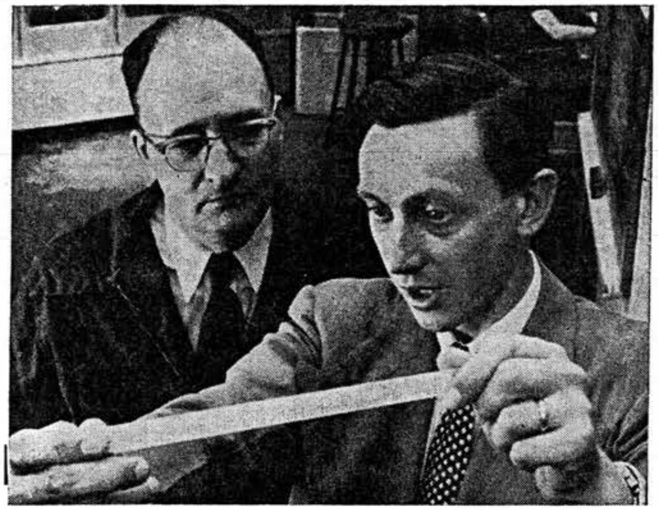

► *Illinois U's Earl R. Swanson decoding Illiac tape solution of special swine feed formulation problem.*

"Flexing" Feed Formulas to Produce Minimum Cost Mix—a Fast Operation as Done by Illiac

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Exclusive Preliminary Report for National Miller Publications

A NEW mathematical technique called "linear programming" may soon be used by feed manufacturers to solve the old problem of cutting costs without lowering product quality. Briefly, it is a method for minimizing the cost of performing a given operation when a large number of variables needs to be considered, simultaneously. (It is called "linear programming" since it involves linear equations.) Because it is a mathematical method, calculation is aided greatly by an electronic computer. In fact, for very complicated problems with ingredient prices changing rapidly, it is not likely that you would get the "answer" in time to use it if you had to rely on paper and pencil or even an ordinary desk calculator.

Earl Swanson

Illiac, the automatic electronic digital computer at the University of Illinois, is well suited to solving linear programming problems. The Illiac performs mathematical operations at an amazing rate of speed. For example, it can add two numbers in about 75 microseconds. To utilize such speed it is necessary that the machine be automatic. This means that upon receiving orders it can proceed with the calculations without any human aid. Presently the Illiac has a "memory" or storage space for 1024 numbers. This memory is needed because numbers used in the early stages of a problem are sometimes needed at later stages. The memory also holds the orders that instruct the machine during the course of its operation.

Let us take an example. Suppose you wish to mix a ton of hog feed that would meet the following requirements:

Fiber	not more than	10 %
Protein	not less than	35 %
Fat	not less than	1.5 %
Calcium	not less than	3 %
Phosphorus	not less than	1.25 %
Vitamin A or carotene	not less than	20,000 units per lb.
Riboflavin	not less than	7 Mgms per lb.
Niacin	not less than	48 Mgms per lb.
Pantothenic acid	not less than	12 Mgms per lb.
Choline	not less than	1,400 Mgms per lb.
Vitamin B_{12}	not less than	.025 Mgms per lb.
Salt	not less than	1.5 %
Iodine	not less than	.00014 %
Manganese	not less than	80 parts per million
Antibiotic	not less than	.025 Gm. per lb.
Vitamin D_2	not less than	900 units per lb.

Assume, then, that you have available the 20 ingredients shown in Table 1 on Page 16. The problem is to combine these in the "right" proportion. This means that the requirements must be satisfied—and also that ingredient cost must be minimized.

There are a very large number of ways that these ingredients might be combined to satisfy the nutrient requirements. However, there is likely to be only one combination which will do this and also minimize cost. Linear programming guarantees this combination.

Here is an idea of the way the problem is solved on the Illiac. First, a set of coded orders on ticker tape is fed into the machine. These tell the machine to prepare for a linear programming problem of a certain size. *In this case, we have 20 possible ingredients and 17 requirements. Next, a ticker tape with the requirements, ingredient analyses and prices is fed into the computer. Then the computer starts to work.*

In about 10 minutes the results come out, again on ticker tape. This rather simple linear programming problem could easily take several days to solve with a desk calculator. A "common-sense" or "trial-and-error" method would of course take less time. But such methods cannot consider *all* possible alternative combinations that satisfy the requirements in arriving at a least-cost feed mix.

(Editor's Note: Some of the most advanced work on linear programming as applied to feed formulation has been accomplished at Kansas State College by Prof. Leonard Schruben, of Manhattan, Kan. Use of an electronic computer—like Illiac—would speed up applications of "l.p." techniques.)

Minimum-Cost Mixes

Let us look at the results of meeting the requirements under two different price situations. The minimum cost mixes are in Table 2. Price situation A represents the ingredient prices facing an Illinois feed mixer in May, 1954. Price situation B is slightly altered from A.

Table 2. — MINIMUM-COST MIXES

Ingredients	*Price Situation A*	*Price Situation B*
Alfalfa meal	500.000	500.000
Distillers solubles	0.000	314.693
Meat and bone scraps	516.130	511.164
Molasses	146.035	0.000
Soybean oil meal	783.452	623.876
Riboflavin supplement	0.503	0.408
Niacin	0.150	0.125
Calcium pantothenate	0.287	0.294
Irradiated yeast	0.113	0.113
Manganese sulfate	0.696	0.696
Choline chloride	12.602	8.599
Antibiotic supplement	10.000	10.000
Salt	30.000	30.000
Potassium iodide mixture	0.032	0.032
Total weight (pounds)	2,000.000	2,000.000
Cost (dollars)	99.63	90.80

(Continued on Page 44)

TABLE 1. — ANALYSIS AND PRICES OF INGREDIENTS

Ingredient	Price situation (dollars per ton) A	Price situation (dollars per ton) B	Percent protein	Percent fat	Percent fiber	Percent calcium	Percent phosphorus	Mgms. per pound: Riboflavin	Niacin	Pantothenic acid	Choline	Vitamin B_{12}
*Alfalfa meal	66.00	50.00	17.0	2.0	25.0	1.50	0.20	7.00	14.0	14.0	400.0	0.00
Distillers solubles	92.00	60.00	25.0	5.0	3.0	0.40	1.50	6.00	50.0	10.0	2000.0	0.00
Fish meal	156.00	140.00	60.0	7.0	1.0	5.00	3.20	2.00	25.0	4.0	1400.0	0.15
Fish solubles	140.00	120.00	32.0	3.0	0.0	0.10	0.80	6.00	120.0	18.0	1000.0	0.25
Meat and bone scraps	128.00	112.00	50.0	9.0	2.5	10.00	5.00	2.50	21.0	2.0	750.0	0.10
Molasses	30.00	25.00	3.0	0.0	0.0	0.50	0.05	1.00	20.0	17.0	300.0	0.00
Dried skim milk	200.00	150.00	34.0	0.5	0.0	1.30	1.00	9.00	5.0	15.0	500.0	0.00
Soybean meal	96.00	100.00	45.0	0.5	6.5	0.20	0.65	1.30	9.0	5.5	1200.0	0.00
Dried whey	116.00	100.00	12.0	0.5	0.0	0.80	0.70	12.00	5.0	20.0	700.0	0.00
Riboflavin supplement	1,280.00	1,000.00	1 gram riboflavin per ounce									
Niacin	9,000.00	8,000.00	pure niacin									
Calcium pantothenate (feed grade)	3,840.00	3,000.00	2 grams pantothenic acid per ounce									
Potassium iodide mixture	4,000.00	4,000.00	8.8% iodine									
Salt	30.50	30.50	pure salt									
Irradiated yeast	960.00	960.00	16,000,000 units D_2 per pound									
Manganese sulphate (65%)	96.00	96.00	23% elemental manganese									
Choline chloride (25% grade)	340.00	300.00	21.5% choline									
Vitamin B_{12} supplement	480.00	400.00	6 gms. B_{12} per pound									
Antibiotic supplement	1,200.00	1,200.00	5 gms. antibiotic per pound									
Vitamin A oil	850.00	800.00	8000 units vitamin A per gm.									

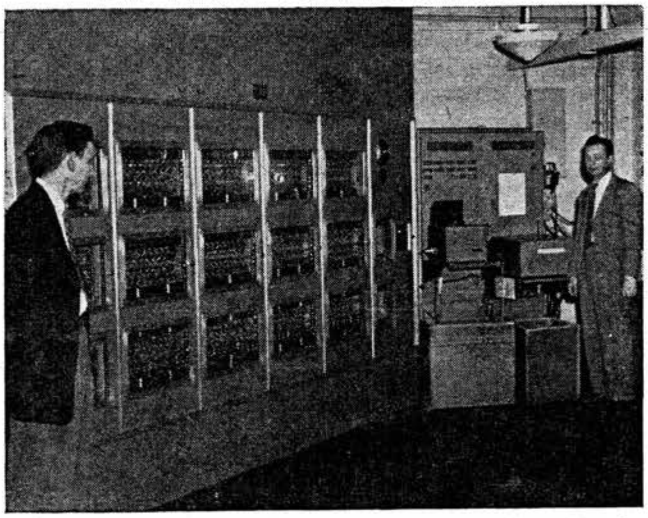
*Also contains 80,000 units carotene per pound.

"Flexing" Feed Formulas to Produce Minimum-Cost Mixes — a Fast Operation as Done by Electronic Illiac (CONTINUED)

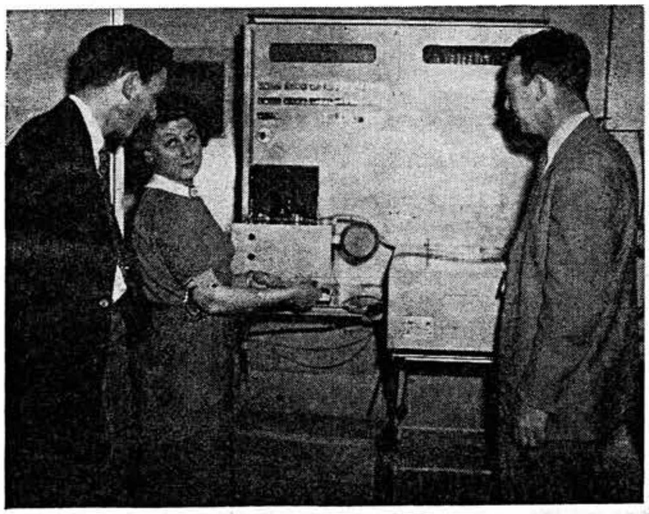
The question is—how do we "flex" the mix from the minimum cost mix for "A" prices to meet the new situation.

To answer this, the problem is re-run through the computer with only the prices changed. This again takes only about 10 minutes of computing time. Comparing price situation A with B we see that the major sources of protein have the same rank with respect to cost per pound of protein. Soybean oil meal is the cheapest source per pound of protein under both situations; meat and bone scraps represent the next least expensive source of protein, etc.

HOW "ILLIAC" GOES TO WORK ON FEED FORMULATION



► *Unit at right receives formulation problem in the form of punched paper tape. Results of computation which Swanson (left) and Peterson will receive in about 10 minutes might take days to approximate if desk calculator were used. The electronically produced solution to the problem emerges on ticker tape within a few minutes. The punched tape unit then is decoded.*



► *Illiac at work on hog-feed formulation—to show possibilities of electronic digital computer in the feed manufacturing business. Holes punched in tape give instructions to the computer; data feed in rapidly, and the machine goes to work on the problem. Earl Swanson (left) and G. A. Peterson discuss a problem of coding with Ramona Russell, operator of the digital computer.*

"Flexing"

These two ingredients comprise the major portion of each least-cost mix. However, as we move from price situation A to B, distillers solubles replace all of the molasses and a portion of the soybean oil meal and meat and bone scraps. Yet if cost per pound of protein had been the basis for selection, distillers solubles are cheaper than molasses—and more expensive than soybean oil meal or meat and bone scraps under both price situations.

Computer Vs. "Common-Sense"

Feed mixers say that "flexing" too much in an attempt to minimize ingredient cost may alter the appearance of the feed. This simply means that additional requirements need to be added. For example, both a minimum and maximum amount may be specified for an ingredient like alfalfa meal. This would keep the color more uniform. Such an additional requirement can readily be handled by the linear programming method.

Whether linear programming, either by desk calculator or by electronic computer represents an economical substitute for "common-sense" is a question that will be ultimately settled by the feed manufacturers themselves. It appears to be a possibility worth exploring. END