A SHEEP PRODUCTION MODEL FOR MAXIMUM NUTRITIONAL EFFICIENCY

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I. INTRODUCTION

This presentation is entitled, "A Sheep Production Model for Maximum Nutritional Efficiency," and I hope to arrive at a production model but the premise of nutritional efficiency will not be obvious. Unfortunately, in the sheep business we seldom deal with complete production models. This is especially obvious in the organization of our present university and governmental agencies along "subject" rather than "species" lines. Even the Sheep Industry Development Program Symposia are subject oriented; i.e., one each for Genetics, Reproduction, Diseases, Nutrition and now Production and Business Management. I fully realize this sort of an organization is the only way we can get our outstanding scientists together to discuss our knowledge and problems in sheep production. However, it is imperative, that we try and put everything together and maybe I can come up with a model system that will stimulate criticism and hopefully withstand at least some of that criticism.

First, let's describe an approach which will be slightly different to that which you are accustomed. I will try and define a product (i.e., lamb retail cuts) and then work backwards through the type of marketing, nutritional, reproduction and genetic systems to produce this product while maximizing nutritional efficiency. It is this nutritional efficiency bit that is interesting to me. After looking through the literature and spending much time in discussion with my colleagues I have concluded that there are no major nutritional by non-nutritional interactions that would severely affect a production model. That is, if we were to set up four sample nutritional regimens and test these four on several systems of sheep production, the four nutritional regimens would rank the same in each of the several systems of production. To really simplify this concept we can assume that growing lambs will gain faster if fed a high grain diet than if fed a low quality hay diet whether they are Southdowns, Suffolks or Columbias and whether they are fed on slats, on dry range, or in pens.

If this assumption of no interaction is true, then our job of producing a production model becomes infinitely easier. This means that we can determine the model that maximizes nutritional efficiency under one type of feeding and it will also maximize nutritional efficiency under other feeding systems. Ignoring feeding system, the production model that is best for the Corn-belt may also be best for the mountain states, for the Northeast, for the Southwest, for range sheep, for confined sheep, etc.

This assumption of no interaction may not be acceptable to everyone here but I see no justification for not accepting it and proceeding to some sort of a production model that will maximize nutritional efficiency under one (and all) nutritional regimes.

Only data collected at Cornell in recent years will be presented.

These data are by no means complete but are relevant and will be very useful examples of the reasons for acceptance or rejection of segments of our "model."

II. WHAT SHALL WE PRODUCE?

Lamb! What kind of lamb? How shall we describe it? What descriptive factors are important? We shall produce lamb that will yield carcasses that will yield retail cuts of a given weight and chemical composition. We shall produce a standard weight and chemical as retail cuts so that every retail leg or chop in every store in the U. S. will be of the same type and predictably so. O.K., what weight and chemical composition shall we choose. Table 1 is a starting point (George et al., 1966). Included are the average weights of the four major retail trimmed cuts from lambs weighing 110 lb unshorn and unshrunk. The chemical data given are from loins of comparable lambs weighing 100 pounds. I have referred to these as "ideal" and have biased the chemical data toward the leaner lambs. We can best define our product in these terms, weight and chemical composition. These are objective terms and have a direct relationship to our production model.

Table 1. Weight and chemical composition of "Ideal" trimmed retail cuts of lamb

	Leg	Loin	Rack	Shoulder
Weight, lb	14.7	4.4	5.3	13.9
Chemical composition				
Water, %		53.4		
Fat, %		26.5		
Protein, %		16.4		
Ash, %		3.7		

III. WHAT AFFECTS WHAT WE PRODUCE?

If we have settled on what we shall produce now we can attempt to produce it and shall consider the following factors that may affect the weight and chemical composition of lamb retail cuts: body weight, age of lamb, sex, breed, sire and type of nutrition. We shall cover each of these very briefly.

1. Body weight. Considerable data are now in the scientific literature indicating that without doubt body weight is the main de-terminate of body composition in the growing lamb. Reid et al., has analyzed several hundred sheep and reports that body weight is the best, prediction of body chemical components. Gardner et al. (Figure 1) have acquired similar data on suckling lambs. George et al. (Figure 2) re- port the effects weight has on marketing losses and notes the significance of these. George et al. reported that about 1% of the lamb was lost as fat trim in 70-lb lambs but 7% was lost as fat in 130-lb lambs. Interestingly enough, this difference was nearly exactly offset by differences in dressing percentages. Heavier lambs are fatter lambs and these have higher dressing percentages and greater fat trim losses.

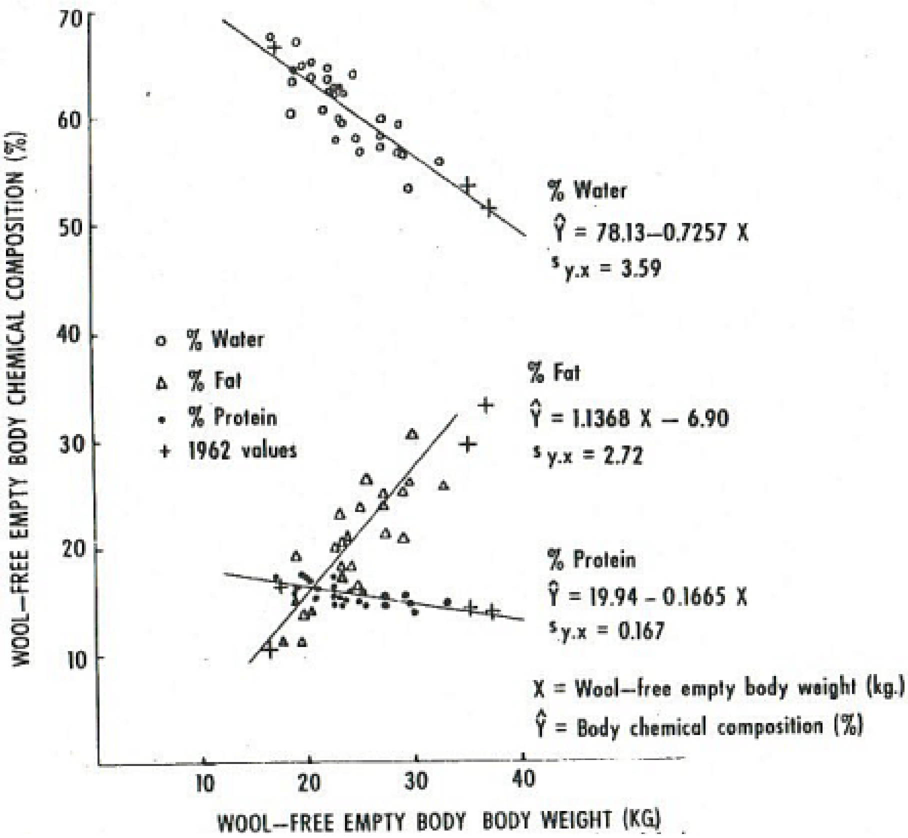

Figure 1. Effect of body weight on chemical composition of lambs.

The yield of retail cuts is not markedly affected by the body weight of lambs but the weight and chemical composition of the cuts are affected by the weight of the lambs at slaughter.

So we will conclude that body weight is very important and lambs should be slaughtered at a given weight and thereby minimize that source of variation. Let us conclude that lambs should be killed at 110 lb and all lambs will be killed at that weight and hopefully produce the type of retail cuts indicated in Table 1. Now body weight is no longer important and we can move on to other sources of variation that should be considered.

2. Age of lamb. The data of Ringkob et al., are presented in Table 2 as the effect of age independent of diet type on marketing losses and yields of slaughter lambs. In this case all lambs were slaughtered at the same body weight but varied greatly in age as they were fed different levels of the same feed from birth to slaughter. The notable point in these data is the lack of differences. Even different levels of intake before and after 70 lb live weight had little effect on the final product. Apparently age has no real affect on marketing losses and yields and can be essentially ignored in our production model. This is especially important nutritionally because it indicates that rapid (or slow) growth is not advantageous in market lambs and economics can supersede growth rate.

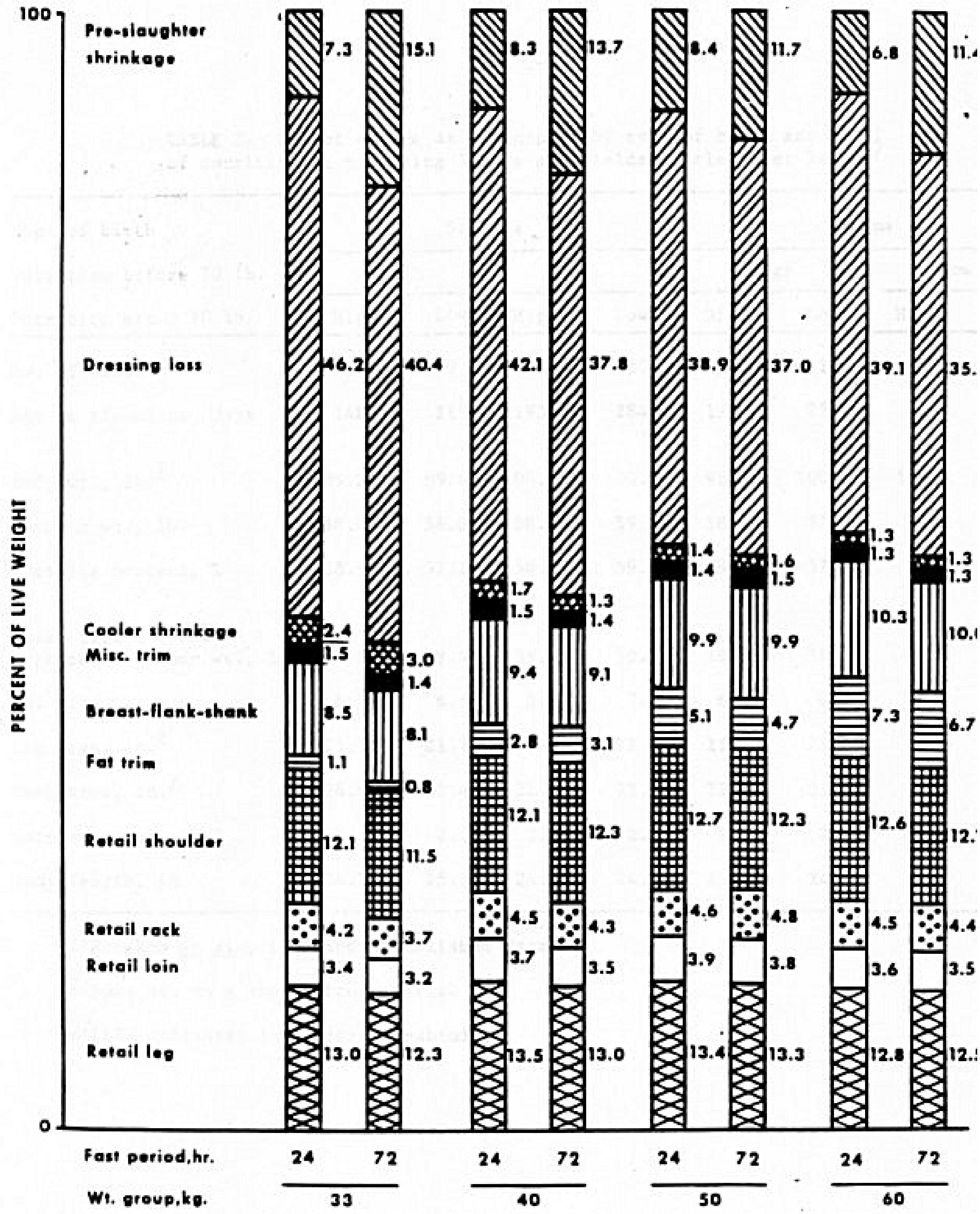

Figure 2. Effect of body weight and fast period on marketing losses and yields of lambs.

Table 2. Effect of age as influenced by type of birth and level of nutrition in marketing losses and yields of slaughter lambs[a].

Type of birth	Singles				Twins			
Nutrition before 70 lb	High		Low		High		Low	
Nutrition after 70 lb	High	Low	High	Low	High	Low	High	Low
No. of lambs	10	9	10	10	11	12	9	9
Age at slaughter, days	148	219	195	284	175	251	260	366
Carcass weight, lb	58.4	56.8	58.4	59.5	58.7	57.9	57.2	59
Dressing percent, %	58.9	57.1	58.3	59.1	58.9	57.8	57.1	57.2
Total retail LLRS, % of body weight[b]	39.9	38.4	39.4	39.5	39.8	38.7	38.6	39.2
Fat trim, %	6.7	6.5	5.9	7	6.6	6.8	5.8	6.1
Leg, %	21.3	21.7	21.9	22	21.2	21.6	21.9	22.5
Rack, %	24.0	22.4	22.2	22.5	22.6	22.5	21.7	22
Loin eye, in^2	2.32	2.15	2.33	2.31	2.28	2.24	2.24	2.33
Body length, inches	24.7	25.3	24.7	24.9	25	24.6	24.9	25.2

[a]Ringkob et al., 1966 and unpublished data.
[b]Body weight on a shorn-shrunk basis, LLRS indicates leg-loin-rack-shoulder.

3. Sex of lamb. Limited data on the effect of sex are included in Tables 3 and 4. At the same weight ram lambs are less fat than ewes and the wethers are intermediate. At this stage we can do little about the sex of lambs at birth and whether or not to castrate is usually determined by management practices and market custom.

Table 3. Effect of sex on market characteristics of lambs[a].

	Rams	Ewes	Wethers
Number of lambs	5	6	8
Shorn-shrunk wt, lb	104.7	103.8	101.3
Dressing percent	54.1	57.7	56.4
Retail LLRS[b]			
% body weight	38.2	39.1	38.7
% carcass weight	70.7	67.8	68.6
Fat trim			
lb	4	6.5	5.4
% body weight	3.8	6.3	5.3
% carcass weight	7.1	11.1	9.3

[a]Hogue et al., unpublished data.
[b]LLRS = Leg-loin-rack-shoulder.

4. Breed. Tables 4 and 5 include data on the effect breed may have in determining the chemical composition of lambs at a given weight and the effect this may have on retail yield. Of those breeds sampled, the Suffolk is the leanest and the Southdown the fattest with the other "down" breeds intermediate. The whiteface breeds tested are fatter than one would first guess when looking at the data from the other breeds.

Table 4. Chemical composition of 110-lb sheep of various breeds (Reid et-al.).

Breed	Chemical Component Water	 Fat	 Protein
	%	%	%
Ramb. x Columbia	50.6	31.8	14.4
Hamp. X Suff. X Shrop.	52.4	30.4	14.2
Suffolk	54.8	26.4	15.4
Hampshire	52	30.2	14.1
Corriedale	48	36.8	12.4
Shropshire	48.4	35.4	13.6
Southdown (rams)	49.4	33.8	14
Southdown (ewes)	41.4	44.2	12

These differences in composition and retail yields are apparently related to the mature size of the breeds involved. So we can easily conclude that if one wants leaner lambs one should start with bigger parents and still slaughter lambs at the same weight. This should not alter the standard weights of retail cuts but should alter their chemical composition toward less fat and more water.

There is one severe hitch in this idea! Big sheep require more feed than small sheep so getting bigger sheep may not be nutritionally efficient.

Table 5. Effect of breed and weight at slaughter on marketing characteristics of lambs.

	Dorset		Suffolk		Corriedale		Southdown	
	Light	Heavy	Light	Heavy	Light	Heavy	Light	Heavy
No. of lambs	11	10	10	10	10	10	8	8
Live weight	85.8	119.4	85.8	119.7	88.9	121.7	86.6	119.9
Shorn-shrunk weight	77.0	107.3	75.3	107.3	77.4	106.7	78.0	107.3
Carcass weight	41.9	62.0	37.5	59.6	40.4	61.4	45.2	66.4
Retail LLRS								
lb	29.71	38.66	28.08	40.37	27.61	37.01	29.85	39.70
Percent of carcass	70.89	62.37	74.87	67.84	68.36	60.29	66.14	59.83
Percent of body weight	38.59	36.03	37.29	37.61	35.70	34.67	38.33	36.99
Fat trim, lb	2.24	8.25	0.92	5.07	3.29	9.35	5.90	12.56

5. Sire. Data on half-sib groups from 7 Suffolk rams are included in Table 6 (Brannon, 1967). In this case, where all lambs are killed at approximately the same weight few significant differences can be detected. Apparently this sample of Suffolk rams are near enough to the same size that they do not really have significant effects on the market characteristics of their progeny. This is very convenient because we can remove sire within size from our model considerations.

6. Diet. Type of diet fed (i.e., hay vs. grain) is normally considered to have an effect on growth rate of lambs but few studies have been reported where a significant effect on carcass composition has been observed. Most experiments conclude little or no effect of hay:grain ratio on carcass composition of lambs. This is not necessarily in accord with the common usage of terms like "fattening ration," "growing ration," etc.

Table 6. Effect of sire within breed on marketing characteristics of lambs (Brannon, W. F., unpublished data).

	Ram number							Analyses of variance		
								Ram	Error	F
Item	A002	238	008	002	32	1573	21	M.S	M.S.	(40,6 d.f.)
Number of lambs	7	8	8	5	6	7	6			
Shorn-shrunk weight, lb	96.57	100.50	97.62	101.30	100.75	102.14	100.75	29.20	7.76	3.76*
Carcass weight	53.14	54.12	53.37	57.40	55.00	56.57	56.50	18.49	7.70	2.40*
Retail LLRS										
Lb.	36.51	35.53	36.43	38.63	37.65	38.14	38.67	10.16	2.18	4.66*
% of live weight	37.80	35.37	37.31	38.13	37.69	37.35	38.40	7.07	2.10	3.36*
% of carcass	68.72	65.75	68.28	67.42	68.49	67.45	68.54	8.15	4.97	1.64
Fat trim, lb	4.65	5.32	4.64	5.37	4.57	5.16	4.63	0.82	1.87	0.43
Loin eye, in²	1.92	1.78	2.02	2.11	2.01	2.09	2.02	0.088	0.058	1.51
Back fat, in	0.25	0.028	0.22	0.23	0.22	0.23	0.26	0.0037	0.054	0.68
Rib fat, in	0.63	0.61	0.59	0.63	0.54	0.63	0.59	0.0033	0.022	0.15

Table 7. Effect of hay:grain ratio fed-on growth and on market characteristics of lambs (Vidal and Hogue, unpublished data).

Item	100 Hay	75 Hay:25 Grain	50 Hay:50 Grain
No. of animals	12	12	12
Initial weight, lb	68.0	67.3	66.4
Final weight, lb	103.8	101.9	100.8
Days on feed	140	147	145
Daily gain, lb	0.28	0.25	0.25
Shorn-shrunk weight, lb	89.7	91.7	91.4
Carcass weight, lb	46.6	50.6	52.2
Dressing percentage	52.0	55.2	57.1
Mesenteric fat, lb	1.7	2.3	2.5
Retail LLRS			
Pounds	33.7	36.5	37
% of live weight	37.6	39.8	40.5
% of carcass	72.3	72.1	71.0
Fat trim, lb	2.9	4.5	4.6

Table 7 includes data from one small study designed to test the affect of hay vs. grain on market characteristics of lambs. Three hay-grain ratios were fed to groups of lambs of equal initial weights so that all groups gained at the same rate, thereby eliminating level of energy intake or growth rate as sources of variation. All lambs were killed at approximately the same weight and by such measures as dressing percentage, fat trim and mesenteric fat weight the grain fed animals were fatter than the hay fed animals. However, this difference is small and if variations in fill could be completely accounted for it would be very small indeed. Diet will not receive any major attention in our production model.

IV. MID-POINT CONCLUSIONS

1. Retail lamb cuts should be objectively defined in terms of weight and chemical composition.

2. Body weight of the slaughter lamb is the major factor affecting both the weight and chemical composition of retail cuts of lamb meat.

3. Parental size differences (confounded with breed) can affect the composition of lambs of a given weight.

Therefore, our model should be based on both parental size and slaughter weight.

V. FACTORS AFFECTING NUTRITIONAL EFFICIENCY

Probably the major factor affecting the nutritional efficiency of a sheep operation is the size of the animals, assuming numbers are not changed. Bigger sheep require more feed for maintenance than smaller sheep and maintenance is the major nutritional requirement for sheep. Another important factor affecting feed efficiency is the composition of gain of the lambs. As lambs are taken to heavier weights they are gaining more fat which theoretically requires more feed per unit gain. Breed and composition of gain tend to work in opposite directions since the bigger sheep which eat more have lambs which are not as fat at a given weight and these lambs should be more efficient. Somewhere there must be a balance between parental size, chemical composition of lambs and nutritional efficiency of an entire sheep enterprise. Another consideration though, is the relative size of the different parents. That is, does a 300-lb ram bred to a 100-lb ewe produce the same lamb as if both parents were 200-lb and do it more efficiently?

We will now proceed to an experiment to test the effect of parental size on nutritional efficiency.

VI. EFFECTOF PARENTAL SIZE

In an experiment recently completed at Cornell in cooperation with USDA, parents of greatly different sizes were individually fed for one year and all lambs continued in individual pens until slaughter at which time carcass cut-out data was obtained. The ewes varied in weight from 81 to 193 lb and in sort of a factorial-method were bred to rams weighing either 120 or 260 lb These ewes then lambed either single or twin lambs and the lambs were slaughtered at either 80 or 120 lb as a shorn-shrunk weight. Sixty ewes were used initially and 45 finished the entire experiment. A portion of the data is summarized in Table 8 which is further summarized in Table 9. The general design of the experiment is indicated in Table 8. To avoid complicated regression and covariance analyses the ewes-are handled as two groups (large and small) and average data presented on three variables only. These three are total ewe feed per ewe, total lamb feed per lamb and fat trim from the lamb carcasses.

These should be the three most important variables in simplifying the data without losing its significance.

The summary of Table 8 presented in Table 9 indicates that using larger rams resulted in a small increase in feed required by the ewe (increased lactation requirement), a larger decrease in the feed required by the lamb to reach market weight and a leaner carcass as indicated by the reduction in fat trim. The conclusion here is obvious. Let's have big rams! We should probably use rams just as big as we possibly can and still avoid breeding and lambing difficulties.

The net effect of ewe size on feed required is greater than that of ram size but conclusions are more difficult. The larger ewes required an average of 230 lb more feed than the smaller sized ones and their lambs required 73 lb less feed for a net difference of 159 lb of feed favoring the smaller ewes. Considering this figure only, we can conclude that to maximize nutritional efficiency we should use the smaller ewes. However, the larger ewes do produce leaner lambs and many costs of sheep production are on a per head rather than a per unit of weight basis. Furthermore, several papers in the literature indicate that larger ewes have a higher reproductive rate than smaller ones. I, therefore, find it hard to go along with nutritional efficiency all the way and recommend small ewes; especially since the difference in reproductive rate was so marked in this experiment.

Table 8. Summary of ewe-ram size experiment (Hogue and Lindahl).

Ewe size:	Small				Large			
Lambs:	Single		Twins		Single		Twins	
Slaughter weight:	80	120	80	120	80	120	80	120
	120-lb ram							
No. of ewes	9		2		5		5	
Ewe weight, lb	103		98		144		148	
Total feed/ewe, lb	987		1125		1186		1342	
Lamb slaughter weight	79.8	119.4	84.2	122.5	79.8	118.5	81.4	118.8
Total feed/lamb, lb	316	862	260	1183	286	805	182	1130
Fat trim/lamb, lb	3.2	12.1	4.9	15.2	3.4	9.4	2.8	11.1
	260-lb ram							
No. of ewes	10		1		4		9	
Ewe weight, lb	109		109		150		158	
Total feed/ewe, lb	993		1130		1265		1372	
Lamb slaughter weight	79.1	118.8	81.5	122.5	80.0	119.5	78.8	121.7
Total feed/lamb, lb	261	771	201	1013	172	614	162	928
Fat trim/lamb, lb	2.3	10.1	2.8	11.6	1.6	8.6	1.6	8.6

The summary of the effect of number of lambs born on feed required (Tables 8 and 9) indicates ewes with twin lambs required 134 lb more feed than those with singles but on a market lamb basis each twin lamb was produced on 366 lb less feed than each single. This is a saving of about 25% in feed. The twin lambs were slightly fatter at slaughter than the singles but in most groups they were also slightly heavier, thus the actual saving in feed may be greater than the 366 lb indicated.

Table 9. Summary of Table 8 showing unweighted main effect means and ignoring interactions.

Comparison	Average ewe feed, lb	Average lamb feed, lb	Average total feed, lb	Average carcass fat trim, lb
Large rams (260 lb)	1190	515	1705	5.9
Small rams (120 lb)	1160	628	1788	7.8
Difference	+30	-113	-83	-1.9
Large ewes (150 lb)	1291	535	1826	5.9
Small ewes (105 lb)	1059	608	1667	7.8
Difference	+232	-73	+159	-1.9
Twin lambs (per ewe)	1242			
Single lambs (per ewe)	1108			
Difference	+134			
Twin lambs (per lamb)	621	632	1253	7.3
Single lambs (per lamb)	1108	511	1619	6.3
Difference	-487	+121	-366	+1.0

VII - THE MODEL

We now have a simple straight-forward sheep production model for the production of standard market lambs and with maximum nutritional efficiency.

1. Kill lambs at a standard weight, 110 lb.
2. Use large rams, 275-325 lb.
3. Use moderate sized ewes - this will depend on future research on the effect of size on reproductive efficiency.
4. Select replacement ewes primarily on the basis of twinning.

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