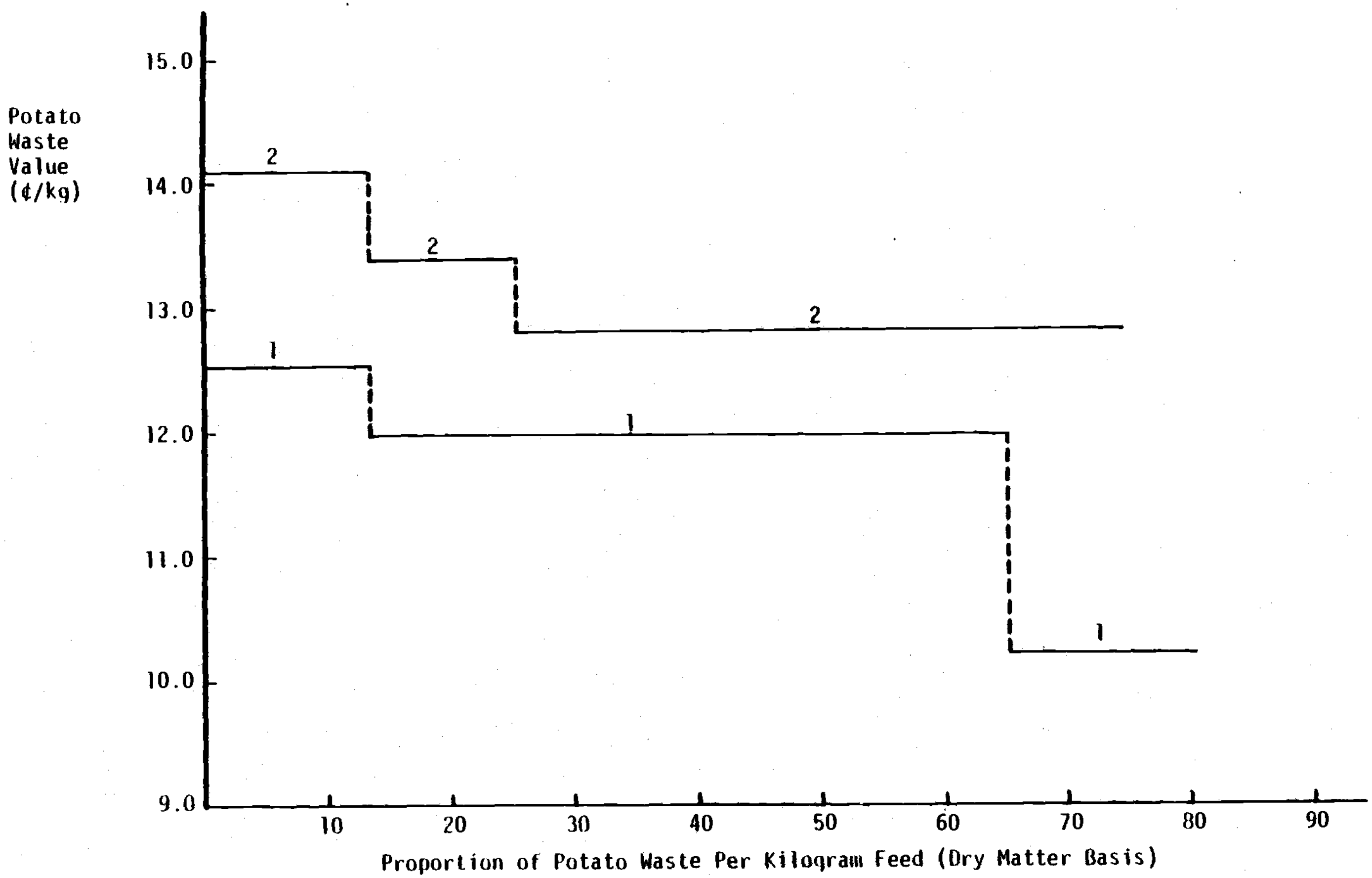

Figure 1.3. Potato Waste Value for Various Proportions of Potato Waste in Ration with Constant NEg

1 Corn based rations, NEg equals 1.27 Mcal/kg.

2 Barley based rations, NEg equals 1.20 Mcal/kg.

The only real abrupt changes in potato waste values occurred at the lower extremes of the value range for corn based rations (a, Figure 1.1) and the higher extremes of the value range for barley based rations (b, Figure 1.2). In both cases, these values are brought about because of the relatively low amount of digestible protein being contributed to the ration by the major feed ingredients. This results in the addition of urea and/or soybean meal to the ration to offset the protein loss due to the low degree of feedgrain and roughage utilization. When protein supplements are used, the major value of the other feed ingredients is determined more for their ability to furnish digestible protein relative to urea and/or soybean meal. For corn based rations, both urea and soybean meal are required in the ration when the amounts of corn, alfalfa hay, and potato waste are too low to meet the digestible protein constraint (a, Figure 1.1). The potato waste virtually substitutes for corn and alfalfa hay per unit of NEg, thereby removing two important sources of protein from the rations. The potato waste contributes a low amount of protein relative to the corn and hay it is replacing, which serves to decrease the marginal value of potato waste per kg on a protein basis. This results in a lower shadow price value for potato waste than was the case when soybean meal was not required in the ration.

When the amounts of major feed ingredients in barley based rations are too low to supply the required amount of protein, urea is added. Potato waste substitutes for barley per unit of NEg, but adds alfalfa hay in the process. Since the alfalfa hay is a larger contributor of protein to the ration than barley, the value of potato waste increases on the basis of the total protein contribution to the ration. This results in a higher shadow price value per kg of potato waste compared to rations where urea is not required.

For the remaining rations, the set of maximum shadow price values for potato waste occurred in both the corn and barley based rations when the potato waste level was approximately 11 percent and below. This is also the level of potato waste fed to cattle in actual feedlot rations, according to information obtained from selected Pacific Northwest feedlots. Potato waste value per kg varied by 35 percent for corn based rations and by 27 percent for barley based rations for different levels of NEg (Table 1.8).

The majority of the rations formulated by Model 1 evaluate potato waste principally upon the basis of its net energy for gain, or NEg, contribution to the rations. The total energy value of the potato waste is dependent not only upon the amount of NEg that is embodied per unit, but also upon its ability to effectively substitute for other feed ingredients on an NEg basis. The substitution properties of potato waste with corn, barley, and alfalfa hay per unit NEg becomes an important determinant of potato waste value since the proportion of ingredients contained in the ration mix other than corn, barley, potato waste, and alfalfa hay is minimal, and the digestible protein requirement is generally satisfied by the major ingredients in the ration. Three major results explain the argument:

(1) Overall, barley based rations displayed higher potato waste values than did the corn based rations. Within the ration set, potato waste may substitute for either barley or corn to provide units of NEg to the ration. The price of barley per unit of NEg is greater than the price of corn per unit of NEg. If the potato waste is valued for

Table 1.8. Potato Waste Values at Various NEg Levels for Corn and Barley Based Rations Containing 11 Percent Potato Waste. (Units per kilogram 100 percent dry)

Corn Based Rations		Barley Based Rations	
NEg	Potato Waste Value	NEg	Potato Waste Value
Mcal	¢	Mcal	¢
1.415	12.291	1.258	14.104
1.398	12.381	1.243	14.104
1.380	12.998	1.228	14.095
1.362	12.998	1.214	14.095
1.343	12.998	1.199	14.095
1.307	12.550	1.170	13.437
1.267	12.550	1.134	13.437
1.227	12.550	1.106	13.437
1.137	12.550	1.034	13.437
1.047	12.550	0.960	12.850

its ability to provide NEg units on a one to one ingredient substitution basis, potato waste should be valued more highly in barley based rations than corn based rations, which is precisely what occurred.

(2) All values of potato waste in the corn based rations were less than the price of corn per unit of dry weight, while potato waste values in the barley based rations were greater than the price of barley for any NEg level. It takes more dry weight units of potato waste than corn to supply some fixed amount of NEg. Therefore, one kg of potato waste should be valued below one unit of corn using the NEg valued criterion. Similarly, it takes more physical units of barley than potato waste to supply some fixed amount of NEg. Therefore, one unit of potato waste should be valued above one unit of barley, as the results show.

(3) The value of potato waste generally increased for rations containing 11 percent potato waste as the level of NEg contained in the ration was increased. Increasing the NEg requirement for any ration places a premium upon those ingredients capable of providing relatively abundant amounts of NEg. Potato waste is one such ingredient, so its value subsequently increases as the level of NEg increases. The exceptions occur once more for corn based rations that require the addition of urea which correspond to rations containing 4 percent alfalfa hay and less. However, rations which contain less than 5 percent roughage are not practical due to the high probability that they will produce digestive disfunction in cattle. Barley based rations did not require any urea at the lower alfalfa hay levels, since the protein requirements were primarily met by the barley.

The impact of an increase in the relative prices of corn, barley, and alfalfa hay was analyzed (Tables 1.9 and 1.10). Prices for barley and alfalfa hay were derived from the price of corn by increasing the price of corn and using the regression analysis derived earlier for relative ingredient prices. Diagonal elements in the tables represent potato waste values for proportional increases in the price of corn or barley and alfalfa hay. The value of potato was once again determined principally from its ability to substitute for major feed ingredients on a NEg valued basis. Feedgrains and potato waste are close energy substitutes for one another so that the net effect of a feedgrain price change upon potato waste value is positive. The substitution process between ingredients based on NEg differs between corn and barley based rations (Figures 1.1 and 1.2). In corn based rations, alfalfa hay and potato waste are substitutes in terms of providing NEg to the feed ration. Therefore, a change in the price of alfalfa hay has a positive effect upon the value of potato waste in the corn based ration. Both alfalfa hay and potato waste substitute for barley on an NEg valued basis, and in this sense are competitive ingredients. A change in the price of alfalfa hay in barley based rations has a negative effect upon the value of potato waste. By the same rationale, the magnitude of the energy valued substitution effect is greater for corn and barley price changes which outweigh the effects of alfalfa hay price increases. Consequently, a proportional change in the prices of corn or barley and alfalfa hay has a positive net effect upon the value of potato waste.

Model 2: Optimal Feeding Program With Cost Minimization

The value of potato waste was determined in Model 2 as optimal

Table 1.9. Potato Waste Value in Rations Containing 11 Percent Potato Waste with Selected Ingredient Prices (cents per kilogram 100 percent dry)

	Alfalfa Hay Price			
Corn Price	7.7	11.3	15.5	23.2
13.3	13.0	13.3	13.5	13.5
19.5	18.6	19.0	19.3	19.4
26.5	25.0	25.3	25.7	25.9
39.8	35.4	35.4	35.4	35.4

Table 1.10. Potato Waste Values in Rations Containing 11 Percent Potato Waste with Selected Ingredient Prices (cents per kilogram 100 percent dry)

	Alfalfa Hay Price			
Barley Price[a/]	7.7	11.3	15.5	23.2
12.8	14.1	13.6	13.2	13.2
17.9	19.9	19.3	18.7	18.7
25.6	28.6	28.1	27.5	27.0
38.4	43.1	42.6	42.0	40.8

feed rations were selected when total feed costs were minimized; and again when total feed costs plus feedlot expenses were minimized. Potato waste was assigned an ingredient price of zero, and the level of potato waste availability was gradually restricted. This allowed the value of potato waste to be determined when different combinations of feed rations were selected by the model. Each combination of feed rations that is optimal in Model 2 will contain the total amount of feed ingredients (in dry weight pounds) which produce a total weight gain of 440 pounds per head of cattle.

Ration 5 was selected in the solution when the level of potato waste available for feed was unrestricted (Table 1.11). This ration contains the highest percentage of potato waste of any of the experimental rations (Table 1.2). As the availability of potato waste was limited, ration 3 was utilized, first in combination with ration 5, and then in combination with ration 1. The addition of feedlot expenses to the objective function had no effect upon the combinations of rations chosen for the minimum feed cost solutions.

The values generated for potato waste for the various solutions of feed ration combinations in Model 2 were very comparable to the values of potato waste generated in Model 1. The value of potato waste in both models remained fairly constant as the composition of the feed rations changed. There was a modest decline in potato waste value in Model 2 when feedlot expenses were added. The value of potato waste associated with the feeding of ration 5 in Model 2 was somewhat lower than the values associated with other feed ration combinations. The lower potato waste value reflected the slightly lower

Table 1.11. Potato Waste Values and Optimal Feed Rations Selected for Various Amounts of Potato Waste in Model 2 Versus Potato Waste Values Developed in Model 1 (units per kilogram 100 percent dry)

		Potato Waste Value		
		Model 2		Model 1
Total Available Potato Waste[a/]	Ration Number Fed[b/]	Minimum Feed Costs	Minimum Feed Costs and Expenses	Minimum Feed Costs
		¢	¢	
1609.94	5	11.2	10.2	12.8
813.43	3	14.4	14.3	13.4
0	1	14.4	14.3	14.1

[a/] Pounds, dry matter; Model 2

[b/] Model 2

degree of performance attributed to ration 5 relative to the other rations in the model.

Model 3: Optimal Feeding Program Model With Profit Maximization Per Year

The value of potato waste was determined by analyzing data from Model 2 with the objective function of profit maximization per head of cattle per year under the assumption of full feedlot capacity. Model 3 places a greater emphasis upon the average weight gain produced by each ration by selecting the feeding process that provides ingredient cost savings to the feedlot and causes animals to spend less time in the feedlot. This allows the producer to turn cattle over quickly and more frequently so that greater revenues can be earned.

The average daily weight gains produced by the feed rations containing potato waste are all slightly lower than the average daily weight gain produced by ration 1, which contains no potato waste (Table 1.2). Cattle that are fed a ration containing potato waste will spend more time in the feedlot than if they were fed ration 1. The number of cattle which can be fed and sold during the year is consequently reduced, thereby lowering the revenue which producers would have earned if ration 1 was fed to the cattle. The result is that potato waste is valued slightly lower in Model 3 than in Models 1 and 2 for the same sets of optimal rations (Table 1.12).

As the prices of choice beef is increased in the model, with all other prices constant, greater emphasis is placed upon the average daily rate of weight gain produced by each of the rations. Greater profits can be obtained by the producer by bringing more cattle to

Table 1.12. Potato Waste Value, Optimal Feed Rations, Total Cattle Fed, and Total Profit for Various Potato Waste Amounts and Various Beef Prices in Model 3

Choice Beef Price[a/]	Total Available Potato Waste[b/]	Ration Number Fed	Number Cattle Fed	Potato Waste Value[c/]	Total Profit[d/]
67.50	3592.52	5	2.23	4.8	255.44
74.50	3111.26	4	2.40	9.6	363.27
74.50	1963.60	3	2.41	14.1	323.52
74.50	0	1	2.43	14.1	323.52
80.00	3111.26	4	2.40	9.4	504.32
90.00	3111.26	4	2.40	9.1	760.79
100.00	3111.26	4	2.40	8.7	1017.25
100.00	1963.60	3	2.41	13.6	974.30
100.00	0	1	2.43	13.6	974.30

a/ Dollars per hundredweight

b/ Pounds dry matter

c/ Cents per kilogram dry matter

d/ Dollars, adjusted for estimated potato waste value market during the one year period. This is best accomplished in the model by feeding those rations that promote the higher rates of gain so that earlier replacement can occur. Therefore, as the marketing margin rises, two primary outcomes result:

(1) The optimal ration mix selected by Model 3 differs from the ration mix selected by Model 2 as the availability of potato waste changes. Ration 5, which contains the highest percentage of potato waste among the rations, remains optimal in Model 3 at low profit margins and high potato waste availability. Although the rate of gain produced with ration 5 is lower than any of the rations, its selection allows significant ingredient cost savings for feedlots. The low value of potato waste associated with this ration is a result of the ration's low rate of gain. As profit margins increase, ration 4, which contains less potato waste than ration 5, replaces ration 5 to take advantage of ration 4's higher rate of gain.

(2) The value of potato waste declines slightly compared to the potato waste value estimated with a choice beef price of $67.50 per cwt., for any optimal ration combination (feed process) selected by Model 3 with a constant level of potato waste availability. This can be illustrated by examining the potato waste values corresponding to Ration 4 as the choice beef price rises (Figure 1.4). Once again, the slightly lower rates of gain produced by rations containing potato waste cause the value of potato waste in these rations to be discounted when the profit margin is increased.

Discussion

The results generated by the simple least cost feed blend model

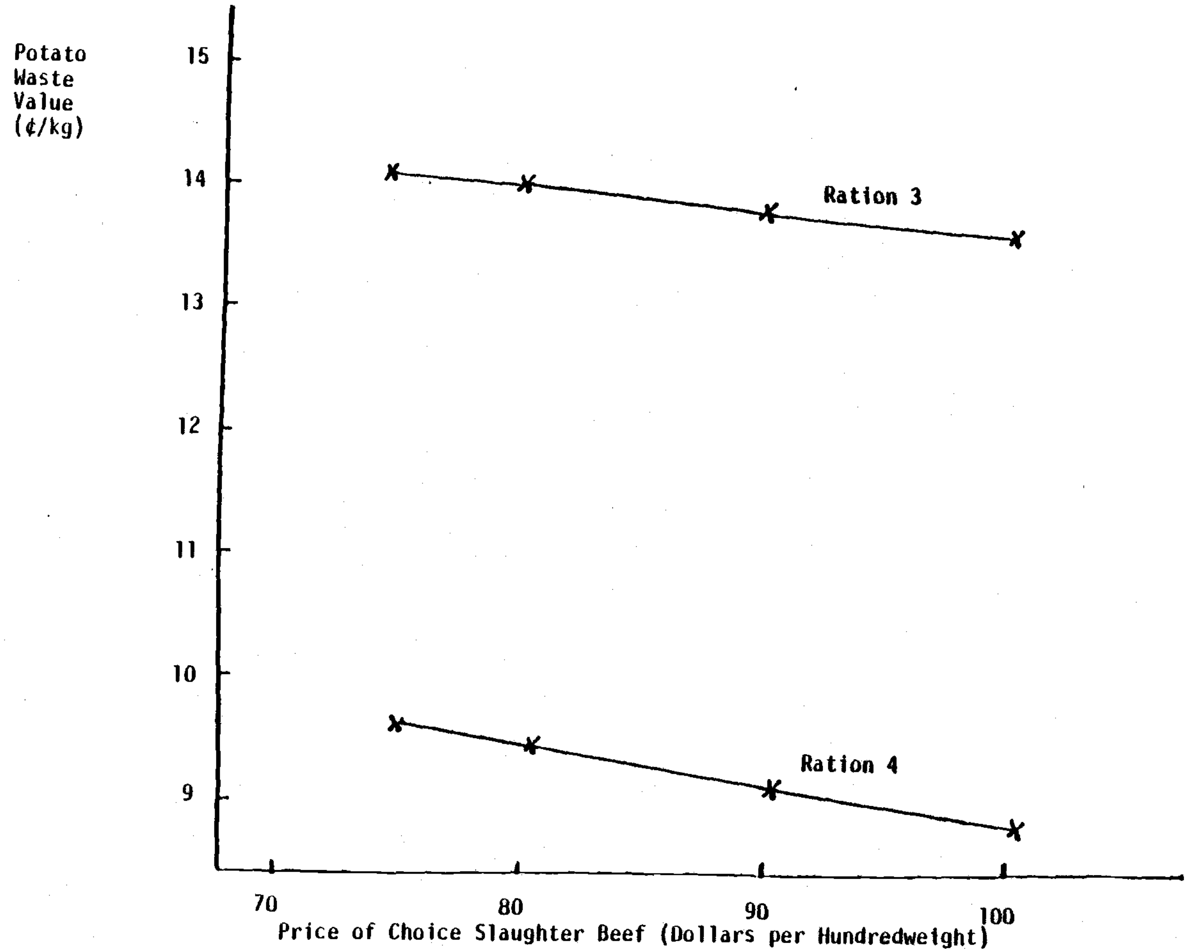

Figure 1.4. Relationship of Potato Waste Values to Choice Beef Prices for Potato Waste Fed in Rations 3 and 4 in Model 3.

and the optimal feeding program model for the value of potato waste in cattle feeding were very similar. The optimal feeding program model displayed different results only when the assumption of full feedlot capacity with animal turnover per fixed time period was addressed. Except for this situation, it can be concluded that the simple feed blend model serves as a fairly reliable method for estimating the value of potato waste in cattle feeding. The real advantage of the simple blend model lies in its rather simplified approach toward evaluating potato waste. The value of potato waste may be estimated with the least cost blend model for any number of rations with multiple combinations of ingredients. On the other hand, the information that is available on experimental feed rations that use potato waste is very limited, making the range of ingredient combinations in rations analyzed by the optimal feeding programs models much smaller than in the least cost feed blend model.

Efforts can be made by researchers to expand the range of ration formulations in feeding trials by limiting the number of diets in the intermediary range of roughage and concentrate proportions, and focusing more on the extremes. For instance, it is plausible to assume that a diet containing less than 20 percent alfalfa hay would be a better control diet for cattle feeding experiments using potato waste than what was used in the experiment (Heinemann and Dyer, 1972) analyzed in this paper. However, a large obstacle that the researchers must still overcome is the cost of conducting more experiments, both in time and money. Also, as the number of rations which need to be analyzed using the optimal feeding programs models increases, the analysis becomes more complex. The size of the model grows, and additional feed ingredient amounts must be included for each new ration. In contrast, the feed blend model can be used to formulate different rations only by ranging right-hand side values for nutrient and/or ingredient constraints. The potato waste may also be evaluated with relative ease using the simple blend model when alternative feed sources, such as corn silage or wheat are fed as part of the ration. The optimal feeding program model must utilize the results of experimental feeding trials, which must be conducted each time a new feed ingredient is introduced. The simplicity by which the least cost model can evaluate potato waste in different feed rations outweighs the extra costs associated with the collection of data and analysis of optimal feeding programs based on numerous feeding trials with various designs.

The results of the study should prove useful to beef producers who feed potato waste or have an opportunity to purchase potato waste. The simple blend model provides the producer with information relating to the value of potato waste and other ingredients for various sets of ingredient prices. The producers can use the information to arrive at their own values for potato waste based upon the size of his herd, the moisture and nutrient content of the potato waste, and the relative availability of the product. Aided with this knowledge, beef producers should be in a position to make better decisions relating to potato waste purchases and use.

Endnotes

1/ Ideally, the prices of all ingredients should be used in the regression analysis to form a series of relative ingredient prices. However, the relative amounts of other ingredients comprising the least cost feed rations is minimal, and any change in their prices has very little effect upon the values in the solutions to the model.

2/ Relative prices are monthly average Portland prices of barley and monthly average Oregon prices of alfalfa hay which are both derived from the monthly average Portland price of corn using the linear price relationships estimated with regression analysis (see Appendix).

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Addendum

Simplified Methods for Approximating Potato Waste Values

The simple blend diet model which establishes requirements for major nutrients provides a valid procedure for estimating the value of any particular ingredient relative to the prices of other ingredients. However, occasions may arise when such a model is not readily accessible. It would be useful if a simple rule of thumb procedure were available that would give adequate approximations in the absence of the linear programming model and computer equipment. Three such procedures were developed.

Using a set of prices for major feed ingredients based on long term price relationships with each other, 84.2 percent of the high energy ration costs is attributed to grain, the major ingredient. Grain and roughage together make up 85.3 percent of the ration cost. Eighty-eight percent of the ration cost can be attributed to the energy requirement and 94.7 percent to the combined energy and protein requirement. These facts suggest that an approximate value of potato waste might be developed in relation to one or two major ingredients or nutrients in the diet problem. The first approach was to regress the shadow price values of potato waste generated by the simple diet model against the corresponding ingredient prices (a) in relation to grain prices alone, and (b) in relation to both grain and hay prices. The relationship between potato waste values and grain price was estimated in the first set of equations for the case where the price of alfalfa hay was assumed to be constant, while the price of grain varied. In the second set of equations, the price of hay was assumed to change in proportion to the price of grain. The data for the regression equations came from Table 1.9 and 1.10 of the least cost feed blend problems, where the price of corn ranges from 13.3¢/kg DM to 39.8¢/kg DM; the price of barley ranges from 12.8¢/kg DM to 38.4¢/kg DM, and the price of alfalfa hay ranges from 7.7¢/kg DM to 23.2¢/kg DM. The results are as follows:

Grain Price Equations for Potato Waste Value;
Constant Hay Price

(1) $PW_c = .021 + .844P_c; \quad R^2 = .99$

(2) $PW_b = -.003 + 1.132P_b; \quad R^2 = .99$

Grain Price Equations for Potato Waste Value;
Proportional Hay and Grain Prices

(3) $PW_c = .024 + .842P_c; \quad R^2 = .99$

(4) $PW_b = .009 + 1.039P_b; \quad R^2 = .99$

Grain and Hay Price Equations for Potato Waste Value

(5) $PW_c = .106P_a + .873P_c; \quad R^2 = .99$

(6) $PW_b = -.077P_a + 1.130P_b; \quad R^2 = .99$

where PW_c is the shadow price value of potato waste (dollars/kg DM) in rations based on corn; PW_b, the shadow price value of potato waste (dollars/kg DM) in rations based on barley; P_c, the price of corn (dollars/kg DM); P_b, the price of barley (dollars/kg DM); and P_a is the price of alfalfa hay (dollars/kg DM).

The regression formulas estimate the value of potato waste given the specific moisture content and nutritional composition of the potato waste that was used to formulate diet rations in the simple blend problem. The potato waste had a moisture content of 86.9 percent, with an NEg value of 1.39 Mcal/kg DM and a digestible protein content of 8.2 percent DM (National Academy of Science, 1971).

The second approach was to evaluate potato waste on the basis of its major nutrient value relative to the nutritional value of other feed ingredients. Formulas based on major nutrient values evaluate potato waste as the nutritional contributions of the potato waste and ingredients change. Three such formulas are provided. The first formula evaluates potato waste on the basis of only one nutrient -- energy, which constitutes the most costly nutritional requirement in terms of total diet costs. The next two formulas estimate potato waste value on the basis of both protein and energy (Huang, 1979). The formula for evaluating potato waste based on energy contribution alone is:

$$(7) \quad f_1 = X_1 P_a + X_2 P_g$$

where f_1 is the value of potato waste (dollars/kg DM); P_a, the price of alfalfa hay (dollars/kg DM); P_g, the price of grain -- either corn or barley (dollars/kg DM); and X_1 and X_2 are amounts of hay and grain substituted for one unit of potato waste so that the energy level of the diet remains unchanged.

The values for X_1 and X_2 are determined by solving the following set of equations:

(7a) $W_1 = a_1 X_1 + a_2 X_2$

(7b) $1 = X_1 + X_2$

Isolating for X_1 and X_2 yields the following:

(7c) $X_1 = \frac{W_1 - a_2}{a_1 - a_2}; \quad X_2 = 1 - X_1$

where W_1 is the amount of NEg (in Mcal) contained in one kilogram of potato waste; a_1, the amount of NEg (in Mcal) contained in one kilogram of alfalfa hay; and a_2 is the amount of NEg (in Mcal) contained in one kilogram of grain (corn or barley). The variables X_1 and X_2 represent amounts of alfalfa hay and grain, respectively, that may be substituted for one unit of potato waste so that the total NEg remains unchanged.

The second formula estimates the value of potato waste relative to its energy and protein value and is expressed by:

(8) $f_2 = W_1 Z_1 + W_2 Z_2$

where f_2 is the value of potato waste (dollars/kg DM); W_1 is defined as before; W_2 is the amount of digestible protein (DP) contained in one kilogram of potato waste; Z_1, the price per kilogram of NEg to be determined from rations based on corn or barley; and Z_2 is the price per kilogram of DP to be determined from rations based on corn or barley.

Values for Z_1 and Z_2 are obtained by solving the following set of equations:

(8a) $C_1 = a_{11} Z_1 + a_{12} Z_2$

(8b) $C_2 = a_{21} Z_1 + a_{22} Z_2$

where C_1 is the price per kilogram of alfalfa hay; a_{11}, the amount of NEg contained in one unit of alfalfa hay; a_{12}, the amount of DP contained in one unit of alfalfa hay, c_2, the price per kilogram of grain (corn or barley); a_{21}, the amount of NEg contained in one kilogram of grain (corn or barley), and a_{22} is the amount of DP contained on one kilogram of grain (corn or barley).

The a_{ij} of equations (8a) and (8b) can be alternatively defined (as by Huang) to yield the third formula for evaluating potato waste based on major nutrient values. Instead of using NEg for a_{11} and a_{21}, the energy value could be expressed as nonprotein TDN (total TDN minus DP), with a_{12} and a_{22} remaining the same, that is, DP = protein TDN. This alternative yielded essentially the same estimates for the value of potato waste as did the NEg and DP basis. The results were not very sensitive to the energy basis selected.

The method of evaluation based on NEg per unit substitution provides the simplest method of the short form formulas for estimating potato waste value. Given the relative amounts of NEg contained in potato waste and the major ingredients, the NEg based method based on energy content alone, provides a formula by which potato waste value can be calculated directly from the prices of the two major ingredients, in this case, hay and grain. Solving equations 7a and 7b and substituting in equation 7 for NEg values given in Table 1.13 obtains:

(10) $f_1 = .091 P_a + .909 P_c$ for corn based rations;

(11) $f_1 = -.125 P_a + 1.125 P_b$ for barley based rations.

Table 1.13. Potato Waste Values for Corn and Barley Rations Generated by Alternative Methods

Method	Based on Corn $/kg	Based on Barley $/kg
L.P. Shadow Price (Simple Blend Problem)	.130	.141
Regression Formula L.P. Shadow Price Against		
a. Price of Grain	.136	.142
b. Price of Hay and Grain	.124	.139
Major Nutrient Values:		
a. Energy Alone (NEg Basis)	.128	.134
b. Energy and Protein (NEg and DP Basis)	.113	.121
c. Energy and Protein (NP-TDN and DP Basis)[a/]	.113	.121

a/ Nonprotein TDN.

The values for alfalfa and corn coefficients shown in equation (10) (.091 and .909, respectively) are close to the coefficients estimated by the regression model in equation (5). Similarly, the values for the alfalfa and barley coefficients shown in equation (11) (-.125 and 1.125) are close to the regression coefficients estimated in equation (6). The differences between the regression coefficients and energy-based value equations can be accounted for by the fact that the value contribution made by ingredients to potato waste values other than grain and alfalfa hay are taken into consideration by the regression equations. However, when grain prices and alfalfa hay prices are substituted into both equation sets, similar values for potato waste are produced (Table 1.13).

Estimates of potato waste value were calculated for the nutrient based formulas and regression equations using the ingredient prices for barley and alfalfa hay that were derived from the price of corn in September, 1982, using the relative price series equation derived from the regression analysis procedure (see Appendix). The potato waste value estimates were compared to the shadow price values of potato waste that were generated from the linear programming diet problem using the same set of prices for corn, barley, and hay with 1982 fall prices for other feed ingredients contained in the model (Table 1.13). A comparison of the potato waste values reveals that the NEg-based equations provide the most accurate estimates of potato waste value among the major nutrient-value equations. The regression formula equations provide reasonably accurate estimates of potato waste value based on one or two feed ingredients. However, the reliability of these estimates will diminish as the nutritional composition of the potato waste varies.

The simple blend model, the regression formulas, and the major nutrient-value equations all provided estimates of potato waste value in barley based rations that were greater than the estimates in corn based rations. This result occurs because of the long run price differential that exists between corn and barley in addition to the differences in the relative energy-protein composition of the two ingredients.

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EFFECTS OF FEEDLOT SIZE AND TRANSPORTATION COSTS ON VALUE OF POTATO WASTE

Two alternative model types have been previously employed to estimate the value of potato waste as a cattle feed ingredient (Turek and Brokken, 1984). The models used were a simple least cost feed blending model and an optimal feeding program model, both of which use potato waste. The feed blend model was used to formulate minimum cost feed rations from among potato waste and other ingredients so that specific nutrient requirements for cattle were satisfied (Model 1). The value of potato waste contained in these rations decreased slightly as the percentage of potato waste in the ration increased. The overall value of potato waste, however, was relatively constant as the ration composition varied.

The optimal feeding program model was used to evaluate potato waste based upon specific ingredient requirements for five different feed rations which could be used to feed an animal from a starting weight of 610 pounds to a finished weight of 1050 pounds -- a gain of 440 pounds. The base data for formulating the rations were taken from the feeding trial experiment conducted by Hienemann and Dyer (1971). The optimal feeding program model was used to minimize the feed costs and expenses associated with the feeding of the rations, so that the value of potato waste was estimated in the feeding process as different combinations of rations were selected for varying amounts of potato waste available for feeding (Model 2).

Both the models estimate similar values for potato waste. The estimated values represent what the value of potato waste is to the feedlot and reveals the maximum prices a feedlot would be willing to pay for potato waste delivered to the feedlot. However, potato waste usually contains a high amount of moisture and, consequently, is costly to transport. As the distance between feedlots and processing plants increases, transportation costs become a significant factor in the determination of potato waste value. Therefore, the effect that increasing transportation costs have upon the value of potato waste will be examined in this paper relative to the information and methods that have been previously used to estimate the feedlot value of potato waste. In addition, potato waste value will also be estimated as the relative feeding capacities change among spatially separated feedlots.

Problem

The major purpose of this paper is to estimate the value of potato waste at the supply center and at the feedlot when there is competition among spatially separated feedlots of different size (capacity) and transportation differentials. A linear programming model is devised which evaluates potato waste in hypothetical market areas by relating the total supply of potato waste in the area to the potential demand by feedlots. The analysis is conducted to incorporate changes in hauling distances and relative sizes of feedlots as the available supply of potato waste varies within the feeding period.

It is assumed that the supply of potato waste available to feedlots is fixed by the size of the potato processing plant. Changes in the available supply of potato waste reflect differences in plant size. Feedlots are capable of storing potato waste up to a 12-week period with only minor losses of nutrients. A constant supply of potato waste is therefore available for rations, and any problems caused by seasonal shifts in potato waste availability are minimal. As a result, rations containing potato waste which are fed to cattle should be consistent from one feeding period to the next.

Model

Two choices are available for selecting a model to evaluate potato waste in cattle feeding when the cost of transporting the waste to spatially separated feedlots is considered. Either the least cost feed blend model used in Model 1 or the optimal feeding program model used in Model 2 (Turek and Brokken, 1984) can be modified to include potato waste shipment activities between a potato processing plant and feedlots. The feed ration information contained in the feeding trial experiment (Heinemann and Dyer, 1971) that was used in Model 2 is not comprehensive and could be improved, perhaps, with further experimentation. However, the optimal feeding program possesses two advantages over the least cost feed blend model which recommend its use in this analysis:

1. The optimal feeding program model provides a better means of relating the dry matter intake of potato waste by cattle to the percentage of potato waste contained in the feed rations.

2. The optimal feeding program model is able to consider the effect on the cattle's weight gains as the proportion of potato waste in the rations changes.

Table 2.1 provides an ingredient description of the five feed rations identified within the modified optimal feeding program model. Each ration contains specific amounts of potato waste and other

Table 2.1. Ingredients Contained in Feeding Methods, Dry Matter Basis

	Rations 1	2	3	4	5
Ingredient	Percent				
Potato Waste	0.0	15.4	27.8	42.5	51.9
Barley	68.0	55.0	42.9	30.6	20.8
Alfalfa Hay	23.2	22.4	23.7	22.9	24.5
Beet Pulp	7.7	6.2	4.9	3.5	2.4
Urea	0.6	0.4	0.3	0.1	0.5
Salt	0.5	0.5	0.5	0.5	0.5
Vitamin A	a	a	a	a	a
Ingredient	Pounds				
Potato Waste	0.0	484.5	813.4	1297.8	1609.9
Barley	2013.6	1730.3	1255.3	934.4	645.2
Alfalfa Hay	687.0	704.7	693.5	699.3	760.0
Beet Pulp	228.0	195.0	143.4	106.9	74.5
Urea	18.1	13.8	7.9	3.4	0.0
Salt	15.1	15.4	14.0	13.7	14.3
Vitamin A	0.3	0.3	0.3	0.3	0.3
	Beef Pounds				
Average Daily Gain	2.93	2.86	2.91	2.89	2.69

[a]Less than .01 percent.

Source: W.W. Heinemann and I.A. Dyer, "Nutritive Value of Potato Slurry for Steers," Washington Agricultural Experiment Station, 1972.

ingredients required per 440 pounds of weight gain per head of cattle at a starting weight of 610 pounds. The productivity of the potato waste is represented in each feed ration through the relative efficiency by which the feed is utilized to achieve the desired weight gain.

The prices of all the ingredients, except for barley and hay, were obtained in the fall of 1982 by contacting Oregon feed purveyors and selected feedlots in Oregon and Washington. Barley and hay prices were derived from the price of corn in September, 1982, through the use of a relative price equation which was estimated using regression analysis upon Portland average monthly cash prices of corn and barley, and Oregon monthly average prices received for alfalfa hay from 1972-1982.[1/] The price of potato waste as a feed ingredient was assumed zero so that its value would be determined within the model. Each feedlot is assumed capable of obtaining unlimited amounts of all feed ingredients except potato waste, which is limited by the total amount available from the potato manufacturing plant. All feed ingredients, except potato waste, are assumed to have the same price at each feedlot.

The model may be expressed mathematically for n feeding methods containing h feed ingredients plus potato waste that may be utilized by m feedlots as follows:

$$(1)\quad \text{Minimize} \sum_{k=1}^{h} C_k X_k + \sum_{j=1}^{m} d_j Y_j$$

subject to

(2) $\sum_{j=1}^{m} \sum_{i=1}^{n} a_{ki} R_{ij} - X_k \leq 0$ for $k = (1, \ldots, h)$

(3) $\sum_{i=1}^{n} b_i R_{ij} - Y_j \leq 0$ for $j = (1, \ldots, m)$

(4) $\sum_{i=1}^{n} R_{ij} - 1 = 0$ for $j = (1, \ldots, m)$

(5) $\sum_{j=1}^{m} Y_j \leq S$

where

X_k is the number of dry matter pounds of feed ingredient k used.

C_k is the cost per dry matter pound of feed ingredient k.

Y_j is the number of dry matter pounds of potato waste ingredient shipped to feedlot j.

d_j is the transportation cost of potato waste to feedlot j.

R_{ij} is the proportion of ration i utilized by feedlot j.

a_{ki} is the amount of feed ingredient k contained within feeding method i.

b_i is the amount of potato waste contained by feeding method i.

S is the total amount of potato waste available for feed in the area.

Equation (1) minimizes the total cost of the feed ingredients used in the feeding methods plus the cost of shipping potato waste to the feedlots.

Equation (2) insures that the total use of feed ingredients in the rations fed by all feedlots does not exceed the total amount of ingredient k purchased by the feedlots.

Equation (3) insures that the use of ingredient Y in the rations fed by feedlot j does not exceed the total amount of the ingredient shipped to feedlot j.

Equation (4) insures that the sum of the feeding methods for feedlot j is unitary, i.e., each ration fed is expressed as a decimal or percent of the total feeding process being used per feedlot.

Equation (5) insures that the total amount of potato waste shipped to all feedlots does not exceed the total available supply of potato waste.

The model chooses optimal combinations of feeding methods for each feedlot through which potato waste may be fed by minimizing the total ingredient purchase costs and potato waste shipping costs associated with the feeding of some specific number of cattle in each feedlot. Solutions to the problem assure the potato processing plant a maximum return from the sale of its waste while a set of shadow prices are generated which reveal the per unit values of potato waste at the supply center and at the feedlots. The processor value will differ from the feedlot value by the amount of the transportation cost for any optimal solution. The potato waste supply for the area is varied within the model under the condition that potential feedlot demand is at least as great as the total available amount of potato waste. This insures that positive supply and demand center values will be generated for potato waste within the solution (Takayama and Judge, 1971, p. 50-51).

Data

The potato waste contains a high percentage of moisture and has a creamy, slurry form of consistency which lends itself to being transported by bulk milk tanker trucks. Consequently, the cost of transportation should closely resemble bulk milk transportation with only minor exceptions. It is therefore assumed that the technological requirements for transporting potato waste is the same for all feedlots: a 5,500 gallon bulk milk transport unit carrying a 48,400 pound (484 cwt.) payload.

The trucking rates used in the model are estimated from cost-of-service components provided by the U.S. Department of Agriculture (Moede, 1971), and a Washington State University study (Curilino, 1983), and are adjusted to 1982 dollars. It is assumed that each truck always carries a full load of 484 cwt. from the supply center to the feedlot, and averages 5.4 miles per gallon of fuel in the process (Lough, 1977). Fuel costs are based upon a price of $1.15 per gallon. Capital and indirect costs of the truck firm are assigned to each vehicle and amortized on an annual per mile basis. Hauling costs used in the linear programming model are derived from the total average costs estimates per cwt. as a function of round trip miles.

Transportation rates for shipping potato waste have been estimated as a function of the number of miles that feedlots are located from the processing plant. The cost equation that was derived for the analysis is

(6) $TC = a + bD$

where

TC = transporation costs of shipping potato waste ($/cwt.)

D = number of miles from processing plant to feedlot.

Two different distance scenarios are developed for the model to represent different feedlot locales. Three feedlots are located at distances of 5, 30, 40 miles from a single potato processing plant under one scenario and 5, 40, and 70 miles from the plant in another. The feedlot capacities are systematically altered between 4,000, 8,000, and 16,000 head of cattle among various hauling distances to account for changes in relative feedlot size and potential demand.

Results and Discussion

Potato waste values were estimated for both market distance scenarios for feedlots which each have a capacity to feed 4,000 head of cattle (Table 2.2). As was the case when the optimal feeding program model was previously analyzed without transportation cost considerations in Model 2 (Turek and Brokken, 1984), feed rations 3 and 5 were selected as being the most efficient methods of utilizing potato waste as a feed ingredient. The efficient rations each contain total dry weight amounts of feed ingredients, including potato waste, to produce a total weight gain of 440 pounds per head of cattle. The values of potato waste corresponding to the efficient rations are based upon specific costs of feed ingredients other than potato waste. Ignoring transportation costs for one moment, potato waste assumes a value at the feedlot of $6.53 per cwt. (100 percent dry) when fed in ration 3. Potato waste is valued at $5.09 per cwt. (100 percent dry) at the feedlot when fed in ration 5 as a higher proportion of the ration

Table 2.2. Optimal Potato Waste Values and Distribution Amounts for 4,000 Head Capacity Feedlots Located at Various Distance from Potato Processing Plants

Total Available Potato Waste a/	Rations Fed b/	Feedlot 1 Quantity Purchased c/	Feedlot 1 Price d/	Feedlot 2 Quantity Purchased c/	Feedlot 2 Price d/	Feedlot 3 Quantity Purchased c/	Feedlot 3 Price d/	Processor Price d/
Feedlots Located 5, 30, 40 Miles from Processing Plant								
(1) 32,536	3-1-1	100.0	6.532	0.0	---	0.0	---	5.218
(2) 65,072	3-3-1	50.0	5.872	50.0	6.532	0.0	---	4.513
(3) 97,608	3-3-3	33.3	5.545	41.6	6.250	33.3	6.532	4.231
(4) 129,468	5-3-3	49.7	5.094	25.1	5.799	25.1	6.081	3.780
(5) 161,328	5-5-3	39.9	4.389	39.9	5.094	20.2	5.376	3.075
(6) 193,188	5-5-5	33.3	4.107	33.3	4.812	33.3	5.094	2.793
Feedlots Located 5, 40, 70 Miles from Processing Plant								
(1) 32,536	3-1-1	100.0	6.532	0.0	---	0.0	---	5.218
(2) 65,072	3-3-1	50.0	5.545	50.0	6.532	0.0	---	4.231
(3) 96,932	5-3-1	66.4	5.094	33.6	6.081	0.0	---	3.780
(4) 129,468	5-3-3	49.7	4.699	25.1	5.686	25.1	6.532	3.385
(5) 161,328	5-5-3	39.9	4.108	39.9	5.094	20.2	5.940	2.793
(6) 193,188	5-5-5	33.3	3.261	33.3	4.248	33.3	5.094	1.947

a/ Dry matter cwt.

b/ Refers to feed rations utilized by each feedlot in market area. For example, in row (1) in scenario 1, where the rations fed are 3-1-3, ration 3 is fed by feedlot 1 located 5 miles from the processing plant, ration 1 is fed by feedlot 2 located 30 miles from the processing plant, and ration 1 is fed by feedlot 3 located 40 miles from the processing plant.

c/ Percent of market total.

d/ Dollars per cwt.

composition than in ration 3 (Table 2.1). The feedlot values establish the maximum per unit price feedlot managers would be willing to pay to the processor for potato waste in order to feed it in rations 3 and 5, transportation costs notwithstanding. The feeding of ration 3 is also preferred to the feeding of ration 5 due to the valuation in ration 3. To induce feedlot managers to purchase additional quantities of potato waste needed for ration 5, processors must be willing to accept a lower price not in excess of $5.09 per cwt. for the product.

When transportation costs for potato waste are included under perfectly competitive conditions, the price that the processor receives per cwt. of potato waste differs from the feedlot value associated with rations 3 and 5 by the per unit shipping costs of the feedlot. If the supply of potato waste offered by the processor is small relative to potential feedlot demand, all of the potato waste may be utilized by one feedlot. The processor price would then be determined by subtracting the per unit transportation costs of potato waste from the feedlot values associated with ration 3 or 5 for that feedlot. This particular case is illustrated in Table 2.2 when the supply of potato waste is 32,536 cwt. (100 percent dry). Feedlot 1 utilizes all of the available potato waste by feeding it in ration 3 in both distance scenarios. Since both feedlots are located 5 miles from the processing plant, each feedlot's transportation cost is the same, and is equivalent to $1.31. The processor price ($5.21) represents the F.O.B. processing plant potato waste value, and is determined by subtracting the transportation cost to feedlot 1 ($1.31) from the feedlot value established by feeding ration 3 ($6.53).

As the available supply of potato waste is increased, additional feedlots may wish to purchase potato waste. At a supply level of 65,072 cwt. in Table 2.2, feedlot 2 in both distance scenarios now purchases the additional amount of potato waste for use in ration 3. The processor price is now determined by subtracting the transportation costs of potato waste for feedlot 2 ($2.30) from the feedlot value at feedlot 2 ($6.53) corresponding with the feeding of potato waste in ration 3. Feedlot 1, as a result, enjoys a locational advantage relative to feedlot 2, thereby requiring it to offer a lower price for potato waste relative to feedlot 2. The difference in the maximum prices each feedlot is willing to offer reflects the relative difference in transportation costs ($.705), and may be viewed as an economic rent accruing to feedlot 1, relative to feedlot 2, due to locational advantage when a uniform price is charged to both feedlots by the processing plant.

Thus far, the discussion of processor value of potato waste has been based upon the feedlot value associated with the feeding of ration 3. It is possible, however, for feedlots to feed ration 5 if the supply of potato waste becomes relatively abundant, or if the maximum price a feedlot is willing to pay to feed potato waste in ration 5 is greater than the maximum price another feedlot is willing to pay to feed potato waste in ration 3. The latter case is illustrated in Table 2.2 in distance scenario 2, when the supply of potato waste is increased from 65,072 cwt. to 96,932 cwt. Rather than provide feedlot 3 with the privilege of feeding potato waste in ration 3, the additional potato waste is fed at feedlot 1 in ration 5. The solution occurs because the additional transportation costs per cwt.

of potato waste that are associated with the location of feedlot 3 relative to feedlot 1 now outweigh the per unit gain in the price of potato waste that the processor could receive when ration 3 is fed at feedlot 3, rather than ration 5 being fed at feedlot 1. Alternately stated, the processor can receive a higher price per cwt. of potato waste if the additional potato waste is purchased by the closer feedlot for use in ration 5 when per unit shipping costs of feedlot 3 minus the per unit shipping costs of feedlot 1 is greater than the difference in feedlot values between rations 3 and 5.

This establishes a pricing rule which determines the maximum price the processor can receive for each cwt. of potato waste that is sold. In this analysis, the critical distance between feedlot locations that induces the closer feedlot to feed ration 5 occurs at 51 miles. Since feedlot 3 is located 65 miles farther from the processing plant than feedlot 1 in the second scenario, the additional potato waste is purchased by feedlot 1. The processor price of the potato waste is subsequently determined by the marginal value of the last additional cwt. of potato waste purchased by feedlot 1, and is equivalent to the feedlot value associated with ration 5 minus the transportation costs to feedlot 1. At this processor price, the locational advantage of feedlot 1 relative to feedlot 2 is expressed by the difference in feedlot prices, and is equivalent to the difference in transportation costs for the two feedlots. The processor price for potato waste is always determined at the margin, i.e., the price the processor receives if 1000 cwt. of potato waste are sold is different from the price the processor would receive if 100,000 cwt. of potato waste are sold.

When the supply of potato waste is increased at the supply center from 65,962 to 97,608 in scenario 1, the additional potato waste is shipped to feedlot 3, which is located 35 miles farther from the processing plant than feedlot 1. The solution is analagous to the solution obtained in scenario 1 when potato waste supply increased from 32,536 cwt. to 65,072 cwt. The difference now is that feedlots 1 and 2 both possess locational advantages relative to feedlot 3, which are reflected in the respective feedlot prices for potato waste. The processor price is now determined by subtracting the transportation costs at feedlot 3 ($2.30) from the feedlot value of the last additional cwt. of potato waste sold to feedlot 3 for use in ration 5 ($6.53).

As the supply of potato waste is increased to 129,468 cwt., the rations fed by the feedlots in both scenarios are identical. The methods by which the potato waste values for feedlots and processors are determined differ in each scenario, however, since the relative locations of the feedlots differ. The processor price in scenario 1 is determined by subtracting the transportation costs of feedlot 1, which purchases the last additional cwt. of potato waste, from the feedlot value of potato waste at feedlot 1 corresponding to ration 5. On the other hand, the processor price in the second scenario is determined at feedlot 3, since this feedlot has purchased the last additional cwt. of potato waste in scenario 2. The processor price in scenario 2 is obtained by subtracting the transportation costs of feedlot 3 from the feedlot value of the potato waste established at feedlot 3.

The difference in processor prices between the two distance scenarios in Table 2.2 indicates that the price of potato waste is lower for given quantities of potato waste supply when feedlots are located father away from the supply source. Figure 2.1 shows the change in the processor price of potato waste as the supply of potato waste is increased in both market areas.

The potato waste values estimated for potato processors and feedlots in both scenarios are derived from the feedlot values of potato waste associated with the selection of rations 3 and 5 in the feeding process. The feedlot values are based upon a specific set of feed costs. Figure 2.2 shows how the processor prices for potato waste change in the first market scenario when feed ingredient prices are increased by 50 percent. With the new set of feed costs, the feedlot value of potato waste associated with ration 3 increases, resulting in a new intercept value ($7.94). The entire estimated market demand curve is shifted upward by the amount of the increase in the feedlot value. The shape of the demand curve with new feed ingredient prices is identical to the demand curve obtained with the original feed prices since the relative location of the feedlots in the market area has remained the same.

Two sets of market solution results are presented for each feedlot location scenario in Tables 2.3 and 2.4 for feedlots with capacities of 4,000, 8,000, and 16,000 head of cattle. Changes in the relative size of feedlots at various locations does not affect the pattern of potato waste distribution by feeding method as the supply of potato waste increases. Therefore, the same set of processor prices is generated when the size of the feedlots are increased. However, an increase in the size of any individual feedlot will increase the estimated market demand for potato waste, and allows the

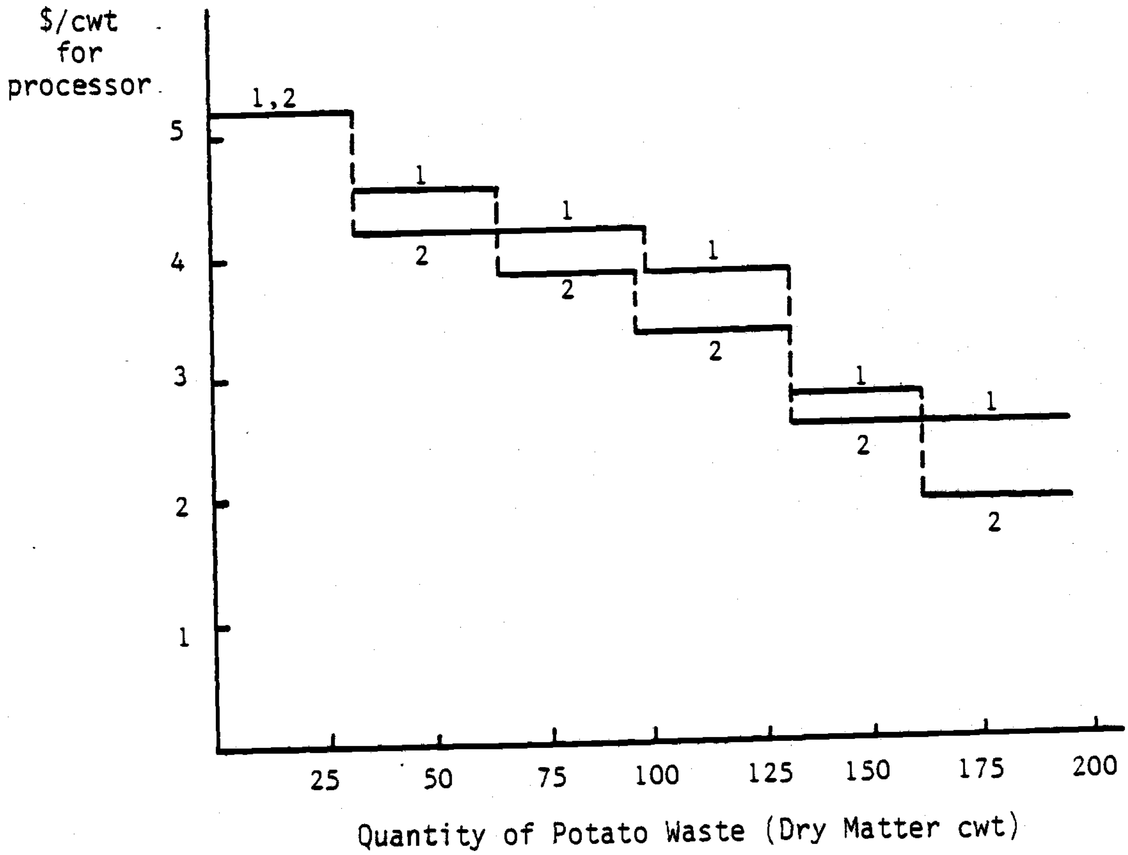

Figure 2.1. Estimated Market Demand for Potato Waste by Market Area for Feedlots Feeding 4,000 Head of Cattle Each

1 Estimated market demand for potato waste for 3 feedlots located 5, 30, and 40 miles respectively from the processor.

2 Estimated market demand for potato waste for 3 feedlots located 5, 40, and 70 miles respectively from the processor.

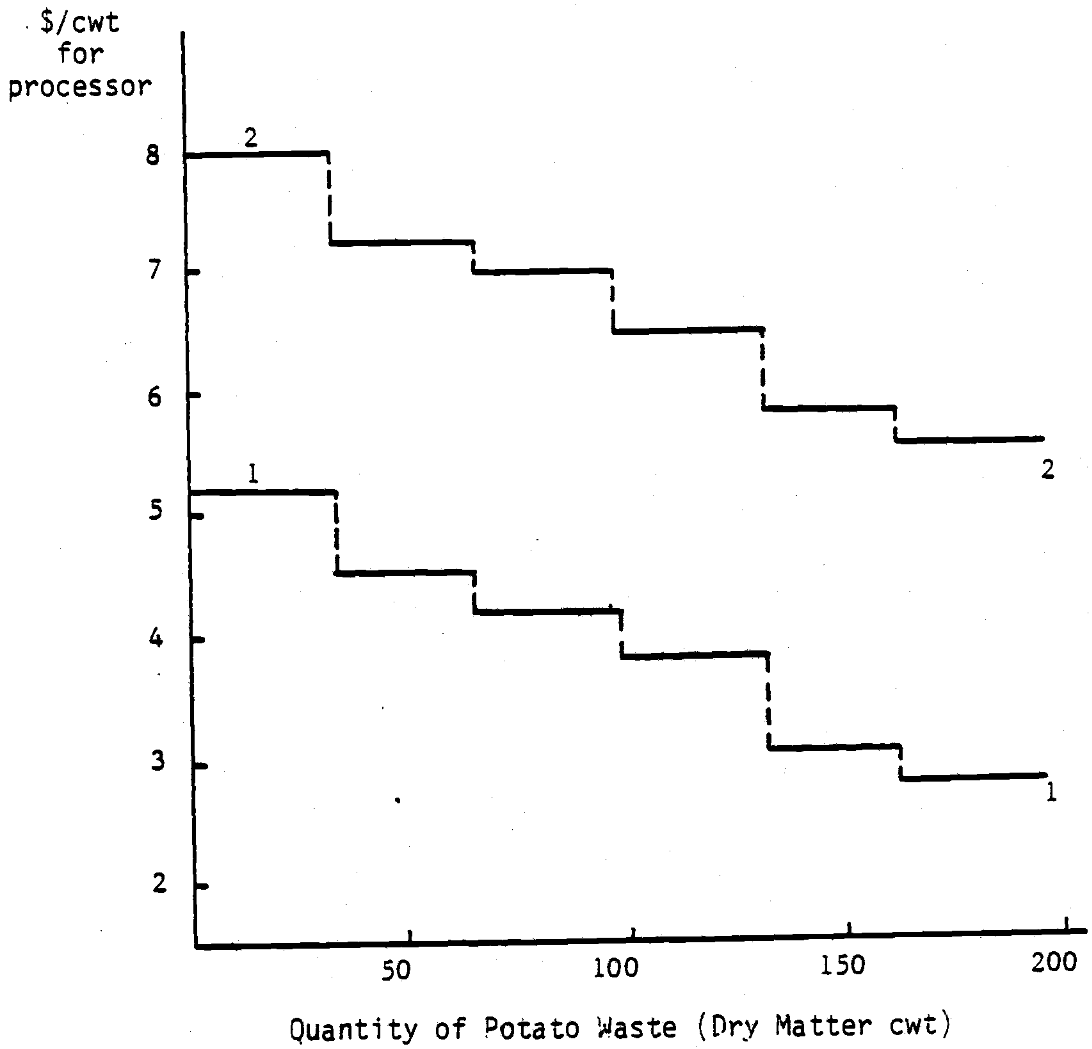

Figure 2.2. Estimated Market Demand for Potato Waste at Alternate Feed Prices for Feedlots Feeding 4,000 Head of Cattle Each

1 Estimated market demand for 3 feedlots located 5, 30 and 40 miles respectively from the processor with 1982 feed prices.

2 Estimated market demand for 3 feedlots located 5, 30, and 40 miles respectively from the processor when 1982 feed prices are increased by 50 percent.

Table 2.3. Optimal Potato Waste Values and Distributional Amounts for 4,000 and 8,000 Head Capacity Feedlots Located at Various Distances from Potato Processing Plants

Total Available Potato Waste[b/]	Rations Fed[c/]	Feedlot 1 Quantity Purchased[d/]	Feedlot 1 Price[e/]	Feedlot 2 Quantity Purchased[d/]	Feedlot 2 Price[e/]	Feedlot 3 Quantity Purchased[d/]	Feedlot 3 Price[c/]	Processor Price[c/]
Feedlots Located 5, 30, 40 Miles from Processing Plant[a]								
(1) 32,536	3-1-1	100.0	6.532	0.0	6.532	0.0	6.532	5.218
(2) 97,608	3-3-1	33.3	5.972	66.6	6.532	0.0	6.814	4.513
(3) 162,680	3-3-3	16.7	5.545	41.6	6.250	41.6	6.532	4.231
(4) 194.540	5-3-3	33.1	5.094	33.4	5.799	33.4	6.081	3.780
(5) 258,260	5-5-3	24.9	4.389	49.9	5.094	25.2	5.376	3.075
(6) 321,980	5-5-5	20.0	4.107	40.0	4.812	40.0	5.094	2.793
Feedlots Located 5, 40, 70 Miles from Processing Plant								
(1) 32,536	3-1-1	100.0	6.532	0.0	6.532	0.0	6.532	5.218
(2) 97,608	3-3-1	33.3	5.545	66.6	6.532	0.0	6.532	4.231
(3) 129,468	5-3-1	49.7	5.094	50.3	6.081	0.0	6.532	3.780
(4) 194,540	5-3-3	33.1	4.699	33.4	5.686	33.4	6.532	3.385
(5) 258,260	5-5-3	24.9	4.108	49.9	5.094	49.9	5.940	2.793
(6) 321,980	5-5-5	20.0	3.261	40.0	4.248	40.0	5.094	1.947

a/ Capacities by distance are 4,000, 8,000, and 8,000 head, respectively.

b/ Dry matter cwt.

c/ Refers to feed rations utilized by each feedlot in market area. For example, in row (1) in scenario 1, where the rations fed are 3-1-1, ration 3 is fed by feedlot 1 located 5 miles from the processing plant, ration 1 is fed by feedlot 2 located 30 miles from the processing plant, and ration 1 is fed by feedlot 3 located 40 miles from the processing plant.

d/ Percent of market total.

e/ Dollars per cwt.

Table 2.4. Optimal Potato Waste Values and Distributional Amounts for 4,000, 8,000, and 16,000 Head Capacity Feedlots Located at Various Distances from Potato Processing Plants

Total Available Potato Waste[b/]	Rations Fed[c/]	Feedlot 1 Quantity Purchased[d/]	Feedlot 1 Price[e/]	Feedlot 2 Quantity Purchased[d/]	Feedlot 2 Price[c/]	Feedlot 3 Quantity Purchased[d/]	Feedlot 3 Price[e/]	Processor Price[e/]
Feedlots Located 5, 30, 40 Miles from Processing Plant[a]								
(1) 32,536	3-1-1	100.0	6.532	0.0	6.532	0.0	6.532	5.218
(2) 97,608	3-3-1	33.3	5.972	66.6	6.532	0.0	6.814	4.513
(3) 227,752	3-3-3	14.3	5.545	28.6	6.250	57.1	6.532	4.231
(4) 259,612	5-3-3	24.8	5.094	25.1	5.799	50.1	6.081	3.780
(5) 258,260	5-5-3	24.9	4.389	39.8	5.094	40.3	5.376	3.075
(6) 450,772	5-5-5	14.3	4.107	28.6	4.812	57.1	5.094	2.793
Feedlots Located 5, 40, 70 Miles from Processing Plant								
(1) 32,536	3-1-1	100.0	6.532	0.0	6.532	0.0	6.532	5.218
(2) 97,608	3-3-1	33.3	5.872	66.6	6.532	0.0	6.532	4.231
(3) 129,468	5-3-1	49.7	5.094	50.3	6.081	0.0	5.532	3.780
(4) 259,612	5-3-3	24.8	4.699	25.1	5.686	50.1	6.532	3.385
(5) 323,332	5-5-3	19.9	4.108	39.8	5.094	40.3	5.940	2.793
(6) 450,772	5-5-5	14.3	3.261	28.6	4.248	57.1	5.094	1.947

a/ Capacities by distance are 4,000, 8,000, and 16,000 head, respectively.

b/ Dry matter cwt.

c/ Refers to feed rations utilized by each feedlot in market area. For example, in row (1) in scenario 1, where the rations fed are 3-1-1, ration 3 is fed by feedlot 1 located 5 miles from the processing plant, ration 1 is fed by feedlot 2 located 30 miles from the processing plant, and ration 1 is fed by feedlot 3 located 40 miles from the processing plant.

d/ Percent of market total.

e/ Dollars per cwt.

processor to sell a fixed quantity potato waste at a higher market price than was previously possible (Figure 2.3).

Implications

By using the results of the analysis to describe the value of potato waste at the feedlot, the differences in potato waste values at spatially separated feedlots, and the value at the supply point, a simplified alternative procedure to the linear programming model can now be suggested for evaluating potato waste for any given market area when computer equipment is unavailable. The procedure estimates a processor price for potato waste corresponding to the optimal distribution of potato waste to feedlots, which, in turn, is based upon the feedlot value of potato waste and the transportation costs of shipping potato waste to the feedlots for given sizes of feedlots and processing plants.

The first step in the procedure is to estimate the feedlot value of potato waste. The estimate can be obtained for specific prices of primary feed ingredients by employing a simplified formula which calculates feedlot values from the prices of grain and roughage (Turek and Brokken, 1984). The calculated values approximate the feedlot value associated with the feeding of ration 3 in the analysis. The lower feedlot value associated with ration 5 occurs when a relatively high proportion of potato waste is contained in the feed ration and can be estimated in relation to the calculated values corresponding to ration 3.

The quantity of potato waste available at the processing plant and the feeding capacities of the feedlots in the market area

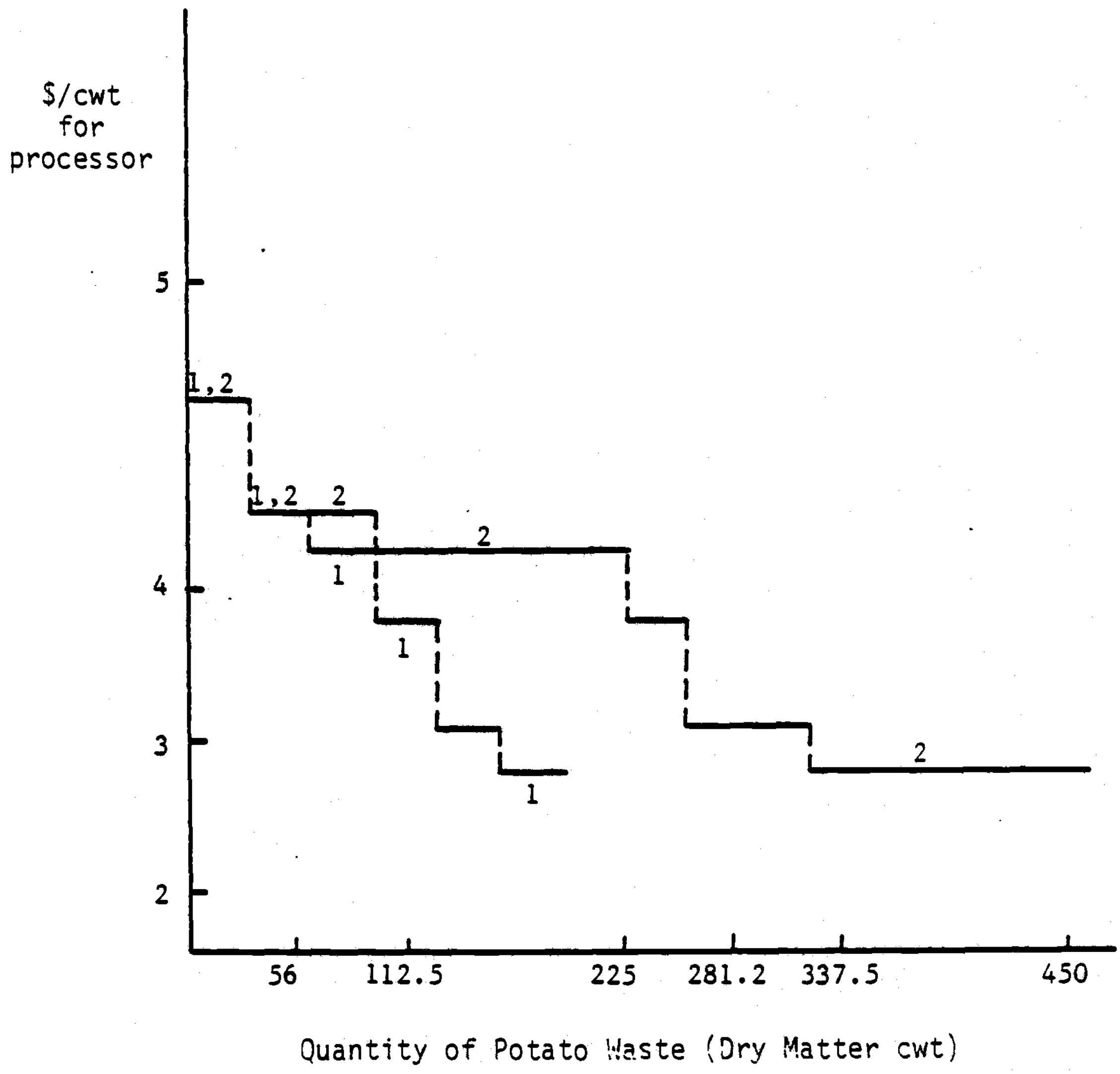

Figure 2.3. Estimated Market Demand for Potato Waste with Differences in Feedlot Size Per Market Area

1 Estimated market demand for 3 feedlots located 5, 30 and 40 miles respectively from the processor with feeding capacities of 4,000 head each.

2 Estimated market demand for 3 feedlots located 5, 30 and 40 miles respectively from the processor with feeding capacities of 4,000, 8,000, and 16,000 head respectively.

establish the relative supply and potential demand for potato waste in the area. The quantity of potato waste that each feedlot utilizes is based upon the total pounds of potato waste each animal consumes in the feeding process (at rations 3 or 5 in the analysis) and the total number of cattle fed by each feedlot (capacity).

The pattern of potato waste distribution to the feedlots by ration is dictated by the feedlot value of the potato waste embodied within the efficient rations and the transportation costs of shipping potato waste to feedlots. Competition for potato waste between feedlots arises due to the locational advantages of certain feedlots in the market area. When the difference in transportation costs between two feedlots is greater than the difference in feedlot values, potato waste is shipped to the closer feedlot to be fed in the lower valued ration rather than to the more distant feedlot to be fed in the higher valued ration. The processor price of potato waste to the feedlots by subtracting the transportation costs of the feedlot which would purchase the last additional cwt. of potato waste, from the feedlot value of potato waste established at the particular feedlot. Once the processor price is determined, all buyers are required to meet this price, net of transportation costs.

Conclusions

The processor price for potato waste determined in the analysis reveals the maximum allowable price which potato processors can charge to all potential buyers in the marketplace for some given quantity of potato waste available from the processing plant. Since potato waste is costly to transport, the processor price of potato waste diminishes as the distance it must be shipped increases. Consequently, potato waste prices will tend to be lower in a market where feedlots are scattered about the processor at distant locations compared to a market where feedlots are clustered within a small distance from the processing plant. Feedlots that have the advantage of being located more closely to the processing plant than other feedlots also enjoy the benefit of incurring lower transportation costs associated with potato waste movements.

As the size of the feedlots in the market increases, the feedlot demand for potato waste is increased, causing the market demand for potato waste to shift outward in proportion to the increases in the feedlot size. Potato processors can expect to receive a higher price for potato waste, thereby increasing the total revenue received from the sale of some fixed quantity of potato waste. The distribution of the potato waste by feedlot should remain the same for feedlots with locational advantages, i.e., larger feedlots located at greater distances from the processor should not be able to increase their purchases at the expenses of smaller feedlots located closer to the plant. However, the proportion of total potato waste purchased by feedlots located near processing plants will increase at the expense of more distant buyers if the size of the closer feedlots increases.

Endnotes

1/ Compiled by the Oregon State University Extension Service, Economic Information Office, Corvallis, Oregon.

2/ This statement does not apply to processing plants that are unable to supply the closest feedlot with potato waste in excess of the total quantity required by that feedlot to feed ration 3 to cattle.

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APPENDIX

APPENDIX

The results of the regression analysis upon Portland average monthly cash prices of corn and barley, and average monthly alfalfa hay prices in Oregon, for 1972-82 are presented below:

$$\text{(A1) BARLEY} = \underset{(.0083)}{-.0038} + \underset{(11.82)}{.9647}\ \text{CORN} \qquad R^2 = .94$$

$$\text{(A2) BARLEY} = \underset{(66.48)}{.9640}\ \text{CORN} \qquad R^2 = .94$$

$$\text{(A3) HAY} = \underset{(.2269)}{.1765} + \underset{(3.999)}{.5579}\ \text{CORN} \qquad R^2 = .64$$

$$\text{(A4) HAY} = \underset{(23.71)}{.5890}\ \text{CORN} \qquad R^2 = .64$$

where BARLEY is the average monthly barley cash price in Portland in dollars per hundredweight; CORN is the average monthly corn cash price at Portland in dollars per hundredweight; and HAY is the average monthly alfalfa hay price received in Oregon in dollars per hundredweight. Approximate t-ratios (absolute values) are in parentheses below the respective parameter estimates. R^2 is the coefficient of determination.