1979

EC79-219 1979 Nebraska Swine Report

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E. C. 79-219

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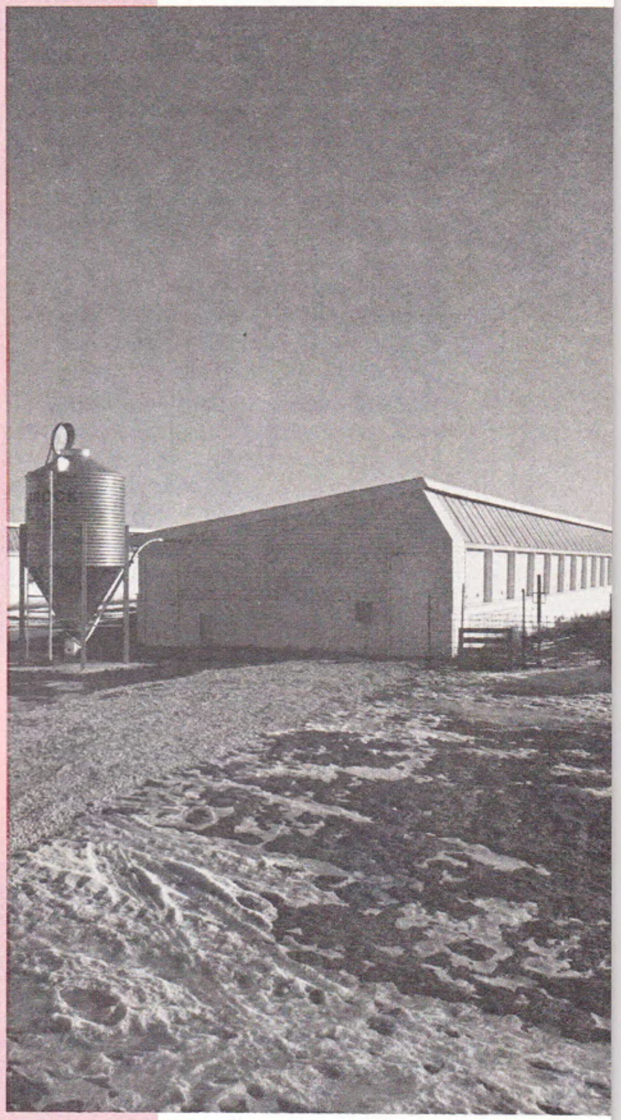
NEBRASKA SWINE REPORT



- Breeding
- Disease Control
- Nutrition
- Economics
- Housing

Prepared by the staff in Animal Science and cooperating Departments
For use in Extension, Teaching, and Research programs

Extension work in "Agriculture, Home Economics and subjects relating thereto," The Cooperative Extension Service, Institute of Agriculture and Natural Resources, University of Nebraska-Lincoln, Cooperating with the Counties and the U.S. Department of Agriculture
Leo E. Lucas, Director

The Agricultural Experiment Station
Institute of Agriculture and Natural Resources
University of Nebraska—Lincoln
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TEACHING RESEARCH EXTENSION

Institute of Agriculture and Natural Resources

Acknowledgments

The authors wish to express their appreciation to the following for grant or product support of Nebraska Research and Extension programs. The dedicated effort of the support personnel in the laboratories and research units is acknowledged and appreciated.

A. L. Laboratories
Englewood Cliffs, New Jersey
American Cyanamid Company, Princeton, New Jersey
American Hoechst Corporation, Somerville, New Jersey
American Stores Packing Company, Lincoln, Nebraska
Bayvet Disivion, Cutter Laboratories, Inc.
Shawnee, Kansas
Bettcher Industries, Inc., Vermillion, Ohio
BZD Livestock Products, Inc., Lincoln, Nebraska
Calcium Carbonate Company Quincy, Illinois
Commercial Solvents Corporation, Terre Haute, Indiana
Dawes Laboratories, Inc., Chicago, Illinois
Diamond Shamrock Chemical Co., Newark, New Jersey
Eli Lilly and Company, Indianapolis, Indiana
Farmland Industries
Kansas City, Missouri
Fats and Protein Research Foundation, Inc., Desplaines, Illinois
George A. Hormel Packing Company, Fremont, Nebraska
Hoffman-LaRoche, Inc.
Nutley, New Jersey
Merck and Company
Rahway, New Jersey
Merrick Foods, Union Center, Wisconsin
National Pork Producers Council, Des Moines, Iowa
National ByProducts, Omaha, Nebraska
National Renderers, Bellevue, Nebraska
Nebraska Farmer, Lincoln, Nebraska
Nebraska Pork Producers Association
Nebraska SPF Accrediting Agency
Lincoln, Nebraska
Pfizer, Inc.,
Terre Haute, Indiana
Rhodia, Inc. (Hess and Clark Div.), Ashland, Ohio
Shell Chemical Company Agricultural Division, San Ramon, California
Urschel Laboratories, Inc., Valparaiso, Indiana
U.S.D.A., ARS, WRRL, Berkeley, California
Waldo Farms,
DeWitt, Nebraska

Contents

Issued January 1979, 10,000

Stress Factors Kill Feeder Pigs

Nutrition, Management Important

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Many pigs in Nebraska and the Midwest are finished on farms other than those they were farrowed on. These pigs are generally called feeder pigs. Estimates indicate that as many as one-third of pigs marketed are started as feeder pigs.

Feeder pigs are purchased and managed under a wide variety of situations. Common to all feeder pigs, however, are stress factors including handling, movement, temperature fluctuations, and changes in housing, nutrition, and disease exposure. The additive effect of these stresses nearly always results in disease, death or both.

A common problem among newly arrived feeder pigs is diarrhea. Diarrhea may be caused by bacteria or virus infections or by non-disease factors such as nutrition or temperature stress. While one cause may be independent of the other, in many instances one often leads to the other.

The Experiment

This study measured the effect 0, 25 or 50 percent oats and method of feeding (limit fed on the floor versus ad lib from self-feeder) on newly arrived feeder pigs. Response criteria measured were gain, feed:gain, diarrhea score, and death loss. This phase of the study lasted 14 days. After 14 days all pigs were placed on a self-feeder and fed ad libitum.

Pigs came from a feeder pig complex and were delivered to the Northeast Station on December 28 after a two hour haul. Purchase weight was about 27 pounds (12.3 kg). Pigs were placed on test within 12 hours based upon weight and sex, 20 per pen. They were housed in an environmentally regulated building with 12 pens—six on each side of a central alley. All pens were half slotted with 8 inch (20.3 cm) wide slats with a 1 inch (2.5 cm) slot. There were four pens on each of the three oat treatments and six pens on each of the feed management treatments.

The floor fed pigs were fed 2 pounds (.91 kg) each on day one, with feed placed on the floor in the sleeping area. Thereafter, the amount fed on the floor was based upon the consumption of those on the self-feeders, as well as the behavior of the pigs. The objective was to limit the intake of the floor fed pigs to about 90 percent of full feed to determine if this affected diarrhea incidence or performance. The floor fed pigs were fed three times daily. The three oat diets are shown in Table 1.

Results

Since these pigs originated from a farrowing complex it can be assumed that they spent at least three weeks in a post-weaning nursery. Therefore we anticipated a lesser response to nutrition and management treatments than the smaller and younger pigs we were accustomed to receiving. Difference in gain and feed:gain during the critical initial two week period was not great (Table 2). Pigs on 25 percent oats gained more rapidly than the control or 50 percent oat treatments. There was no difference in gain between the controls (no oats) and those on the 50 percent level. This comparison is especially interesting in view of the relatively light weight of the pigs and assumed young age.

The floor fed pigs gained one-tenth pound per day slower than those fed al libitum from a self-feeder. This was expected and desired. Since the amount of feed fed on the floor was based on feed consumption of pigs on the self-feeder this would account for most of the difference in gain. Add to this the feed lost due to wastage from walking and other pig activity and all of the difference in gain becomes logical.

Feed:gain for the first 14 day period follows much the same pattern. Pigs on the 25 percent oat diet required 6.7 percent less feed per unit gain than the controls and 5.8 percent less feed than those on the 50 percent oat diet. Again, the 50 percent oat diet was about equal to the corn-soybean diet (controls) for feed:gain. Apparently the reduced energy and increased fiber in the 25 and 50 percent oat diet had a beneficial stress buffering effect. The effect of oat level in the diet on diarrhea score—discussed later—may have a cause-effect relationship.

The feed:gain favored those self-fed over those limit-fed on the floor by 6.6 percent. It is assumed that most of this difference was due to wastage. In the past, on less well started feeder pigs, we've found that limit feeding on the floor helped us judge the actions of the pigs and notice and treat sick pigs sooner and reduced our immediate post-arrival death loss. Death loss on all treatments for this study was zero.

To determine diarrhea score two or three people would go

(continued on next page)

Table 1. Levels of oats for growing pigs.

Ingredient	Oat level, %		
	0	25	50
Corn (9%)	1662.4	1166.0	710.6
Soybean meal (44%)	304.0	261.6	218.2
Ground oats	—	500.0	1000.0
Dicalcium phosphate	30.4	29.2	28.2
Limestone	12.2	12.2	12.0
Trace mineral mix	1.0	1.0	1.0
Salt (iodized)	10.0	10.0	10.0
Vitamin premix + ASP-250[a]	20.0	20.0	20.0
	2000.0	2000.0	2000.0

[a]American Cyanamid; 100 gm aureomycin, 100 gm sulfamethazine and 50 gm penicillin per ton (.91 m ton).

Stress Factors

(Continued from page 3)

through each pen, morning and evening, immediately after feeding and collectively agree on a score of from 1 to 5. A score of 1 would be normal stools with no diarrhea and a score of 5 would be severe diarrhea. Results are shown in Figure 1.

Diarrhea was a threat in only one pen of self-fed pigs and these were on the corn-soybean diet. They received a score of 4 on three successive readings. As indicated in Figure 1, there was a trend toward reduced diarrhea as oat levels increased. Apparently increased fiber levels were partially responsible for this. Others have reported on the ability of the higher fiber diet to absorb fluid in the gastrointestinal tract and the possibility that high fiber diets slow down the rate of food movement through the tract. Those fed ad libitum from a self-feeder had a higher diarrhea score (1.5 versus 1.3) than those limit-fed on the floor. This may be an expression of non-disease diarrhea where those full-fed simply over-ate, resulting in scours.

The result of the diarrhea aspect of the study revealed that as fiber level increased in the feeder pigs' diet, diarrhea started later and was less severe. This is an advantage since delays in the onset of diarrhea generally result in less severe diarrhea.

The Growing Phase

Following the 14-day initial period pigs that had been limit-fed on the floor were placed on a self-feeder. All treatments were managed alike. The 50 percent oat diet was bulky enough so that it required more management to keep the feeder working properly. The bio-data and response criteria are shown in Table 3.

Data show no difference in gain or feed:gain between 0 and 25 percent oat diets. There was a slight reduction in gain and increase in feed per unit gain among those on the 50 percent oat ration. This indicates that when substituting oats for corn for growing pigs a level of oats between 25 and 50 percent will support performance equal to a corn-soybean diet. However, it is likely that the desired level of oats lies closer to 25 than to 50 percent of the diet.

Table 2. Effect of oat level on newly arrived feeder pigs first 14 days.

Percent oats	ADG, lb (kg)			F/G (14 days)		
	Limit fed on floor	Ad lib	Avg.	Limit fed on floor	Ad lib	Avg.
0	.83 (.38)	1.00 (.45)	.92 (.42)	2.41	2.13	2.27
25	.98 (.45)	.90 (.41)	.94 (.43)	2.03	2.22	2.12
50	.81 (.37)	1.00 (.45)	.91 (.41)	2.43	2.07	2.25
Avg.	.87 (.40)	.97 (.44)		2.29	2.14	

Table 3. Effect of oat level on feeder pigs during the growing phase.

Percent oats	0	25	50
No. pigs/treatment[a]	80	80	80
Avg. bg. wt., lb (kg)	27.5 (12.5)	27.8 (12.6)	27.2 (12.4)
Avg. final wt., lb (kg)	93.5 (42.5)	95.2 (43.3)	90.9 (41.3)
ADG, lbs (kg)	1.32 (0.6)	1.34 (.61)	1.27 (.58)
F/G	2.52	2.52	2.57

[a]Four pens per treatment

Conclusions

In some areas of Nebraska, especially in the Northeast, oats is a major component of the crop rotation program. While oats at one time was grown partly because of the need for straw, this need has declined somewhat in recent years. Text books at one time referred to oats as an excellent sow feed. Recently, studies show that under many conditions and in the proper amount oats can be economically substituted for corn and can be recommended for its therapeutic-like effect among stressed pigs.

This study suggests that newly arrived feeder pigs had a lower and delayed incidence of diarrhea as fiber content (oat level) of the diet increased. The evidence also suggests that while limit feeding on the floor slightly reduces performance it also reduces the incidence of diarrhea. Limit feeding on the floor also allows the manager to more easily observe the pigs, thereby treating sick individuals sooner and reducing losses. In practice, limit feeding on the floor should be ended after 7 to 10 days. While pigs on the 50 percent oats had slightly poorer performance than the control or 25 percent oat treatments, there may be times when one could economically justify the 50 percent level. For most situations, however, 25 percent oats in the ration should not result in decreased performance.

And, finally, many problems that commonly afflict newly arrived feeder pigs could be prevented if the buyer would *anticipate* as many stress-disease situations as possible. The time lag between recognizing a problem and reacting to it is critical in preventing feeder pig losses.

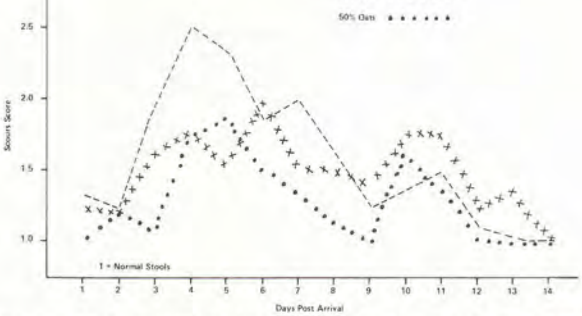

Figure 1. Relationship between oat level, arrival time, and diarrhea score.

Oats for Early-Weaned Pigs

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The swine industry has made great progress in the past few years because of its willingness to change and improve production methods. As costs increase, the pork producer must continue to emphasize production efficiency.

Pig survivability is one area where improvement must be made. If the first two to three days after farrowing is considered the most critical time for pig survival, the first few days after weaning must be a close second. This is especially true since pork producers have been reducing the weaning age of pigs to three-four weeks. The younger the pig is when weaned, the more difficult it is for him to overcome environmental stress which may be detrimental to his health.

The maternal immunity acquired by the newborn pig from the sow's colostrum decreases to a critical level by about three weeks of age. By this time the pig has started to develop his own immunity, but it has not reached a maximum level. This is why pigs weaned at three weeks of age or younger are so susceptible to stress which causes diarrhea and eventually dehydration and death. Of those that survive, many may go through the "post weaning slump." During this time, weight gains are minimal and diarrhea is often present.

Many Adjustments

At weaning, the pig must not only adjust to a new environment, but also to a new diet of dry feed rather than a liquid milk diet. This dietary change could alter the digestive tract's microbial population and favor the increase of certain strains of organisms which could precipitate diarrhea. Thus, adjusting pigs to a new diet is just as critical as adjusting them to a new environment.

Past research at Nebraska has shown that the addition of 20% oats to a weaning diet is beneficial

Table 1. Diet composition (%) — experiment 1.

Ingredient (%)	Control[a] 1	Oats[b] 2-6
Corn (9%)	62.26	44.02
Soybean meal (44%)	23.06	21.34
Oats[a]	——	20.00
Dried whey	5.00	5.00
Dried fish solubles	2.50	2.50
Dried brewer's yeast	1.00	1.00
Lard	2.50	2.50
Dicalcium phosphate	1.40	1.36
Vitamin-trace mineral premix	2.50	2.50

[a]Diet 1 — (0% oats)

[b]Various methods of processing — (20% oats)
2—whole oats, fine ground (⅛"; 18 mm screen)
3—whole oats, coarse ground (⅜"; 9.5 mm screen)
4—whole oats, rolled
5—oat groats, rolled
6—oat groats, ground (⅜"; 9.5 mm screen)

in reducing the incidence of diarrhea and subsequent pig survival after weaning. However, this research generated several questions which should be answered:

1. Why do oats give this kind of response? 2. What level of oats is the proper level? 3. Can I feed whole oats or does it have to be oat groats? 4. If whole oats are used, how fine must they be ground?

Some Answers

Two experiments were designed to answer some of the questions. In the first experiment, 72 crossbred pigs were weaned at two to four weeks of age and assigned to six different treatments. The first was a control diet (0% oats) and then five diets which contained 20% oats with varying methods of processing (Table 1). The oat diets contained either whole oats or oat groats. The whole oats were either rolled through a roller mill or ground through a hammer mill with either a ⅜" (9.53 mm) or ⅛" (3.18 mm) screen.

As in earlier trials, adding 20% oats did not affect daily gain or feed conversion. The average daily gain for the 0% and 20% oat diets were identical while the feed conversion was 1.76 and 1.83 units of feed/unit of gain, respectively. Method of processing had no major effect on pig performance (Table 2). Pigs consuming the diet containing the fine ground whole oats ate less feed and grew slightly slower than pigs on the coarser ground oat diets. The fine ground oat diet may have been a little more dusty, thus causing the pigs to eat slightly less feed. Oat groats, because the hull has been removed, when added to a diet gives a lower crude fiber content than a diet containing the same level of

(continued on next page)

Table 2. Gains and feed conversion of baby pigs fed 20% oats—variation in method of processing, experiment 1.

	Control (0%)	Oats (20%)				
		Whole oats			Oat groats	
		fine[a] ground	coarse[b] ground	rolled	rolled	ground[b]
Item	1	2	3	4	5	6
Initial wt. lb (kg)	11.0 (5.0)	11.3 (5.1)	11.2 (5.1)	11.3 (5.1)	11.4 (5.1)	11.3 (5.1)
Final wt. lb (kg)	33.3 (15.1)	31.2 (14.2)	33.3 (15.1)	34.4 (15.6)	34.0 (15.5)	35.1 (16.0)
ADG lb (kg)	.64 (2.9)	.57 (.26)	.64 (.29)	.66 (.30)	.66 (.30)	.68 (.31)
ADFI lb (kg)	1.12 (.51)	1.0 (.46)	1.17 (.53)	1.30 (.59)	1.17 (.53)	1.25 (.57)
F/G	1.65	1.77	1.83	1.97	1.77	1.84

[a]hammer mill ⅛" (3.18 mm) screen

[b]hammer mill ⅜" (9.53 mm) screen

Oats for Pigs

(continued from page 5)

whole oats. However, there was no difference in pig performance between the diets containing whole oats or oat groats. This would agree with earlier experiments that the young pig can be fed diets with a slightly higher fiber content than a corn-SBM diet without affecting pig performance. It should be noted that all pigs survived the 35 day trial. Some looseness in the feces was observed but scours was not considered a problem.

In the second experiment, 96 pigs weaned at two to four weeks of age were assigned to six diets varying in level of whole oats (0, 10, 20, 30, 40 or 50%). The diets were basic corn-oat-soybean meal diets, balanced to 18% protein. The results of this study (Table 3) show that a few oats are good but a high level of oats may not be so good.

The diet containing the 10% oats produced the fastest gain and the best feed conversion. However, high levels of oats produced slower, less efficient gains. As the level of oats increased above 10%, pig performance decreased. This may be explained by the fact that as the oat level in the diet increases, the energy level of the diet decreases. Thus, pigs fed the high oat diets were unable to consume enough feed to meet their energy requirement for optimal growth and therefore had slower and less efficient gains. Even though scours was not considered a problem, diets containing oats produced firmer feces than the control diet (0%) as indicated by the lower scour scores (Figure 1). The lowest score was observed with 40% oats. Pigs on all treatments showed some looseness by the sixth to seventh day into the trial, suggesting all pigs were somewhat stressed at weaning.

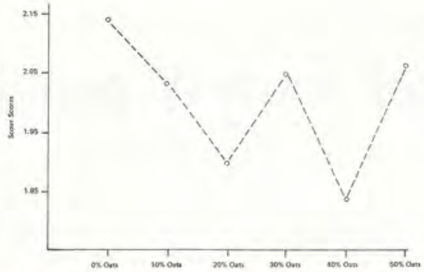

Figure 1. Experiment 2—scour score response to dietary treatment.

Conclusions

From the results of these and earlier trials, it appears that the additions of 10-20% ground oats (medium grind) in the diet will not affect daily gain and feed conversion and may help in reducing the incidence of scours in weaned pigs.

Higher levels (above 20%) may aid in reducing scours but will produce slower and less efficient gains.

The optimum level of oats in the diet appears to be 10% for maximum gain and feed conversion and 20%-40% to minimize the chance for nutritional scours. Thus, the addition of 10%-20% oats processed with a medium grind (⅜"; 9.5 mm) would be recommended in the diet of weaned pigs.

Table 3. Gains and feed conversion of baby pigs fed 0-50% oats, experiment 2.

	Level of oats (%)					
Item	0	10	20	30	40	50
Initial wt. lb (kg)	11.6 (5.3)	11.6 (5.3)	11.6 (5.3)	11.6 (5.3)	11.5 (5.2)	11.6 (5.3)
Final wt. lb (kg)	38.4 (17.5)	39.4 (17.9)	37.4 (17.0)	35.7 (16.2)	34.4 (15.6)	35.0 (15.9)
ADG lb (kg)	.77 (.35)	.79 (.36)	.73 (.33)	.68 (.31)	.66 (.30)	.66 (.30)
ADFI lb (kg)	1.50 (.68)	1.50 (.68)	1.47 (.67)	1.43 (.67)	1.34 (.61)	1.41 (.64)
F/G	1.94	1.89	2.03	2.10	2.03	2.13

For Improved Performance

Selection for Lean Growth

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Profitability of a swine enterprise depends on reproductive efficiency, feed conversion, growth rate, and amount and quality of product produced. Consumer discrimination against fat and low quality meat emphasizes the need to produce low fat products. Improved growth rate reduces nonfeed and maintenance feed costs.

Growth rate and carcass leanness are influenced by genetic and environmental factors to varying degrees. Growth rate has a medium heritability, while carcass leanness has a high heritability. Research indicates that an undesirable genetic relationship exists between the traits. Because of this, selection for rate of lean growth is difficult. However, because of the economic importance, techniques must be developed to genetically improve rate of lean growth.

Protein supplementation is often the most expensive part of swine diets. Pigs performing at an acceptable economic level on diets containing little or no protein supplement would be advantageous. An experiment selecting for lean growth under two nutritional regimes (normal corn-soybean diet, and unsupplemented, opaque-2 corn diet) was started in 1971 to determine the effectiveness of selection for rate of lean growth (based on an index of average daily gain and backfat probe).

Selection Experiment

Average postweaning daily gain

Table 1. Average daily gains for lines and generations, lb/day, (kg/day).

Generation	Select	Control	Lysine
0	1.42 (.64)	1.41 (.64)	1.18 (.54)
1	1.49 (.68)	1.46 (.66)	1.07 (.49)
2	1.56 (.74)	1.49 (.67)	1.18 (.54)
3	1.46 (.66)	1.37 (.62)	1.04 (.47)
4	1.61 (.73)	1.51 (.68)	.84 (.38)
5	1.69 (.76)	1.50 (.68)	.70 (.32)

(ADG) was used to measure growth rate. ADG includes less preweaning environmental effects (amount of milk received, litter size, etc.) and has a higher heritability estimate than other measures of growth. Since average probe backfat (BF) is easily measured on live animals and is a relatively accurate indicator of carcass leanness, it was the second component of lean growth.

Selection for lean growth was practiced for five generations on pigs from the Gene Pool population. From 1958 to 1965 the Gene Pool population was established by the introduction of 13 breeds of swine into a Hampshire female population. After the introduction of the last breed (1965), this 14-breed synthetic population was closed to outside introductions. Selection for lean growth was practiced for five generations beginning in 1971.

Three Lines Assigned

Three lines were designated in the initial generation. In the following generations the Select line was selected on rate of lean growth and fed a 14% protein diet consisting of corn, soybean meal, minerals, and vitamins. This diet was also fed to a randomly selected Control line. Random selection was applied to maintain the same genetic makeup over all generations. Phenotypic changes in the Control line are due mainly to environmental changes. The Control line was used to adjust the Select line for yearly environmental fluctuations. A Lysine line was selected on lean growth and fed a diet consisting of only opaque-2 corn, minerals and vitamins during the growing period.

Research indicates that index selection is the most effective method to improve the overall genetic merit of livestock. Select and Lysine lines were selected on an index involving ADG and BF. I=100 + 130 ADG, lb/day − 100 BF, in. (I=100 + 286.6 ADG, kg/day − 39.4 BF, cm).

Generation means for ADG and BF are given in Tables 1 and 2, respectively. Pigs were weighed at the start of the test (56 days) and weighed off test at about 175 (79.4 kg) pounds. Backfat measurements were taken when pigs were weighed off test and adjusted to 200 (90.7 kg) pounds. Attempts were made to include as many pigs as possible in the data. Pigs not weighing 150 (68 kg) pounds by 250 days of age were excluded.

Fluctuation in daily gain existed between generations in the Control line indicating important environmental influences on growth rate. Generation to generation fluctuation in daily gain also existed in the Select and Lysine lines due to environmental influences and possibly to differential selection pressure applied between generations. In this experiment, pigs were started on test at a constant age. In the Lysine line, pigs which were heavier (due to amount of milk received, litter size, etc.) at the start of test, undoubtedly had some advantage over lighter pigs due to the lower percent protein requirement of heavier pigs. This factor might have caused some of the generation to generation fluctuation in daily gain.

The large drop in daily gain in the Lysine line between generation 3 and 4 (Table 1) was probably the result of a decline from 10.5% to 8.8% crude protein in the opaque-2 corn. In generation 0 the average performance levels for the three lines were 1.42(.641), 1.41(.64) and 1.18(.54) pounds/day (kg/day) for the Select, Control and Lysine lines, respectively. In generation 5 the averages were 1.69(.76), 1.50(.68) and 70(.32) pounds/day (kg/day), respectively.

Less fluctuation existed between generations in backfat (Table 2) compared to daily gain in the three lines. The Lysine line had thicker backfat in the initial generation due to the lower protein level in the diet. Between generations 3 and 4, a reduction in backfat thickness of approximately .20(.50 cm) inches occurred in all three

(continued on next page)

Table 2. Average backfat thickness for lines and generations; inches (cm)

Generation	Select	Control	Lysine
0	1.31 (3.34)	1.31 (3.33)	1.55 (3.93)
1	1.25 (3.19)	1.27 (3.21)	1.44 (3.66)
2	1.24 (3.15)	1.28 (3.24)	1.46 (3.71)
3	1.23 (3.12)	1.28 (3.24)	1.47 (3.73)
4	.96 (2.45)	1.06 (2.69)	1.32 (3.34)
5	.98 (2.48)	1.05 (2.66)	1.20 (3.06)

Table 3. Average index for lines and generations.

Generation	Select	Control	Lysine
0	154	152	100
1	168	162	95
2	178	166	108
3	168	150	88
4	212	190	78
5	222	190	71

Selection for Lean Growth

(continued from page 7)

lines. This reduction can probably be attributed to the change from a leanmeter to an ultrasonic measurement of backfat.

In generation 0 the average backfat thickness was 1.31(3.34), 1.31(3.33) and 1.55(3.93) inches (cm) for the Select, Control and Lysine lines, respectively. In generation 5 the averages were .98(2.48), 1.05(2.66) and 1.20(3.06) inches (cm), respectively.

Lines means for the index fluctuated between generations due to changes in daily gain and backfat (Table 3). In generation 0 the average index was 154, 152 and 100 for the Select, Control and Lysine lines, respectively. In generation 5 the averages were 222, 190 and 71, respectively.

Figures 1-3 graphically demonstrate the differences in performances between the Select and Control lines in the five generations. The line difference indicates the response achieved from selection. Line difference in ADG and BF changed at an inconsistent rate, while the index increased at a constant rate.

The average difference between the Select and Control lines increased .03 lb (0.014 kg) per day in daily gain, decreased by .02 in (.045 cm) of backfat and increased by 5.76 index units per generation.

Line differences between the Lysine and Control lines fluctuated somewhat between generations. In general there was a decline of .11 lb (.05 kg) for daily

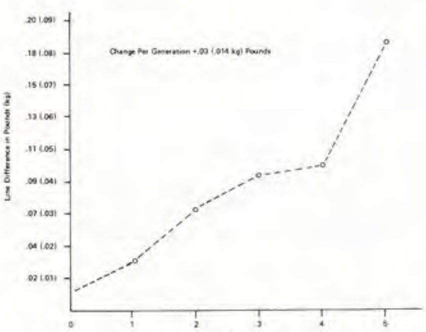

Figure 1. Difference between Select and Control line in average daily gain.

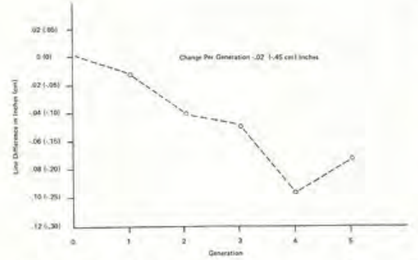

Figure 2. Difference between Select and Control line in backfat.

gain, 13.5 index units and a slight decline of .004 in. (.01 cm) of backfat per generation in the Lysine line.

Summary

Research has indicated that index selection is the most effective method to improve the overall genetic merit of livestock. Index selection was effective in improving lean growth in the Select lines as illustrated by a 12% increase in ADG, 5.4% decrease in BF and a 19% increase in the index compared to the Controls. Selection based on the index will tend to result in less change in each component trait compared to single trait selection. This is due to the fact that less selection pressure can be applied to any one trait when selection is applied to several traits as in an index. Single trait selection, however, often results in undesirable changes in unselected traits due to undesirable genetic correlations.

Selection for lean growth when pigs were fed an unsupplemented opaque-2 corn diet was not effective in improving performance on that diet. The cumulative effects of the low protein diet apparently had a larger effect on the Lysine line than selection for lean growth.

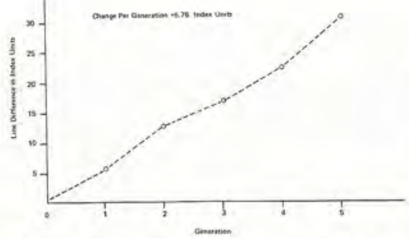

Figure 3. Difference between Select and Control line in index.

Amino Acids

Austin J. Lewis
Assistant Professor
Swine Nutrition

The relative cost of adding supplemental protein to swine diets varies a great deal, depending largely on market prices of corn and soybeans. In most situations protein is an expensive component of the diet. If the protein content is reduced below recommended levels, pig growth rates will be reduced unless the individual amino acids levels are maintained by adding synthetic amino acids. Research has shown that if synthetic Lysine is added to corn-soybean meal diets the protein level can be reduced two percentage points below recommended levels. This can save money when prices of soybean meal and other protein supplements are high.

It is not yet commercially feasible to eliminate all supplemental protein sources and to meet the amino acid needs of swine entirely from corn protein and synthetic amino acids. Reasons: first, some of the synthetic amino acids are very expensive. Second, the lack of information about which amino acids should be added and in what amounts.

Amino Acid Study

Crossbred pigs weighing 125 lb (57 kg) initially were used to determine the sequence of limiting amino acids in corn for finishing swine. Additions of lysine, tryptophan, methionine, and isoleucine in various combinations were made to a basal diet consisting of ground corn with supplemental minerals and vitamins. A standard 14% protein corn-soybean meal diet served for comparison. Pigs remained on the experimental diets until they weighed approximately 210 lbs (95 kg). Their backfat thickness was then measured ultrasonically. The average daily weight gains of pigs fed the different treatments are shown in Figure 1.

Pigs fed diets that contained soybean meal gained weight faster

in Corn Diets

than those fed any of the corn plus amino acid diets, although the differences were small for some treatments. The lowest weight gains (1.17 lb/day (0.53 kg/day)) were made by pigs fed corn alone. The addition of either lysine or tryptophan alone improved weight gain very little, but there was a large improvement when these two amino acids were added together. There was no further improvement when methionine and isoleucine were also added. A similar type of pattern was exhibited by the feed efficiency and backfat data.

Conclusions

The results observed with all-corn diets show clearly that, in contrast to the situation with low

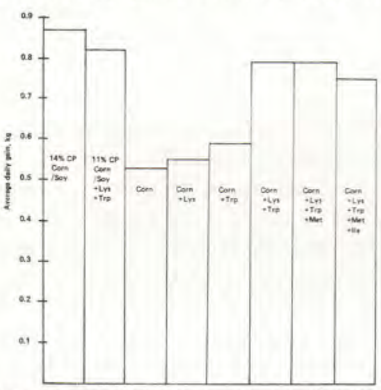

Figure 1. Weight gains of pigs fed diets with various amino acid additions.

protein corn-soybean meal diets which are improved by the addition of lysine alone, lysine and tryptophan must be added together to improve simple corn diets. The small response to lysine or tryptophan alone and the large response to the combination of the two amino acids demonstrates that lysine and tryptophan are co-limiting in corn protein for finishing pigs. At present, tryptophan is too expensive to include in practical rations, but several commercial companies are working to reduce its cost.

The third limiting amino acid was not identified in this experiment, but it does not appear to be either methionine or isoleucine alone or in combination.

One way to pick 'em.

Sow Productivity

Rodger K. Johnson
Associate Professor

Crossbreeding is standard practice in commercial swine production. Producers can readily see that the hybrid vigor expressed by crossbreds results in greater profits than commercial production with purebred pigs.

Several breeds can be used in a crossbreeding system. However, the best breed combinations for production efficiency are not as clear as the overall average advantages of crossbreeding.

In the past 10 years, several experiment stations in the U.S. and Canada have evaluated breeds in various crossbreeding systems. Projects were not exact replicates, but sufficient overlap allowed combining the information to yield more precise estimates of breed differences than was possible from results of any single experiment.

Traits evaluated included reproduction, rate and efficiency of growth, and carcass traits—all important to overall performance. Reproduction traits are perhaps the most important when considering the economic success of an operation. This report summarizes the evaluation of breeds for reproductive performance. Results will be useful to producers when considering breed choices for their specific crossing program.

Table 1 illustrates the average increase in reproductive performance when purebred sows are mated to produce crossbred pigs and when crossbred sows are mated to produce three-breed cross pigs. Little advantage for crossbreds was found for number of pigs per litter at birth. By 42 days, however, crossbred litters were .7 pigs larger than purebred litters. Crossbred pigs had a higher survival rate than purebreds and were heavier at birth, 21 days and at weaning (42 or 56 days).

Farrowing

For some time it was thought that crossbred sows farrowed more pigs than purebreds because they had higher ovulation rates. This does not appear to be the case as there was essentially no difference between them. Crossbred sows, however, had an advantage over purebred sows for every other trait

(continued on next page)

Table 1. Average observed differences among purebred, two-breed cross and three-breed cross litters for reproductive traits.[a]

	Comparison of:			
	2-breed crosses and purebreds[b]		3-breed and 2-breed crosses[c]	
Trait	Observed difference	Percent increase	Observed difference	Percent increase
1. No. eggs ovulated			.04	0.3
2. Conception rate, %			3.00	3.8
3. No. born/litter	.10	1.0	.46	4.7
4. No./litter at 21 days	.56	8.0	.64	8.7
5. No. weaned/litter	.70	10.1	.58	7.7
6. Birth weight, lb (gm)	.09 (41)	3.1	.04 (18)	1.5
7. 21-day weight, lb (gm)	.35 (159)	3.1	.44 (200)	3.7
8. Weaning weight, lb (gm)	1.40 (635)	4.8	2.64 (1197)	8.2

[a]Breeds involved were Berkshire, Chester White, Duroc, Hampshire, Landrace, Spot and Yorkshire.

[b]Absolute difference between two-breed crosses and purebreds and percent increase of crossbreds over purebreds. (1042 litters combined from experiments conducted in Iowa, Oklahoma and Oregon).

[c]Absolute difference between three-breed crosses with crossbred females and two-breed crosses with purebred females and percent increase of three-breed crosses over purebreds. (1052 litters combined from experiments conducted in Iowa, Oklahoma and North Carolina).

Table 3. Performance, as a deviation from the overall average, for sows that are one-half of each breed.[a]

Breed	Conception rate, % No.	Conception rate, % Avg.	No. Litters	Birth Litter size	Birth Pig wt. lb (gm)	21-Days Litter size	21-Days Pig wt. lb (gm)
Average	2003	87.2	1820	9.94	3.00 (1361)	7.92	11.7 (5306)
Berkshire	330	3.2	259	−.27	−.02 (−9)	−.25	−.26 (−118)
Duroc	824	−.7	919	.21	0 (0)	.08	−.15 (−68)
Hampshire	799	−2.0	840	.12	−.04 (−18)	−.07	−.02 (−9)
Landrace	347	−1.5	386	.17	.09 (41)	.40	.02 (9)
Yorkshire	593	.7	1072	.31	−.11 (−50)	.19	−.15 (68)
Chester White			114	.37	−.02 (09)	.26	−.08 (−36)
Spot			51	.05	.00 (0)	−.44	−.08 (−36)

[a]Agricultural experiment stations conducting studies contributing to these averages are: Canada Department of Agriculture, Oklahoma, Iowa, North Carolina and Purdue.

Sow Productivity

(continued from page 9)

except birth weight of their pigs. Their conception rate was higher, they farrowed and weaned more pigs and their pigs were heavier at 21 days and at weaning. Crossbred sows provided an environment, both in the uterus and preweaning, that resulted in a higher survival rate of their offspring. They also milked more than purebreds since they raised more pigs to heavier average weights.

When the heterosis estimates for conception rate, litter size at weaning, and pig weaning weight are combined, two-breed crosses weaned 15.4% heavier litters per female in the breeding herd than purebreds and three-breed crosses (crossbred female mated to a boar of a third breed) were 21% above the average of the two-breed crosses.

The difference between purebreds and crossbreds was not the same for all breed crosses. There are rather large differences in the reproductive traits of breeds. Breeds with low average performance responded more to crossbreeding than breeds with high average performance. Regardless of the breeds or the experiments, however, two-breed crosses had higher levels of performance than purebreds and three-breed crosses outperformed two-breed crosses.

Reproduction Traits

Table 2 presents the average for reproduction traits when purebred sows were mated to produce crossbred litters. With the exception of Duroc, breeds ranked about the same for litter size regardless of the age of the litter when measured. Duroc sows had litters with .3 pigs more than average at birth, but litter size was .1 pig below average by weaning. Chester White and Yorkshire consistently ranked high for numbers of pigs per litter. Chester White had litters that were 2.1, 1.5 and 1.4 pigs above average at birth 21 and 42 days, respectively. Berkshire, Hampshire, and Spot sows were consistently below average in litter size.

Differences among breeds of dam were not as consistent for average pig weight in their litters. In most experiments pigs were given creep feed at three weeks of age. Thus, pigs from breeds of dam that were below average at birth and 21 days but were above average at weaning may reflect pigs with above average genetic merit for growth that were nursed by dams that are below average in milking ability. This is also confounded with litter size. Pigs from large litters may be expected to be lighter than pigs from small litters during the period when they are completely dependent on the sow for nutrition.

Table 3 presents the deviation from the overall average for

Table 2. Reproductive performance, expressed as a deviation from the overall average, for purebred sows when producing crossbred litters.[a]

Breed of sow	Conception rate n	Conception rate Avg.	n	Birth No/litter	Birth Pig wt. lb(gm)	21-days[b] No/litter	21-days[b] Pig wt. lb (gm)	Weaning No/litter	Weaning Pig wt. lb (gm)
				Traits measured from birth to weaning					
Average	1939	82.0	1416	9.7	3.06 (1388)	7.4	11.5 (5215)	7.6	29.3 (13288)
Berkshire	22	8.8	50	−.7	−.15 (−68)	−.7	−.3 (−590)	−.4	−.4 (181)
Duroc	726	−.8	346	.4	.09 (41)	0	0 (0)	−.1	−.7 (−317)
Hampshire	601	8.2	338	−.7	.09 (41)	0	0 (0)	−.3	−.7 (−316)
Landrace	117	−6.3	117	−.1	.31 (141)	−.3	−.2 (−91)	0	1.1 (499)
Yorkshire	706	−6.5	391	.8	−.31 (−141)	.6	.2 (91)	.5	−.9 (−408)
C. White	164	8.5	53	2.1	−.31 (−141)	1.52	−.9 (−408)	1.4	−.4 (−181)
Spot	——	——	42	−.8	.04 (18)	——	——	−.4	−.9 (−408)

[a]Agricultural Experiment stations conducting studies contributing to these averages are: Canada Department of Agriculture, Iowa, Oregon, North Carolina and Oklahoma.
[b]Some studies did not report 21-day measurements.

crossbred sows that are half of each breed for conception rate and for litter size and pig weight at birth and 21 days. The performance of a breed as a purebred did not predict very accurately the average performance of the breed as a crossbred. As purebreds, Berkshire, Hampshire and Chester Whites had conception rates well above average whereas Landrace and Yorkshire were considerably below average. Crossbred sows that were 50% of each breed had similar conception rates.

The breed composition of the crossbred sows made substantial differences in litter size at birth and at 21 days. Sows that were half Chester White or Yorkshire ranked highest for litter size at birth, whereas sows that were half Landrace were superior in litter size at 21 days.

When specific crosses and all experiments were considered, litter size at birth was highest for Hampshire-Landrace cross sows (+1.22 pigs) followed closely by Chester White-Yorkshire crosses (+1.15 pigs). Hampshire-Landrace cross dams also had the largest litters at 21 days (+1.11 pigs) followed by Yorkshire-Landrace (+.73 pigs). In general Duroc-Yorkshire, Landrace-Yorkshire, Chester White-Yorkshire, and Hampshire-Landrace crosses ranked high while sows that were half Berkshire or Spot were below average.

Choice of breeds for a crossing program will depend on the mating system used and the availability of healthy, quality breeding stock. Rotation crosses do not make maximum use of heterosis but are popular because of their simplicity. In rotation crosses, sows are always greater than 50% of one breed; consequently each breed in the rotation should be above average in reproductive performance. In terminal crosses, crossbred females superior in maternal characteristics can be mated to a third breed or breed cross of boar. Boars should be aggressive breeders but do not need to be breeds superior in maternal characteristics.

Litter size—result of effective culling.

Basis of Improved Sow Productivity

Litter Size Repeatability

William T. Ahlschwede
Extension Livestock Specialist
Swine

Commercial pork producers are giving more attention to sow productivity. Management, identification, and record keeping systems are being developed to help producers identify production problems and eliminate non-productive sows. However, if sow culling decisions are not based on a good understanding of the biology of sow production, even computerized systems will be unable to cause improvement. Currently, our understanding of the biology of sow production lags behind our ability and desire to develop management programs.

This study was undertaken to quantify some of the biological basis for developing effective sow culling programs. Many producers have a good notion of the relationship of litter size from one farrowing to the next. It is understood that sows which farrow large litters are likely to farrow large litters next time also. Everyone knows that gilt litters are smaller than sow litters. However, to develop effective culling programs we need to quantify these relationships.

Lifetime Litter Records

Lifetime litter records from 646 crossbred sows from a Feeder Pig Cooperative were used to evaluate parity affects on litter size and the predictability of litter size based on the size of the previous litter. The effects of season and farrowing interval were also investigated. The 646 sows produced 2,539 litters during the period studied. The data included litters born in August of 1969 through October of 1977. The age of the sows was such that gilt litters were born in all but 23 of the 98 months during the period.

During this period one sow had 16 litters, and 41 had 10 or more litters. Culling on litter size was not strong. Sows with small litters were generally given another chance. Farrowing interval also was not a strong criteria for culling. These culling practices make this set of sow performance records particularly helpful for this study. Sow retention in the herd was high. Not all records available were used in the study. Records from sows with excessively long farrowing intervals were not used. Sows with lost ear tags were deleted. Thus the unit was actually more productive than would appear from the data.

The sow management in this unit was similar to that found on many Nebraska farms. All sows were identified with ear tags, ear notches, or both. Some sows were

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Litter Size

(continued from page 11)

bred in open dirt lots. Some sows were bred in confinement. Sows were moved to the farrowing rooms within a week of farrowing. Litters were recorded as born. Sows and litters were moved to lactation rooms on day one and pigs were fostered among litters to even them out. Pigs were weaned at 21-24 days of age. Sows were exposed to boars immediately upon farrowing.

Since litters were evened out at day one, only litter size at birth and number born alive were recorded. Farrowing interval was calculated as the number of days between two litters of the same sow.

Litter Size

Litter size through the first 10 litters is shown in Table 1. The decline in the number of sows from litter to litter represents sow culling. Also, gilts which farrowed late in the study period may have had time for only two or three litters. The difference between total born and born alive was expected. In recording litter size, pigs found dead were recorded as born dead. Hence litter size born alive should be thought of as litter size found alive. There is a tendency for the difference between total born and born alive to increase as the sow gets older. While the trend is small, it is consistent with results reported from other studies.

The increase from first litter to second litter was smaller than anticipated. The pattern generally expected is a substantial increase from first litter to second (more than a one pig increase), an additional increase between second and third litter (similar to the increase observed here), and little increase after third litter.

Several factors may have been important in making these results different than expected. First, the age of the first litter gilts in this study was not known. Gilts were purchased in large groups at about five months of age, but were bred when needed. Hence some of the gilts may have been 15-18 months old when they farrowed the first time. This would cause the size of the first litter to be higher. Secondly, sows were bred back immediately after weaning at three weeks. Previous studies, which are few in number, reported litter size following weaning at older ages. Early weaning may not give the gilt sufficient time to completely recover from farrowing and thus farrow a smaller than expected second litter. This possibility deserves further study.

Table 1. Litter size through 10 litters.

	Littersize by parity									
	1	2	3	4	5	6	7	8	9	10
Number of litters	646	496	370	309	205	169	124	75	55	41
Total born	10.0	10.2	10.8	11.3	11.1	11.1	11.2	11.6	11.3	11.6
Born alive	9.2	9.5	9.9	10.3	10.2	9.9	10.2	9.6	10.0	10.2

Litter Performance

Table 2 shows the litter performance and farrowing interval by month. Although litter size does vary considerably from month to month no particular pattern is apparent, except to note that sows farrowing in February and March, the two high months for litter size, would tend to farrow in July and August, months also higher than average in litter size.

The farrowing intervals reported in Table 2 refer to the days until the next litter for those sows which farrowed again. Sows farrowing in January which had another litter averaged 155 days until the next litter. The monthly differences in farrowing interval do follow an interesting pattern. Sows farrowing in July and August had considerably longer farrowing intervals than sows farrowing in other months. Sows farrowing in July took an average of 18 days longer to rebreed than those farrowing in June. While several components of rebreeding are involved, it is known that hot weather often causes breeding problems. From these results, we cannot tell what the exact problem was. Perhaps the sows were slow returning to heat. Perhaps the boars were unwilling to mate or were infertile. Perhaps hot weather affected the sows ability to conceive. Probably all of these factors were involved. The consequences were that few litters were farrowed in December. It has been suggested that summer breeding problems cause reduced litter size as well as extended farrowing intervals. The litter size of sows farrowing in December was not reduced, even though they were bred during the stressful period.

Additional aspects of farrowing interval were revealed by this study. It has been suggested that farrowing interval should be a criteria for culling and for genetic improvement. In this study there was no relationship between successive intervals of a given sow. The correlation among 1,263 pairs of adjacent farrowing intervals was 0.04. This low correlation indicates that farrowing interval is not a permanent trait of the sow and thus not a candidate for selection.

The regression of litter size on the interval preceeding was quite small, 0.004 pigs/day. This would indicate that skipping a cycle between weaning and farrowing would not improve litter size. However, when only first and second litters were considered the regression was somewhat higher, $b=0.02$, indicating that skipping a cycle with the gilts in this study might increase the size of the second litter 0.4 pig. Litter size farrowed appeared to have no effect on the amount of time until the

Table 2. Monthly average litter size and farrowing interval.

	J	F	M	A	M	J	J	A	S	O	N	D
No.	153	138	196	177	120	171	157	227	193	145	139	77
Total born	10.3	11.0	11.2	10.9	10.3	10.2	11.0	10.8	10.8	10.7	10.7	10.9
Born alive	9.5	10.0	10.2	10.0	9.5	9.5	10.1	9.9	9.8	9.7	9.8	9.8
Farrowing interval[a]	155	155	155	161	154	156	174	164	155	158	157	154

[a]Days until the next litter for those which farrowed.

sow rebred.

The primary purpose of this study was to estimate the repeatability of litter size. Do sows which have a large litter one time have a large litter the next time? Repeatability measures the relationship between the size of the two succeeding litters. Expressed as correlation, the repeatability was 0.27 for total born. A repeatability of 0.24 was found for born alive. What this means is that for each pig larger than the average of her group a sow's litter is, we expect her next litter to be 0.27 pigs larger. Since sows farrow only whole pigs, this expectation is for a group of sows rather than individuals.

The estimates of repeatability from this data are somewhat higher than the single study reported 30 years earlier. A large number (1,893 pairs of litters) of records were used in this study. The distribution of litters and the period of time covered make these estimates quite reliable.

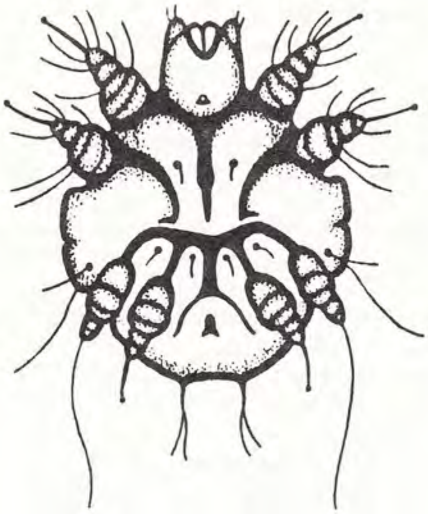
The estimate of repeatability from this study gives a basis to evaluate the expected response from culling on litter size. Repeatabilities of 0.27 for total born and 0.24 for born alive indicate that culling on litter size would be expected to improve litter size. However, they are not sufficiently large to suggest intense culling on litter size. Culling 10-15% of the sows on low litter size would be suggested.

Conclusion

Results of this study provide a numerical basis to evaluate the effectiveness of programs and systems designed to improve sow productivity. Statistics are provided which are needed to design more effective improvement programs. The seasonal farrowing pattern indicates that summer breeding problems are common in this unit. Based on this study, farrowing interval is not an appropriate criteria for culling or genetic improvement. The relationship between the sizes of adjacent litters is sufficiently large to encourage moderate levels of culling on litter size and to expect measurable results in sow production.

Serious Problem

Sarcoptic Mange in Swine



Mange mite

Alex Hogg
Extension Veterinarian

Sarcoptic mange can be found in most Nebraska non-SPF swine herds. Mange is becoming an increasingly serious problem as more intensive swine production methods are practiced. Some reasons for this are:

1. Pressure of other tasks such as breeding and feeding makes it easy to neglect the scheduled spraying program necessary to control mange.
2. Lack of knowledge of the mange mites' life cycle and how to successfully combat this pest.
3. Lack of knowledge of the effects of a severe mange outbreak.

21% Had Mange

A recent survey of 1,000 market pigs at a Nebraska packing plant showed that 21.6% of the carcasses had moderate to mild visual evidence of mange infestation. Sarcoptic mange is rarely fatal although itching and the resultant restlessness reduce feed efficiency. The constant rubbing and scratching can also increase the normal wear and tear on buildings and equipment. Severe anemia has been observed in sows with severe mange infestations with resultant reproductive problems.

Sarcoptic mange mites affect only swine. However, they can live in the skin of man for a short period of time (a day or two), long enough to be transported to a mange-free herd. They ordinarily die two or three days after being off the pig but under ideal conditions may survive for two weeks. They are, therefore, easily eliminated from the premises in the course of a routine swine depopulation program.

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Table 1. Mange control product guide.

Product	Dilutions	Application rate	Withdrawal time (days)	Cautions
Sprays				
Lindane, 20%	1 pt./50 gal water	2-4 qts./hd.	30	May be used as dip or spray.
Lindane, 12.4%	1½ pt./50 gal water	2-4 qts./hd.	30	Do not treat pig before weaning.
Malathion, 57% EC*	2 qts./50 gal water	2-4 qts./hd.	0	
Toxaphene 60%	3 pt./50 gal water	2-4 qts./hd.	28	Do not treat pig before weaning.
Dusts and Granules				
Malathion, 4-5% dust*		¼-½ tbs./head	0	Dust entire animal.

Usage and withdrawal information reflects current label restrictions. These may change at anytime. Therefore, read and follow *all* label directions.

Check with state regulatory officials or county extension directors for state use restrictions.

*=Partial—for temporary control only.

Sarcoptic Mange

(continued from page 13)

The life cycle of sarcoptic mites is 10 to 15 days from egg to egg-laying adult. Adult females lay 40 to 50 eggs during their one-month life span. The preferred site is the inner surface of the ears. The mites are found less frequently on the outer surface of the ears, face, top of the neck, shoulders and over the body. Positive diagnosis is by finding the mites in deep skin scrapings.

Eradication of mange from a herd is difficult. A routine spraying program should keep this parasite under control.

Treatment

Successful treatment requires breaking the life cycle. The recommended insecticides do not kill the eggs so at least two sprayings at 10-day intervals are required. Actually, dipping vats are the most effective way to apply the insecticide.

Spray 30 and 20 days before farrowing. Since mites live in the skin layers high pressure sprays work best. The whole animal must be treated, particularly inside the ears.

Spray all herd additions twice at 10 day intervals while in isolation before adding them to the main herd.

Spray growing and finishing pigs twice at 10 day intervals when they are 8 to 10 weeks of age.

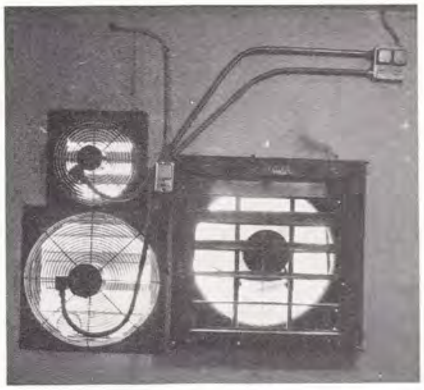
Lindane and toxaphene have been the most successful insecticides used on mange.

Cautions

Take caution with these insecticides as there have been reports of abortions and death of baby pigs following careless use of lindane-toxaphene combinations. Avoid spraying gestating sows in pens where floor feeding is practiced as poisoning may occur.

Wetting agents may increase the penetration of insecticides and improve the efficiency of the parasite control program.

A mange control product guide is given in Table 1.



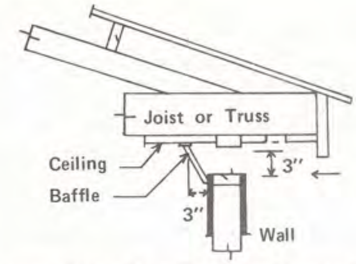


Figure 2. Double plate baffled air inlet.

Figure 1. Typical fan bank for 3-fan system.

Ventilation Systems

Farrowing, Nursery Facilities

Gerald R. Bodman
Extension Agricultural Engineer

The success of a swine production enterprise is generally related to the quality of pigs produced. The quality of the feeder pig produced depends to no small extent on the quality of the environment within the farrowing or nursery facility. A well-designed ventilation system is a primary factor involved in maintaining a healthy environment.

The performance of a ventilation system depends on the individual system components such as fans, inlets, and controls being able to work together to produce the desired conditions. Among the system requirements are the removal of toxic or noxious gases, and control of dust, heat, and moisture.

A well designed ventilation system introduces good quality air from outside the building in the proper amounts to maintain desirable humidity and temperature while avoiding drafts and chilling and expending minimal energy. This can be achieved through proper fan selection, location, and control and properly located and designed air inlets.

Sizing Fans

Wintertime (cold weather) ventilation is necessary to remove moisture produced by the animals. Airflow rates are calculated using the outside and inside temperatures and the rate of moisture production by animals. Spring and fall (mild weather) airflow rates are determined by the need to remove additional moisture as temperatures increase and a need to remove excess heat—both that gained through movement of heat into the building, and heat produced by the animals. Summer (warm weather) ventilation is designed to remove excess heat and to achieve cooling through the evaporation of moisture.

Recommended airflow rates for farrowing and nursery facilities are listed in Table 1. Fans should be selected on the basis of their ability to move the required quantities of air at a static pressure of 0.10 to 0.125 inches (0.25-0.32 cm) water. For proper fan perfor-

Table 1. Recommended ventiliation rates for farrowing and nursery facilities.

	Farrowing house (per sow and litter)		Nursery (per 30 lb (13.6 kg) pig)	
	cfm	m^3/s	cfm	m^3s
Winter	35	0.0165	4	0.00189
Addition spring/fall	+110	+0.0519	+15	+0.00708
Addition summer	+300	+0.1416	+45	+0.02124
Summer total	445	0.2100	60	0.03021

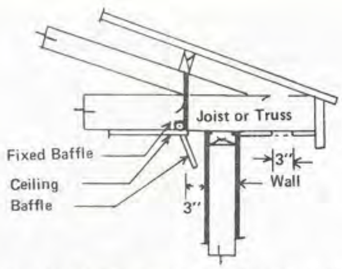


Figure 3. Single plate over-the-wall air inlet.

mance, use only fans bearing an Air Moving and Conditioning Association (AMCA) "Certified Rating" seal. Fans having an AMCA seal are more certain to perform in accordance with information printed in the manufacturer's literature. All AMCA rated fans will bear a 1 inch by 2 inch (2.5 × 5.0 cm) blue and gold seal.

The winter airflow rates in the table can be reduced slightly during extremely cold weather by restricting the air inlet opening. However, under no circumstances should the airflow be stopped entirely. Nursery rates are calculated on a weight basis. Adjust rates in proportion to the average weight relative to 30 pounds (13.6 kg).

Fan Locations

A basic three-fan system (Figure 1) provides good ventilation. One of the three fans is operated continuously for winter ventilation. This results in uniform temperature and relative humidity levels. Spring/fall and summer fans are thermostatically controlled. The use of a single larger fan with either interval or thermostatic control for winter ventilation is not recommended. The relationship between high and low volume on 2-speed fans generally makes them unsatisfactory as well. An added advantage of having several single speed fans is flexibility in case of equipment malfunction.

Individual thermostats should be used on the spring/fall and summer fans. The winter fan should be wired to operate continuously. Additional fans are added as necessary for larger installations. For building lengths of up to 150 ft. (45.7 m) all fans should be grouped in one bank as shown in Figure 1. For longer buildings, two or more banks of fans are used.

Locating fans midway along the south or east wall will assure uniform air inflow and achieve good fan performance by minimizing back-pressure due to wind. Curved, exterior hoods are also beneficial in reducing the influence of wind pressure on fan performance.

Air Inlets

Good distribution of incoming air is achieved by providing inlets around as much of the exterior wall as possible. Doing so results in a smaller slot width opening and less air coming in per unit length. This reduces the potential for draft. Figure 2 illustrates one type inlet that can be used in new construction. Figure 3 shows a construction technique for use in either new or existing construction. It is recommended that inlets be continuous along the wall opposite the fans. Do not provide inlets immediately above the fans or for a distance of 6 to 8 ft. (1.8 to 2.4 m) on each side of the fan bank to prevent short-circuiting of air.

All inlets should be equipped with adjustable baffles to allow season to season adjustment. This adjustment is necessary to provide uniform airflow and control air speed. Protect inlets on the exterior with ½ × ½ in. (1.3 cm × 1.3 cm) cloth (welded wire mesh) to prevent the entrance of birds. Under no circumstances should fly screening type materials be used. They restrict airflow and are easily clogged by dust or other airborn particles. If outside air is tempered by moving it through the attic and then into the animal space, exercise precautions to prevent the flow of warm moist air up into the attic. Failure to do so will result in condensation and wet insulation.

Air inlet openings can be adjusted by a variety of means. Manual adjustment is most common. The help of a static pressure gauge to indicate proper adjustment is recommended. Use care in setting baffles because it is possible to achieve the desired static pressure and still achieve non-uniform airflow via a 'tight" opening on one part of the inlet and an "extra wide" opening on another part of the inlet.

Motorized inlet control mechanisms are becoming more widely available. These automatically adjust the inlet opening as the number of operating fans change.

Another alternative, and one preferred by the author, is the use of designed slot openings for various seasons of the year. The use of springs or spring-loaded hinges to keep the baffles closed and stepped spacer blocks (Figure 4) to provide the desired opening have been used successfully. Design slot openings to provide for an air velocity of about 750 to 800 feet per minute (fpm) (3.81 to 4.06 m/s) as the air passes through the inlet slot.

The following example illustrates the calculations. In a 24-sow farrowing house the recommended airflow is 24 sows × 35 cfm (0.0165 m^3/s) per sow and litter for a total airflow of 840 cfm (0.396 m^3/s). If the farrowing house is 65 ft. (19.8 m) long it would have total inlet length of about 65 + 45 = 110 ft. (33.5 m). The required slot opening would therefore be

$$\frac{840\text{cfm} \times 12 \text{ in/ft}}{775 \text{ fpm} \times 110 \text{ ft}} = 0.118 \text{ in. } (0.30 \text{ cm}).$$

Controls

Controls such as thermostats and humidistats should be centrally located and grouped together to facilitate system calibration and maintenance. Locate thermostats away from hot or cold surfaces. Avoid locations in air inlet or heater air streams.

Research has shown that sows are more comfortable at temperatures in the range of 65 to 70° F (18 to 21° C) while newborn pigs may require temperatures as high as 95 to 98° F (35 to 37° C). This variation in temperature can be achieved by maintaining an interior air temperature of 65 to 70° F (18 to 21° C) for sow comfort and using zone heating to maintain higher temperatures in the creep area for young pigs.

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Ventilation Systems

(continued from page 15)

If the heated creep area is covered, pig comfort is further enhanced. Some producers object to this type of hover because they cannot easily observe the pigs. Clear plexiglass hovers avoid this inconvenience. Hovers should be placed over the front 50% of each creep area in the farrowing crate or stall. Within the nursery unit, hovers can be used in the same fashion by providing a covered hover area at the end of the pen away from the intended dunging area. This makes it possible to provide cooler temperatures in the dunging area while still maintaining the warmer temperatures in the sleeping and eating area. The result is generally the development of better dunging habits.

Other Considerations

In addition to heat and moisture control, ventilation systems remove odors from the building. Control of moisture also reduces odors. However, with in-barn or under-floor manure storage systems, pit exhaust is sometimes desirable. Exhausting some of the ventilation air from the pit will reduce the risk of toxic or irritant gases entering the animal space. This minimizes the levels of methane, hydrogen sulfide, and ammonia in the animal space. The use of an air duct extending from the fans down through the slats is one way in which under-slat ventilation can be achieved. The duct can be built around the winter and spring-fall fans so that all airflow is pulled through the inlet, down through the slats and consequently to the exhaust fans. Since summer fans are used more for cooling, this air is more effectively moved straight across the building, as contrasted to moving it down through the slats. In buildings with two separate pits, ducts connecting the two pits allow one set of fans to provide for total ventilation needs. In all cases, provide access to the fans to facilitate maintenance.

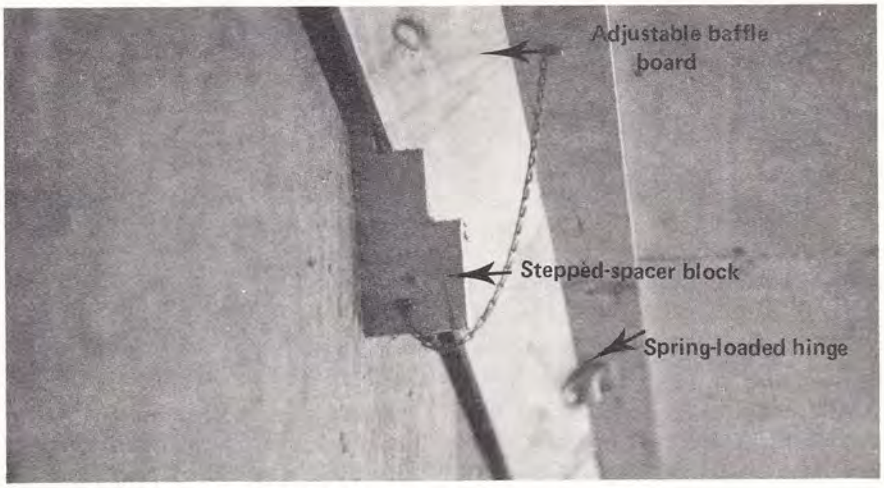

Figure 4. Adjustable baffle controls.

Recirculation type ventilation systems are not generally recommended. Unless the system includes condensing plates, filters, and scrubbers, recirculation is ineffective in removing dust, moisture, and odors from the building. High maintenance requirements have limited the application of such equipment.

Control of interior environmental conditions must also include consideration of supplemental heating systems. Alternate heating systems include unit space heaters, heat exchangers, floor heat, fin pipes below air inlets, solar heat, and radiant heat. Where additional cooling is desired, the benefits of space cooling should be weighed against snout cooling for sows. Air-conditioners, heat pumps, and evaporative coolers are the primary means of providing cool air.

Good design requires the use of materials and equipment which will withstand the corrosive atmosphere present in most animal housing facilities. Where animals have access to the structural components, materials must be resistant to the rubbing, chewing, and abrasive action of pigs as well. Materials and construction techniques should be effective in controlling rodents.

Control of condensation requires that the building be well insulated. General recommendations are the equivalent of 3½ inches (8.9 cm) of fiberglass in the sidewalls and 6 inches (15.2 cm) of fiberglass in the ceiling. Table 2 shows the equivalent thickness of various insulating materials. Other considerations in selecting insulation materials include the cost per unit R value and possible hazards in using it. Cellulose and foam insulation materials should not be used in an exposed location due to their flammability. The potential for damage from birds, rodents, and insects must also be evaluated and considered.

Regular maintenance of the ventilation system components is required. This involves cleaning and adjusting thermostats, inlets, shutters and fans and resetting slot openings seasonally. Checking of fan shutters is especially important during cold weather to be sure they do not become frozen in one position. Dust buildup of ⅛ inch on fan blades and shutters can reduce fan performance by as much as 30%. Additionally, allowing dust to build up on the shutters so that the shutters do not open fully further restricts the fan performance. The result is reduced quality of the interior environment and a much higher cost per unit of air moved through the facility.

Trouble Shooting

Being able to diagnose problems with a ventilation system is as important as good design. The following check list will help identify some common problems found in swine facilities.

A. Problem: High odor levels, high relative humidity

Table 2. R values and thickness of various insulation materials required to equal the R value of 1 in. (2.5 cm) of fiberglass.

Material	R Value (per in. or 2.54 cm)	Thickness to equal 1 in (2.54 cm) of fiberglass batt
Fiberglass batts and blankets	3.40	1.00 (2.54) = 1"
loose	2.51	1.35 (3.44) = 1 3/8"
Polystyrene beadboard	3.57	0.95 (2.41) = 15/16"
extruded, cut cell surface	4.00	0.85 (2.16) = 7/8"
extruded, smooth skin surface	5.00	0.68 (1.73) = 11/16"
Polyurethane	6.25	0.54 (1.38) = 9/16"
Urea-formaldehyde (Est.)	4.00	0.85 (2.16) = 7/8"
Cellulose	3.42	0.99 (2.53) = 1"

Possible Causes:

1. Low quality non-AMCA certified fans.
2. Improperly sized fans.
3. Insufficient number of fans.
4. Inaccurate or dirty controls.
5. Improperly adjusted controls.
6. Restricted inlets.
7. Loose fan belts.
8. Dirty fans and shutters.
9. Shutters not freely operating.
10. Number of pigs exceeds design capacity.
11. Improperly adjusted inlets.
12. Insufficient air inlet opening.
13. Poorly designed air inlets.
14. Improperly located fans.
15. Improperly located controls.

B. Problem: Wide fluctuations in building temperature

Possible Causes:

1. Dirty or inaccurate controls.
2. Faulty heating system.
3. Large fans with interval timers being used.
4. Loose fitting doors and windows.

C. Problem: Non-uniform conditions within building

Possible Causes:

1. Poorly designed inlet system.
2. Insufficient airflow (See "A").
3. Poorly designed heating system.
4. Improperly located fans.
5. Loose fitting doors and windows.
6. No foundation (perimeter) insulation.

D. Problem: High heating bills

Possible Causes:

1. Overventilation caused by
   a. improperly sized fans.
   b. improper inlet adjustment.
   c. inaccurate or improperly set controls.
   d. dirty control sensing elements.
2. Insufficient insulation.
3. Leak in fuel system.
4. Loose fitting doors and windows.

E. Problem: Condensation on walls or ceiling

Possible Causes:

1. Inadequate airflow (See "A").
2. Inadequate wall or ceiling insulation.

F. Problem: Inability to keep building cool during warm weather

Possible Causes:

1. Insufficient insulation.
2. Inadequate airflow (See "A").

Summary

Regardless of the system, it is still the system manager or operator who will determine its ultimate success. Every system, every building, has some unique peculiarities. It is essential that the operator learn how to work with these peculiarities early in the operation of a new system.

The ventilation system will not in itself guarantee the successful operation of any facility. Good design and management are required in all cases.

Prenatal Survival in Gilts Selected for High Ovulation Rate

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Litter size at birth represents the net effect of three component traits. *Ovulation rate* (number of ova) establishes the upper limit for litter size. *Fertilization rate* determines the proportion of the ova that are activated by spermatozoa and begin development as embryos. *Embryo and fetal survival* determine the proportion of the beginning embryos that survive the gestation period and are born as live pigs (Figure 1).

Ten generations of selection for high ovulation rate have been completed at Nebraska in an attempt to increase ovulation rate and in turn improve litter size. Gilts selected for high ovulation rate showed marked improvement in ovulation rate (3.4 ova advantage over controls) but failed to show a statistically significant improvement in litter size at birth (1.0 pig advantage over controls) after nine generations of selection. The present study was conducted to evaluate why more of the difference in ovulation rate was not expressed as a difference in litter size at birth.

Gilts Artificially Inseminated

Ninth and tenth generation select and control line gilts were

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Prenatal Survival

(continued from page 17)

artificially inseminated on the first and second days of estrus with 75 ml of pooled (from 2 or 3 Large White boars) liquid semen stored 24 to 48 hours at 59° F (15° C) and containing five billion spermatozoa. Ovulation rate (estimated from counting the number of corpora lutea, CL, on the ovaries), and number and condition of embryos and fetuses were recorded following slaughter at 27 to 31 days (generations 9 and 10) and 68-72 days gestation (generation 10).

Both ninth and tenth generation select line gilts produced greater numbers of embryos than control line gilts because of superior ovulation rate (Table 1). However, the advantage in litter size at 30 days (1.7 embryos in generation 9 and 2.6 embryos in generation 10) was proportionately less than the difference in ovulation rate. Select line gilts suffered greater ova loss to day 30 than controls (2.7% in generation 9 and 5.2% in generation 10).

Trend Continued

The trend for greater prenatal loss in the select line continued after day 30. The 2.6 embryo advantage decreased to a 1.0 fetus advantage at day 70 of gestation in tenth generation gilts. Select line gilts experienced 5.2% higher fetal mortality than controls between days 30 and 70 of gestation. The litter size advantage at day 70 was similar to the litter size advantage observed in ninth generation select line gilts at birth (1.0 live pig born)

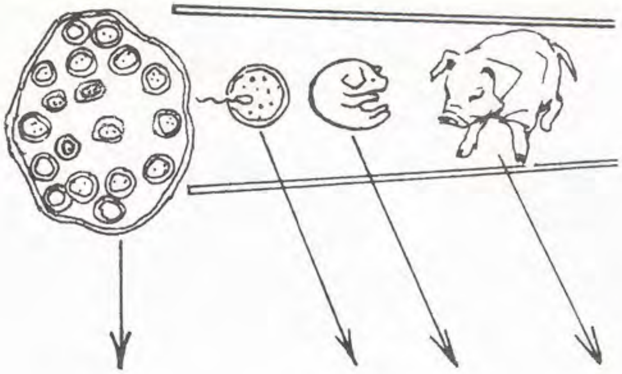

Figure 1. Pathway to live births.

and suggests that most of the difference in prenatal loss has occurred by day 70.

A more precise determination is needed as to when the increased fetal loss is occurring. However, since fetal death after day 40 should be identifiable at day 70 of gestation, it is hypothesized that the majority of fetal loss is occurring soon after day 30.

Reduced uterine space per embryo may be one possible cause of the increased fetal mortality in the select line. Florida researchers experimentally reduced the uterine space to half the normal amount and observed increased fetal loss between 30 and 40 days of gestation as well as during the remainder of gestation. Placental length, weight and surface area were reduced in experimentally altered gilts at all stages of pregnancy and fetal weight decreased after day 40. These researchers suggested that fetal survival and development may depend on the extent of placental growth earlier in gestation.

Line comparisons in the present study reveal similar embryo weights at day 30 and fetal weight at day 70. However, placental weight of select gilts was lighter than control line gilts at day 30. Placental insufficiency may be involved in the greater prenatal mortality of the higher ovulating select line.

The limited improvement in litter size at birth resulting from genetic improvement of ovulation rate is similar to the response obtained with other approaches for increasing the number of ova. Superovulation (hormone induction of increased ovulation rate) and superinduction (transfer of additional embryos into the uterus) have both proven effective for increasing litter size at 25 to 30 days of gestation but have failed to consistently improve litter size at later periods in gestation and at term. More research is needed to determine the causes of increased embryo and fetal mortality that occurs when the number of ova entering the uterus is increased.

Table 1. Differences in ovulation rate and prenatal survival between gilts selected for high ovulation rate and controls.

	Embryo survival						Fetal survival		
	Ninth generation			Tenth generation			Tenth generation		
Trait	Select	Control	Difference	Select	Control	Difference	Select	Control	Difference
No. gilts pregnant	34/38	21/21		41/48	20/28		36/42	23/27	
No. CL	15.8	13.2	2.6**	19.3	14.3	5.0**	19.7	15.2	4.5**
No. nondegenerate embryos or fetuses	11.9	10.2	1.7[a]	13.7	11.1	2.6**	11.1	10.1	1.0
Embryo or fetal survival, %	76.1	78.8	−2.7	73.0	78.2	−5.2*	57.7	68.3	−10.6*

[a]P<.10
*P<.05
**P<.01

Effect on Behavior, Performance

Swine Nutrition and Housing

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Behavior problems among livestock are perhaps as old as history. Indeed, with a major thunderstorm imminent it is quite likely that Noah had problems getting all the animals on the ark.

We have reported in the past that space allowance influences behavior as well as performance. As a result of our studies and others, space recommendations are quite well agreed upon.

Tail biting is a persistent behavioral problem. Reports from the field suggest that nutrition may be a factor in tail biting. Others suggest that weather factors such as barometric pressure changes may influence the aggressive nature of pigs.

The Investigation

One mineral, magnesium, has been reported to have a tranquilizing effect on pigs; fat in the diet may have a satiating effect. Thus, if pigs could be calmed with magnesium and have their appetites satisfied with fat, the aggressive behavior of confined pigs might be reduced or eliminated. We developed an experiment to study the effects of the addition of both magnesium and fat in the diet of growing-finishing swine reared in two types of housing on the incidence of tail biting and pig performance.

Magnesium oxide was fed at 0, ½ pound/ton (250 gm/m ton) and 1 pound/ton (500 gm/m ton). The three magnesium levels were fed with either 0 or 5 percent tallow in a modified open front (MOF) or environmentally regulated (ER) building. Pen arrangements in all buildings were the same with the gross space equalling 9.6 square feet (.89m^2) per pig and the net space about 9.1 square feet (.84 m^2). The ER building is windowless. A 40 watt bulb was left on continuously and placed in a different location every 14 days. If this isn't done, occasionally pigs will become so excited when the workers come in and turn on the room lights, they may jump over the pen dividers.

To evaluate the role of barometric pressure on pig behavior, barometric pressure was recorded at 9:00 a.m. daily and whenever tail biting occurred. Average daily gain and feed efficiency were determined at 14-day intervals. There were 240 pigs involved, 120 in each of the two buildings. The initial weight was 29 pounds (13.3 kg), and the final weight was 198 pounds (90.1 kg). The study took place during the summer of 1977. The six dietary treatments are shown in Table 1.

The Results

Results of the magnesium treatments are summarized in Table 2. The effect of adding magnesium was to reduce gain, increase the feed required per unit gain, and increase the incidence of tail biting. While those proponents of magnesium make no claims about the relationship between the mineral and performance they do claim magnesium will be effective in preventing or stopping tail biting. As data in Table 2 indicate, the three criteria measured show a detrimental effect from increasing levels of magnesium in the diet.

Results agree quite closely with a study done earlier at Purdue University.

The reason for the treatment responses is not clear. Some have reported that high levels of magnesium have a tranquilizing effect on the pig and that feed intake is thus reduced. Reduced feed intake was observed in this study.

Results of the tallow treatments are shown in Table 3.

Tallow addition to the diet improved gain by 4.2 percent and feed:gain by 8.5 percent. This is within the range of benefit that tallow has provided in studies reported previously by the Nebraska Experiment Station. There was a slight increase in carcass backfat ($P<.05$) when tallow was added. While this difference is not consistent between studies it is not uncommon, but is usually not great enough to be of consequence, assuming the economics of energy alternatives favor the use of tallow. Fat addition to the diet increased tail biting (27 versus 39 percent).

Building differences in animal

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Table 1. Dietary treatments. Magnesium, tallow and housing effects on tail biting incidence and performance of G-F swine.

Treatments	
1	14% corn-soybean meal basal
2	14% basal plus 5% tallow
3	14% basal plus ½ lb/ton (250 gm/m ton) magnesium oxide
4	14% basal plus 5% tallow plus ½ lb/ton (250 gm/m ton) magnesium oxide
5	14% basal plus 1 lb/ton (500 gm/m ton) magnesium oxide
6	14% basal plus 5% tallow plus 1 lb/ton (500 gm/m ton) magnesium oxide

Table 2. Effect of magnesium feeding on gain, feed:gain and percent of pigs tailbitten.

	Basal	Magnesium oxide ½ lb/ton (250 gm/m ton)	1 lb/ton (500 gm/m ton)
Avg. da. gain, lb (kg)	1.69 (.77)	1.65 (.75)	1.60 (.73)
Feed:gain	2.78	2.82	2.84
% Tail bitten	28	34	39

Nutrition, Housing

(continued from page 19)

performance are shown in Table 4. There was no difference in daily gain between the two buildings. However, there was a difference (P<.01) in feed:gain in favor of the ER building. This was the first summer study at this station where the ER supported better feed:gain than the MOF building. This difference is accounted for in the tail biting incidence where 41 percent of the pigs in the MOF were tailbitten as compared to 26 percent in the ER buildings.

Some researchers have reported that the light intensity in a building may contribute to tail biting—the darker buildings resulting in less tail biting. If this is the case, and we believe it is a possibility, differences in light intensity between the two buildings could account for the difference in tail biting.

The utility cost is the expense attributable to electricity at $.04 per kilowatt hour to operate fans and lights. Since the MOF is a gravity ventilated building, hardly any electricity is needed for this purpose compared to the mechanically ventilated ER building.

The summer of 1977 was marked by above normal precipitation and corresponding weather fronts. As a consequence there were sudden and frequent barometric pressure changes. Table 5 summarizes the relationship between tail biting and barometric pressure change. When tail biting occurred, barometer readings were made and compared with the 9 a.m. barometer reading for that day.

While the summary on barometric pressure is somewhat general it appears that changing barometric pressure does play a role in pig behavior as expressed by tail biting.

Table 3. Effect of tallow on gain, feed:gain, tail biting and backfat thickness.

	Basal	Basal + 5% tallow
Avg. da. gain, lb (kg)	1.60 (.73)[a]	1.67 (.76)
Feed:gain	2.87**	2.63
% Tailbitten	27	39
Backfat, in (cm)	1.42 (3.66)*	1.48 (3.76)

[a]P<.10
*P<.05
**P<.01

Table 4. Effect of building type on gain, feed:gain, tail biting and utility cost.

	MOF	ER
Avg. da. gain, lb (kg)	1.65 (.75)	1.63 (.75)
Feed:gain	2.68**	2.81
% Tailbitten	41	26
Utility cost	$0.72	$141.92

**P<.01

Table 5. Effect of barometric pressure change on tail biting incidence.

Barometer condition	Percent tailbitten
No change from 9 a.m. reading	27.0[a]
Below 9 a.m. reading	24.4
Above 9 a.m. reading	48.6

[a]Those tailbitten—where there was no pressure change from 9:00 a.m. reading.

Conclusions

Based upon this investigation, it is very doubtful that magnesium above nutritional requirements has a place in swine production. Anything that makes a pig feel uncomfortable is often expressed as tail or ear biting. Therefore we should perhaps refer to tail biting as the "anti-comfort syndrome." There is a rationale among some in the swine industry that when tail biting occurs that changing something or anything will be beneficial. Oftentimes the diet is changed simply because it is the most convenient factor.

The results of tallow addition to the diet supported conclusions from earlier research. Even though a considerable improvement in feed to gain is predictable when 5 percent tallow is added the overall cost:benefit must be considered in terms of energy costs from alternative sources, such as corn. If a 4 to 5 percent improvement in gain were as predictable as the improvement in feed to gain, this would help determine whether to add tallow or not. Added tallow in this study had no effect on reducing the incidence of tail biting.

The realization that weather phenomenon influences human and animal behavior is not new. The practical significance of the effect of barometric pressure changes on tail biting or aggression from this study may not be readily apparent. However the wise livestock husbandman will be alert to this relationship—forewarned is forearmed.

H_2O—Critical Swine Nutrient

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Water is a critical nutrient for swine. When you consider that the body of the newborn pig is about 80% water, it is not difficult to see how important water is to life. Lack of water or diseases such as scours and agalactia (no milk) in the sow will result in severe dehydration of the pig and early death. The young pig should never "want" for a good, clean, continuous supply of fresh water.

On the other hand, water is also a precious commodity. Although it is extremely important to have water available for the animal, it is also important that water not be wasted. Swine producers do not purposely waste water, but pigs do. The amount and extent of water wasted is associated with the device used to supply water to the pig.

For example, Tribble and co-

Table 1. Water use by pigs on cup versus nipple waterers. (Tribbel *et al.*, Texas Tech).

Item	Type of waterer			
	Cup		Nipple	
No. pigs	16		16	
Average daily gain, lb	1.65	(0.75)	1.62	(0.73)
Feed/gain ratio	3.0		3.0	
Total water used, [a] gal (l)	3382	(12,852)	1985	(7,543)
Average water used/pig/day, gal (l)	2.78	(10.6)	1.70	(6.5)

[a]Two pens of 8 pigs/pen; 76-day test.

workers at Texas Tech University found that pigs being supplied water with a cup waterer with a nose paddle to activate the water release valve used 70% more water than pigs getting water from a nipple waterer (Table 1).

Since the study at Texas Tech was conducted with growing-finishing swine, we decided to conduct a similar test to determine (1) if baby pigs would perform as well on nipple waterers as on cup waterers and (2) how much water would be used by baby pigs on the two types of waterers.

Nebraska Study

Crossbred pigs were weaned at 2-3 weeks of age and divided by age and weight into 24 nursery pens 5 ft. (1.52 m) × 5.75 ft (1.75 m) in size, six pigs per pen. There were equal numbers of barrows and gilts. All pigs were fed a 20% protein starter containing 20% ground oats. The diet was self-fed in a metal feeder providing 1.5 ft (.46 m) of trough space.

Twelve of the pens were equipped with cup waterers and twelve with nipple waterers. A water orifice 1.0 mm in diameter was used with the nipple waterers. The line water pressure was 40-50 psi (2.8-3.5 kg per sq cm).

The pens had concrete block walls 2.5 ft (.76 m) high on three sides and a metal panel gate on one end. Four feet (1.22 m) of the floor was solid concrete and 1.75 ft (.53 m) was a metal grate over a shallow flush trough.

Room temperature (3.25 ft (1 m) from the floor) was 87° F (30.6° C). A supplemental electric quartz infrared heater was used in each pen for the first week. The temperature was gradually reduced to 74° F (23.3° C) by the end of the third week. All pigs were weighed and feed records obtained weekly for the 25-day experiment.

Water usage was measured by a Triseal meter (courtesy Lincoln, Nebraska, Water System). Due to existing plumbing conditions, one

meter measured flow to five cup-watered pens, another meter measured flow to the twelve nipple-watered pens and a third meter measured flow for the remaining seven cup-watered pens. Water usage was considered only that ingested and wasted by the pigs and did not include water used for cleaning purposes.

To train the pigs to drink, a paper wad was stuck in the side of the nipple waterer so there was a small constant stream of water. During the 18 hour training period, 822 gal (3112 l) of water were used by the pigs on nipple waterers, but only 97 gal (368 l) were used by those exposed to cup-type waterers.

Results of the study are shown in Table 2. Average daily gain and feed conversion were similar between pigs receiving water from cup or nipple-type waterers. There was a tendency for pigs on cup waterers to be more efficient in feed conversion (5%). The most striking aspect of the results is the fact that pigs on the cup waterers used 72% more water than pigs on nipple waterers. The results are remarkably similar to the 70% difference in water usage observed by Tribble *et al.* for older swine when comparing cup versus nipple waterers.

We feel that the major difference in water usage by the baby pig is actually a difference in wastage. Pigs appeared to activiate cup waterers more frequently than nipple waterers (visual observation).

Aside from the economic considerations of water, if a swine unit had a manure pit 4′ × 8′ × 144′ it would only take 175 days to fill the pit if cup waterers were used as compared to 289 days with nipple waterers. The calculations are based on the assumption that solid waste and urine would replace water actually consumed. If you have to pump pits, type of waterer to use in the swine unit would merit consideration.

Cup waterers are not all bad, as the results of the two studies might suggest. There are some production systems where nipple waterers do not fit because of severe climatic conditions. However, equipment is being developed which will allow nipple waterers to be used outside in severe winter with no freeze-up.

Table 2. Cup versus nipple waterers for baby pigs (Nebraska Station).

Item	Type of waterer			
	Cup		Nipple	
No. pigs/treatment	72		72	
Initial wt., lb (kg)	11.2	(5.1)	11.2	(5.1)
Final wt, lb (kg)	28.8	(13.1)	28.1	(12.7)
Avg. daily gain, lb (kg)	0.68	(.31)	0.67	(.30)
Daily feed intake, lb (kg)	1.13	(.51)	1.16	(.53)
Feed/gain ratio	1.67		1.74	
Water used/hd/day, gal (l)	2.86	(10.8)	1.66	(6.3)

Alfalfa, Tallow, Gestation and Lactation

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Previous work with diets containing large quantities of alfalfa have indicated a reduction in piglet birth weight. This could be due to a reduction in available energy. There appears to be a close correlation between birth weight and number of pigs produced per litter. Available energy is essential in a balanced gestation diet. Animal tallow is a source of energy. Studies including this product in conventional swine diets have indicated an improvement in animal performance. Thus, the addition of stabilized tallow to gestating diets containing large quantities of alfalfa might increase the birth weight of the offspring and increase the pigs weaned per litter.

The objective of this study was to determine if there is an additive effect when replacing a portion of the diets (corn-soy or alfalfa) with stabilized tallow for gestating animals from approximately 90 days of gestation through 14 days following parturation.

Eighty-eight second litter crossbred sows were selected. They remained on their respective diet treatments for three consecutive farrowings (parities). A group of 44 animals were allotted to a control corn-soy gestation diet (C). A second group of 44 animals were allotted to a gestation diet formulated with 50% sun-cured alfalfa hay (A). These diets were each fed in pelleted form beginning when the sows were bred. Individual gestation feeding stalls accommodated feeding. The quantity of diet was such that each individual received 6000 kcal metabolizable energy per day, 4.3 lb (1.95 kg) and 5.2 lb (2.36 kg) for the basal and alfalfa diets, respectively. At about 90 days of gestation all animals were placed on a lactation diet. Fifty percent of each of the groups of sows were fed a tallow free lactation diet (CC) and (AC). The remainder of each group received a lactation diet where 8% of the corn was replaced with 8% stabilized tallow (CT) and (AT). These diets were fed at the rate of 2.72 kg/hd/day until farrowing. Following farrowing all animals were fed ad libitum. Ges-

Table 1. Composition of gestation diets.

Ingredient %	Diet C	Diet A
Yellow corn, ground	76.94	35.97
Soybean meal (44%)	15.00	10.0
Alfalfa hay, S-C, MB	2.50	50.0
Dicalcium phosphate	3.81	——
Monosodium phosphate	——	2.25
Limestone, ground	.15	.2
Salt, iodized	.5	.5
Trace mineral (Hi-Zn)	.1 [a]	.08[b]
Vitamin Premix[c]	1.00[d]	1.0[e]

[a]Contributed 200 mg Zn, 100 mg Fe, 54 mg Mn, 11 mg Cu, 1.0 mg Co and 1.5 mg I per kg diet.

[b]Contributed 160 mg Zn, 80 mg Fe, 43 mg Mn, 8.8 mg Cu, 0.8 mg Co and 1.2 mg I per kg diet.

[c]Finely ground corn was used as carrier.

[d]1044 IU vitamin A, 286 IU vitamin D_3, 2 mg riboflavin, 6.4 mg niacin, 8.4 mg calcium pantothenate, 591 mg choline chloride and 105.5 mct vitamin B_{12}/kg of diet.

[e]881 IU vitamin A, 238 IU vitamin D_3, 1.8 mg riboflavin, 5.3 mg niacin, 7.3 mg calcium pantothenate, 498 mg choline chloride and 88.9 mcg vitamin B_{12}/kg diet.

Table 2. Composition of lactation diets.

Ingredient, %	Diet LC	Diet LT
Tallow	——	8.00
Yellow corn, ground	54.71	46.71
Whole oats, ground	15.0	15.0
Soybean meal (44%)	15.0	15.0
Alfalfa hay, S-C, MB	4.13	4.13
Wheat bran, dry milled	7.5	7.5
Dicalcium phosphate	2.06	2.06
Salt, iodized	.5	.5
Trace minerals (Hi-Zn)[a]	.1	.1
Vitamin premix[b]	1.00	1.0

[a]Contributed 200 mg, Zn, 100 mg Fe, 54 mg Mn, 11 mg Cu, 1.0 mg Co and 1.5 mg I per kg diet.

[b]Finely ground corn was used as carrier. 1136 IU vitamin A, 92 IU vitamin D_3, 2.3 mg riboflavin, 8.2 mg calcium pantothenate, 15.9 mg choline chloride, 6.8 mg niacin and 7.7 mcg vitamin B_{12} per kg diet.

Table 3. Experimental data.

Item	Treatments CC	CT	AC	AT
Initial no. sows	22	22	22	22
No. litters (3 farrowings)**	42	42	57	60
No. live pigs/litter	11.2	11.1	11.9	11.2
No. weaned, 14 da.**	8.3	8.0	9.2	9.0
% survival	74.4	71.5	77.2	80.7

**P<.01

Table 4. Performance data as affected by diet treatments.

Item	Gestation Control	Gestation Alfalfa	Lactation Control	Lactation Tallow
Initial no. sows	44	44	44	44
No. sows farrowed (3 litters)**	31	39	33	34
No. live pigs	11.2	11.5	11.6	11.1
Pig birth weight* lb, (kg)	3.20 (1.45)	3.04 (1.38)	3.08 (1.40)	3.13 (1.42)
No. live, 7 da.	8.8	9.4	9.2	9.1
Weight, 7 da. lb (kg)	5.54 (2.51)	5.36 (2.43)	5.33 (2.42)	5.54 (2.51)
No. live, 14 da.**	8.2	9.1	8.8	8.6
Weight, 14 da. lb (kg)	8.58 (3.89)	8.29 (3.76)	8.25 (3.74)	8.57 (3.89)
Survival, %	73	79	76	78

*P<.05 Alfalfa vs Control
**P<.01 Alfalfa vs Control

tation and lactation diet formulations appear in Tables 1 and 2, respectively. Other than diet treatment differences management throughout the gestation and lactation phases of production was comparable.

Three Farrowings and Mortality

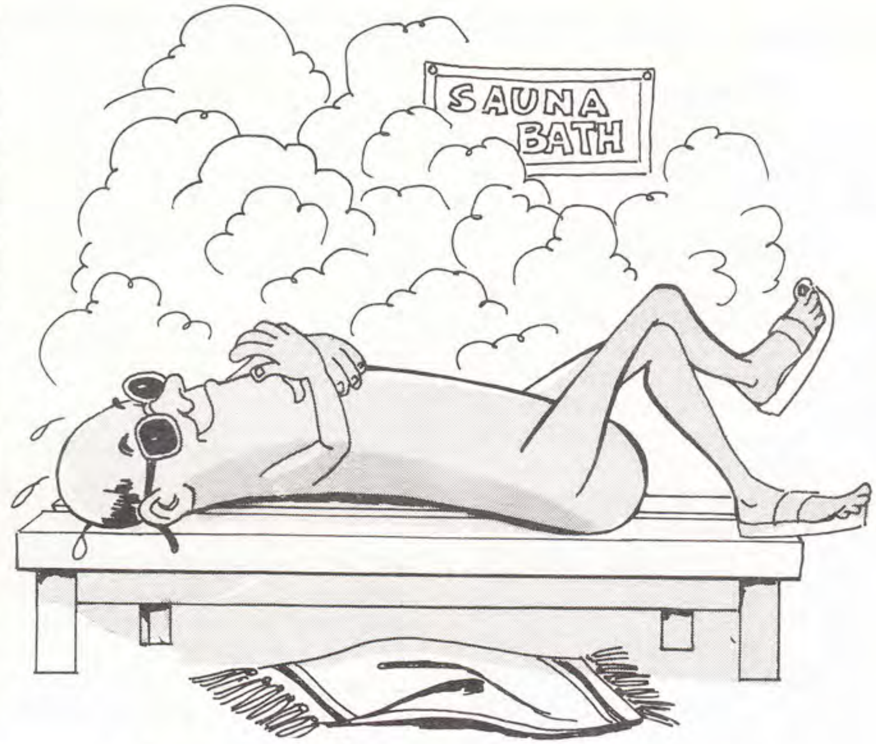
When starting with 88 sows and desiring to keep each of them for three successive farrowings there is a potential of 264 litters. However, there always seems to be a mortality because of some reason or another. Table 3 shows the performance of the sows that furnished three successive litters of pigs for each of the respective diet treatments.

The data indicate a highly significant increase in the number of sows remaining on the study when fed the diet containing alfalfa. Eighty nine percent of the initial sows on the alfalfa diet completed three successive gestations compared to 69% for the sows on the corn-soy diet. When comparing the tallow lactation fed group with non-tallow fed groups 77% of the tallow and 75% of the non-tallow fed animals completed three gestations.

Piglet Birth Weight

Birth weight of the offspring (Table 4) was slightly increased for sows with access to tallow. However, this little increase didn't appear to carry through for the percent of pig survival of sows on the corn-soy diet. There did appear to be a little advantage in offspring survival for the pigs from the sows that received alfalfa plus tallow. Overall the number of pigs weaned was significantly higher for the alfalfa fed sows regardless of tallow treatment.

The data collected in this study (Table 3) indicates the alfalfa gestation diet to be superior in the reduction of sow mortality, an increase approaching one pig per litter weaned at 14 days and an increase in survival of pigs born alive. The replacement of 8 percent of the corn of the lactation diet with 8 percent tallow didn't contribute to increase in overall animal performance.



Smokehouse Humidity Affects Texture and Energy Loss

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Processed meats are generally smoked and cooked during manufacturing to develop flavor, preserve the product, make new products, develop color, and to protect the product from oxidation. Product color, shrinkage during cooking, and stability of the emulsions can be affected by relative humidity during the cooking steps. Texture and palatability as measured by tenderness, firmness, and juiciness of products have been shown to change with changes in the relative humidity during processing.

Processing time can be reduced by increasing the relative humidity in a smokehouse. The amount of heat (BTU/lb dry air) in the smokehouse can be doubled simply by doubling the relative humidity. The reduced processing time is due to reduced evaporation because less moisture is lost from the product during high humidity processing. The food industry in the United States is rated sixth in total energy usage. One third of the 6,100 trillion BTUs used in 1975 were used for food processing. Energy costs have been increasing at a rate of 30% per year. Heated air is exhausted from a smokehouse through the smokestack at a rate of 1 to 4 cubic feet per minute per square foot of floor area during drying. This indicates a large amount of energy is escaping directly into the atmosphere.

This article reports results of a study to determine the effects of relative humidity during processing on product characteristics. Chemical and physical measurements and consumer sensory panels were used to evaluate the products. In addition, the study evaluated smokehouse thermal ef-

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Smokehouse Humidity

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ficiency by comparing losses from the three different relative humidity treatments.

Bologna Processing

Raw bologna emulsions were obtained from American Stores Packing Co., Lincoln three days a week over a four-week period. The bologna was processed in the smokehouse at the Loeffel Meat Laboratory, University of Nebraska–Lincoln. This standard bologna emulsion was selected because it was very homogenous and consistent in composition from week to week. Following an initial one hour drying cycle to help set up the skin on the bologna, the products were processed at either 35, 55, or 75% relative humidity. Cooking times and temperatures as well as the heat loss up the smokehouse exhaust stack were measured. After cooking to an internal temperature of 155° F (68.3° C), the bologna was showered in cold water and air dried before chilling.

The raw emulsion and the finished cooked bologna were sampled for compositional analyses. In addition to chemical composition determinations, the raw emulsions were tested for stability (emulsion breakdown), capacity (ability to hold additional fat) and back extrusion. Texture estimates of the finished bologna were made on the Instron Universal Testing Machine. Chemical composition and color were measured at two days and three weeks post-processing.

Table 1. Raw emulsion analyses of bologna.

	Mean values[a]	S.E.
Stability[b]		
Moisture (ml)	2.808	.58
Fat (ml)	0.433*	.08
Solids	0.150	.05
Emulsion capacity[c] (ml)	123.250	2.83
Back-extrusion[d] (cm^2)	32.880	2.07
Fat (%)	24.81	.16
Moisture (%)	58.05	.75
Protein (%)	11.39	.38
Ash (%)	2.72	.06
Salt (%)	2.39	.10
Nitrite (ppm)	67.75	11.72

*Significant differences ($P<0.05$) between samples.
[a]From 12 observations
[b]Stability = ml released from 34 g emulsion
[c]Emulsion capacity = ml oil/12.5 g tissue.
[d]Area under force-distance curve

Table 2. Effect of relative humidity (RH) on bologna, color and chemical analyses.

	Treatment means[a]			
	35% RH	55% RH	75% RH	S.E.
Gardner color score				
"L" brightness [c,d]	55.019	56.569	53.825	.63
"a_L" redness	+11.819	+12.359	+11.778	.06
"b_L" yellowness	+ 5.619	+ 6.009	+ 5.597	.12
Fat (%)	26.78	27.01	26.43	.89
Moisture[b] (%)	55.41	55.48	55.70	.92
Protein[b] (%)	12.40	12.18	12.17	.15
Ash (%)	3.00	2.94	2.94	.07
Salt (%)	2.71	2.56	2.65	.11
Nitrite (ppm)	26.03	23.58	26.35	2.05

[a]Gardner values = 32 observations, chemical analyses = 8 observations per treatment
[b]Significant differences ($P<0.05$) with time of analysis.
[c]Significant difference ($P<0.01$) with time of analysis.
[d]Significant ($P<0.05$) quadratic treatment effect.

Sensory panels evaluated the bologna three weeks post-processing. Fifty consumers each week rated samples from each of the three treatments for color, flavor, juiciness, texture, and overall acceptability.

Results and Discussion

Raw emulsions used in each treatment over the four weeks of the experiment were consistently uniform as shown by chemical composition, emulsion stability, capacity, and back extrusion measures (Table 1). While fat phase stability differed from week to week, the mean fat loss of 0.4 ml was considerably smaller than typically reported by other workers. Variation in nitrite levels was high due to the time differences in analyzing for nitrite.

There was no difference found due to processing treatment for the cooked chemical analyses (Table 2). Smokehouse relative humidity caused significant quadratic effects in the Gardner Color Score "L" and "b_L" treatment means. The "L" value significance indicated a darkening in color going from the 55 to 75% treatments, while little change occurred between the 35 and 55% treatments. The "b_L" values indicated an increase in the yellow component of the color from the 35 to 55% treatments, and then a decrease from the 55 to 75% relative humidity treatments.

Physical texture measures showed significant differences due to treatment effects for peak force values of the LEE-Kramer and compression shear tests (Table 3). The LEE-Kramer results showed a firmer product at the 35% versus the 55% and 75% treatments. The compression shear test indicated a firmer product at both the 35% and 55% RH than at 75% RH. No significant differences due to treatments were found for the Warner-Bratzler shear measures.

Consumer panel scores (Table 4) showed no significant differences due to relative humidity for color, flavor, juiciness, and overall acceptability. Differences that existed in the mechanical measures of texture due to the treatments were too small to be detected by an untrained consumer panel. A total of 206 panelists took part in the study, 148 males and 58 females.

Relative humidity caused significant linear treatment differences in cooking losses. Mean treatment values (Table 5) indicated that cooking losses decreased with increasing humidity during processing. The added moisture in the smokehouse at higher relative humidities retarded cooking losses by slowing the transfer of moisture from the interior to the surface of the product. The significant differences in cooking losses between

Table 3. Effect of relative humidity (RH) on physical texture measurements.

	Treatment means[a]			
	35% RH	55% RH	75% RH	S.E.
Warner-Bratzler Peak force (kg)	0.503	0.435	0.527	.04
LEE-Kramer[b] Peak force (kg)	1.129	1.056	1.055	.02
Compression-Shear[b] Peak force (kg)	22.556	22.500	19.425	.81
Compression test Hardness (kg)	90.813	85.750	77.938	5.91

[a]From 16 observations per treatment.

[b]Significant (P<0.05) linear treatment differences.

Table 4. Effect of relative humidity (RH) on consumer sensory panel scores.[a]

	Treatment means[b]			
	35% RH	55% RH	75% RH	S.E.
Color score	3.4	3.4	3.5	.06
Flavor score	3.5	3.5	3.5	.08
Juiciness score	3.4	3.5	3.5	.06
Texture score	3.4	3.5	3.5	.07
Overall acceptability score	3.5	3.5	3.5	.06

[a]Scores: 5=Extremely liked and 1=Extremely disliked.

[b]From a total of observations per treatment.

treatments may have affected the chemical composition of the products. Processing time was decreased with increasing relative humidity levels (Table 5). The decrease in processing time with increased humidity was caused by the abundance of energy in the added moisture in the smokehouse environment. A greater reduction in processing time was found between the 75% and 55% treatments than between the 55% and 35% treatments. This is reflected in a 20% increase in energy loss between the 55% and 75% treatments compared to a 39% increase in energy loss between the 35% and 55% treatments.

Conclusions

The effects of increasing smokehouse relative humidity for processing bologna were significant decreases in cooking losses and processing times. Conversely, energy loss from the smokehouse was found to increase significantly with increasing relative humidity. Faster processing and increased yields came at the expense of energy efficiency. No significant differences due to relative humidity treatments were observed in the consumer sensory panel results. Thus, any product differences caused by the treatments were slight. If alternate uses and recapturing of smokehouse exhaust stack energy could be found, then the loss of energy could be reduced. Acceptable quality products can be processed at the high relative humidity levels (75%).

Table 5. Effect of relative humidity (RH) on percent cooking loss, processing time and total energy loss.

	Treatment means			
	35% RH	55% RH	75% RH	S.E.
Cooking loss [ab] (%)	4.248	3.605	3.166	.09
Processing times[ac] (hr)	7.753	7.007	6.006	.14
Energy loss[ac] (BTU)	396967.250	552697.750	631644.000	24300.00

[a]Significant (P<.01) linear treatment differences.

[b]From 16 observations per treatment.

[c]From 4 observations per treatment.

Finishing Phase

Growth Promotants, Housing

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Pork producers are under increasing pressure to reduce the use of certain feed additives. Since pigs cannot be fed, housed, and managed in a stress-free situation response to some antimicrobial additives will be obtained. Without these additives the cost of production would be much higher. The question of which additive to use and when is often more economic than scientific. Continued evaluation of feed additives is necessary.

The Study

The effects of two additives, two building types and two dietary fat sources were studied on finishing pigs. ASP-250[1], Flavomycin[2] and no additive were compared in both a modified open front (MOF) and an environmentally regulated building. All diets were supplemented with 5% added fat. Half of the diets contained liquid tallow and half contained dry fat (liquid fat on a carrier). The 240 pigs used in the study averaged 101 pounds (46 kg) at the start of this study.

Before the test all pigs were on ASP-250 at the 5 pound per ton level. Thus the ASP-250 treatment groups continued the additive with no change in drug level. Visual evaluation indicated that nearly 30 percent of the pigs had symptoms of atrophic rhinitis (distorted snouts and/or crescent shaped dirt patches below the eyes).

All pens were half slotted. The pen arrangement was the same in each building. Utility meters on each building allowed measurement of utility use on an individual

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Growth Promotants, Housing

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building basis. The MOF had no supplemental heat and was gravity ventilated (non-mechanical) while the ER building had mechanical ventilation and supplemental heat.

Results

There was little difference in performance between the two buildings (Table 1). The most important difference was utility cost. The total for the MOF was $0.56 compared to $169.35 for the ER building. The practical importance of a building designed for natural ventilation can only be realized when animal performance is weighed against utility and initial construction costs.

The effect of buildings and additives on gain and feed:gain is shown in Table 2. Building effects were somewhat different with each additive type. When additives (ASP-250 and Flavomycin) are pooled across buildings and compared with the controls there is little if any advantage credited to the additives. This is especially interesting since, as mentioned earlier, about 30 percent showed visual symptoms of atrophic rhinitis.

The ASP-250 was removed from the pigs' diet for the last two weeks of the study. No other additive changes were made. Table 3 shows the performance of all three groups after withdrawal and for the previous two weeks. Withdrawal of ASP-250 did not reduce gain and appeared beneficial to feed:gain.

Lack of response to either ASP-250 or Flavomycin during the finishing phase supports conclusions others have made that maximum response to most additives is achieved during the growing periods with little response during the finishing period. Flavomycin has been reported to give a response in finishing swine. We did not observe this. The practical significance of this is that ASP-250 can, in most cases, be withdrawn after 100 to 125 pounds with no reduction in performance. Widespread use of this practice should reduce the incidence of sulfa residues in pork carcass tissues.

In the past, considerable work from the Nebraska Experiment Station has shown that tallow added at the rate of 5 percent per ton results in an improvement in feed:gain of 8 to 12 percent. However, there are physical problems in working with melted tallow on the farm. As a consequence, a dry fat product was compared with liquid tallow—both at the 5 percent level. Results are shown in Table 4.

Results suggest that dry fat (liquid fat dispersed on a carrier) and tallow were about equal. Assuming dry fat was equal in cost to tallow, this would greatly simplify mixing at the farm level. However, because of the processing cost involved in drying fat, this form is considerably more expensive than tallow at the present time.

Conclusions

This winter study showed that the MOF gravity ventiliated building was equal to the ER building in promoting gain and feed efficiency during the finishing phase. Earlier studies showed this was true during the growing phase, starting at 40 pounds. The savings in utility cost in favor of the MOF is major. In addition the fear of electrical power failures is eliminated with the MOF building.

The addition of either Flavomycin or ASP-250 during the finishing phase benefited performance only slightly. Further evidence of older pigs' ability to do without additives was clearly shown during the withdrawal of antibiotics early in the finishing period.

Dry fat and tallow supported equal performance in this study. The cost difference generally favors tallow to the extent that dry fat probably can be used only in special diets.

[1]ASP-250; American Cyanamid; 100 gm Aureomycin, 100 gm sulfamethazine, 50 gm penicillin per ton (.91 m ton)

[2]Flavomycin; American Hoechst Corp.; 2 gm/ton (2.2 gm/m ton)

Table 1. Effect of housing on pig performance and energy usage in winter during the finishing period.

	Modified open front (gravity ventilation)	Environmentally regulated (mechanically ventilated supplemental heat)
Avg. initial wt., lb (kg)	100.8 (45.8)	102.1 (46.4)
Avg. final wt., lb (kg)	205.8 (93.5)	205.3 (93.3)
Avg. da. ga., lb (kg)	1.91 (.87)	1.87 (.85)
Feed:gain	3.19	3.17
Utility usage,[a]	$ 0.56	$169.35

[a]Based on electricity cost of $.04/kwh and gas cost of $.37/gal. Feb. 22-Apr. 18, 1978. University of Nebraska Northeast Station, Concord.

Table 2. Effect of additives or housing on pig performance during the finishing period.

	Control			ASP-250			Flavomycin		
	ADG,	lb (kg)	F:G	ADG,	lb (kg)	F:G	ADG,	lb (kg)	F:G
MOF	1.87	(.85)	3.22	1.93	(.88)	3.20	1.92	(.87)	3.15
ER	1.86	(.84)	3.18	1.90	(.86)	3.19	1.85	(.84)	3.16
Avg.	1.86	(.84)	3.20	1.92	(.87)	3.19	1.88	(.85)	3.16

Table 3. Additive withdrawal effect.

	Mar. 28-Apr. 6	Apr. 6-Apr. 18 withdrawal period	Mar. 28-Apr. 6	Apr. 6-Apr. 18 withdrawal period
	Avg. Da. Ga. lb (kg)		Feed:Gain	
ASP-250	1.81 (.82)	1.96 (.89)	3.38	3.29
Flavomycin	1.86 (.84)	1.99 (.90)	3.26	3.30
Control	1.77 (.80)	1.94 (.88)	3.34	3.40

Table 4. Effect of fat type on performance.

	Dry fat[a]	Tallow[b]
Avg. da. ga., lb (kg)	1.89 (.86)	1.89 (.86)
Feed:gain	3.20	3.16

[a]Hol Milc 7-6, Merrick Foods, Union Center, Wisconsin.
[b]Bleachable fancy tallow, Natural Renders, Bellevue, Nebraska.

Manure Management Systems

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Manure management must be considered in planning new or modified livestock production facilities. Selection of a manure management system is based upon factors such as cost, potential for air and water pollution, labor requirements, site considerations, land application considerations, operator preference, system flexibility, and dependability. There is no single best system for all operations. Each system has advantages and disadvantages which must be considered.

Covered Confinement

In the early years of raising livestock in confinement, the common practice was to use solid floors and bedding. Urine was absorbed by the bedding and the total manure was then hauled as a solid. In some instances, no bedding was used and the manure was handled as a semi-solid or liquid. Modifications of these systems are still in use, but use is declining because of bedding shortages and high labor requirements. They do have the advantage of minimum nitrogen loss by volatilization as compared to other methods of manure management.

More recently confinement facilities with liquid manure systems have gained popularity. The procedure is to use partly or totally slotted floors, allowing the manure to drop directly into under-floor storage pits or tanks. All the manure can be stored in the pit and periodically hauled and spread on the land with a tank wagon.

Manure storage requirements for finishing hogs is generally figured at 1.0 cubic foot per 1000 pounds of hog per day (0.028 cubic meter per 454 kilograms per day). Under no circumstances should the pit or tank be sized for less than three months storage. When land is accessible and weather permits, the manure is hauled to the field. To help assure accessibility to land when the pit is full, a six month storage time is recommended. Because a pit can never be completely emptied, some additional depth should be added to the overall design.

Systems which combine a pit and an anaerobic lagoon or outdoor storage for the pit overflow have worked well for many producers. Allowing the liquids to overflow into a lagoon results in a greater concentration of solids in the pit. Because of this, the pit should be pumped as soon as conditions permit in order to lessen the difficulty of pumping manure with a higher solids concentration. Some pit agitation is required to remove the solids after they have been allowed to build up over a period of time.

Agitation of manure releases noxious gases and creates dangerous and possibly lethal conditions (if manure must be agitated with animals in the building, use full ventilation and watch for signs of ill effects. At the first indication of illness, discontinue agitation and let the ventilation system dissipate the toxic gases). This system gives the producer more flexibility in spreading operations and allows use of the less costly outdoor earthen storage. However, additional equipment will be necessary to efficiently pump the lagoon effluent onto adjacent cropland.

Another variation of the liquid manure system is the use of scrapers, either in open gutters or under slats, to move the manure to a storage unit outside the building. The storage may be open earthen pits, underground tanks or above-ground tanks. Generally, above-ground tanks are more expensive than earthen pits, but above-ground tanks may be preferable when groundwater or bedrock is close to the soil surface. Since the manure is not allowed to accumulate in the building, odor levels in the building are usually significantly reduced. The liquid manure itself is still handled after storage in the same way as from under-floor storage pits.

Systems for handling manure as a liquid have been popular and successful because of the minimal labor involved. Although some nitrogen is lost by volatilization, pit or tank storage systems are very good in conserving fertilizer nutrients when compared to anaerobic lagoon treatment of swine manure.

Oxidation ditches have been used with slotted-floor systems to aerobically treat liquid manure. The aerobic action is achieved through the mechanical introduction of air into the manure. The major advantage of oxidation ditches is the reduction of the odors inside the building and reduction of the amount of manure to be handled as a solid. Treated oxidation ditch effluent is usually stored in a lagoon until it is finally pumped onto cropland. The main disadvantages of oxidation ditches are investment and maintenance costs and the energy requirements. Oxidation ditches combined with anaerobic lagoons also have high nitrogen losses.

Removal of animal manure hydraulically from buildings by flushing has been successful in both Europe and the United States. The hydraulic system can be used to wash out a shallow open gutter — 3 to 5 inches deep — (7.6 to 12.7 cm) or a pit or channel be-

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Manure Management

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neath slotted floors. Odors inside the building are greatly reduced because the manure is washed into a lagoon at frequent intervals. In most systems a tank of flush water is stored at one end of the gutter and rapidly released several times a day, washing the manure (liquid and solid) out of the building. In farrowing and nursery buildings flushing is under slotted floors.

In growing — finishing houses, some flushing water can be recycled from a lagoon having 2-stages or cells. The first cell receives the manure flushed from the building and overflows into the second cell. Because the second cell is relatively clean, it is the source of the recycled flushing water. Recycling flush water reduces the large demand for fresh water and the excessive amount of liquid resulting if all fresh water is used.

Lagoons serve a dual purpose in manure management in that they function both as a treatment and storage facility. Lagoon effluent can be spread on cropland by conventional irrigation equipment, thereby eliminating all hauling. Periodically, lagoons must be pumped down to avoid overflow or to control salt accumulation which leads to lagoon failure. Before pumping, determine the land application rate based on an analysis for fertilizer nutrients and salt concentrations in the lagoon effluent. Nitrogen losses in lagoons can be as high as 80 percent. For this reason lagoon systems are preferable when insufficient cropland is available for full utilization of fertilizer nutrients in manure.

When lagoons become a source of objectionable odors, floating aerators can be used to aid in more complete treatment of the liquid wastes and help reduce odor emmissions. However, due to the high power requirements, aeration is normally considered uneconomical and unnecessary except when complete odor control or a very high level of treatment is required. Proper sizing of all system components will generally eliminate the need for aeration.

Table 3. Estimated nitrogen losses during storage, treatment, and handling for various waste-management systems.[a]

System	Nitrogen[a]
Liquid pit or silo storage liquid spreading	30 to 65
Anaerobic lagoon, irrigation, or liquid spreading	60 to 80
Oxidation ditch, anaerobic lagoon, irrigation, or liquid spreading	70 to 90
Bedded confinement, solid spreading	30 to 40
Open lot, solid spreading, runoff collected and irrigated	50 to 60

[a]Nitrogen loss values assume that manure is applied to the ground surface and is incorporated within a few hours.

Table 1. Investment and annual costs of swine facility alternatives.

System	Cost per hog marketed	
	Investment	Annual
Open lot, solid floor w/shed	58.93	10.67
Modified open-front, partly slotted-floor finishing	96.13	17.33
Enclosed, totally slotted-floor finishing	115.73	20.80
Enclosed, flush system, anaerobic lagoon	88.93	16.00

Table 2. Approximate fertilizer nutrients per animal per year in excreted manure.

Swine	Wt.	Nitrogen	Phosphorus[a]	Potassium[b]
(English units)	lb		lb/yr.	
Nursery pig	35	5.7	1.9	3.8
Growing pig	65	11	3.6	7.1
Finishing	150	25	8.2	16
	200	33	11	22
Gestating sow	275	23	7.7	15
Sow and litter	375	84	28	55
Boar	350	28	9.5	19
(Metric units)	kg		kg/yr.	
Nursery pig	16	2.6	.9	1.7
Growing pig	29	5.0	1.6	3.2
Finishing	68	11.3	3.7	7.3
	91	15.0	5.0	10.0
Gestating sow	125	10.4	3.5	6.8
Sow and litter	170	38.1	12.7	24.9
Boar	159	12.7	4.3	8.6

[a]To convert to P_2O_5, multiply by 2.3

[b]To convert to K_2O, multiply by 1.2

Open Feedlots

Depending somewhat on the area, large numbers of pigs are still produced in open feedlots. The manure management procedure has not changed much in past years. Solid manure is scraped from the lot surface and either hauled directly to cropland or stockpiled (in some instances, composted) before land application. Recent federal and state water pollution laws have required many open feedlots to control precipitation-caused lot runoff from precipitation. Runoff is usually collected, stored, and eventually pumped back onto cropland. The housing or shelter associated with open lot systems has little effect on the manure management except possibly the addition of some bedding to the manure solids hauled. Clear roof water should be guttered and directed away from the runoff control system unless additional water is needed for irrigation and the runoff holding pond has been sized to include the extra volume.

In open lot systems, most of the fertilizer nutrients are retained in the solid manure portion. A South

Table 4. Nitrogen losses at various incorporation intervals.

Time between application and incorporation (days)	% Nitrogen loss		
	Warm, dry soil	Warm, wet soil	Cold, wet soil
1	20 - 40	5 - 20	0 - 10
4	30 - 50	10 - 30	5 - 15
7 or more	40 - 60	20 - 40	5 - 20

Dakota study indicated that less than 5 percent of the excreted nutrients leave the lot in runoff. However, because of ammonia volatilization and leaching of nitrates, only about 50 percent of the excreted nitrogen will be recovered when handling the solids.

System Costs

It is difficult to separate the cost of manure management from total facility costs. For this reason, costs are presented for total facilities with different manure management systems, with the realization that considerations and factors other than just manure management affect the selection and cost differences. A cost comparison from Illinois for four types of swine facilities is presented in Table 1.

Manure Fertilizer Value and Nutrient Losses

The fertilizer value or crop nutrient content of excreted manure varies with age and species of animals, ration, environment, and other factors. During treatment, storage, and handling, nutrients will be lost or converted to other forms, thus affecting their availability for use by growing plants. For example, large quantities of ammonia nitrogen can be lost from manure by volatilization into the atmosphere. Phosphorus and potassium compounds may settle to the bottom of lagoons and become available only when the sludge is removed. Since the manure actually applied to the land is so variable, a periodic analysis of the manure at each installation is necessary to accurately predict fertilizer value.

In the absence of specific analyses, the information in Tables 2 and 3 can be used to estimate excreted nutrient values and nutrient losses to arrive at the approximate fertilizer value of the land-applied manure. Nitrogen losses shown in Table 3 do not include losses associated with land application methods. If manure is not incorporated within a few hours after spreading, up to 60 percent of nitrogen remaining after storage can be lost as shown in Table 4. It is estimated that nitrogen losses from soil injection or immediate incorporation will be less than 5 percent on warm, dry soils.

The following example shows how to estimate the approximate value of land-applied manure.

Example: Assume a hog operation for finishing feeder pigs with a capacity for 500 growing pigs having an averge weight of 65 lb (29.5 kg) and 500 finishing hogs at an average weight of 150 lb (68 kg). Buildings with totally slotted-floors and liquid manure pits are used. From Table 2, approximate amounts of nutrients produced in manure can be calculated.

	lb/yr	kg/yr
N: 500 pigs × 11 lb/yr (5.0 kg/yr)	**5,500**	**2,500**
500 hogs × 25 lb/yr (11.3 kg/yr)	**12,500**	**5,650**
Total	**18,000**	**8,160**
P: 500 × 3.6 lb/yr (1.6 kg/yr)	**1,800**	**1,818**
500 × 8.2 lb/yr (3.7 kg/yr)	**4,100**	**1,864**
Total	**5,900**	**2,682**
K: 500 × 7.1 lb/yr (3.2 kg/yr)	**3,500**	**1,614**
500 × 16 lb/yr (7.3 kg/yr)	**8,000**	**3,636**
Total	**11,550**	**5,250**

If the nitrogen loss is estimated at 40% (Table 3) and current fertilizer prices are assumed, the total value of nutrients reaching the soil annually could be calculated as follows:

N: 18,000 lb/yr × .6 × \$.15/lb = (8.160 kg/yr × .6 × \$.33/kg)	**\$1620**
P: 5,990 lb/yr × \$.44/lb = (2,680 kg/yr × \$.97/kg)	**\$2596**
K: 11,550 lb/yr × \$.10/lb = (5,240 kg/yr × \$.22/kg)	**\$1155**
Total	**\$5371**

Fertilizer values shown in Table 5 were calculated using the example procedure.

Annual system costs, as presented in Table 1 and annual fertilizer value as presented in Table 5 can be used to compare the various types of systems. For example, the annual cost of open lot is \$10.67 per hog marketed versus \$17.33 for the modified open front. However, the fertilizer value for the open lot is \$3.00 per hog and \$3.30 for the modified open front. It is obvious that the increased fertilizer value is not adequate by itself to justify the more expensive swine facility. However, fertilizer value is only one aspect of selecting a manure management system and many other considerations such as cost of gain, system flexibility, odor potential, labor requirements, operator preference, and other cost and non-cost factors are also important and must be taken into account.

Careful planning and good management will help reduce costs and increase the benefits of each part of the system. It is only through careful consideration of all factors involved in the total enterprise that the "best" manure management system for your operation can be selected.

Table 5. Fertilizer value of manure from swine facility alternatives.

System[a]	Annual value of fertilizer nutrients per hog marketed
Open lot, solid floor w/shed	\$3.00
Modified open-front, partly slotted-floor finishing	3.30
Enclosed, totally slotted-floor finishing	3.30
Enclosed, flush system, anerobic lagoon	2.10

[a]32 sows farrowing, 6 farrowings per year; or 192 litters, 7.5 pigs per litter. Manure quantities are for pigs raised from farrow to finish plus manure from breeding stock.

Low Sodium Bologna

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Salt has been an important food ingredient for centuries. The body has a definite need for adequate consumption of salt. The salt shaker on the table is commonly, sometimes almost indiscriminately, used to "bring out" the flavor of our food. The desire for the "salty" taste is a real one. When the body needs more salt, we tend to sprinkle more salt on our foods. When our bodies need less salt, we unknowingly sprinkle less salt on our food or the food seems too salty. There are many foods that already have salt added. Processed meats are examples. While we typically sprinkle salt over roasts or steaks, seldom do we add salt to hot dogs, bologna, ham, bacon, sausages, or other such processed meats. The salt is already there.

Besides flavor, salt is added for its preservative and protein solubilizing properties. If salt is added at extremely high levels (7% or higher), the meat product will not spoil even at room temperature. Country hams and beef jerky are examples of meat products "preserved" with salt. In other types of meat products, such as bologna or frankfurters, salt is used to "form" an emulsion by solubilizing protein. The fine texture of an emulsion product is made possible by the salt acting on some of the meat proteins making them soluble. These soluble proteins act like "glue" to bind and hold the very fine particles of meat tissue together. Emulsion products would be virtually impossible to make without salt.

Salt Use and Health Studied

While salt plays important roles in meat processing, the practice of adding salt to any food product has recently come under intense scrutiny. The reason is that high salt consumption has been related to hypertension and high blood pressure. More specifically, it is the sodium in table salt (sodium chloride) that is associated with these conditions. Sodium allows the body to retain fluids. Excess retained fluids results in increased blood volume in the body. Excessive blood volume may cause high blood pressure. A similar elevation of blood pressure may be caused by constriction of blood vessels unrelated to the sodium level in the body. While it is only suspected at this time that sodium is directly related to high blood pressure and hypertension of some individuals, many individuals having high blood pressure are typically placed on low-sodium diets.

The concerns with sodium additions to food products and especially meat products could result in regulations limiting the amount of sodium added to meat products. If regulations limiting sodium were too restrictive, production of frankfurters, bologna, ham and bacon would be difficult if not impossible. The challenge to the meat industry then would be to produce low-sodium meat products without sacrificing quality or desirability of those products.

Low Sodium Research

Work at Loeffel Meat Lab, University of Nebraska–Lincoln has been conducted on methods of producing low sodium bologna products. Neutral salts similar to sodium chloride (NaCl) were used as substitutes. These salts were magnesium chloride ($MgCl^2$), and potassium chloride (KCl). In addition, tripotassium phosphate (K_3PO_4) was used to improve the firmness of the low-sodium products. A standard formulation was used for each product except for variations in salt types and quantities. This formulation included half pork and half beef trimmings which were emulsified with a cure containing sugar, nitrite, erythorbate, and a bologna seasoning mixture.

Three groups of treatments were used in the study. The first group contained salts at a level

Table 1. Nine treatments used in study.

Control[a]			Low salt level[b]					
Group 1			Group 2			Group 3		
Normal salt level			No phosphates			Phosphates added[c]		
NaCl	$MgCl_2$ NaCl	KCL NaCl	NaCl	$MgCl_2$ NaCl	KCl NaCl	NaCl K_3PO_4	$MgCl_2$ NaCl K_3PO_4	KCl NaCl K_3PO_4

[a]Each normal salt level treatment had an ionic strength of 0.42 or 2.5% sodium chloride equivalent.

[b]Each low salt level treatment had an ionic strength of 0.21 or one-half of the normal level of sodium chloride equivalent.

[c]Phosphates added had an ionic strength of 0.042.

Table 2. Means[a] and standard errors of cook loss, extrusion force and pH of uncooked emulsions.

	Normal salt level			Low salt level: No phosphates			Low salt level: Phosphates added			Standard error
	Na	Na & MG	Na & K	Na	Na & Mg	Na & K	Na	Na & Mg	Na & K	
Cook loss (ml)	0.87	2.23	0.72	4.35	5.17	3.37	1.23	1.58	1.07	0.43
Extrusion force[b]	1.63	1.28	1.61	1.51	1.39	1.39	1.52	1.61	1.53	0.02
pH	5.9	6.0	6.1	6.0	6.0	6.1	6.3	6.4	6.3	0.07

[a]Two observations per treatment.

[b]Force (kg) per 10 gm of uncooked emulsion.

normally found in bologna today. The second group contained only half the normal level of salt typically added to bologna. The third group was the same as the second group except that phosphate was added to each treatment. Within each group the treatments were sodium chloride alone, sodium chloride and magnesium chloride in equal strengths, and sodium chloride and potassium chloride in equal strengths. With three treatments in each of three groups, nine different treatments were tested in the study (Table 1).

To determine the effects of reducing sodium and partially replacing sodium with other salts on the uncooked emulsion properties, three measures were used: (1) the Townsend emulsion stability test measures fluid loss from cooking a sample in a test tube, (2) pH measures the acidity of the emulsion, and (3) an extrusion of the emulsion using an Instron Universal Testing Machine measures the viscosity-elasticity of the emulsion. The mean values and standard errors of these measures are shown in Table 2.

Lowering the salt level (group 2) decreased the stability of the emulsion since there was a higher loss of fluid. However, adding a small amount of phosphate (group 3) improved the stability to a level near that of the normal salt level (group 1). In group 1, partial replacement of sodium chloride with magnesium chloride gave lower stability values. Magnesium had a similar adverse effect in the low salt group, but phosphate diminished the adverse effect considerably. Similar results are shown with the extrusion force measure. The low salt group was generally less visco-elastic than the normal salt group or the low salt group with added phosphate. The pH measure differs only in the added phosphate group. This higher pH, caused by the phosphate, probably accounts for the firmer, more stable emulsion when compared to the low salt group without phosphates.

After the bologna was cooked in the smokehouse, several measures were used to indicate the textural properties of the finished product. Two Instron measures used were the LEE-KRAMER shear test which has multiple blades that shear the sample and the COMPRESSION test which compresses the sample a specific distance between two flat plates. The compression test is used to indicate the hardness, springiness and cohesive properties of the bologna product. In addition, pH was measured as in the uncooked emulsion samples. The means and standard errors for these measures are shown in Table 3.

Results with the cooked bologna were similar to the uncooked emulsion measures. In general, low salt levels made the bologna softer, less cohesive and more deformed during compression than the normal salt group or the low salt group with added phosphate. In the normal salt group, magnesium chloride gave more adverse effects than the potassium chloride. The higher pH of the low salt group with added phosphate probably accounts for the improved textural properties compared to the no phosphate, low-salt group.

Conclusions

It is obvious from these results that reduced sodium bologna can be produced which has physical properties similar to bologna with normal sodium chloride levels. The five formulations which appeared to be closest in their properties are: (1) normal sodium chloride level, (2) normal salt level with equal strengths of sodium and potassium chloride, (3) low salt level with sodium chloride and phosphates, (4) low salt level with equal strengths of sodium and magnesium chloride with phosphates, and (5) low salt level with

(continued on next page)

Table 3. Means[a] and standard errors of Lee-Kramer force, compression hardness, deformation and cohesiveness of cooked bologna products.

	Normal salt level			Low salt level: No phosphates			Low salt level: Phosphates added			Standard error
	Na	Na & Mg	Na & K	Na	Na & Mg	Na & K	Na	Na & Mg	Na & K	
Lee-Kramer force[b]	1.34	.94	1.19	1.06	1.06	.96	1.15	1.20	1.08	0.03
Hardness	81.1	61.8	103.7	52.6	64.9	55.6	80.8	81.1	76.2	4.0
Deformation (mm)	2.1	5.7	1.7	4.8	4.5	5.2	2.5	2.3	2.6	0.44
Cohesiveness	0.30	0.35	0.39	0.30	0.33	0.34	0.37	0.35	0.40	0.03
pH	6.0	6.3	6.3	6.0	6.0	6.0	6.2	6.6	6.5	0.06

[a]Two observations per treatment.

[b]Force (kg) per gram of bologna.

Low Sodium Bologna

(continued from page 31)

Table 4. Consumer panel means[a] for flavor, texture, color and bitterness.

	Flavor[b]	Texture[b]	Color[b]	Bitterness[b]
Normal NaCl	2.6	2.5	2.6	1.6
Normal NaCl-KCl	2.7	2.6	2.5	2.1
Low NaCl-PO_4	2.6	2.7	2.6	1.5
Low NaCl-$MgCl_2$-PO_4	3.4	2.8	2.8	1.5
Low Nacl-KCl-PO_4	3.5	2.9	2.8	1.6
Standard Error	0.09	0.10	0.08	0.11

[a]127 observations per mean

[b]Scores for traits were: 1=extremely like, 3=neutral, 5=dislike extremely

equal strengths of sodium and potassium chloride with phosphates.

Samples of these five products were given to 127 consumers to evaluate how much they liked or disliked them. Panelists were asked to evaluate flavor, texture, color, and bitterness. The mean values and standard errors for these traits are shown in Table 4. All products were judged acceptable by the consumer panel. Products containing magnesium and potassium at the low salt levels were rated slightly lower for flavor than the other three treatments. The product containing potassium at the normal salt level was judged slightly more bitter than the other products. No important difference was found among the products for texture and color.

Conclusions from this study are that low-sodium bologna products can be manufactured that have physical and sensory properties similar to typical bologna products on the market today. The total sodium reduction in some of the products was 65%. Future work is planned to investigate the effect of reducing sodium in other meat products such as coarse ground emulsions, ham and bacon.