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Least-Cost Broiler Ration Formulation Using Linear Programming Technique

Bassam Al-Deseit
Department of Agricultural Economics and Extension, Faculty of Agriculture,
Jarash Private University, P.O. Box 311, Jarash, 26110 Jordan

Abstract: This study was on the economic use of the local feedstuffs to formulate least cost rations for broilers using Linear Programming (LP) technique to investigate, analyze and indicate how best the available local ingredients can be combined effectively and efficiently to formulate least-cost ration for broilers. Specifically, a linear programming technique was employed to determine the most efficient way of combining these locally available ingredients. Mathematical models were constructed by taking into consideration nutrient requirements of the broilers, nutrient composition of the available ingredient and any other restriction factor of the available ingredients for the formulation. The result of this study showed that the least cost ration for starter broiler produced by linear programming model consists of 68.0% yellow corn, 25.07% soybean, 4% wheat bran, 0.5% fish meal, 0.5% Ca diphosphate, 0.1% lysine, 0.32% methoinine, 0.3% limestone, 0.3% NaCl, 0.5% ready premix, 0.4% soya oil and 0.01% vitamins and mineral mix. For the finisher ration the results showed that the ration consists of 67.5% yellow corn, 20.45% soybean, 5% wheat bran, 0.25% fish meal, 1.5% ca diphosphate, 0.25% lysine, 0.35% methoinine, 0.3% limestone, 0.5% NaCl, 3% ready premix, 0.75% soya oil and 0.15% vitamins and mineral mix.

Key words: Linear programming, least-cost ration, broilers, ingredients, vitamins, mineral

INTRODUCTION

It is imperative for broiler producers to source for cheap alternative feedstuffs without affecting the quality of the feed, productive performance of the birds and the economics of production. One of the major problems facing broiler producers is high prices and non-availability of feed ingredients. The feed cost incurred about 60-65% of the total cost of broiler production. Availability of quality feed at a reasonable cost is a key to successful poultry operation (Hooge and Rowland, 1978). Linear programming is one of the most important techniques to allocate the available feedstuffs in a least cost broiler ration formulation (Dantzig, 1951a, b; Aletor, 1986; Ali and Leeson, 1995).

Linear Programming (LP) is a technique for optimization of a linear objective function, subject to linear equality and linear inequality constraints (Kuester and Mize, 1973). Informally, linear programming determines the way to achieve the best outcome (such as maximum profit or lowest cost) in a given mathematical model and given some list of requirements represented as linear equations. Patrick and Schaible (1980) stated that linear programming is technically a mathematical procedure for obtaining a value-weighting solution to a set of simultaneous equations. Linear programming was first put into significant use during World War II when it was used to determine the most effective way of deploying troops, ammunitions, machineries which were all scarce resources (Chv´atal, 1983). There are hundreds of applications of linear programming in agriculture (Taha, 1987). Olorunfemi *et al*. (2001) reviewed extensively the use of linear programming in least cost ration formulation for aquaculture. Olorunfemi *et al*. (2001) also applied linear programming into duckweed utilization in least-cost feed formulation for broiler starter.

MATERIALS AND METHODS

Data: NRC (1994) was the main source of data collection about feedstuffs specifications, constraints imposed on the selected feedstuffs and the dietary nutrient requirements for broilers. Costs of feedstuffs used in the diet formulation were obtained from the prevailing market prices of feedstuffs in Jordan through survey. The analysis of feed ingredients and minimum and maximum levels of various feedstuffs used in diet obtained from standard tables and sources (Aduku, 1993; Tacón, 1993; NRC, 1994). NRC (1994) recommended nutritional and restriction levels of the Metabolizable Energy (ME), protein, limiting amino acids, calcium, phosphorus, fiber and fat will be adopted in this study.

Data analysis: The method of data analysis employed in this study was Linear Programming (LP) model. The model was designed to reflect various feedstuff combinations used in the diet formulation, current market prices, nutrient composition and range of inclusion to obtain a least-cost ration.

Assumptions of linear programming: Before a valid result can be obtained from linear programming technique, the following assumptions must be holding:

Linearity: There must be a linear relationship between the output and the total quantity of each resource consumed. If the objective function is not linear, the technique will not be applicable (Dantzig, 1955).

Simple objective: The objective can either be maximization or minimization of one activity.

Certainty: All values and quantities must be known with certainty.

Additivity: This means that the sum of resources used by different activities must be equal to the total quantity of the resources used by each activity for all the resources (Dantzig, 1963).

Divisibility: Perfect divisibility of outputs and resources must exist.

Non-negativity: Decision variables cannot be added to the final objective function in a negative way. That is each of the decision variables must either be positive or zero.

Finiteness: The constraints and the variables must be finite so that it can be programmed. Hence, a finite number of activities and constraints must be employed (Gale *et al*., 1951).

Proportionality: This implies that the contribution of each variable to the final objective function is directly proportional to each variable. If we want to double the output then all decision variables must be doubled.

Model construction: Mathematical models were constructed for starter and finisher types of broiler ration using limited ingredients. The objective of the models was to minimize cost of producing a particular diet after satisfying a set of constraints. These constraints were mainly those from nutrient requirements of each bird and ingredient constraints (Harper and Lim, 1982). The variables in the models were the ingredients while the cost of each ingredient and the nutrient value of each ingredient was the parameter (Hillier and Lieberman, 1995). To compare rations costs and to determine the least cost ration, 4 types of rations were formulated (basic ration and 3 alternatives). The specified LP model for the attainment of the objective function is:

$$\text{Minimize } Z = \sum C_{ij} X_j$$

where:

Z = Total cost of the ration
C_{ij} = Ingredient cost
X_j = Ingredient quantity

Subject to the following constraints:

$$x1 + x2 + x3 + \ldots\ldots + x12 = b1$$
$$a1\ 1\ x1 + a1\ 2\ x2 + \ldots\ldots + a1\ 12\ x12 \geq b2$$
$$a2\ 1\ x1 + a2\ 2\ x2 + \ldots\ldots + a2\ 12\ x12 \leq b3$$
$$a3\ 1\ x1 + a3\ 2\ x2 + \ldots\ldots + a3\ 12\ x12 \leq b4$$
$$a4\ 1\ x1 + a4\ 2\ x2 + \ldots\ldots + a4\ 12\ x12 = b5$$
$$a5\ 1\ x1 + a5\ 2\ x2 + \ldots\ldots + a5\ 12\ x12 = b6$$
$$a6\ 1\ x1 + a6\ 2\ x2 + \ldots\ldots + a6\ 12\ x12 \geq b7$$
$$a7\ 1\ x1 + a7\ 2\ x2 + \ldots\ldots + a7\ 12\ x12 \geq b8$$
$$a8\ 1\ x1 + a8\ 2\ x2 + \ldots\ldots + a8\ 12\ x12 \geq b9$$
$$a9\ 1\ x1 + a9\ 2\ x2 + \ldots\ldots + a9\ 12\ x12 = b10$$
$$a10\ 1\ x1 + a10\ 2\ x2 + \ldots\ldots + a10\ 12\ x12 = b11$$

where:

ai = Technical coefficients of nutrient components in feedstuffs
bi = Constraints of the ration

The most popular feedstuffs used in ration formulation for local farms and broiler feed factories include yellow corn, soybean, fish meal, premix, vitamin/mineral, salt, lysine, limestone, soya oil, methionine, wheat bran and calcium di-phosphate. These feedstuffs were used in this study. Cost implications of feedstuffs and nutrient levels of feed ingredients. Constraints imposed on the selection of feedstuffs by computerized linear programming for broiler rations and least-cost formulation restrictions on nutrients and feedstuffs for broiler rations are summarized in Table 1-4.

The models: The linear programming model for the least cost starter ration is:

$$\text{Min}(Z) = 165X_1 + 335X_2 + 1200X_3 + 1400X_4 + 120X_5 + 850X_6 + 3500X_7 + 3000X_8 + 150X_9 + 20X_{10} + 685X_{11} + 5000X_{12}$$

S.t.,

Table 1: Cost implications of feedstuffs and nutrient levels of feed ingredients

Ingredients	Cost (JDs kg^{-1})	Crude protein (%)	Fat (%)	Crude fiber (%)	Ca (%)	P (%)	Lysine (%)	Methionine (%)	ME (Kcal kg^{-1})
Yellow corn: x1	0.165	8.8	4.0	2.0	0.01	0.09	0.25	0.18	3432
Soybean (44% p): x2	0.335	44.0	3.5	6.5	0.20	0.20	2.80	0.59	2230
Fish meal: x3	1.200	65.0	4.5	1.0	6.10	3.00	4.50	1.80	2860
Soya oil: x4	1.400	0.0	98.0	0.0	0.00	0.00	0.00	0.00	3428
Wheat bran: x5	0.120	15.7		5.1	0.14	1.15	0.59	0.42	1300
Ca/di-phosphate: x6	0.850	0.0	0.0	0.0	21.00	18.50	0.00	0.00	0
Lysine: x7	3.500	60.0	0.0	0.0	0.00	0.00	100.00	0.00	0
Methionine: x8	3.000	60.0	0.0	0.0	0.00	0.00	0.00	100.00	0
Salt: x9	0.150	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0
Limestone: x10	0.020	0.0	0.0	0.0	38.00	0.00	0.00	0.00	0
Premix: x11	0.685	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0
Vitamin/mineral:x12	5.000	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0

NRC (1994); Nutrient Requirement of Poultry; 9th Rev. Edn., Washington D.C., USA; 1US$ = JDs 0

Table 2: Constraints imposed on the selection of feedstuffs by computerized linear programming for starter broiler rations

Nutrients	Maximum level	Minimum level
Crude protein (%)	-	23
ME (Kcal kg^{-1})	3200	2800
Fat (%)	5	-
Ca (%)	1.5	1.0
P (%)	-	0.45
Crude fiber (%)	5	-
Lysine (%)	-	1.1
Methionine (%)	-	0.5

Table 3: Constraints imposed on the selection of feedstuffs by computerized linear programming for finisher broiler rations

Nutrients	Maximum level	Minimum level
Crude protein (%)	-	21
ME (Kcal kg^{-1})	3400	3200
Fat (%)	6	-
Ca (%)	1.5	1.0
P (%)	-	0.45
Crude fiber (%)	5	-
Lysine (%)	-	1.1
Methionine (%)	-	0.5

$$X1 + X2 + X3 + \ldots\ldots + X12 = 1000$$
$$0.088\,X1 + 0.44\,X2 + 0.65\,X3 + 0.157\,X5 + 0.60\,X7 + 0.60\,X8 \geq 230$$
$$0.04\,X1 + 0.035\,X2 + 0.045\,X3 + 0.98\,X4 \leq 50$$
$$0.02\,X1 + 0.065\,X2 + 0.01\,X3 + 0.051\,X5 \leq 50$$
$$0.0001\,X1 + 0.002\,X2 + 0.061X3 + 0.14\,X5 + 0.21\,X6 + 0.38\,X10 = 15$$
$$0.0009\,X1 + 0.002\,X2 + 0.03\,X3 + 0.0151\,X5 + 0.185\,X6 = 4.5$$
$$0.0018X1 + 0.0059\,X2 + 0.018X3 + 0.0042X5 + X8 \geq 5$$
$$0.0025\,X1 + 0.028\,X2 + 0.045\,X3 + 0.0059\,X5 + X7 \geq 11$$
$$3.432\,X1 + 2.23\,X2 + 2.86\,X3 + 3.42\,X4 + 1.3\,X5 \geq 2800$$
$$X9 = 2.5$$
$$X11 \geq 5$$
$$X12 = 3$$
$$X1, X2, X3, X4, X5, X6, X7, X8, X9, X10, X11, X12 \geq 0$$

The linear programming model for the least cost finisher ration is:

$$\text{Min}(Z) = 165X_1 + 335X_2 + 1200X_3 + 1400X_4 + 120X_5 + 850X_6 + 3500X_7 + 3000X_8 + 150X_9 + 20X_{10} + 685X_{11} + 5000X_{12}$$

Table 4: Least-cost formulation restrictions on nutrients and feedstuffs for broiler rations

Item	Starter stage	Finisher stage
Weight (kg)	1000	1000
Crude protein (kg)	≤230	≤210
Fat (kg)	≥50	≥06
Crude fiber (kg)	≥50	≥50
Ca (kg)	15	15
P (kg)	4.5	4.5
Methionine (kg)	≤5	≤5
Lysine (kg)	≤11	≤11
ME (Kcal kg^{-1})	≤2800	≤3200
Salt (kg)	3	3
Vitamin/mineral (kg)	2.5	2.5

S.t;

$$X1 + X2 + X3 + \ldots\ldots + X12 = 1000$$
$$0.088\,X1 + 0.44\,X2 + 0.65\,X3 + 0.157\,X5 + 0.60\,X7 + 0.60\,X8 \geq 210$$
$$0.04\,X1 + 0.035\,X2 + 0.045\,X3 + 0.98\,X4 \leq 60$$
$$0.02\,X1 + 0.065\,X2 + .01\,X3 + 0.051\,X5 \leq 50$$
$$0.0001\,X1 + 0.002\,X2 + 0.061X3 + 0.14\,X5 + 0.21\,X6 + 0.38\,X10 = 15$$
$$0.0009\,X1 + 0.002\,X2 + 0.03\,X3 + 0.0151\,X5 + 0.185\,X6 = 4.5$$
$$0.0018X1 + 0.0059\,X2 + 0.018X3 + 0.0042X5 + X8 \geq 5$$
$$0.0025\,X1 + 0.028\,X2 + 0.045\,X3 + 0.0059\,X5 + X7 \geq 11$$
$$3.432\,X1 + 2.23\,X2 + 2.86\,X3 + 3.42\,X4 + 1.3\,X5 \geq 3200$$
$$X9 = 2.5$$
$$X11 \geq 5$$
$$X12 = 3$$
$$X1, X2, X3, X4, X5, X6, X7, X8, X9, X10, X11, X12 \geq 0$$

RESULTS AND DISCUSSION

The following Table 5-8 shows the results of the optimum solution obtained using the computerized linear programming technique. The basic ration and the three alternatives for starter broiler, the chemical composition of the ration and the total cost are shown in the Table 5 and 6. The basic ration and the 3 alternatives for finisher broiler, the chemical composition of the ration and the total cost are shown in the Table 7 and 8.

Table 5: Basic ration and alternatives for starter broiler

		Alternative (kg)		
Ingredients	Basic ration (kg)	1	2	3
Yellow corn	599.8	625.5	655.5	680.0
Soybean meal	335.7	305.2	270.2	250.7
Wheat bran	5.200	5.000	20.00	40.00
Fishmeal	10.00	5.000	5.000	5.000
Calcium Diph.	15.00	10.00	10.00	5.000
Lysine	1.000	1.000	1.000	1.000
Methionine	3.200	3.200	3.200	3.200
Limestone	3.000	3.000	3.000	3.000
NaCl	3.000	3.000	3.000	3.000
Premix	20.00	35.00	25.00	5.000
Soya oil	4.000	4.000	4.000	4.000
Vit. and Min.	0.100	0.100	0.100	0.100
Total	1000	1000	1000	1000

Table 6: Chemical composition of basic ration and alternatives for starter broiler

Chemical composition		Alternative		
of ration	Basic ration	1	2	3
Crude protein (%)	23.231	23.148	23.068	23.711
ME (Kcal kg^{-1})	2868.330	2881.440	2898.240	2967.000
Fat (%)	3.866	3.763	3.475	3.921
Ca (%)	1.013	1.421	1.187	1.029
P (%)	0.534	0.532	0.548	0.537
Crude fiber (%)	3.269	3.222	3.174	3.117
Lysine (%)	1.305	1.229	1.397	1.083
Methionine (%)	0.619	0.601	0.725	0.577
Cost	265.171	262.337	253.124	236.365

Table 7: Basic ration and alternatives for finisher broiler

		Alternative (kg)		
Ingredients	Basic ration (kg)	1	2	3
Yellow corn	685.0	632.5	610.0	675.0
Soybean meal	192.0	228.5	25.60	204.5
Wheat bran	45.00	50.00	45.00	50.00
Fishmeal	2.500	2.500	2.500	2.500
Calcium Diph.	15.00	15.00	15.00	15.00
Lysine	2.500	2.500	2.500	2.500
Methionine	3.200	3.500	3.500	3.500
Limestone	4.000	4.000	4.000	3.000
NaCl	5.000	5.000	5.000	5.000
Premix	50.00	50.00	50.00	30.00
Soya oil	7.500	7.500	7.500	7.500
Vit. and Min.	1.800	1.500	1.500	1.500
Total	1000	1000	1000	1000

Table 8: Chemical composition of basic ration and alternatives for finisher broiler

Chemical composition		Alternative		
of ration	Basic ration	1	2	3
Crude protein (%)	21.514	21.423	21.045	21.743
ME (Kcal kg^{-1})	3232.500	3222.710	3220.100	3200.540
Fat (%)	4.215	4.614	4.001	4.101
Ca (%)	1.311	1.274	1.254	1.313
P (%)	0.523	0.542	0.521	0.503
Crude fiber (%)	3.899	3.745	3.914	3.466
Lysine (%)	1.384	1.510	1.465	1.321
Methionine (%)	0.530	0.515	0.521	0.564
Cost	261.005	272.361	277.421	259.462

CONCLUSION

The results of least cost diet formulation produced by linear programming model showed that the starter ration consists of 68.0% yellow corn, 25.07% soybean, 4% wheat bran, 0.5% fish meal, 0.5% ca diphosphate, 0.1% lysine, 0.32% methoinine, 0.3% limestone, 0.3% NaCl, 0.5% ready premix, 0.4% soya oil and 0.01% vitamins and mineral mix is the least cost ration for starter broilers according to the local feedstuffs availability. This ration meets all the nutritional requirements needed for starter broiler. The cost of the ration is around 236 JDs ton^{-1}. This cost saves about 29 JDs ton^{-1} compared to the basic ration. For the finisher ration the results showed that the ration consists of 67.5% yellow corn, 20.45% soybean, 5% wheat bran, 0.25% fish meal, 1.5% ca diphosphate, 0.25% lysine, 0.35% methoinine, 0.3% limestone, 0.5% NaCl, 3% ready premix, 0.75% soya oil and 0.15% vitamins and mineral mix is the least cost ration for finisher broilers according to the local feedstuffs availability. This ration meets all the nutritional requirements needed for finisher broiler. The cost of the ration is around 259 JDs ton^{-1}. This cost is almost the same as the prevailing cost which means that the basic used ration the least cost ration according to the feedstuffs availability.

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