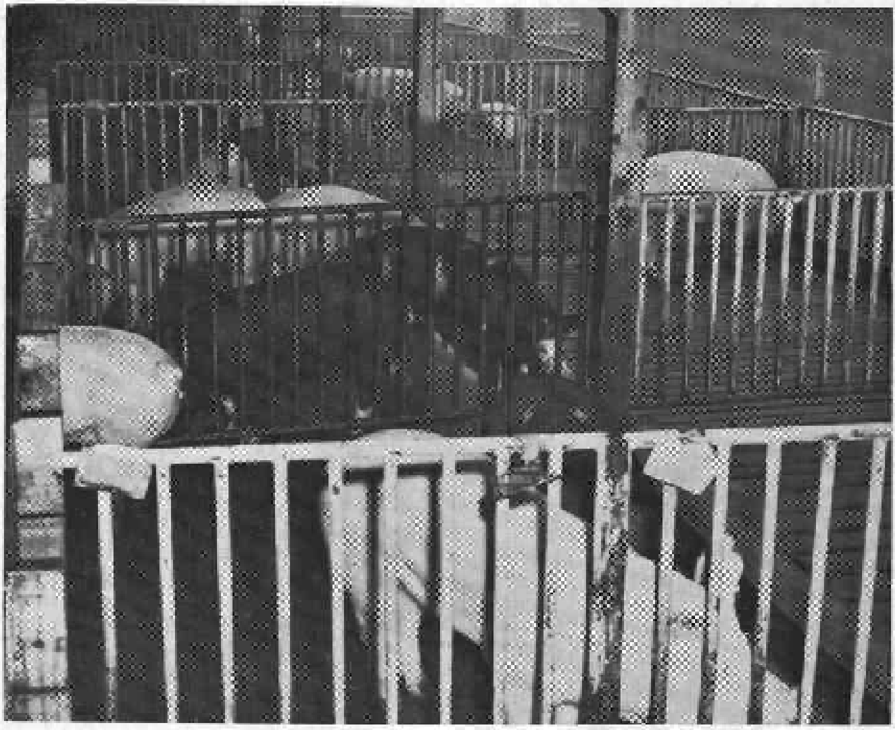
Reports of the Ninth Annual Swine Day



Special Report 245

December 1967

Agricultural Experiment Station • Oregon State University • Corvallis

Contents

Sponsored by the Department of Animal Science, Oregon State University and the Western Oregon Livestock Association

Full-Cycle Performance of Swine Confined on Slotted Floors

D. C. ENGLAND

Confinement of swine during farrowing and preweaning, and from weaning to market is a common practice in the United States. Confinement of brood stock from time of selection of replacement gilts and boars through breeding and gestation to farrowing is not a common practice. The latter is, however, becoming of increasing interest because of potential advantages of more intensive observation, increased sanitation, better control of temperature, and release of land for other uses. Knowledge of nutritional needs and development of slotted floors and lagoons to minimize labor for pen cleaning and manure disposal have given strong impetus toward confinement at all stages.

Confinement at OSU

For the past two years, swine in all phases of the production cycle have been continuously maintained in confinement at Oregon State University. Three separate units constitute the facilities. The farrowing-nursing-growing unit has 48 pens for nursing and growing pigs and a farrowing room with 12 farrowing crates measuring 5 by 7 feet. Each nursing-growing pen is approximately 8 by 10 feet. The pens are arranged in two rows, with an alley four feet wide between them. The brood stock unit is designed to handle about 65 mature animals. It contains individual pens for boars and group pens for sows with stalls 2 by 8 feet for feeding the sows individually. The nutrition research unit has 48 pens 4 by 6 feet in size, a laboratory-workroom, scales, and a feed-handling room.

All units housing animals possess the following features:

1. Partially slotted floors made from low-cost standard dimension lumber laid flat over manure-collection pits. (The ratio of slotted to solid floor is either 1.5:1 or 1:1.)

2. Slats recessed about one-half inch below the solid floor. One-inch spacers nailed to one side of each slat at each end provide one-inch openings between slats. Each slat is individually nailed to the underlying support.

3. Storage of manure and urine under water in collection pits underneath slotted floors for gravity disposal to an outside lagoon when the drain plug in the floor of each pit is removed.

4. Use of water spigots in the manure collection pits to direct a stream of water into the drain openings during discharge of collected manure.

5. Drain openings in each pit ringed with $\frac{5}{8}$-inch metal rods embedded 3 inches apart in the cement and extended vertically about 12 inches. (This helps prevent the entrance of objects that might clog the drains. A drain plug within this circle can be lifted with a hook to secure the outflow of manure.)

D. C. ENGLAND is associate professor of Animal Science, Oregon State University.

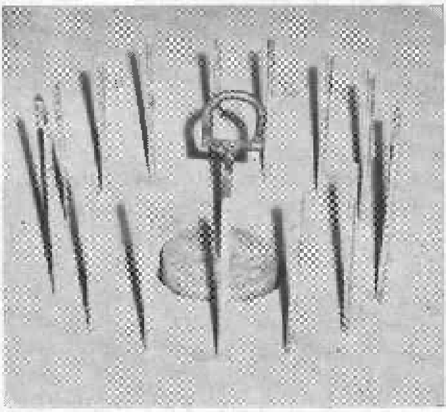


Figure 1. The drain opening in a liquid-manure collection pit under a slotted floor. Metal rods prevent the entrance of objects that might stop up the drain. The concrete drain plug can be lifted with a hook.

Heat lamps in the farrowing crates are the source of heat in the farrowing unit. The front four feet of the farrowing crate floor is concrete; the remainder was originally 2- by 4-inch Douglas-fir laid flat $\frac{3}{8}$ inch apart. This design for the slotted area proved undesirable because (1) the baby pig area was too cold as it could not be bedded, and (2) the area under the sow clogged with manure. The design was changed to provide a solid area under the pigs and one-inch openings under the sow with an expanded metal overlay over the slotted area to prevent the newborn pigs from getting entrapped in the one-inch openings.

This arrangement was adequate for self-cleaning and safety of the baby pigs but was still too drafty and cold for maximum survival of newborn pigs without installation of supplemental heat. Consequently, the floor was made solid and bedded with shavings to provide desirable conditions for newborn pigs. The use of slotted floors in the farrowing crates was not satisfactory in the nonheated farrowing unit; aspects other than survival were satisfactory with the second design and presumably would be satisfactory for survival in an adequately heated unit. The slotted design was especially helpful in keeping the pens dry.

Nursing-growing pens

At about a week of age, litters are moved from the farrowing crates to the nursing-growing pens. These pens are 8 by 10 feet, with 4 feet of concrete floor and 6 feet of slotted floor. A protected area for the baby pigs is available on the solid floor. The feeder for creep feed and sow feed and, after weaning, for the growing pigs is also located on the solid floor.

Initially the slats were 2- by 4-inch Douglas-fir laid flat one inch apart except for four pens that had 2- by 6-inch slats. During the first season of use, baby pigs seldom became caught in the slots. By the second season of use, the frequency of entrapment increased, and it became of serious magnitude by the third season during the first week or 10 days after litters were moved from the farrowing crates to the nursing pens. Three observations led to a satisfactory new design: (1) The edges of the slats had rounded off so that entrapment was enhanced; (2) little or no entrapment occurred in the pens floored with 2- by 6-inch slats; and (3) floors cleaned as well with 2- by 6-inch slats as with 2- by 4-inch slats. Tests with 2- by 8-inch slats in a few pens indicated that these also were satisfactory. Accordingly, 2- by 4-inch slats were re-laid together to form 2- by 8-inch slats with one-inch slots. These slats have virtually eliminated entrapment, and they are self-cleaning.

At weaning, the sows are moved to the brood stock unit. Pigs remain in the nursing-growing pens and are performance tested in litter groups from initial weights of 60 pounds to final weights of 200 pounds, unless they are used for other purposes. There has been no pneumonia, and scouring has occurred only infrequently without appreciable adverse effects. Auero S. P.-250 is used at recommended levels in the creep and grower rations. Performance of suckling and weaned pigs and carcass data are shown in Table 1.

Performance results

On the whole, daily gain has been somewhat lower in the three seasons of confinement on slotted floors than during the six prior seasons of confinement on solid floors washed daily. This is seen both in 56-day (weaning) weights and in average daily gains from 60 to 200 pounds. Feed efficiency has changed relatively less than daily gains. Carcass length is unchanged, while backfat thickness shows a slight increase and loin-eye area shows a favorable change.

The causes of the somewhat slower daily gain are not entirely established. Possible contributing causes are: (1) feeder design that permits varying degrees of contamination of feed with manure; (2) waterers that become contaminated with manure and urine; (3) tail-biting; and (4) roundworm infestation. Adequate information in our records indicates that the following conditions do not appear to be causes: (1) the number of pigs that have been allotted per pen or space allotted per pig; (2) any disease condition, including scours or pneumonia; (3) odors or gases from the under-floor manure-collection pits; (4) nutritional deficiencies; and (5) hereditary ability for adequate performance. Experiments and operational changes are planned to determine the causes.

Tail-biting was present sporadically with confinement on solid floors. With daily washing of pens, however, severe infections of the tail stub seldom occurred. Tail-biting has also occurred in some groups on slotted floors. Frequency, severity, and effect on gains are shown in Table 2.

In about 30% of the Yorkshires and in about 7% of the cross-foundation pigs, tail-biting was severe enough to cause a significant reduction in average daily gains. These animals had three-fourths or more of their tails chewed

Table 1. Average Daily Gain, Feed Efficiency, and Carcass Traits of Swine Reared in Confinement

Breed group[1]	56-day weight	Avg. daily gain[2]	Feed per lb. gain[2]	Carcass length	Backfat thickness	Loin-eye area
	Lbs.	*Lbs.*	*Lbs.*	*In.*	*In.*	*Sq. in.*
(Average of three seasons in confinement on slotted floors)						
Berkshire	34.5	1.68	3.16	30.5	1.39	4.64
Yorkshire	33.0	1.60	3.02	31.5	1.38	3.90
Cross foundation	36.0	1.72	2.99	31.1	1.44	4.06
(Average of six prior seasons in confinement on solid floors)						
Berkshire	37.8	1.79	2.91	30.3	1.28	4.24
Yorkshire	36.2	1.78	2.93	31.6	1.32	3.59
Cross foundation	37.8	1.92	2.96	31.0	1.37	3.92

[1] Most animals were somewhat inbred; cross foundation was derived from F_1 Berkshire x Yorkshire.
[2] From 60 pounds to 200 pounds.

Table 2. Severity of Tail-biting Among Affected Litters of Market Swine and Effect on Average Daily Gains

Severity group[1]	Berkshire	Yorkshire	Crossbred ancestry	Average daily gain
	%	%	%	*Lbs.*
0	100	31.3	48.8	1.65
1	0	28.1	32.5	1.67
2	0	10.9	11.3	1.72
3	0	10.9	6.2	1.56
4	0	12.5	1.2	1.46
5	0	6.3	0.0	Removed from experiment

[1] None, one fourth, one half, three fourths, and more than three fourths of the tail chewed off, respectively. Pigs with "5" rating were so severely affected that they were removed.

off and usually had infected tails. As an attempted preventive measure, tails are now cut off at one day of age when pigs are weighed and ear notched.

In the OSU herds, all animals are reared to 200 pounds weight in litter groups in pens 8 by 10 feet. Replacement animals are then moved to the brood stock unit where space per animal is about 32 square feet for gilts and about 60 square feet for boars. The animals remain under these latter conditions through breeding and gestation, except when placed under other conditions for experimental purposes.

During three seasons, about half of the females were kept under the above conditions in the brood stock unit. The remainder were confined in the brood stock unit in 2- by 8-foot individual pens from before breeding until a few days before farrowing. All were fed the same ration and all were fed individually. Breeding performance is shown separately for sows and gilts in Tables 3 and 4.

Breeding performance

Occurrence of heat and conception were regular and within normal ranges, with no mating problems encountered for sows. Gilts, however, were less regular in occurrence of heat and acceptance of the male. Only 83% of the gilts kept in individual pens mated, while 94% of the gilts kept in groups mated. Twenty-seven percent of the individually confined gilts and 33% of the group-confined that mated rebred once; 7% and 10%, respectively, rebred twice. In addition, 28% of the gilts kept in individual pens and 16%

Table 3. Occurrence of Estrus and Conception for Sows in Two Systems of Confinement

	Individual pens	Group pens
Total sows	46	39
Average days weaning to first mating	5.3	5.7
Bred (%)	97.8	97.4
Bred within 6 days after weaning (%)	91.3	94.8
Conceiving at first mating period (%)	71.1	81.6
Conceiving at second mating (%)	26.6	10.5
Requiring a third or more mating periods (%)	2.2	7.9
Number that bred but did not farrow	3	0

Table 4. Occurrence of Estrus and Conception for Gilts in Two Systems of Confinement

	Individual pens	Group pens
Total gilts	36	32
Bred (%)	83	94
Conceiving at first mating period (%)	73	67
Conceiving at second mating period (%)	20	23
Requiring a third or more mating periods (%)	7	10
Exhibiting irregular estrual behavior[1] (%)	28	16

[1] Includes some that subsequently bred (see text for description).

of those kept in group pens showed irregularities such as no expression of heat, partial or irregular enlargement of the vulva, or excessive and prolonged enlargement without willingness to mate. Of those that showed disturbed heat patterns, seven eventually bred and farrowed an average of 6.3 live pigs.

Litter size for sows and gilts kept in the two kinds of confinement are shown in Tables 5 and 6. Farrowing results from three seasons prior to confinement and for the fall of 1967 in which all females were group-confined are shown also for comparison.

The number of pigs born alive, the number born dead, or the total number born were not significantly different for the treatments of individual confinement, group confinement, or nonconfinement in the three prior seasons. Added indication of the lack of adverse effects of confinement on the number of pigs born per litter is shown in the data for litters farrowed in the

Table 5. Farrowing Data for Sows Confined Either Individually or in Groups During Gestation

Treatment unit	No. litters	Avg. no. born alive	Avg. no. born dead	Total born
Berkshire[1]				
Individual	13	7.46	1.00	8.46
Group	12	7.50	1.75	9.25
Yorkshire[1]				
Individual	14	10.93	1.35	12.28
Group	15	10.73	1.00	11.73
Cross Foundation[2]				
Individual	21	10.38	0.48	10.86
Group	16	11.19	1.06	12.25
Total				
Individual	48	9.59	0.95	10.54
Group	43	9.81	1.27	11.08
Other Comparisons				
Three prior seasons—nonconfined[3]	82	10.25	0.94	11.19
Fall 1967—all animals group-confined	23	10.39	1.00	11.39

[1] Most dams were somewhat inbred.
[2] Derived from a Berkshire-Yorkshire cross; most dams were somewhat inbred.
[3] Immediately before beginning confinement of the herd.

Table 6. Farrowing Data for Gilts Confined Either Individually or in Groups During Gestation

Treatment unit	No. litters	Avg. no. born alive	Avg. no. born dead	Total born
Berkshire[1]				
Individual	6	7.17	2.33	9.50
Group	4	7.46	1.25	8.71
Yorkshire[2]				
Individual	9	6.56	1.00	7.56
Group	8	9.88	0.50	10.38
Cross Foundation[2]				
Individual	11	8.91	0.64	9.55
Group	15	9.13	0.66	9.79
Total				
Individual	26	7.55	1.32	8.87
Group	27	8.82	0.80	9.62
Other Comparisons				
Three prior seasons—nonconfined[3]	38	8.25	0.85	9.10
Fall 1967—all animals group-confined	19	9.21	1.63	10.84

[1] Most dams were somewhat inbred.
[2] Derived from a Berkshire-Yorkshire cross; most dams were somewhat inbred.
[3] Immediately before beginning confinement of the herd.

fall of 1967 in which all females were kept in group confinement.

Strength and vigor of pigs at birth were not recorded, but litters from both systems of confinement appeared to be of normal strength and vitality. Birth weights were significantly heavier for pigs born to sows in group confinement than in individual confinement; in both, however, weights were within normal range of litters from nonconfined dams. There was no significant difference in birth weight of litters from gilts in the two systems of confinement.

Boars maintained in confinement have shown normal willingness to mate and ability to settle sows. Calloused growth on the pads of the rear feet may occur and require trimming.

Management findings

Many aspects of the buildings and facilities of the swine unit were experimental. Included were materials for floors, design of the floors, depth of under-floor manure-collection pits, slope of the pit bottoms, number of outlets for emptying manure, and feeder design. Likewise, management practices have been experimental to a large extent. Both the facilities and management experience now have been used long enough to allow some general observations in addition to the information already presented.

Use of 2- by 8-inch slats has been more satisfactory than use of 2- by 4-inch slats. On the former, the animals have most of the advantages of both a solid floor and a slotted floor. Self-cleaning of the slotted floors by the pigs does not keep the floors as clean as solid floors washed daily, but slotted floors require very little labor to remain in a satisfactory state of cleanliness. Slots more than one inch wide are not necessary or desirable for brood stock.

Douglas-fir slats are suitable for the well-being of the animals, but pigs do chew them. Records on 20 pens in the nursing-growing unit show that almost half of the slats have been replaced due to chewing or wear at the end of two years. On the basis of these records, it appears that complete replacement might be necessary every three years.

Disposal of manure from under-floor pits through drain tile openings has been essentially trouble free. Emptying twice weekly has been beneficial in completeness of emptying, in reduction of odors, and in preventing migration during the summer of "rat-tail" maggots from the pits onto pen and alley floors. (Rat-tail maggots are the larvae of a harmless hover fly that hatches in heavily polluted waters.) Odors from the field lagoon have been essentially nonexistent; odors from the under-floor collection pits have been more prominent and are of a permeating nature. They have not been apparent more than a few hundred feet away from the unit, and they are not usually of objectionable magnitude to the workers in the units unless doors and windows are closed. (The nursing-growing unit does not have forced ventilation.)

Control of roundworm infestation of growing pigs has been more difficult than anticipated. Pen floors usually have enough moisture and warmth to rapidly develop eggs to an infective state; pigs have ready access to any eggs present. Likewise, healing of wounds in pigs beyond 100 pounds is slow, perhaps because of the ease of contamination and "picking" by pen mates. Feet and leg weaknesses or injuries have been relatively few; fighting among sows occurs upon initial grouping but seldom persists to a critical stage unless one or two strange animals are allotted to an already established group.

Differences in confinement

An important generalization is that full-cycle confinement production is different from nonconfinement production. Appearance may be changed, animals may not behave the same as in nonconfinement, and they may have a distinctive "character" that differs from that observed in nonconfinement. The well-being of the herd is almost completely dependent upon managerial skill; necessities of the herd must be attended to promptly and regularly. For example, a broken slat or an open pen gate will result in difficulty if not detected and corrected at once; temperature control must be provided since the animals do not have the opportunity to seek shade, moisture, or shelter unless the facilities provide the opportunity to do so. Injured animals are subject to the harassment of pen mates. Nevertheless, for an operator who carefully seeks beneficial changes in management methods, increased performance levels and efficiency may well result from full-cycle confinement.

Current Practices and Problems in Swine Waste Management

E. Paul Taiganides

It is more meaningful to approach the farm waste-disposal problem from a management viewpoint rather than considering disposal alone. This allows us to look at the problem in its totality. Disposal is only one of the major operations in the management of wastes, as shown in Figure 1. To properly and effectively manage these wastes we must consider the source and modes of generation of the wastes, the promising and possible methods of transport, the degree and type of processing, the potential utilization, and the final disposal of these wastes. In the good old days, anyone who contemplated becoming a farmer and raising hogs had to resign himself to shoveling manure and spreading it with wheelbarrows or manure spreaders onto his fields. A lot of things have changed since those days and many things have improved, but the manure chores have not. As a matter of fact, the problem of manure disposal has been recognized only recently. To better appreciate the problem of manure management, let us examine both the national and the producers' problem.

E. Paul Taiganides is associate professor of Agricultural Engineering at Ohio State University.

There are approximately 100 million head of cattle, 400 million poultry birds, and close to 50 million pigs in production on any single day in the United States. This means that for every two persons in the United States there are two chickens, one head of cattle, and half a pig. These animals void 1,000 million cubic yards of manures per year. The urban human population of the United States generates only 200 million cubic yards of sludge per year. In terms of potential water pollution, it has been estimated that farm animals defecate manures whose pollutional strength is equivalent to ten times the wastes from the human population of the United States.

The pollution problem

In 1964, the U. S. Public Health Service reported that approximately 1.1 million fish were killed because of manure discharge into rivers and lakes. Even though this constitutes only 6.5% of the 17.9 million fish killed in 1964 because of pollution, it still constitutes a significant problem, especially if we consider the large amount of potential pollution that would result from inadequate disposals of manures. The recent trends in concentration of large numbers of animals per unit of area have

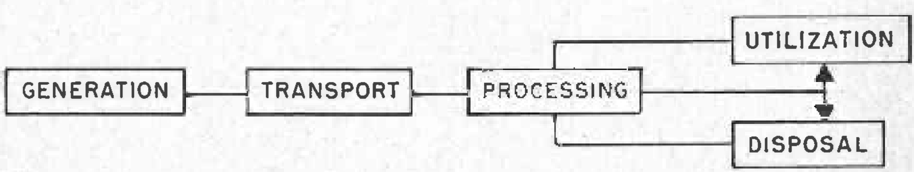


Figure 1. Major operations in the management system of wastes.

increased the possibilities for fish kills due to agricultural operations.

Over the past six years there has been a growing recognition of the problem by farmers, extension agents, researchers, administrators, the President, and the Congress. Finally in 1965, Congress passed the Solid Wastes Disposal Act, which provides some funds for research in farm-waste management. Several state agricultural experiment stations initiated research projects in farm-waste management in 1961. These research projects will be discussed in more detail in my second report.

The producers' problem

The factors that cause or aggravate the producers' waste-disposal problems may be grouped as follows:

1. Manure properties.

2. Present methods of manure handling and disposal.

3. Expansion of urban centers into rural areas plus public awareness of the need for a healthy and aesthetically pleasant environment.

Properties of animal wastes

The quantity and composition of animal manures depend so much on the feed ration, the environment in which the animals are raised, and the size of the animals that it is difficult to give a general figure that would apply in every situation. Wide variations occur in both the quantity and composition of animal excretions. In confinement production, the daily quantity of manure varies with the time of year. It is lower during the hot months than during the cold months of the year, mainly because of the higher ventilation rates and, thus, higher evaporation losses in the summer months.

The average daily manure production from cattle, swine, and poultry is shown in Table 1. The data in Table 1 show the daily manure defecation rates expressed in weight and volume units. Furthermore, Table 1 shows that manure-production rates are related to the size of the animal. If the average size of your animals is less or greater than those shown in Table 1, then the manure production is going to be proportionally smaller or larger. For example, on the average, a 100-pound pig will defecate 5 pounds of manure and a 700-pound cow will defecate 45 pounds of manure per day.

Although the liquid portion of the total excrement is only 30 to 40%, urine is more valuable than the solid portion of the manure. It contains most of the potassium, little of the phosphorus, and often over 30% of the nitrogen. The urine constitutes 40 to 70% of the fertilizer value of the total excrement. Therefore, extra care must be taken to avoid undue loss of the liquid portion of the manure. Handling procedures that allow exposure of urine to the atmosphere and loss of the liquid portion of the manure are unsatisfactory.

From the standpoint of maximum utilization of the fertility value of manure, continuous spreading is considered ideal. However, daily spreading is practically impossible because of the weather, the labor demand, and the costs involved. Therefore, some temporary storage must be provided for the manure. Table 2 gives the volume required to store manure for a given period of time. If you are interested in providing storage for the manure during the winter months, you should provide 36 cubic feet per 100 hens,

Table 1. Daily Manure Production (Urine and Feces—No Bedding)

Animal	Average size	Total excrement				
		Solid	Liquid	Lbs. per day	Gallons per day	Cu. ft. per day
	Lbs.	%	%			
Hen	4–5	100	0	0.25	0.03	0.004
Hog	130	63	37	9.1	1.1	0.15
Cow	1,000	70	30	64.0	7.7	1.0

Table 2. Storage Capacities for Manure per Animal for Different Periods of Time (No Bedding)

Animal	Average size	Length of storage				
		1 month	2 months	3 months	6 months	1 year
	Lbs.	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*	*Cu. ft.*
Hen	4–5	0.12	0.24	0.36	0.73	1.50
Hog	130	4.5	9.0	13.5	27.0	54.0
Cow	1,000	30.0	60.0	90.0	180.0	360.0

1,350 cubic feet for each 100 hogs, and 9,000 cubic feet for 100 cattle. In a 100-hog confinement unit with slotted floors, 1.5 feet of clearance between the slats and the bottom would provide room for three months' manure storage.

Major elements. As with defecation rates, wide variations exist in the composition of excretions—not only between classes of livestock but between individual animals of the same species. Factors responsible for these variations include the composition and quantity of feed consumed, the size, age, and breed of the animal, the environment in which the animal is raised, and the quality and quantity of water consumed.

In confinement production, manure contains all of the ingredients of the feed, some of them in their original form and others in a chemically simpler form. Plant nutrients in manures come entirely from the feeds consumed by the animals. The proportions of the nutrients originally present in the feed that are excreted in the manure vary considerably. Growing animals and milking cows use higher proportions of the fertilizer elements of the feed than mature animals.

On the average, about 75% of the nitrogen, 80% of the phosphorus (as P_2O_5), 85% of the potash (K_2O), and about 40 to 50% of the organic matter of the feed can be recovered in the manure.

Table 3 shows the pounds of each of the major manure plant nutrients contained in a 1,000-gallon tank wagon load. It can be noted in Table 3 that, on the basis of equal volume, chicken manure contains far more plant nutrients than hog or cattle manure. To fill a 1,000-gallon tank wagon, it would take 1,000 chickens a whole month, 1,000 hogs only one day, and only 100 cattle one day.

Table 4 shows the fertilizer elements found in the daily and yearly excrement from poultry, swine, and cattle

Table 3. Moisture and Major Plant Nutrients in Fresh Animal Manures

			Nutrients/1,000 gallons as:			
Animal	Defecation	Moisture	Organic	N	P_2O_5	K_2O
	Lbs./day	*%*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Hen	0.25	70	1,830	135	104	48
Hog	9.1	84	1,130	60	36	57
Cattle	64.0	84	1,060	49	15	40

Table 4. Major Fertilizing Elements of the Complete Animal Excrement per 1,000 Pounds of Live Weight

Element	Hens		Hogs		Cattle	
	Lbs./day	*Lbs./yr.*	*Lbs./day*	*Lbs./yr.*	*Lbs./day*	*Lbs./yr.*
Wet manure	56.0	32,200	70.0	22,400	64.0	20,600
Total mineral matter	3.9	1,400	1.8	600	2.1	800
Organic matter	12.2	4,400	9.4	3,400	8.2	3,000
Nitrogen (N)	0.93	333	0.50	185	0.38	138
Phosphorus (PO_5)	0.69	253	0.26	110	0.11	41.3
Potassium (K_2O)	0.34	118	0.48	172	0.31	112

Table 5. Minor Fertilizing Nutrients in 1,000 Gallons of Fresh Animal Manures

Manure	Calcium	Magnesium	Sulphur	Iron	Zinc	Boron	Copper
	Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
Hen	300	24.0	26.0	3.9	0.75	0.50	0.12
Hog	47	6.6	12.0	2.3	0.50	0.33	0.13
Cattle	17	8.7	5.8	0.33	0.12	0.12	0.04

averaging 1,000 pounds of live weight. In other words, Table 4 gives you the average quantities of the major manure ingredients you can expect to get from about 220 laying hens, ten 100-pound hogs, and two 500-pound steers. Note that on the basis of live weight, chicken manure contains 1.5 times as much organic matter as hog or cattle manure, almost twice as much nitrogen as hog manure, and over twice as much nitrogen as cattle manure.

Minor elements. The value of manure does not lie only in the major fertilizing nutrients it contains, but also in a number of minor elements. Even though they are found in manure in very small quantities, they are essential for plant growth. Plants also require very small quantities of these elements for their proper growth. Soils deficient in these elements would definitely benefit from generous manure applications, and as a result they would support higher crop yields. Table 5 shows some of the elements that can be found in livestock and poultry manures, and the approximate quantities of these elements per 1,000 gallons of fresh manure.

In addition to calcium, magnesium, sulphur, iron, zinc, boron, and copper, manures contain varying amounts of molybdenum, manganese, and numerous other elements which are included in the feed. Futhermore, generous applications of manures in soils over a long period of time supply the soil with considerable amounts of mineral and organic matter which maintain soil fertility and improve soil structure.

When the manure is excreted, it contains billions of bacteria which inhabit the intestinal tract of the animals. These bacteria, whose cell mass amounts to as much as 30% of the total solid portion of the manure, play a very important role. They are responsible for all the changes that occur in the manure. They can act to improve the fertilizer properties of the manure under certain conditions or they can reduce the manure value under unfavorable conditions. They are the agents that liquefy the manure in storage and, thus, make the manure easier to handle and apply. These bacteria along with soil microorganisms are responsible for breaking down the manure into simple nutrients that can easily be utilized by the crops.

Fertilizer value of manure. Until the development of the fertilizer industry, green and animal manures were the main sources of plant nutrients. Today, in light of the plentiful supply of commercial fertilizers, the question has been raised whether it pays to collect and use animal manures as fertilizer. An evaluation of manure and experimental results indicates that the application of manure on soils is well justified. Manure is a source of major and minor plant nutrients. It promotes soil aggregation by supplying food to the soil microorganisms, supports higher crop yields, has long-continued effects, and has commercial and agricultural value.

According to work done at the Michigan Agricultural Experiment Station, at 1961 prices for commercial nitrogen, phosphorus, and potassium, animal manures would pay more than the cost of handling and spreading them on the field. Liquid hog manure used as a soil fertilizer has been estimated by University of Illinois agricultural economists to be worth about $0.80 per market hog after storage and spreading costs are deducted.

You must keep in mind that it costs something to have the manure removed from your building even if you do not spread it. This cost might be equal to the cost of spreading it on your fields.

Dollar value. The dollar values assigned here to manures from different animals represent an estimate of the potential value of the manures at present retail prices for commercial nitrogen, phosphorus, and potassium. The cost of handling and spreading manure varies from farm to farm. It would be very difficult to arrive at a general handling cost because of the great variation in manure-management practices.

Table 6 shows the potential commercial value of the manure on the basis of its fertilizing elements, assuming no losses. The dollar values reported in Table 6 represent the commercial value of the manure provided all the plant nutrients of the manure become available to the crops grown in the soil. In determining the actual value of manure, you must adjust the figures of Table 6 by the value of the amount of nutrients that would be wasted during handling and spreading operations, and by the cost incurred when moving and spreading the manure on the field.

Availability of manure nutrients. The amount and the rate at which plants utilize the fertilizing nutrients of manure depend on the availability of the nutrients and on the plant itself. Corn, wheat, oats, clover, sugar beets,

Table 6. Potential Worth of Animal Manure, Assuming No Losses From the Total Excrement (No Bedding)

Manure	Animal per year	Potential dollar value[1] per: 1,000 lbs., live wt. Day	Year	Ton	1,000 gallons	1,000 cu. ft.
Hen	$ 0.32	$0.2	$71	$7.00	$29.00	$217
Hog	5.50	0.11	42	3.40	14.00	105
Cattle	26.00	0.07	26	2.30	9.40	72

[1] Based on current retail prices of 12¢ per pound of nitrogen, 10¢ per pound of phosphoric acid, and 5¢ per pound of potash.

potatoes, and other vegetables are highly responsive to the manure plant food. However, the nutrients must be in a chemical form which can be utilized easily by the plants.

It has been shown that the nitrogen of the urine is equal in availability to most of the nitrogen of commercial fertilizers. This is one of the reasons why extra care must be taken to preserve the liquid portion of the excrement. The nitrogen of the solid portion of the manure becomes available to the plants slowly and lasts over a period of three to five years.

The availability of the phosphoric acid and the potash of the manures is practically equal to that of commercial fertilizers, with manure phosphorus at times more available than mineral phosphoric acid.

Manure handling and disposal

If you are interested in realizing the maximum value of manure, you must consider carefully the methods to be used in manure management.

Storage. Losses start with the failure to appreciate the value of the liquid portion of the manure. When animals are kept on earth floors, much of the fertilizing content of manure is lost. Many of the manure elements are leached out, much of the nitrogen is lost to the atmosphere, and a considerable portion of the urine is absorbed and wasted in the soil.

Manure left to accumulate in outdoor feedlots with no bedding to absorb and hold the urine could lose over 50% of its value as fertilizer.

Manure keeps best if: (1) it is not moved much from where it was excreted; (2) it is not exposed for long to dry winds, rain, and high temperatures; (3) it is kept moist when in storage; and (4) it is stored in an airtight tank if possible.

Field application. The rate at which manure should be applied on the field depends on the type of manure and soil requirements. The best way to arrive at a manure application rate is to test your soil at an official soil testing laboratory to determine the amounts and type of plant nutrients it needs for maximum production of the plants you will be growing. Once the needs of your soils are established, Tables 7, 8, and 9 can be used to arrive at the amount of manure needed to satisfy the requirements of the soil for nitrogen, phosphorus, and potassium.

Note in Table 7, for example, that if you want 60 pounds of nitrogen, you would need to incorporate into the soil about 600 gallons (2.5 tons) of chicken manure per acre, or 1,300 gallons (5.4

Table 7. Estimated Gallons of Manure per Acre Required to Provide Given Amounts of Nitrogen

Animal manure	Nitrogen requirements, pounds per acre: 60			80			100			120		
	Manure needed	P_2O_5 applied	K_2O applied	Manure needed	P_2O_5 applied	K_2O applied	Manure needed	P_2O_5 applied	K_2O applied	Manure needed	P_2O_5 applied	K_2O applied
	Gal./A	*Lbs./A*	*Lbs./A*	*Gal./A*	*Lbs./A*	*Lbs./A*	*Gal./A*	*Lbs./A*	*Lbs./A*	*Gal./A*	*Lbs./A*	*Lbs./A*
Hen	600	62	29	800	83	38	1,000	104	48	1,200	125	58
Hog	1,300	47	74	1,800	65	103	2,200	79	125	2,700	95	154
Cattle	1,600	24	64	2,200	33	88	2,700	41	108	3,300	50	132

Table 8. Estimated Gallons of Manure per Acre Required to Provide Given Amounts of Phosphoric Acid

Animal manure	Phosphoric acid (P_2O_5) requirements, pounds per acre: 60			80			100			120		
	Manure needed	N applied	K_2O applied	Manure needed	N applied	K_2O applied	Manure needed	N applied	K_2O applied	Manure needed	N applied	K_2O applied
	Gal./A	*Lbs./A*	*Lbs./A*	*Gal./A*	*Lbs./A*	*Lbs./A*	*Gal./A*	*Lbs./A*	*Lbs./A*	*Gal./A*	*Lbs./A*	*Lbs./A*
Hen	600	60	29	800	80	38	1,000	100	48	1,100	115	57
Hog	1,700	76	97	2,200	99	125	2,800	126	160	3,300	148	188
Cattle	4,000	147	160	5,300	195	212	6,700	246	268	8,000	294	320

Table 9. Estimated Gallons of Manure per Acre Required to Provide Given Amounts of Potash

Animal manure	Potash (K_2O) requirements, pounds per acre: 60			80			100			120		
	Manure needed	N applied	P_2O_5 applied	Manure needed	N applied	P_2O_5 applied	Manure needed	N applied	P_2O_5 applied	Manure needed	N applied	P_2O_5 applied
	Gal./A	*Lbs./A*	*Lbs./A*	*Gal./A*	*Lbs./A*	*Lbs./A*	*Gal./A*	*Lbs./A*	*Lbs./A*	*Gal./A*	*Lbs./A*	*Lbs./A*
Hen	1,300	131	135	1,700	172	176	2,100	212	218	2,500	256	260
Hog	1,000	45	36	1,400	63	50	1,800	81	65	2,100	95	76
Cattle	1,500	55	225	2,000	73	30	2,500	92	38	3,000	110	45

tons) of hog manure, or 1,600 gallons (6.7 tons) of cow manure.

Of course, by applying manure to fulfill the requirements of one of the elements, you will provide the soil with certain quantities of the other nutrients present in the manure. For example, note in Table 8 that to get 100 pounds of phosphoric acid in your soil, you will apply 2,800 gallons (11 tons) of hog manure, but at the same time, the soils will receive 148 pounds of nitrogen and 188 pounds of potash.

Assume that the recommended fertilizer application for your soil is 100 pounds of nitrogen, 200 pounds of phosphoric acid, and 100 pounds of potash per acre and that you raise cattle. Table 7 reveals that if you apply 2,700 gallons of cattle manure, you will satisfy the nitrogen and potash requirements, but you will be short of phosphoric acid by 160 pounds. You can provide the additional phosphorus required by using commercial phosphates. Commercial phosphates can be applied mixed with the manure or at other times in the rotation. In rotations including both corn and wheat, it is better to apply the manure to the corn and the phosphate to the wheat because wheat has higher phosphorus requirements than corn.

Reinforcing manure with phosphate or other minerals has been found very profitable in general cropping.

It was mentioned before that the fertilizing nutrients of animal manures are released to plants over a period of time. Therefore, portions of manure nutrients applied this year will be available to plants next year. Table 10 gives an estimate of the amounts of the nutrients that will carry over and become available a year later.

Table 10. Estimated Average Carry-Over Credit for the Plant Nutrients of Animal Manures

Manure nitrogen		Manure phosphoric acid		Manure potash		
Applied last year	Carryover for this year	Applied last year	Carryover for this year	Applied last year	Carryover: Only grain removed	Carryover: Whole plant removed
Lbs./A	*Lbs./A*	*Lbs./A*	*Lbs./A*	*Lbs./A*	*Lbs./A*	*Lbs./A*
40	4	40	16	40	16	0
60	10	60	30	60	28	4
80	20	80	48	80	42	12
100	33	100	66	100	59	24
120	47	120	85	120	76	38

Table 10 should be used with Tables 7, 8, and 9 and the results of your soil tests. For example, if the soil tests indicate that you need to apply 100 pounds of nitrogen per acre and last year you applied 2,700 gallons of hog manure (see Table 7), then you need to apply only 60 pounds of nitrogen this year because, according to Table 10, you will have 47 pounds of nitrogen available from last year's manure application.

It has been shown that, in general, light rates of manure application over large areas result in greater returns than heavy application rates over small areas.

For best results, incorporate manure into the soil as soon as possible after it has been spread. Spreading manure just ahead of tillage operations, which will incorporate it in the soil, is preferred.

Manure is more effective if it is spread and plowed under just before the crop is planted than it is at earlier times.

Grasslands benefit from manure applications. Furthermore, they make a convenient place to spread manure at times when manure cannot be applied to plowed land. However, to reduce losses, try spreading the manure during a cool, damp day or immediately before a moderate rain.

Apply manure to pastures as thinly as possible. Thin spreading will control fly breeding and odors. Animals find manure odors objectionable.

To save in the cost of manure application, spread it as close as possible to where the manure is stored.

Avoid spreading the manure during hot, dry days.

Remember that poor soils benefit more from manure applications than good soils. Hence, most of the manure produced on your farm should be applied to fields with poor soil characteristics.

Urban sprawl

Since World War II, there has been a steady expansion of cities into rural areas. Furthermore, the miraculous achievements of American agriculture in providing us with surplus foods and eliminating the concern for famine have helped create a sharp awareness among the people of the need for a healthy and aesthetically pleasant environment. The increasing encroachment of urban developments into agricultural areas plus increased public awareness of the need for pollution control spotlights the need for more careful handling and disposal of animal wastes. The concentration of animals within buildings or on small land areas intensifies the importance of manure disposal systems. For example, concrete lots minimize space requirements, simplify cleaning, and improve sanitation within the lot. However, manure from these lots then may be flushed into drainageways rather than being absorbed by the soil, adding to the possibility of pollution of public waterways.

Even though an area might be zoned for animal production, this could not completely protect the swine producer from the wrath of irate neighbors who sniff the odors that the wind picks up at the pig unit and carries to them. The swine producer does have a right to produce pigs on his land provided that he does not create a nuisance; and pig smells are a nuisance to one who is not intimately associated with swine production.

You, as swine producers, can no longer be concerned only with the easiest way of getting rid of manure. Our society, your neighbors, and even your wife (particularly when the price of hogs is high) cannot and should not tolerate sloppy methods of manure management which result in public nuisance and pollution of our soil, water, and air.

Current Research in Swine Waste Management

E. Paul Taiganides

When agricultural engineers, swine nutritionists and husbandrymen, veterinarians, and other specialists were hard at work in the early 1950's developing the knowledge that resulted in today's pork production centers where thousands of pigs are raised in an area several times smaller than the space required ten years ago, they did not realize that they were really creating a modern monster. Buildings were designed in which feed and water were automatically piped directly into the mouth of this monster, he was vaccinated to protect him from disease and was given nutritious food to make him content, but these specialists had not figured on this monster having another opening at the other end. So the manure started piling up and soon reached the fan. This was about five or six years ago.

Research in the area of farm waste management began about seven years ago. Although all the answers are not in yet, monitoring recent progress has convinced me that the research that is now under way, plus the research that is being initiated as a result of the funds made available by various agencies to researchers, and the recognition of the magnitude of the problem, will certainly provide you, the animal producer, with more acceptable alternatives than are presently available. However, it will be up to the animal producer to adopt and adapt the new technology to his unique situation. In this report some of the systems that are being researched for the management of hog wastes will be highlighted, and sources of more detailed information will be indicated.

The most recent and up-to-date publication on current research in this field is *Management of Farm Animal Wastes* by The American Society of Agricultural Engineers, St. Joseph, Michigan. It contains the *Proceedings of the National Symposium on Animal Waste Management* held in May of 1966 at East Lansing, Michigan.

Field spreading

Field spreading is still a satisfactory method of manure disposal if land is available and care is taken not to contaminate nearby streams or create an odor nuisance. Research is under way to determine what and how much of the plant nutrients of the manure may be available to the crops, and how and when field spreading should be done to be most effective.

After a slow and reluctant start, several major equipment manufacturers are investing in the development of new equipment to make it possible for the farmer to mechanize the collection and distribution of animal manures. The trend toward liquid manure systems opens up more possibilities for the automation of the field-spreading operation for animal manures. In Europe, where I visited several swine farms in 1964 and 1966, some of the progressive or well-subsidized farmers have invested considerable amounts of money on the manure-handling aspects of their operations. Liquid manure is collected in storage tanks, and with the push of a button it is automatically pumped through pipe installed underground or laid on the surface, and then the manure is spread by sprinkler nozzles.

A new idea that is being investigated is the plow-furrow cover method, whereby liquid manure is dropped into a furrow and covered with soil. Professor Charles Reed of the Department of Agricultural Engineering at Rutgers University reported that he applied as much as 200 tons of poultry manure on an acre of land. At Ohio State University we have begun a research program to determine the maximum and optimum qualities of organic wastes, animal and household refuse, that can be utilized by agricultural soil.

Anaerobic digestion

The anaerobic digestion process involves the production of methane gas and renders the manure inoffensive and enhances its fertilizer value. At present it can be justified economically only in very large animal-production centers.

In Europe, because of the lack of fuel sources after World War II and the availability of subsidy funds from the Marshall Plan, several manure digestors were built to produce methane gas which was used for cooking gas and even for farm tractors. Almost all of these installations are no longer operational, not only because they were never really economical but also because of many maintenance problems. Much simpler digestors are now being used in India, where the federal government is subsidizing their adoption by small farmers. Mr. John Fry, of Santa Barbara, California, and I both published several articles on this subject in the *National Hog Farmer* in 1962.

Anaerobic lagoons

Anaerobic lagoons as they are designed at present are not satisfactory. However, there is reason to believe that anaerobic lagoons will prove to be one of the most effective methods of swine and poultry waste disposal when research develops the design criteria and means of controlling the odors and potential ground-water pollution hazards associated with lagoons. Even then, lagoons will be limited in their application because of their space requirements.

Several people have experimented with the use of lagoons during the past several years. Lagoons have been used throughout the country for all types of animal wastes. Success with these lagoons has varied from poor to good, depending upon geographic location and engineering know-how. The most important point to consider seems to be the proper selection of a lagoon site as to soil type, water table, distance from urban areas, and prevailing winds.

An adaption of the lagoon system is its use as a storage area during inclement weather and hauling from such a lagoon at a later date.

The stabilization of manure slurries in lagoons may be affected by copper or antibiotics. These, of course, are being fed in swine rations and often pass through into the manure in quite large concentrations, enough to disturb microbial action.

Oxidation ditch

Oxidation ditches for the treatment of sewage from small cities in Holland have been very effective. Their use for the treatment of swine wastes is now at an experimental stage both here and in Holland. Dr. Don Day of the Agricultural Engineering Department of the University of Illinois has been experimenting with the use of an oxidation ditch under the slotted floors of swine buildings. This involves the placement of a rotor with brushes immersed a few inches into highly diluted manure. It has been found fairly effective in controlling odors inside the building, but excessive foaming and inadequate treatment of the solids in the liquid manure are problems that are still to be resolved.

A combination of an anaerobic lagoon with an oxidation ditch would have potential because of the complementary roles that each can play; the anaerobic lagoon is not effective in reducing odors but can remove most of the organic pollutants of the wastes, while oxidation ditches are effective in rendering a polishing type of treatment to the wastes and do control odors. Such a system is being researched by Dr. Thamon Hazen of the Agricultural Engineering Department at Iowa State University.

Recommendations

Plan ahead

- Consider the waste-management system at the time you consider the plans for buildings.
- Integrate your system in the design for your buildings.
- Think in terms of a total system.
- When visiting farms with automated feeding systems, take time to visit farms with good waste-management systems.
- Evaluate the waste-management systems as to their suitability in total or in part for your particular conditions.
- Integrate the other farm wastes into one overall system.

Consider the total system

- Keep in mind the nature of the material; i.e., its pollution potential, odor, and so forth—not just the quantity you have to handle.
- Decide on handling procedures. Different equipment is needed if you go into a liquid system rather than dry collection and transport. However, if

you are going to invest in a liquid system, look seriously into hydraulic transport and complete mechanization of your system.

- Before deciding on a method of treatment, be sure to consider the final disposal of the wastes and the nearness of your neighbors. There are laws which regulate the quality of effluent you may discharge into a public waterway or into our air environment.

- Remember that the only real disposal medium for highly organic wastes, such as swine manures, is soil. However, soil pollution once established cannot be easily corrected.

Evaluate your system

- The system should be the safest one possible from the standpoint of your health and that of your family, your farm laborers, and the total public, and, of course, the health and sanitation of your animals.

- The economics of the system should be favorable, but do not expect to make money on any system.

- The aesthetic aspects of your system should be considered seriously. A clean, pleasant, and sanitary operation can go a long way toward convincing a would-be irate neighbor that you cannot eliminate all odors but that you are doing your best.

In the meantime, those of us who are working in research hope to provide you soon with the technical know-how with which to wage the battle at "the other end."

Swine Nutrition: Some Recent Experimental Approaches

J. E. Oldfield and D. C. England

Swine occupy an important place among the domestic animals that contribute to mankind's food supply, for a number of reasons. They are prolific (producing more young per mating than any other large animal species), they are fast-growing, and they have the ability to convert efficiently a wide range of feed materials into meat. Research has been helpful in identifying ways to enhance the pig's efficiency of feed conversion. Among the many research contributions, two avenues of approach have been particularly fruitful. First, experiments have been conducted at Oregon State and many other agricultural experiment stations to identify more accurately the nutritional requirements of the pig for the various productive functions. Second, the tremendous advances in the electronic processing of data have aided greatly in the application of experimental results to swine ration formulation. This report includes some examples of work along each of these lines.

Energy requirements and dietary fats

The largest part of the feed given pigs, or any other domestic animals, is used for the production of energy; to some extent, all the other uses of feed are related to the energy function. This means that the supply of dietary energy to the pig is of utmost importance in determining its overall extent and efficiency of production.

As a source of energy, fat has an advantage over other feed nutrients, such as carbohydrates and proteins. Carbohydrates are commonly supplied in the form of grains and proteins in the form of various meat or oilseed meals. At an earlier meeting in the series (*1*)*, it was pointed out that fats such as lard or tallow supply $2\frac{1}{4}$ times as much energy per unit of weight as is supplied by other nutrients. This makes fat supplementation a convenient means of manipulating the "energy concentration" of swine ration formulas, with the cost of the energy supplied as an important consideration. One can, for example, produce a "high energy" ration by the simple expedient of replacing grains or other high-carbohydrate ingredients with fat.

Because the consumer of pork products has indicated a preference for lean meat over fat and because producers are aware of this preference and seek to cater to it, there has been some reluctance to feed fats to pigs. This is based on the assumption that pigs will provide themselves with more energy from high-fat diets than from low-fat ones, and hence will produce fatter carcasses. This is not necessarily valid, as indicated by the data in Table 1.

Although the addition of fat to these rations caused increased rates of gain among the pigs, the daily intake in terms of pounds of feed decreased. This fact is emphasized by the greater efficiencies of feed conversion which

J. E. Oldfield is professor of Animal Science and D. C. England is associate professor of Animal Science, Oregon State University.

* Italic numbers in parentheses refer to references cited on page 26.

Table 1. Swine Performance at Various Levels of Dietary Fat (*2*)

Ration type	Low fat	Medium fat	High fat
Avg. daily gain, lbs.	1.71	1.76	1.89
Avg. daily feed,* lbs.	5.05	4.31	3.91
Avg. feed[1]/lb. gain, lbs.	2.95	2.45	2.07
Avg. backfat thickness, in.	1.51	1.49	1.58
Avg. loin-eye area, sq. in.	4.04	4.19	3.89

[1] Data refer to the dry matter content of the feed.

accompany the increasing levels of dietary fat (Table 1). Although the pigs gained faster as the level of diet fat was increased from about 2% to 17% and to 28%, the fatness as measured by backfat thickness did not increase significantly and the area of the loin-eye muscle did not diminish. It can be concluded that fat supplementation of swine rations need not result in lowered carcass quality; however, it is important that the calorie: protein ratios in these diets were narrow (i.e., there was a high level of protein fed : 20, 25, and 28, respectively).

Other reasons for hesitancy in feeding fats include the possibility of creating a soft carcass fat by this means and the fear of some sort of toxic reaction from fat which has become oxidized in storage. Both of these problems can be readily prevented. Choice of a hard type of feeding fat, such as lard or tallow, means that the resulting carcass fat will be similarly hard, while addition of a suitable antioxidant, like vitamin E, will prevent oxidized-fat toxicity (*3*). A practical consideration, certainly, is that fats are somewhat difficult to mix with other feed ingredients and that they tend to reduce the firmness of pelleted diets. There is reason to believe that these objections can be eliminated by application of modern mill technology (*4*).

On the positive side, fats offer a concentrated energy source for swine rations. If they are properly used and adequately supplemented with other dietary essentials, they will allow more rapid rates of gain on considerably reduced feed intakes.

Linear programming

Once the possibilities of improving performance by manipulating swine ration ingredients are identified by feeding experiments such as those described, the producer is faced with the problem of applying the results in a least-cost ration formula. Such application used to be a very formidable task and consequently was imperfectly achieved, but it may now be carried out quickly and accurately by the electronic computer via a process termed linear programming.

Linear programming consists of presenting the computer with two sets of facts: (1) the specifications desired in the finished ration; and (2) the characteristics, including both nutritional and cost factors, for the various possible feed ingredients. Given this information, the computer is able to calculate a solution which appears as a balanced, "least-cost" ration. Experience at this Station has shown the value of this technique in formulating rations for poultry, (*5*), mink (*6*), and sheep (*7*); a similar application seems probable with swine.

Initially, it seemed desirable to explore the general possibilities of cost reduction in swine rations, and preliminary experiments in this direction have been conducted at the Umatilla Experiment Station at Hermiston. These experiments compared performances of pigs on rations that were programmed according to various specifications with performances of pigs on a conventional ration that had previously been fed.

The data provided for the computer on ration specifications took the following form:

Ration weight figured	99 lbs.
Grain component (type specified)	74 lbs.
Protein level, crude	14%
Calcium	0.6%
Phosphorus	0.4%
Vitamin-trace mineral supplement	1.0%

These specifications, which are admittedly oversimplified, give the formulation of a ration that meets National Research Council recommendations for protein, calcium, phosphorus, vitamins, and trace minerals (the last two are supplied in a pre-mixed supplement).

As a basis from which to choose ingredients, the computer also was given access to data on the crude protein, calcium, and phosphorus contents and the prices of a number of locally available feedstuffs. An abbreviated summary of the results is listed in Table 2.

Several points are obvious from this work. The possibility of reduction in ration cost increases with the freedom of choice allowed the computer. For example, neither rations 1 or 2, where the grain component was specified, achieved the economy of ration 3, where no restriction on type of grain was applied. The animals grew faster on the programmed wheat ration than they did on any of the others, including the one where no grain source was specified. This indicates a need for a more accurate description of ration specifications, so that the computer may formulate a ration which is nutritionally adequate for rapid growth at least cost. Reference to the data presented on fat supplementation suggests that specification of a higher energy level would have permitted the inclusion of fat, and this would have resulted in both more rapid gains and more efficient feed : meat conversion. Further trials are planned to investigate this point, and it is hoped that they will lead to refined techniques for determining specific nutrient components of swine rations (i.e., opti-

Table 2. Performance Factors on Programmed and Conventional Rations

	Lot no.			
	1	2	3	4
Ration type[1]	Computed: Barley	Computed: Wheat	Computed: Free	Conventional
Avg. daily gain, lbs.	1.37	1.50	1.36	1.44
Feed/lb. gain, lbs.	3.93	3.72	4.32	3.72
Ration cost/ton, $	68.71	67.76	58.28	67.96

[1] The computed rations specified barley as the grain component, wheat as the grain component, and free choice among grain components, respectively.

mum amount and source of energy, optimum amount and source of protein, and so forth).

Summary

Experimental evidence has shown that the growth of pigs can be increased by increasing the energy content of their ration, and this may be conveniently accomplished by supplementing with fat. A hard fat, such as lard or tallow, should be used to prevent softening of the carcass fat of the animals. It is important that adequate protein be supplied along with the fat so that carcass quality can be maintained.

Preliminary experiments with computer formulation show that ration costs can be reduced substantially by this technique. Further work involving linear programming to more exact specifications is anticipated.

References cited

1. Oldfield, J. E. Some factors affecting efficiency of barley as a swine feed. Ore. Agric. Expt. Sta. Special Rept. 179, pp. 12-16. 1964.
2. Pate, F. M. Energy-protein relationships in high-fat rations for growing-finishing swine. Ore. State Univ. M.S. thesis, 1967.
3. Oldfield, J. E., R. O. Sinnhuber, and A. A. Rasheed. Nutritive value of marine oils. II. Effects of *in vivo* antioxidants in feeding menhaden oil to swine. Jour Am. Oil Chem. Soc., *40*:357. 1963.
4. Chapin, R. E. Effects of pelleting and of supplementation of barley rations for swine with tallow, enzymes and zinc. Ore. State Univ. M.S. thesis, 1961.
5. Brown, W. G., and G. H. Arscott. Substitution value of barley and fat for corn in broiler rations. Ore. Agric. Expt. Sta. Circ. of Information 585, 1957.
6. Stout, F. M., J. E. Oldfield, and J. Adair. Increasing productive efficiency—New concepts in dry rations. National Fur News, *34*:8. 1962.
7. Church, D. C., C. W. Fox, T. P. Davidson, W. G. Brown, and J. A. B. McArthur. Lamb-feeding practices. Ore. Agric. Expt. Sta. Special Rept. 241, 1967.