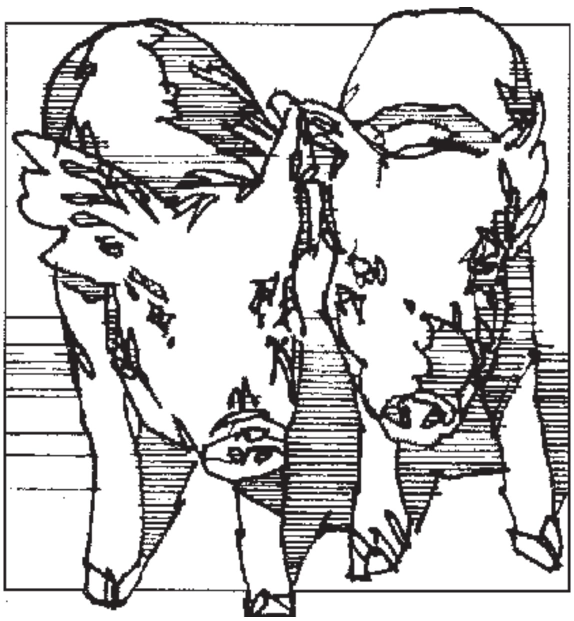

KANSAS STATE UNIVERSITY

SWINE DAY 1990

REPORT OF PROGRESS 610, AGRICULTURAL EXPERIMENT STATION, MARC A. JOHNSON, DIRECTOR

FOREWORD

It is with great pleasure that we present to you the 1990 Swine Day Report. This report contains summaries of applied and basic swine research conducted at Kansas State University during the past year. Topics range from economics to meats, and physiology to nutrition. We hope that the information will be of benefit, as we attempt to meet the needs of the Kansas swine industry.

Editors, 1990 Swine Day Report,

Bob Goodband Joe Hancock

ABBREVIATIONS USED IN THIS REPORT

avg	=	average	Mcal	=	megacalorie(s)
BW	=	body weight	mEq	=	milliequivalent(s)
cm	=	centimeter(s)	min	=	minute(s)
CP	=	crude protein	mg	=	milligram(s)
cwt	=	100 lb	ml	=	cc (cubic centimeters)
d	=	day(s)	mo	=	month(s)
DM	=	dry matter	µg	=	microgram(s)
°F	=	Fahrenheit		=	.001 mg
ft	=	foot(feet)	N	=	nitrogen
ft^2	=	square foot(feet)	ng	=	nanogram(s)
g	=	gram(s)		=	.001 µg
gal	=	gallon(s)	no.	=	number
h	=	hour(s)	ppm	=	parts per million
in.	=	inch(es)	sec	=	second(s)
IU	=	international unit(s)	wk	=	week(s)
kg	=	kilogram(s)	wt	=	weight(s)
Kcal	=	kilocalorie(s)	yr	=	year(s)
lb	=	pound(s)			

NOTICE

CONTENTS

BIOLOGICAL VARIABILITY AND CHANCES OF ERROR

Variability among individual animals in an experiment leads to problems in interpreting the results. Animals on treatment X may have higher average daily gains than those on treatment Y, but variability within treatments may indicate that the differences in production between X and Y were not the result of the treatment alone. Statistical analysis allows us to calculate the probability that such differences are from treatment rather than from chance.

In some of the articles herein, you will see the notation "P<.05." That means the probability of the differences resulting from chance is less than 5%. If two averages are said to be "significantly different," the probability is less than 5% that the difference is from chance or the probability exceeds 95% that the difference resulted from the treatments applied.

Some papers report correlations or measures of the relationship between traits. The relationship may be positive (both traits tend to get larger or smaller together) or negative (as one trait gets larger, the other gets smaller). A perfect correlation is one (+1 or -1). If there is no relationship, the correlation is zero.

In other papers, you may see an average given as 2.5 ± .1. The 2.5 is the average; .1 is the "standard error." The standard error is calculated to be 68% certain that the real average (with unlimited number of animals) would fall within one standard error from the average, in this case between 2.4 and 2.6.

Many animals per treatment, replicating treatments several times, and using uniform animals increase the probability of finding real differences when they exist. Statistical analysis allows more valid interpretation of the results, regardless of the number of animals. In all the research reported herein, statistical analyses are included to increase the confidence you can place in the results.

Val Stillwell preparing the 1990 Swine Day Report.

COMPUTERIZED RECORDS: USE IN TROUBLESHOOTING REPRODUCTIVE PROBLEMS OF COMMERCIAL SWINE HERDS

Gary D. Dial[1]

Swine production has become, in a relatively short time, one of the most competitive agribusinesses. The increase in international exportation of pork, dynamic changes in the efficiency of hog production, and the increasing preference of consumers for alternative meats has mandated that the swine industry be competitive with other producers of protein foodstuffs. Recent changes in the American swine industry have been dynamic. During the past 10 years, the financial advantage of volume selling and buying has led to an unwavering, irreversible evolution toward increasingly larger herd sizes. Accompanying this has been an ongoing trend toward decentralization away from the traditional grain-rich regions of the Midwest and consolidation of the meat packing industry. Although America remains one of the largest international producers of pork, imports into the domestic market have increased dramatically in recent years and now constitute approximately 8 percent of all pork consumed. In this climate of increased competition for more discerning markets, the independent producer has been faced with the challenge of either becoming efficient in the next decade or running the risk of no longer being competitive and no longer having a product desired by the marketplace. So, why keep records? A necessary prelude to being competitive in hog production is a usable record system allowing the producer to monitor both biological and financial performance and to troubleshoot production and financial problems.

(Key Words: Swine, Records, Analysis, Evaluation.)

Biological Records

Numerous systems are currently available commercially for assessing the biological performance of the breeding herd. Although varying considerably in data entry, report format, and report content, all of the systems provide statistical summaries of breeding, farrowing, and weaning information. For example, most provide either time-related or group summaries for information relating to fertility, fecundity, lactational performance, entry/weaning to service, and piglet survival until weaning. Distinct differences among the systems are evident in terms of monitoring and troubleshooting reports. Monitoring reports are those that allow the producer to assess some measure of sow or boar performance either over time or by group, such as the changes in farrowing rate by week or by group number. Troubleshooting reports are those that can be used for diagnosing the cause of production problems, such as the day following service that sows are found nonpregnant.

---

[1]College of Veterinary Medicine, University of Minnesota.

Monitoring Reports

Reports for production monitoring should be designed so that they are flexible. For example, it should be possible to examine changes in farrowing rate at weekly, monthly, quarterly, or yearly intervals or any other interval, including the farm-specific interval between consecutive farrowing groups for batch-farrowing farms. The time-window for reports should be easily varied allowing the generation of reports back into time or the creation of reports over various time-periods. In addition to means, simple descriptive statistics, such as the measure of variation about the mean (e.g., standard deviation) and median values, should be given for each measure of biological performance. The information system should accomodateintensively managed farms as well as those managed extensively. For example, the system should accommodate pen-mated breeding programs, in which the weaning-to-reservice interval, dates of services, and boar identification are not known, as well as hand-mating programs.

Targets or interference levels should be included in production reports, and they should be changed easily and regularly as herd performance changes. Monitoring reports should give estimates of sow and facility utilization. For example, sow utilization might be reported in terms of litters/inventoried sow/year, farrow-to-farrow interval, and nonproductive days; facility utilization might be reported as percent farrowing capacity (number of litters farrowed/potential litters farrowed), litters farrowed/farrowing crate/year, and pigs weaned/farrowing crate/year. In addition, the record information system should allow the producer to monitor how effectively he/she is meeting previously established breeding and farrowing targets. Cumulative sum (CUSUM) figures displaying the cumulative number of females bred or farrowed over time relative to a target should be available to assist a producer in understanding how efficiently facilities are being utilized.

Action lists (management aids) should be available to prompt producer to perform an activity, thereby promoting more efficient use of females. Commonly used action lists include: gilts entering the herd but not yet mated; sows weaned but not yet mated; and females to be checked for estrus or pregnancy status, loaded into farrowing crates, vaccinated, or weaned. Action lists should be sufficiently flexible to allow dates of events to be changed to fit management needs.

Monitoring records should display herd population characteristics, including culling, mortality, and replacement rates and animal inventories. It is also helpful for reports to list the current production stage and/or facility location for all inventoried females and to list the number of females in each stage of production.

Troubleshooting Reports

Although most record information systems allow satisfactory monitoring of biological performance, few facilitate the troubleshooting of production problems. There are numerous risk factors or differentials for the different types of reproductive failure. Many, if not most, of the differentials can be incriminated or ruled out through examination of records. In fact, although a diagnostic examination of environment, facilities, management, disease status, and nutrition may suggest one of them as a cause of reproductive failure, the diagnosis typically must be corroborated through the records. For example, a suboptimal total pigs born/litter may involve: parity distribution, lactation length, weaning-to-service interval, season and ambient temperature, systemic reproductive disease, genetics, nutrition, and breeding management. Several of these differentials are totally dependent upon the generation of customized troubleshooting reports in order to evaluate their role in the litter size problem (i.e., parity, lactation length, weaning-to-reservice interval, season, genetics, and breeding management). Other differentials (i.e., nutrition and disease) usually use other diagnostic tools beside records, such as laboratory tests, to incriminate them as a cause of suboptimal reproductive performance. But, even when a diagnosis is dependent upon a laboratory test, the diagnostic findings should be collaborated by looking for the "fingerprint" of clinical signs usually evident in the records.

The most widely used measure of the overall biological performance of the breeding herd is pigs produced (born alive, weaned, or sold)/inventoried sow/year. The two components of pigs weaned/sow/year are litters farrowed/inventoried sow/year and pigs weaned/litter farrowed (Figure 1). In turn, nonproductive days and farrowing schedule (lactation length) are the major factors influencing litters/sow/year. Nonproductive days is influenced largely by time from entry or weaning until first service; time from service until detection of nonpregnancy status; and time from service, entry, or weaning until female is culled or dies. Pigs weaned/farrowed litter is influenced primarily by number of pigs born alive/litter and the percent of those surviving until weaning. In order to be comprehensively useful in improving the biological performance of the breeding herd, computerized record systems must monitor all the components of pigs/sow/year and must allow the risk factors influencing each of the components to be individually assessed. For example, nonproductive days not only must be calculated, but also must be broken down into constituents (entry/weaning-to-service, service-to-reservice, and entry/weaning/service-to-cull intervals), and the risk factors for those constituents must be detailed in the reports.

Farrowing rate, litter size, preweaning mortality, and weaning-to-service intervals are parameters calculated by most computerized record systems. Although not very predictive of either biological or financial efficiency, they are commonly understood parameters that indirectly influence pigs/sow/year. Thus, record systems should be selected that allow the delineation of influencing factors.

Farrowing Rates. As shown in Figure 2, the principal causes to consider for suboptimal farrowing rates are:

- accelerated herd turnover where sows do not have an opportunity to farrow,
- farrowing-to-service interval (including prolonged weaning-to-service intervals and/or short lactation lengths),
- accumulation of repeat breeding females,
- asynchrony between ovulation and mating (estrus detection, timing of matings, matings/service),
- boar usage,
- individual boar differences,
- quality of matings,
- reduced pregnancy maintenance in females mated during the summer season,
- elevated ambient temperature,
- genetics,
- housing,
- inordinately high proportion of either low or high parity sows,
- mycotoxicoses (especially zearalenol and zearalenone toxicoses),

•urogenital disease, and
•systemic reproductive diseases (e.g., pseudorabies, parvovirus, leptospirosis, encephalomyocarditis virus).

The factors that cause a sow to fail to conceive are often different than those causing a sow to fail to maintain pregnancy (Figure 2). For example, the number of matings/service affects conception but not pregnancy maintenance, whereas season primarily influences the capacity of the sow to maintain pregnancy. To be useful in troubleshooting fertility problems, a computerized information system must be capable of indicating the pattern of return to service following an unsuccessful service. In addition, it should be capable of listing sows returning to estrus separately from preg-test negative sows, not-in-pig sows, and fail-to-farrow sows, when time of pregnancy loss cannot be determined.

Additional attributes of record systems useful in troubleshooting fertility problems are that they allow the generation of reports in formats highlighting the most common causes for infertility. In order to troubleshoot farrowing rates, record systems should determine:

1) whether served sows have had an opportunity to farrow or are being culled for health or managements reasons not relating to fertility;
2) the interval from service until return to estrus;
3) the proportion of each group that is repeat-served;
4) time-related, especially seasonal, changes in farrowing rates;
5) parity break-out of farrowing rates;
6) the relationship between lactation length, weaning-to-reservice intervals, and farrowing rate;
7) the temporal association between changes in litter size parameters, especially percent mummies and stillbirths, and fertility;
8) the relationship between boar usage during the time-period when a group of sows is being served and their subsequent fertility;
9) the effect of number of matings/service on fertility;
10) the influence of genetics, especially the impact of purebred boars on fertility; and
11) the impact of individual boars on group fertility.

Litter Size. As indicated in Figure 3, the principal causes for reduced litter size are:

•parity distribution,
•lactation length and weaning-to-service interval,
•season and ambient temperature,
•boar influence,
•systemic reproductive disease,
•genetics,
•nutrition (e.g., prebreeding flushing), and
•breeding management (e.g., number of matings/service and boar usage).

Many of the causes for suboptimal total pigs born/litter can be investigated using record systems that determine:

1) litter size parameters for all parities and parity combinations;

2) the relationship between lactation length, weaning-to-service interval, and subsequent litter size;
3) the effect of season and ambient temperature at service and prior to the completion of implantation on subsequent litter size;
4) the repeatability of litter size in individuals from one parity to the next parity;
5) the influence of genetic line on litter size;
6) the temporal association between reductions in total pigs born and increases in stillbirth or mummy rates or the occurrence of abortions and pregnancy failures;

7) the effect of boar usage on litter size;
8) the identities of individual boars having reduced litter sizes;
9) the influence of matings/service and timing of matings relative to onset of estrus on litter size;
10) the relationship between lactation feed intake and subsequent litter size; and
11) the influence of either gilt age at mating or interval from entry to service on subsequent litter size.

In North America, pigs born alive represents the number of pigs remaining from total pigs born/litter after correction for the stillbirth and mummy rates (Figure 4). Possible causes for suboptimal liveborn litter sizes with elevated stillbirth rates include:

•a high proportion of farrowing sows having advanced parities,
•prolonged gestation lengths,
•an increased percentage of sows having elevated stillbirth rates at consecutive farrowings,
•piglet birth weight and within-litter variation in pig size at birth,
•misdiagnosis of postpartum deaths as being stillborn,
•systemic reproductive diseases,
•poor prefarrow conditioning of sows,
•genetics,
•elevated levels of toxic gases in farrowing room (especially carbon monoxide),
•mycotoxicoses,
•sow housing prior to farrowing, and
•suboptimal levels of micro- and macrominerals and vitamins.

Reports useful in investigations of the differentials for suboptimal pigs born alive/litter should determine:

1) the relationship between parity and stillbirth rate,
2) the influence of gestation length on number of stillbirths/litter,
3) the identification of sows repeatedly having high stillbirth rates,
4) the relationship between birth weight and stillbirth rate, and
5) the relationship between stillbirth and preweaning mortality rates.

Preweaning Mortality. The four major types of preweaning mortality are traumatic injuries (pigs stepped upon, laid upon, or savaged by the sow); low viability piglets (pigs born undersized or weak at birth); starvation; and disease. Many of the risk factors for the different types of piglet mortality are the same; for example, facility and equipment design, piglet microenvironment, piglet size at birth, season, and parity affect mortality rates related to trauma, low viability, starvation, and disease (Figure 5). However, some of the contributing causes for the major types of preweaning mortality differ.

Troubleshooting reports for preweaning mortality should assess:
1) piglet mortality by category of death;
2) the relationship between age at death and the proportion of piglets dying from specific causes;
3) the relationship between birthweight, variation in birthweight among littermates, and specific causes of preweaning mortality;
4) time- and season-related changes in preweaning mortality; and
5) the effect of mean group parity or herd parity distribution on piglet survival.

Lactation Performance. Light weaning weights can be the result of either an infectious or noninfectious process (Figure 6). Infectious causes include generalized infections of sows, singular mammary gland infections (where only one or a few glands are infected and have reduced milk production), and infections causing reduced milk production by the entire mammary chain. Noninfectious causes of suboptimal weaning weights include:
•insufficient nutrient intake by the lactating sow (e.g., nutrient density of rations, facility and equipment design, feed management, etc.);
•mycotoxicoses;
•genetics;
•litter management (e.g., crossfostering, use of nurse sows, fractionated weaning, etc.);
•average piglet birth weight; and
•parity.

Reports to be used in troubleshooting problems of suboptimal weaning weights should determine:
1) the adjusted 21-day weaning weights of piglets, so as to allow comparison with established targets and with other farms;
2) the relationship between feed intake during lactation and weaning weights;
3) the relationship between birth weights and weaning weights;
4) weaning weight differences among different genetic lines on a herd; and
5) the effect of parity on weaning weights.

Facility Utilization. Troubleshooting reports should be available not only for assessing the biological performance and efficiency of utilization of the sow and boar but also for estimating facility utilization. Calculations potentially helpful in allowing the troubleshooting of suboptimal utilization of facilities include the ratios:
•number of inventoried females:total number of farrowing crates,
•number of inventoried sows:number of weekly farrowings, and
•number of gestation places:number of farrowing crates.

Commonly used measures of facility utilization include:
•litters farrowed or weaned/farrowing crate/year,
•pigs weaned/crate/year, and
•percent farrowing crate utilization.

Financial Records

Financial Enterprises

Swine producers generally can be described as being of three types: farrow-to-finish, finishing, and feeder-pig producers. Feeder pig producers breed and farrow sows and grow pigs though the nursery phase of production, when pigs first become marketable. Finishing-pig producers (growers) take feeder pigs and grow them through slaughter weight, the second time pigs are marketable. When considering the two stages at which pigs can be marketed together with the three producer types, swine farms can be considered as having three distinct financial enterprises: the breeding herd enterprise, which includes the financial aspects of producing the weaned pig (i.e., the costs and income associated with the breeding, gestation, and farrowing phases of production); the nursery-pig enterprise, which takes the pig from weaning until it is marketable as a feeder pig; and the grow/finish-pig enterprise, which includes the pig from its first marketable weight as a feeder pig until it is marketed for slaughter. Feeder pig producers are concerned about the breeding-herd and nursery-pig enterprises; finishing-pig producers are concerned primarily about the grow/finish-pig enterprise; and the farrow-to-finish producers are involved with all three enterprises.

The major costs for producing a pig are proportionately different for the three enterprises. For example, feed costs are less for producing a weaned pig than for producing a market pig; labor and breeding costs (cost of the replacement animals minus the salvage value of the adults) are higher for the feeder pig than for the market pig; and capital costs (facility, utilities, and interest) are about the same for the two enterprises. Thus, when trying to improve profitability of a finishing-pig enterprise, feed costs followed by capital costs are major areas of emphasis. In contrast, feed cost remains the greatest expense for producing a weaned pig, just as it is for the finishing pig, but capital, labor, and breeding costs contribute proportionately more to the total cost of producing a pig. Consequently, all four major costs centers must be considered when attempting to improve the profitability of the breeding herd.

Records for the breeding herd should keep financial information relative to producing a weaned pig independent of that for the other two enterprises. It is not possible to evaluate the financial efficiency of the breeding herd if costs and receipts for the grow-finish and nursery phases are included with weaned-pig financial information. Norms for production costs for the weaned pig reared in the Midwest have only recently been made available.

Feed Costs

The major cost of producing a weaned pig is sow-feed cost. Feed cost/weaned pig is typically computed based upon total gestation plus lactation feed disappearance corrected for the number of pigs weaned during a given time period. In addition to feed cost/pig, record systems should report or easily allow the hand-calculation of several other feed related parameters.

Regional differences in diet ingredient costs require that record systems be capable of reporting pounds fed/weaned pig, if farm-to-farm comparisons are to be made rationally. Because of its higher nutrient density, a lactation diet is generally more expensive than gestation feed. Lactation feed also influences the piglet and the postweaning reproductive performance of the sow to a greater extent than gestation diets. Thus, in order to optimize productivity while minimizing feed costs, record systems monitoring sow-feed disappearance should differentiate lactation feed consumption from gestation feed consumption.

Nutrient intake during lactation substantially influences the postweaning performance of the sow and the weaning weight of the pig. Thus, record systems also should allow the monitoring of lactation feed disappearance, so that average daily nutrient intakes during lactation can be calculated and diets reformulated as needed to ensure optimal performance at minimal feed costs. Lactation feed disappearance can be entered into a computerized swine record system either on the basis of feedbin inventories or summaries from individual sow feed consumption records. Because lactating sows eat more feed than gestating sows, consumption and cost data for weaned pigs on farms with longer lactations (e.g., 5 weeks) typically will be different from those with shorter lactations (e.g., 16 days). Thus, feed comparisons among farms may have only limited value without a knowledge of lactation lengths and diet ingredient costs.

In order to allow biological and financial monitoring of feed-related performance, record systems should record gestation and lactation feed deliveries and/or inventories, diet ingredients and costs. In turn, feed information should be related to average number of pigs weaned and feed disappearance/d.

Capital Costs

Collectively, facility (depreciated facilities and maintenance costs), utilities, and interest (operating capital, nondepreciated facility costs) account for the second largest cost of producing a weaned pig, Although slightly larger, capital costs are similar to labor and breeding costs, accounting for approximately 15-25% of the total costs of production.

Capital costs vary considerably from region to region. In general, regions with milder climates have lower capital costs, but higher feed costs, than cooler regions. Facility costs often attributed to a weaned pig can be given in terms of cost/pig space to construct a facility. When examined in this way, the most costly phase of production would appear to be the farrowing phase. However, when facility costs are corrected for the days that space is tied up by either the sow producing a pig or by the pig itself, the farrowing phase is second behind the finishing phase in terms of its contribution to facility cost/pig. In general, as efficiency of facility utilization improves (i.e., more pigs are produced per pig space), the facility cost/pig decreases. Record systems of the future should not only compute facility costs/weaned pig but should also enable the producer to determine the phases of production that are least financially competitive.

Breeding Costs

Breeding costs are the salvage values of culled breeding stock minus the costs of replacement stock corrected for number of pigs weaned. As with other fixed costs, improvements in pigs weaned/sow/year are accompanied by decreased breeding cost/pig. The decision to tolerate high breeding costs or to attempt to decrease breeding costs/pig is influenced by potential changes in sow productivity (e.g., pigs born alive/litter, pigs weaned/litter, and weaning weights) and the potential influence of herd genetics on market pig performance (e.g., feed efficiency, rate of gain, and carcass merit). Thus, lower breeding costs are not consistently related to increased profitability.

Labor Costs

Labor costs are difficult to accurately determine for the weaned pig because of producer uncertainties of the value of their labor and because of an inability to allocate time accurately to the breeding herd. In general, capital costs and labor costs are inversely related, so that highly capitalized facilities usually have a proportionately lower labor cost.

Additional Features

Data Entry

One of the most common frustrations with information systems is the inability to reconcile computer-generated reports with hand-held records. Data entry into computerized record systems should be flexible so as to allow multiple events for one sow to be recorded easily at one time or for the same event to be entered at one time for multiple sows. Prompts should indicate to the person entering data when there are missing events or erroneous information and when entered data are not biologically realistic. For example, a sow should not be allowed to farrow without having been exposed to a boar, and sows should not be allowed to farrow approximately 135 days after a recorded service.

Data Integrity

Many information systems calculate production parameters even when information is missing. For example, farrowing rates may be calculated on groups in which all sows have not yet had sufficient time to farrow. Reports should be available that assess data integrity, quality, and completeness. Furthermore, systems should not allow reports to be generated that are not biologically or statistically meaningful. Examples of less-than-meaningful production parameters include: the mean weaning-to-reservice intervals for a group of females, in which part have been bred at the first postweaning estrus and part have had services delayed intentionally until the second postweaning estrus, and the computation of nonproductive days for herds in which gilts are not inventoried in the herd until they are mated. An example of a statistically nonmeaningful computation is the calculation of a frequency distribution for the ages of piglet death prior to weaning when there is an insufficient number of sows farrowing during the time interval.

The adage "garbage in, garbage out" is extremely applicable to computerized swine records. Inaccuracies in the recording of events commonly results in meaningless reports. Common data recording errors potentially having profound effects on calculated parameters include: inaccurate determinations of the cause of piglet or sow mortality, not recording all piglets born mummified or stillborn, and failure to record piglets transferred on or off a sow.

Hand-Held versus Computerized Records

Computerized record systems are often intimidating to the inexperienced user, but they have several potential advantages. They

1) are more accurate;
2) provide more complete information;
3) provide more flexible report format;
4) require less time to maintain data;
5) can be used to improve financial credibility; and
6) can be used in conjunction with accounting packages, spreadsheets, decision aids, and other compatible software.

Disadvantages of computerized record systems are that
1) they may be difficult for the inexperienced user to initiate,
2) hardware problems may be frustrating,
3) computer-generated reports may not always be reconciled with hand-held reports, and
4) missing data and data entry errors may lead to inaccurate reports.

On-Farm versus Bureau Records

On-farm record systems have the following potential advantages:
1) Turn-around time from data recording until receipt of records is shorter, so records may be more up-to-date.
2) Special reports can be easily generated as needed (e.g., litter size diagnostic report). 3) The format of reports can be varied and customized for the farm or for a specific need (e.g., set up reports with varying time-intervals).
4) Troubleshooting is more flexible and extensive.
5) Error correction of data entries can be done more easily and promptly.
6) Disks can be mailed to consultants prior to farm visit, allowing the generation of special and custom reports.
7) On-farm systems are usually cheaper on a per-sow or per-entry basis than bureau systems to operate, even with depreciation of hardware and software and data entry time.
8) Data privacy and security are assured.
9) Start-up is usually easier and more rapidly made.

On-farm record systems have the following potential disadvantages:
1) Start-up costs are usually higher.
2) Some computer training or experience is required.
3) Valuable on-farm time is lost if records are not reviewed by consultants prior to arrival on the farm (time must be spent upon arrival reviewing records).
4) Software and hardware support may be less than optimal.
6) Assistance for report interpretation may not be available.

Commercial bureau systems have several potential advantages over on-farm systems:
1) more efficient and accurate data entry,
2) generation of statistically meaningful reports,
3) between farm comparisons are possible,
4) lower start-up costs than on-farm systems,
5) no computer skills required of the producer or consultant, and
6) support for production and computer problems often provided by bureau.

Commercial bureau systems have several potential disadvantages compared to on-farm systems:
1) longer turn-around time from data collection until receipt of report by farm,
2) error correction and incomplete data not easily handled,
3) difficult in getting numerous diagnostic reports during a problem investigation in a timely and expedient fashion,
4) formats of reports usually being standardized across farms, instead of being customized for each farm, and

4) lower start-up costs than on-farm systems,
5) no computer skills required of the producer or consultant, and
6) support for production and computer problems often provided by bureau.

Commercial bureau systems have several potential disadvantages compared to on-farm systems:

1) longer turn-around time from data collection until receipt of report by farm,
2) error correction and incomplete data not easily handled,
3) difficulty in getting numerous diagnostic reports during a problem investigation in a timely and expedient fashion,
4) formats of reports usually being standardized across farms, instead of being customized for each farm, and
5) being more expensive in the long-term than on-farm systems.

Advantages of Computerized Records

Computerized record systems allow more accurate monitoring of breeding herd production and the assessment of a much broader range of production parameters than are possible with hand-held record systems. Thereby, they greatly facilitate an awareness of problem areas. Computerized records also enable the troubleshooting of production problems. Troubleshooting with hand-held records is much more time-consuming and much less complete than with computerized records. In fact, it is not possible to troubleshoot many types of reproductive failure using hand-held records without time-consuming hand calculations. Computerized systems minimize self delusion about performance level and enable more meaningful comparisons among farms. They also allow prognostication of levels of production and improve financial credibility. Computerized records can be used to validate progress and assess response to management changes. By being a substantial motivating influence, records also can modify producer attitudes toward the swine enterprise.

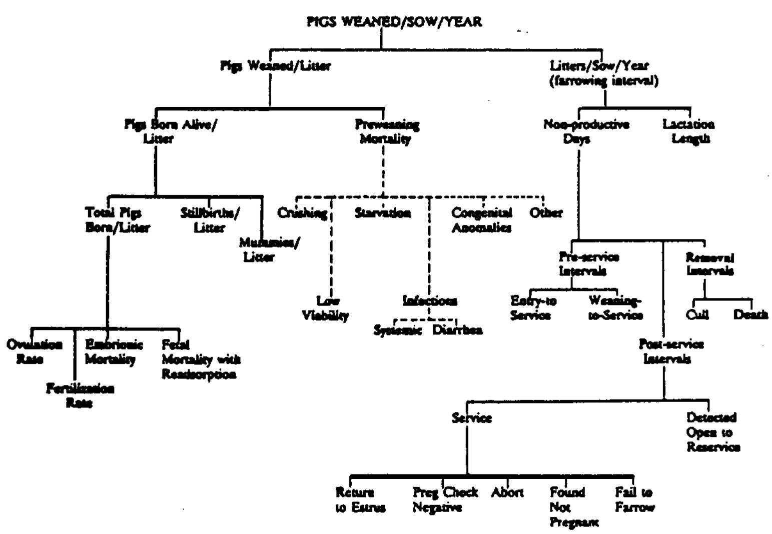

Figure 1. Flow diagram of the factors influencing pigs weaned/sow/year that must be capable of being troubleshooted in order for a record system to be competitively useful.

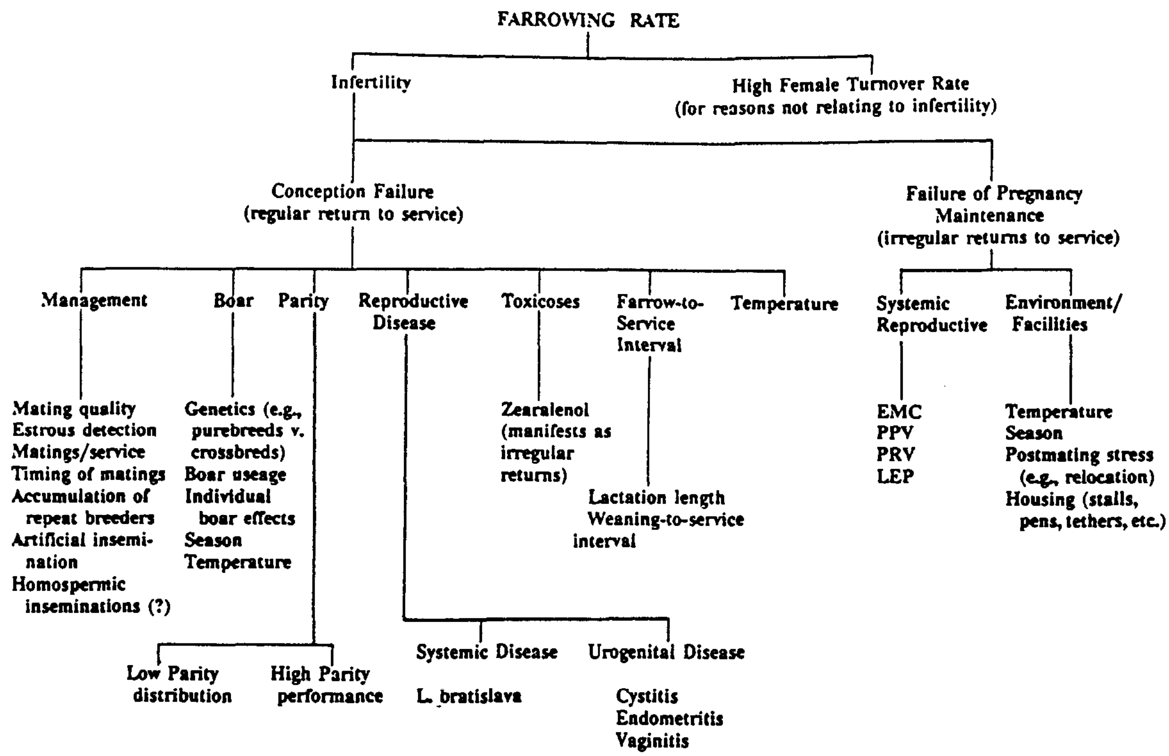

Figure 2. Flow diagram of the factors influencing farrowing rate.

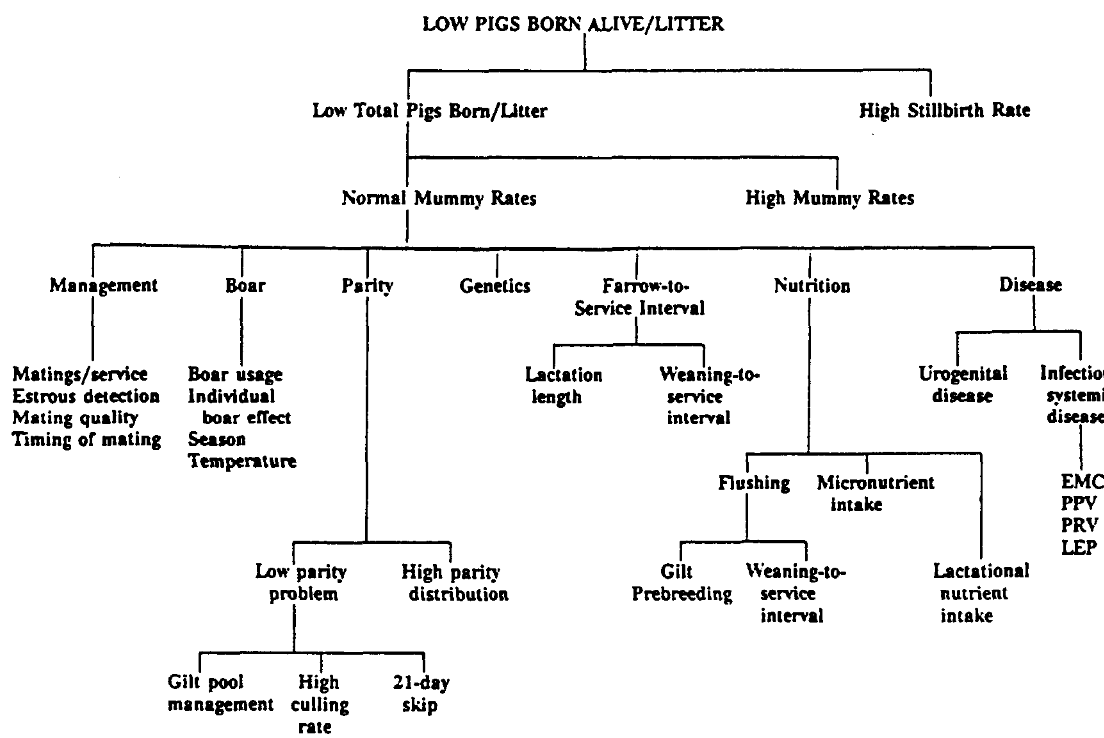

Figure 3. Flow diagram of the factors influencing litter size.

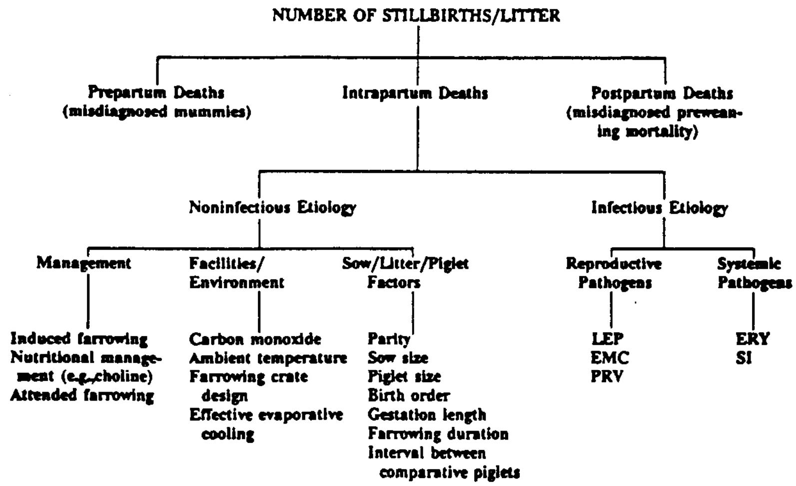

Figure 4. Flow diagram of the factors influencing number of stillbirths/litter

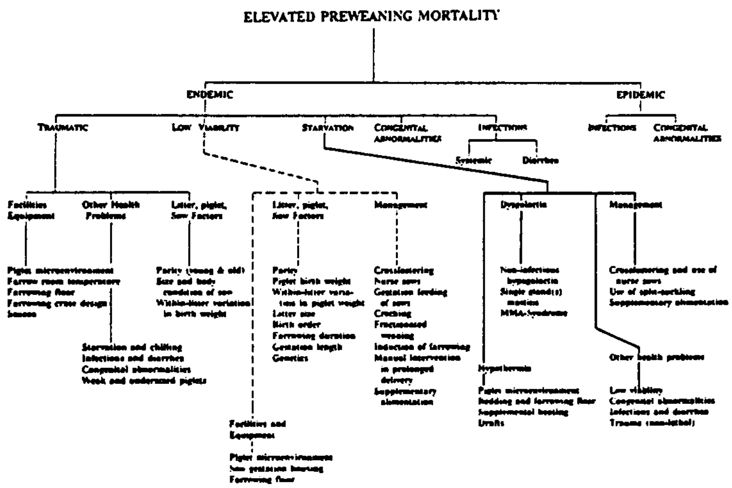

Figure 5. Flow diagram of the factors influencing preweaning mortality.

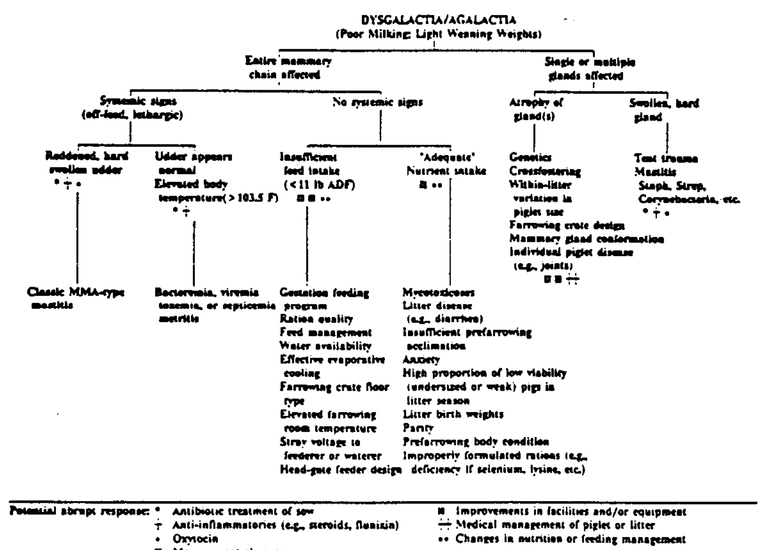

Figure 6. Flow diagram of the factors influencing lactational performance.

IMPROVING ON-FARM MIXING EFFICIENCY

Bob Goodband

Summary

Particle size reduction has a great impact on efficiency of feed utilization. Decreasing particle size improves digestibility of nutrients by increasing surface area and allowing for greater interaction with digestive enzymes. In addition, particle size reduction can influence how uniformly feed is mixed and potential for segregation of ingredients. Mixing equipment and times also need to be evaluated to ensure feed uniformity. Very often suggested mixing times underestimate the amount of time necessary to thoroughly mix feed. Items such as worn paddles or ribbons, ribbon or paddle speed, and overfilling mixers increase the time necessary for adequate feed mixing and uniformity. The consequences of undermixed feed will be observed in poorer feed conversion. This will be most evident in younger or limit-fed pigs. A mixing efficiency test is a simple procedure to check if your feed is adequately mixed and, therefore, should be used as an indicator of feed quality control.

(Key Words: Diet, Process, Swine.)

Introduction

Because cereal grains are the primary energy sources in swine diets, producers must be concerned not only about the composition of the grain but also how it is processed. Feed costs represent 65 to 75% the cost of production for a swine operation; therefore, feed utilization will be a critical factor in determining profitability. Very often, minor changes in feed processing, i.e., particle size reduction or uniformly mixing feed, can improve whole-herd feed conversion from 3 to 8%. As producers take on more of the responsibility of mixing their own feed, quality control measures might go unchecked. Particle size and mixing efficiency are two simple tests that are often overlooked.

Discussion

A survey of particle size analysis of feed samples over the past 5 years indicates that the majority of producers are possibly losing 3 to 8% of their feed utilization costs because of coarsely ground feed. Of the over 1,500 samples analyzed, only 20% of those samples fall within the 700 to 800 micron particle size recommended for swine feeds (Table 1). If there are whole kernels in the diet, then this is an indicator that the feed isn't ground fine enough. It should be noted, however, that grinding too fine, below this recommended range, increases the potential for gastric ulcers, bridging of feeders, dustiness, and energy costs of grinding feed. The following paper, Feed Mills for On-Farm Feed Manufacturing, discusses some of the aspects of particle size reduction and key management decisions to maintain optimum particle size reduction.

Mixing efficiency is another term for feed uniformity or how thoroughly a batch of feed is mixed. The testing procedure involves taking at least 10 individual samples from a single batch of feed and analyzing each sample for salt content. Salt is used for the analysis because it is relatively easy and inexpensive to test. If the variation in salt content between the 10 samples is greater than 10%, then the feed has not been mixed properly. Several factors may affect mixing efficiency. The following are brief descriptions of how each of them affects feed uniformity.

Feed Mixers. Different types of mixers require different amounts of time to thoroughly mix feed. Horizontal mixers with either paddles or ribbons typically require about 5 to 10 min. to get below the recommended 10% coefficient of variation (Figure 1). Rotating drum or "cement" mixers also have been shown to be effective in adequately mixing feed and typically require 5 to 10 min. mixing time. Vertical mixers usually will require approximately 15 min. for optimum feed uniformity. Generally, single-screw vertical mixers require longer mixing times than twin-screw mixers; however, there appears to be a great deal of variation in mixing time of vertical mixers. Portable grinder mixers fall into the same category as single-screw vertical mixers and require at least 15 min to adequately mix a batch of feed. However, usual mixing time of these mixers is the length of time required to get to the feeder or to grind the grain portion of the diet.

A common misconception is that overmixing or unmixing can occur if feed is mixed too long. There is little information to support this concept; therefore, there is little chance for problems to occur if feed is mixed slightly longer than recommended.

Particle Size. Particle size and density can increase the amount of time necessary to thoroughly mix feed. In addition, they may also increase the potential for particle segregation. A recent study evaluated the effects of different particle sizes of either corn- or milo-based diets on mixing efficiency. Each grain was ground through a hammer mill or a roller mill to produce either fine or coarse particle sizes. They were then mixed with soybean meal, vitamins, and minerals in a 1-ton, horizontal, double ribbon mixer for either .5, 1.5, or 3.0 min. At each time increment, samples were collected and mixing efficiency was determined. Results indicate that as particle size increased, the diet needed to be mixed longer to get below the 10% variation level (Table 2). Although mixers and mixing times may vary, it may be safe to assume that with other types of mixers, coarsely ground feed ingredients may require slightly longer mixing times. Other factors such as particle shape, density, hygroscopicity, adhesiveness, and susceptibility to electrostatic charges may influence feed uniformity.

In addition to slightly longer mixing times, increased particle size may also increase the potential for segregation. Although difficult to measure, potential for segregation by trucking and feed handling equipment may be increased with coarsely ground feeds.

Over-filling the Mixer. Very often to save time, producers try to mix more feed than a mixer is designed to handle. This common practice seriously limits the action of the mixer by creating "dead zones". As a result, adequate feed mixing may not take place, even if the mixer is allowed to run for extended periods of time (Figure 2). Paddles should emerge 2 to 3 in. above the level of the feed in a horizontal mixer, whereas vertical mixers should have at least 8 to 12 in. between the top of the screw housing and the top of the mixing chamber.

Worn Equipment. Worn paddles, ribbons, and screws also contribute to increased mixing times (Figure 3). In addition, ribbon or paddle build-up from adding fats or oils and milk products also can interfere with mixing action (Figure 4). Wear on screws and their housing in vertical mixers will reduce mixing action. Because most of the wear will occur at the bottom of the mixer, this will limit the amount of feed that can be lifted. A rule of thumb is that if the diameter of the screw is reduced by 1/2 in., then you should increase mixing time by 5 min.

Mixer RPM. Low revolutions per minute will limit mixing action in both horizontal and vertical mixers (Figure 5). Horizontal mixers should be turning at 30 to 40 RPM, whereas single-screw vertical mixers operate in the 200 to 300 RPM range.

In conclusion, mixing times will vary based on the type of equipment used and its condition. Many other factors, such as particle size, over-fill, worn paddles and screws, build-up of fats and oils, and low operating speeds, can increase the amount of time needed to thoroughly mix a batch of feed. A mixing efficiency test is a simple and effective means of establishing whether your mixer is producing a uniform product.

Table 1. Summary of On-Farm Particle Size Reduction[a]

	Particle size, microns					
	400-599	600-799	800-999	1,000-1,299	1,300-1,999	>2,000
Percentage of samples	3.2	20.3	41.2	28.1	6.5	.7

[a]Analysis of 1,578 samples collected between 1986 and 1990.

Table 2. Effect of Particle Size on Mixing Efficiency[a]

	Mixing time, min[b]		
Particle size, microns	.5	1.5	3.0
<699	35.1[c]	8.3	8.8
700 to 899	43.1	10.3	8.7
>900	50.1	14.3	11.6

[a]Adapted from Martin, 1983.
[b]Samples were mixed in a 1-ton, horizontal double ribbon mixer.
[c]Coefficient of variation below 10% indicates adequately mixed feed.

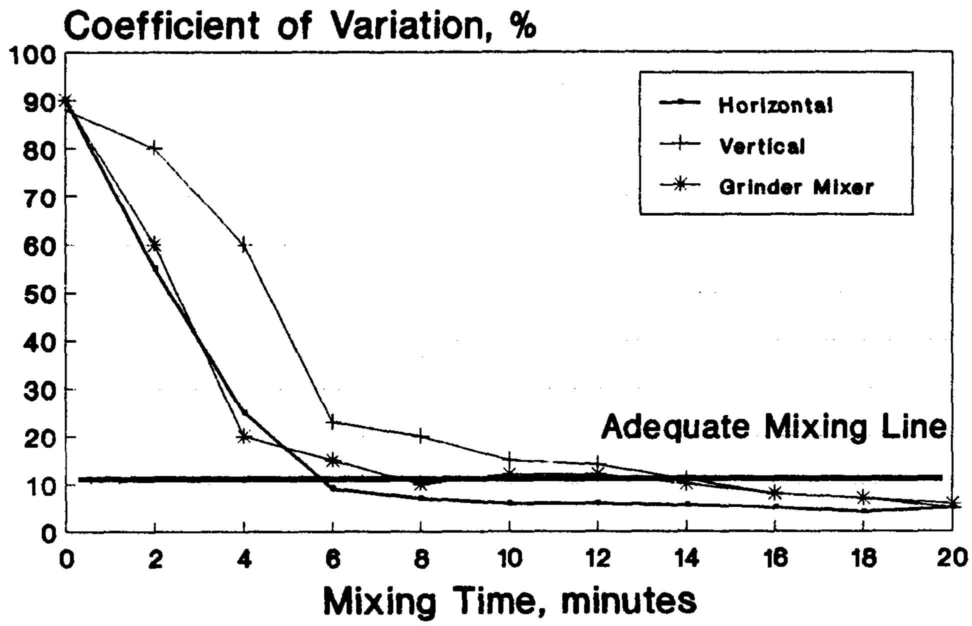

Figure 1. Effect of mixer type on time required to adequately mix feed.

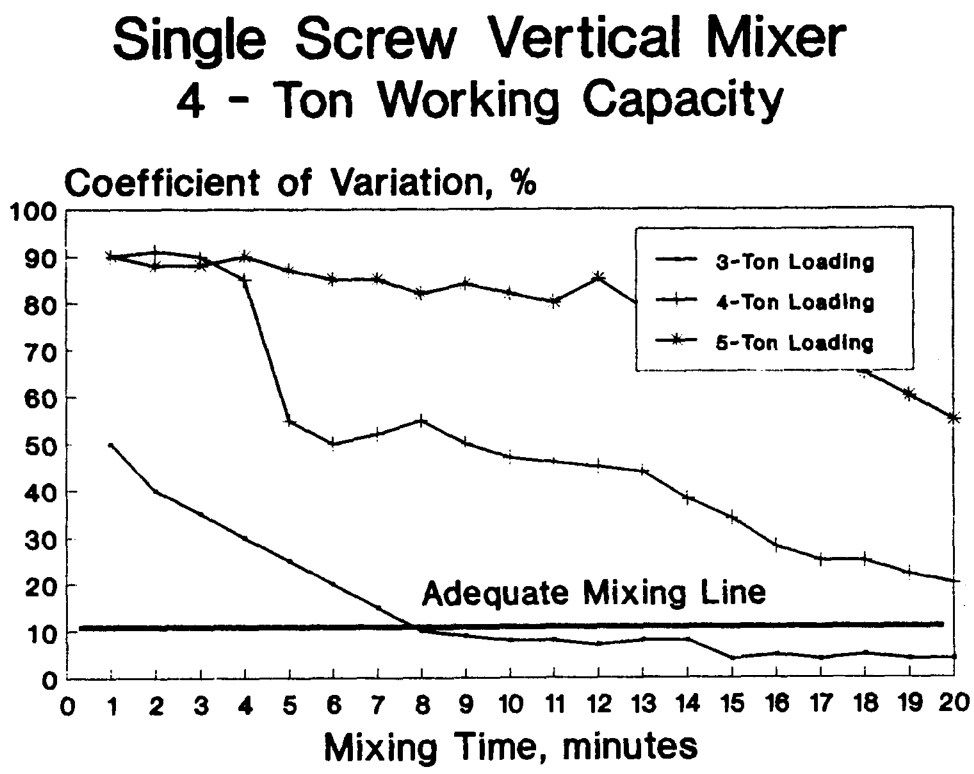

Figure 2. Effect of over-filling a mixer on mixing efficiency.

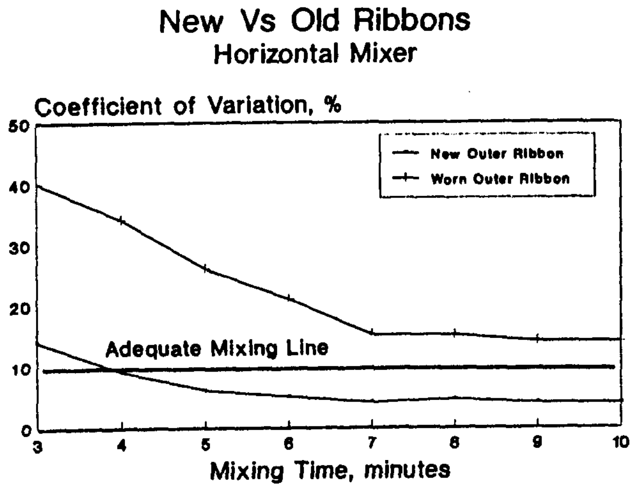

Figure 3. Effect of a wear on mixing efficiency of a single-screw mixer,

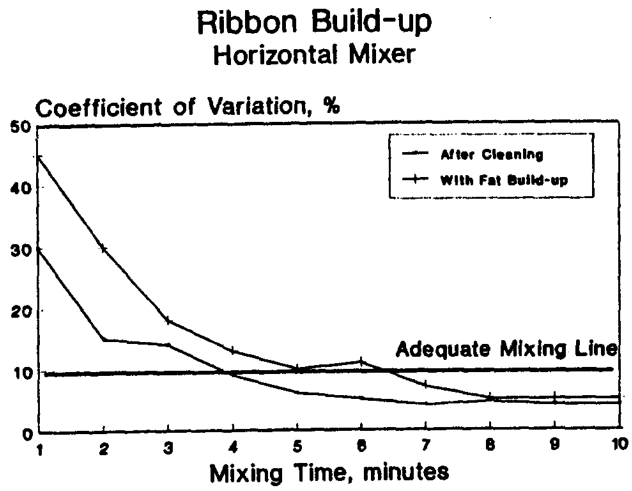

Figure 4. Effect of ribbon build-up on mixing efficiency,

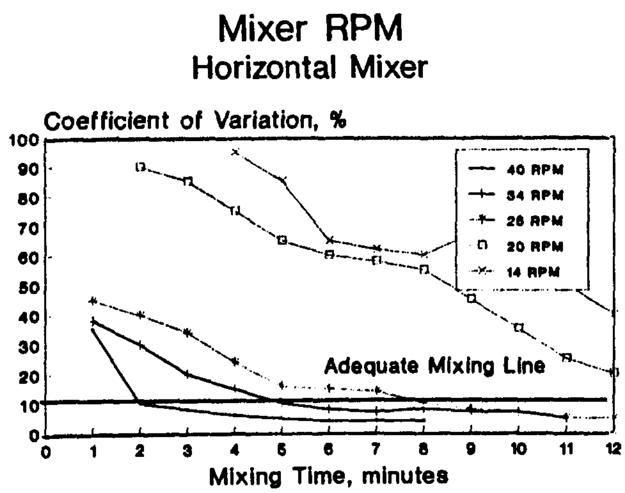

Figure 5. Effect of mixer RPM on mixing efficiency.

FEED MILLS FOR ON-FARM FEED MANUFACTURING

J. P. Murphy and J. P. Harner[1]

Summary

Quality feed can be manufactured on farm using hammer or roller mills for particle size reduction and volumetric or weighing devices for proportioning ingredients. An understanding of each of the seven steps involved will enhance the ability to manufacture a quality feed for maximum feed efficiency at a feasible price.

(Key Words: Process, Swine, Diets.)

Introduction

Quality swine feed can be manufactured on the farm with many different types of equipment, as long as the feed mill operator understands the limitations of his feed processing equipment. Seven steps are necessary to manufacture feed: acquire ingredients, store and retrieve ingredients, reduce of particle size, proportion ration, mix ration, store ration, and deliver ration.

Hammer Mills

Reducing particle size normally involves two types of mills, hammer mills and roller mills. Hammer mills have the following characteristics relative to roller mills:

1) easier maintenance
2) higher horsepower
3) process wider variety of materials
4) greater range of particle size
5) nosier
6) more dust
7) greater capacity per size

Hammer mills are advantageous because they will handle any combination of grains and have a low maintenance cost. These mills will grind all kinds of feed including hay and are used when it is desirable to mix hay and grain for a ration. Particle size reduction occurs in three ways: 1) explosion from impact of the hammers; 2) cutting by the edge of the hammers; and 3) attrition or rubbing action. The rubbing action is important with small cereal grains and the impact is important with corn and heavy, brittle materials.

[1]Extension Agricultural Engineers.

Capacity of a hammer mill will vary depending on condition of the feed being processed and the fineness of the grind. An average range for a hammer mill is from 600 to 1,200 lb of feed per horsepower hour.

Hammer mills consist of fixed or swinging hammers mounted on a hub/rotor assembly (normally dynamic and static balanced), which is on a rotating shaft. Hammers rotate at speeds from 1,800 to 4,000 RPM, depending on the overall diameter at the tips of the hammers; tip speed varies from 5,000 to 20,000 ft/min.

The screen (usually perforated metal) is mounted below, above, and/or around the hammers through which the reduced product must pass. The product being ground remains in the grinder until it is small enough to pass through the holes in the screen. The hammers do not touch the screens, but as a general rule, if the hammers are farther away from the screen, it will be beneficial for chopping hay or fodder, will use less horsepower, and will create less fine material (powder, flour, dust, etc.). If a fine product is desired, the hammers should be very close to the screen, which will increase horsepower requirements. Most hammermills have 10 to 12 sq in. of screen area per input horsepower. A 10 to 15°F rise in feed temperature through the mill is acceptable, but greater than 15°F indicates inefficiency (worn hammers or screens). Efficient hammer mill operation is depended on the distance from the end of the hammer to the screen surface. Replacement of hammers is necessary when the hammer length shortens from its original length (Figure 1). It is very important to use magnets to remove metal and protect hammer mills. In some cases, parallel bar scalpers are necessary to remove non-magnetic objects such as rocks. The hammers also very greatly in size and shape and can be reversed to ‘give four wearing surfaces; removable tips and various wearing materials are also offered.

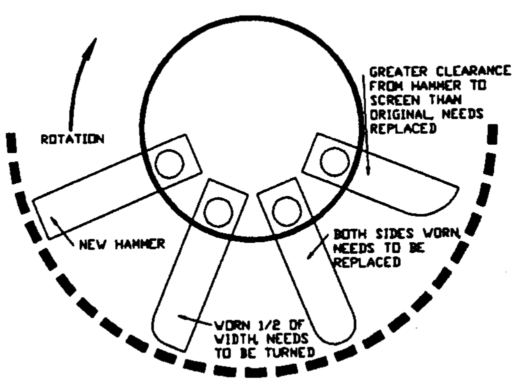

Figure 1. Maintenance of hammers on hammermills.

Roller Mills

Roller mills have the following characteristics:

1) maintenance requires regrooving of rollers
2) low horsepower

4) narrow range of particle sizes produced
5) quiet
6) little dust produced when milling

Roller mills offer the advantages of low power requirement per ton of feed, very little flouring and dusting, and simple compact equipment. Roller mills are limited to non-fibrous product (i.e. cannot be used for hay or fodder). An average capacity for a roller mill is 900 to 1,800 lb per horsepower hour, depending on the size and type of roll. For rolling high-moisture grain, the mill must be carefully selected to prevent problems with grain sticking to the rollers.

Roller mills are sized according to the diameter and length of the rolls. A 10 x 42 mill has a 10 in. diameter roll that is 42 in. long. The most popular sizes for grinding are 9, 10, and 12 in. diameter rollers with a length of 6 to 52 in. Foreign objects such as nails and bolts will damage roller mills and should be removed with magnets. The mills cannot be started with product on or in the rolls. It must be up to speed prior to starting the feeding of the rolls. The setting of the rolls is different for each product desired. A sample should be run prior to starting a production run. Too close a setting causes fines (or flouring) and increases or wastes power. On the other hand, too wide a setting does not grind the product enough.

Roller mills can be furnished with rolls having 5 to 18 corrugations/in. As a rule, the fewer the corrugations per inch, the higher the capacity for a given mill and the less frequent regrooving will be necessary. However, more corrugations/in are required for smaller-sized kernels to prevent uncracked grain from passing through the rolls. Although there is some variation in recommendation among manufacturers, the general range used for feed grains are: 5 or fewer corrugations/in for corn; 7 to 8 corrugations/in for corn, wheat, milo, oats, or barley; 10 or more corrugations/in for milo, oats, barley, or wheat (limited capacity on corn).

There are approximately 50 different types of corrugations for roller mills. Most mills will use a saw tooth or a Dawson configuration. In order to get the recommended particle size of 800 microns, it is necessary to use rollers that have 10 to 12 grooves/in. Most manufacturers will also use a differential drive (one roller will turn slower than the other) of 10-25%. Roll speed ranges from 350 to 600 RPM depending on surface speed. This relative low speed causes less wear and less dust. The rollers are normally turned so that the sharp edge of each roll meets the grain (called sharp-to-sharp action). Roller mills can process grain with half the energy of a hammer mill and give equal particle size. The efficiency of a roller mill can be affected greatly by the roll corrugations, roll spacing, and the efficiency of the roller drives. Swine producers who wish to obtain a particle size analysis of their feed can send a 150 gram (3 cups) sample along with $10.00 to Dr. Jim Nelssen, 243 Weber Hall, Kansas State University, Manhattan, Kansas 66506.

Proportioning Ingredients

Equipment to measure out each part of the ration with the required accuracy must be selected and worked into the overall flow plan. All ingredients must be combined in the proper proportions to produce the intended ration. Two methods are used to proportion the ration, volume and weight. Nutritionists normally formulate rations by weight. Proportioning devices meter by volume. If the bulk density (test weight), flow characteristic, or moisture content of an ingredient changes, the volume proportioning device must be recalibrated. Some PTO driven grinder mixes use viewing windows for volume measurement. More accuracy is obtained by using a weight measurement that normally involves electronic scales. Portable grinder-mixers and portable mixers with built-in electronic scales are available. The scales are sufficiently accurate for weighing grain and soybean meal; however, they are not adequate for small quantities, such as minerals and premixes. For adding small amounts of ingredients such as minerals, vitamins, and salt, these materials should be premixed by weight in correct proportion with the protein supplement. Some of the low capacity grinder mixers have accurate meters for special minerals and medication as part of the unit.

Commercial equipment to proportion ingredients volumetrically is available that uses either augers or belts. Using different augers to proportion ingredients prior to a roller mill is an example of volumetric proportioning. Electric mills with volumetric ingredient measurement usually have four or more augers, all of which must be calibrated. Proportioning is accomplished by using intermittently timed or variable speed augers. The auger speeds must be set with respect to one another. Because swine rations are predominantly grain, the auger supplying the grain should be set first. The remaining augers are then set to deliver a flow rate in the proper proportion to the flow rate of grain.

The belt-type blender has an adjustable spout for each ingredient mounted over the belt. The height of each spout is adjusted to give the correct ratio of the ingredients. This equipment provides a satisfactory method of measuring rations when several free flowing ingredients are used. The equipment does not work well on material such as bran.

A number of continuous weighing devices are available for attachment to augers for volumetric or weight determination of auger output. Most of these devices have a two-chamber design that flip/flops or a trip weight that measures small unit quantities continuously. These devices are sufficiently accurate for grain and soybean meal, but not for minor ingredients. The best measuring method is to use scales to weigh out the ingredients for a "batch". Scales can be incorporated into a system in three ways: 1) a hopper bottom bin, large enough for a batch of feed, is mounted on scales, each ingredient is added individually until the required weight for each is reached, and the feed flows into a grinder and then into a mixer or directly to a mixer; 2) the mixer is mounted on scales, and each ingredient is added in turn to formulate a batch ; 3) large platform scales are used to accommodate a wagon, truck, or portable mixer; feed is added to the wagon, truck, or mixer while it is on the scales. The last method works well for large feeding operations.

Mixing

Portable or stationary mixing equipment is available commercially. A batch mixer to prepare separate batches of feed is a practical system. On-farm feed systems normally use three types of mixers: vertical, horizontal, or rotating drum. Vertical mixers take up the least floor space and have the greatest height requirement. Mixing times on vertical mixers normally run 10 to 15 min. Horizontal and rotating drum mixers can mix in 5 to 10 min. Either type will do a satisfactory mixing job for farm use.

The vertical mixer is composed of an upright tank, usually round, with a vertical auger in the center to mix the feed. Smaller, less costly mixers are usually of the vertical type. Typical vertical mixers are available in models ranging in size from a 1/2-ton model requiring a 3-horsepower motor up to a 4-ton model requiring a 25-horsepower motor. The vertical distance

The vertical mixer is composed of an upright tank, usually round, with a vertical auger in the center to mix the feed. Smaller, less costly mixers are usually of the vertical type. Typical vertical mixers are available in models ranging in size from a l/2-ton model requiring a 3-horsepower motor up to a 4-ton model requiring a 25-horsepower motor. The vertical distance required for installation can be a limiting factor in the use of vertical mixers on the farm. A typical 3-ton vertical mixer requires an overhead height of about 20 ft for installation.

Larger mixers are usually of the horizontal type with a horizontal shaft in the center carrying paddles or ribbons for the mixing. Power requirements range from 3 to 5 horsepower for a l/2-ton mixer up to 20 to 30 horsepower for a 3-ton model.

Mobile mixers, usually of the vertical type, either with or without a grinder attached, are now available at about the same price (for the mixer) as stationary units. The wheels and frame are added costs, but the units are more versatile than stationary equipment, and the equipment also doubles as a conveyor for delivering feed to self-feeders. Attachments are available for most mixers to add and mix oils, fats, molasses, and other liquids to the ration. Vegetable oils (corn, soybean, sunflower, etc.) are normally added to the mixer through the use of a positive displacement, rotary gear pump. The oil is discharged into the mixer with a nozzle to disperse the oil.

CAUTION: In selecting mixers (and other handling equipment) for rations involving hormones, antibiotics, and other medications, be sure that the equipment will mix the ingredients as required by Federal regulations and that equipment will clean out properly so as not to contaminate other feeds. Sequencing of different feed types can aid in reducing contamination problems. When regulated products (antibiotics, hormones, and medications) with withdrawal times are mixed in the mill, the next succeeding feed mixed in the mill should be rations going to pigs that are farthest from market (Figure 2).

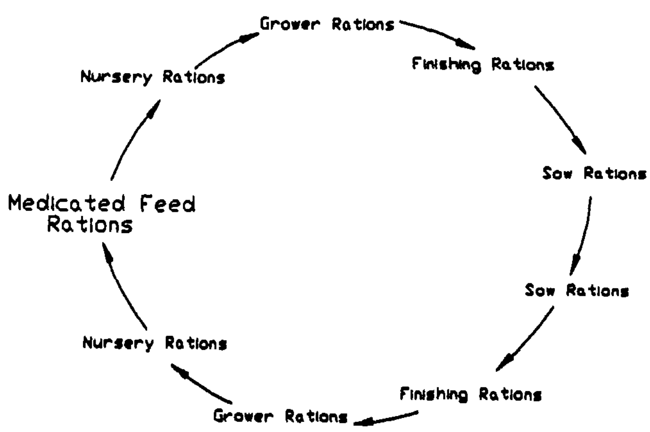

Figure 2. Sequencing of medicated rations,

LITTER SIZE FOR GILTS FED HIGHER LEVELS OF FOLIC ACID AND RIBOFLAVIN DURING GESTATION

D. L. Davis, J. L. Nelssen, C. Zhang, and D. Li

Summary

We fed gilts diets containing either additional folic acid throughout gestation (1.5 g/ton, 4.5 lb/gilt daily), additional riboflavin (100 mg/gilt daily) from d 4 to 10 of gestation, both folic acid and riboflavin, or neither supplement. All diets provided all KSU recommended allowances for all other nutrients. Neither farrowing rate nor litter size was affected by the treatments.

(Key words: VitB, Riboflavin, Gestation, Litter, Sow, Performance.)

Introduction

Thirty percent of potential pigs per gilt, about four pigs at farrowing, are lost by either embryonic (first 30 d of pregnancy) or fetal (after 30 d) death. About 20% of the potential pigs die during the first 14 d after breeding. The causes for embryonic and fetal death are not known, even though the high rate of mortality was discovered over 40 y ago. Recent reports indicate that pigs often are marginally deficient in folic acid during gestation. Thaler and coworkers (1988 Swine Day Report of Progress) observed increased litter sizes for gilts fed diets containing 1.5 g/ton supplemental folic acid. Another water soluble vitamin, riboflavin, exhibits a surge in its concentration in the uterine secretions between d 6 and 8 of pregnancy. There is a report that additional riboflavin provided in the diets of gilts from d 5 to 10 of gestation both increases the riboflavin in the uterine secretions and enhances embryo survival. In light of these reports, we compared the effects of riboflavin and folic acid in an experiment to evaluate their potential interactions.

Procedures

Crossbred (Duroc × Yorkshire × Hampshire × Chester White) gilts were vaccinated twice for leptospirosis and parvovirus and exposed to manure from the breeding herd prior to the initiation of the experiment. When approximately 7 mo old, gilts were moved from a finishing building to outside lots and exposed (fenceline) to mature boars to stimulate puberty. After 4 to 6 d the boars were removed. Beginning 10 d before breeding, gilts were provided free access to feeders containing a corn-soybean meal diet fortified with vitamins and minerals at KSU recommended levels. Eighteen days after their initial move, gilts were re-exposed to boars, and daily estrous checks were initiated 3 d later. Two blood samples, collected 10 d apart and before the beginning of breeding, were evaluated for progesterone. If the concentration of progesterone exceeded 2 ng/ml in either sample, the gilt was considered post-pubertal. Only five gilts that were detected in estrus were not classified as post-pubertal and were excluded from data analyses.

pubertal. Only five gilts that were detected in estrus were not classified as post-pubertal and were excluded from data analyses.

The experiment consisted of seven trials (221 gilts) and was conducted from October 1989 to August 1990. Breeding occurred over 10-d periods, with approximately 25-d intervals between trials. At breeding gilts were assigned to receive 4.5 lb of a corn-soybean meal diet containing one of the following: no supplements, folic acid, riboflavin, or folic acid and riboflavin. The folic acid supplement (1.5 g/ton) was fed throughout gestation. The riboflavin was fed from d 5 to 10 of pregnancy (100 mg/gilt/d). Otherwise, the diets were identical and provided nutrients to meet all KSU recommendations.

Results and Discussion

Seventy-eight percent of the inseminated gilts farrowed, and farrowing rate was not affected by treatment (76 to 81% for individual treatments). Likewise, no treatment effects were observed for either total pigs or live pigs farrowed (Figure 1). Therefore, our results do not agree with other reports showing improvements in litter size (folic acid) or embryo survival (riboflavin). Gilts were not riboflavin-deficient as indicated by the erythrocyte glutathione reductase test, and results of that test were not affected by riboflavin treatment. Concentrations of folic acid in serum are being measured.

In theory, riboflavin supplementation would benefit embryo survival early in pregnancy, and additional folic acid might have effects throughout pregnancy. The number of pigs developed to term (litter sire) was good in our study and may be near the maximum that can be supported by the gilt's uterus. Consequently, if embryo survival in early gestation had increased, fetal survival might have decreased to the limit imposed by uterine capacity. In fact, in other studies, we observed a significant improvement in embryo survival to d 10 of pregnancy attributable to riboflavin. If this enhancement in embryo survival is repeatable, it might be possible to improve litter size in groups of females that have not completely utilized their uterine capacity.

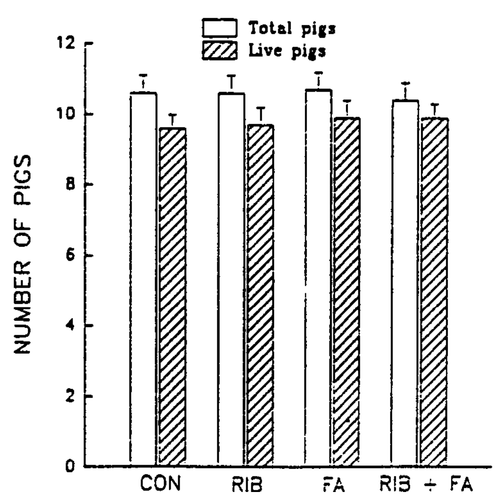

Figure 1. Litter size for gilts fed control (CON), riboflavin (RIB) folic acid (FA), or RIB+FA supplemented diets.

THE EFFECTS OF ADDITIONAL NIACIN DURING GESTATION AND LACTATION ON SOW AND LITTER PERFORMANCE

R. D. Goodband, J. L. Nelssen, T. L. Weeden, and D. F. Li

Summary

One hundred and twenty-one first-litter sows were utilized to evaluate the effects of additional niacin on sow and litter performance through two parities. The control diet provided sows with 50 mg/d niacin during gestation and 100 mg/d niacin during lactation. Dietary treatments were formulated to provide sows with either 5 or 10 times the level of supplemental niacin in the control diet. Litter size was equalized within dietary treatment by 24 hr after farrowing. During the first parity, total pigs born, number of pigs born alive, and pigs equalized per litter decreased then increased as dietary niacin level increased. However, sows fed additional niacin tended to wean more pigs per litter and, therefore, had greater pig survival from birth to weaning. Pig and litter weights at weaning were increased by increasing levels of additional niacin. Sows fed the intermediate level of added niacin had the greatest weight and backfat loss during lactation. During the second parity, additional niacin had no effect on the total number of pigs born or number born alive. However, the number of pigs equalized per litter increased then decreased as niacin intake increased. There were no differences in the number of pigs weaned, pig survival, pig weight, and litter weight at weaning from dietary treatment. These results suggest that first-litter sows fed the intermediate level of additional niacin during gestation and lactation had fewer total pigs born and born alive. However, these sows had more pigs at weaning, better pig survival, and heavier litters at weaning than those fed the 50/100 mg/d niacin gestation/lactation sequence. In addition, the decrease in pigs born and born alive during the first parity was not observed in the second parity.

(Key Words: Sow, Performance, Niacin, Gestation, Lactation.)

Introduction

In 1986, we reported results of a study designed to evaluate the effects of additional niacin on sow and litter performance (KAES Report of Progress #507). Since that time, a second group of 60 sows has been put through the identical protocol to help better determine the effects of additional niacin on sow and litter performance. The results reported herein contain the combined data from both 1986 and the second group of sows in the study just completed.

Procedures

One hundred twenty-one sows were assigned at breeding to one of three gestation-lactation treatments. Control sows were fed a corn-soybean meal diet (14% crude protein) that provided 50 mg/d niacin during gestation and 100 mg/d niacin during lactation (Table 1). Additional niacin was then added to provide sows with either 250/500 or 500/1000 mg/d niacin during gestation and lactation, respectively. All sows were fed 4 lb/d from breeding until d 90 of gestation, at which time feed was increased to 5 lb/d until farrowing. On day 108 of gestation, all sows were moved into the farrowing house, sow weight was recorded, and backfat was measured ultrasonically[1]. Following parturition, sows were fed 9 lb/d of a lactation diet.

Table 1. Composition of Diets

Ingredients, %	Gestation I[a]	Gestation II[b]	Lactation[c]
Corn[d]	80.45	86.17	75.48
Soybean meal (44% CP)	15.55	10.45	19.90
Dicalcium phosphate (21% P)	2.05	1.50	2.25
Limestone	1.10	.95	1.25
Salt	.50	.45	.50
Vitamin premix[e]	.25	.20	.22
Trace mineral premix[f]	.10	.08	.10
Furox (50 g/lb)	--	.20	.20
Biotin (100 mg/lb)	--	--	.10
	100.00	100.00	100.00

[a]Fed from d 0-90 of gestation at 4 lb/d providing 50 mg niacin/sow/d.
[b]Fed from d 90-114 of gestation at 5 lb/d providing 50 mg niacin/sow/d.
[c]Fed during lactation at 9 lb/d providing 100 mg niacin/sow/d.
[d]Corn was replaced by niacin to provide 250 or 500 mg niacin/sow/d during gestation, and 500 or 1000 mg niacin/sow/d during lactation.
[e]Each lb of premix contains the following: vitamin A, 800,000 IU; vitamin D_3, 60,000 IU; vitamin E, 4000 IU; riboflavin, 900 mg; menadione, 310 mg; pantothenic acid, 2400 mg; niacin, 5000 mg; choline chloride, 92,200 mg; vitamin B_{12}, 4.4 mg.
[f]Containing 10.0% Mn, 10% Fe, 1.0% Cu, 10% Zn, 0.30% I, and 0.3% Co.

Sow and pig weights were recorded within 24 h following parturition, and litter weights were recorded at weaning (d 21). Sow backfat was also measured at weaning.

Following weaning, sows were moved into individual gestation stalls and checked once daily for estrus with a boar. Estrous detection continued for a maximum of 30 d postweaning, at which time any sow not showing estrus was slaughtered, and her reproductive tract examined. For the second parity, sows were maintained on the same gestation-lactation treatments previously assigned, and all experimental procedures were similar to parity one.

[1]Technicare 210DX, Johnson & Johnson Co.

Results and Discussion

The effects of niacin intake during gestation and lactation on sow and pig performance (parity 1) are reported in Table 2. Control sows (50/100 mg/d niacin gestation/lactation) had more total pigs born and more pigs born alive (quadratic, P<.05) than those fed 250/500 mg/d gestation/lactation, but were numerically similar to those fed the highest level of added niacin (500/1000 mg/d gestation/lactation). Number of pigs/litter after equalization was also decreased as the level of niacin increased (quadratic, P<.05). This trend was observed for the number of pigs weaned; number of pigs decreased then increased as dietary niacin level increased (quadratic, P<.05). This was a result of the improved pig survival from birth to weaning for pigs from sows fed additional niacin. Pig and litter birth weights were unaffected by dietary niacin intake; however, sows fed additional niacin weaned heavier pigs (quadratic, P<.05) and litters (quadratic, P<.10) than control sows.

Sow weight and backfat thickness changes during gestation were not affected by dietary treatment. Sows fed the 250/500 mg/d niacin gestation-lactation sequence had more backfat on d 108 of gestation than those fed the control or 500/1000 mg/d niacin gestation-lactation sequence (quadratic P<.05). However, sows fed 250/500 mg/d niacin also tended to lose more backfat but less body weight during lactation (quadratic P<.05). Because all sows had the same daily feed intake, this change in backfat during lactation might have been a result of greater milk production, as shown by the slightly heavier pig and litter wt at weaning.

During parity 2, there were no adverse affects of additional niacin on total number of pigs born or number born alive. In fact, number of pigs equalized/litter increased (quadratic P<.05) as niacin intake increased, opposite to the response observed in parity 1. In addition, pig birth wt, survival to weaning, and pigs weaned per litter were not affected by supplemental niacin. Additional niacin had no effect on sow weight or backfat changes during parity 2.

Research with dairy cattle has shown an increase in total milk yield and fat content for cows fed supplemental niacin. The exact metabolic process of how niacin improved milk yield is not known, but researchers feel that supplemental niacin may increase the level of NAD/NADP coenzymes, allowing for increased protein, carbohydrate, and lipid metabolism. Niacin may also increase milk production by elevating plasma glucose and preventing excessive fat mobilization (subclinical ketosis), thus allowing the liver to efficiently utilize normal plasma lipid levels.

From the wide range of niacin levels used in this study, it is difficult to determine the optimum level of additional niacin needed to maximize sow and litter performance. However, pig survival and pig and litter weaning weights appeared to be maximized for sows fed the 250/500 mg/d niacin level, which is higher than the 19 and 53 mg/d available niacin gestation/lactation sequence suggested by the 1989 National Research Council.

Table 2. Effect of Niacin Intake during Gestation and Lactation on Sow and Litter Performance (Parity 1)[a]

	Niacin Intake mg, Gestation/Lactation		
Item	50/100	250/500	500/1000
No. of litters	40	38	43
Total pigs born[b]	10.30	9.18	10.16
Pigs born alive	9.35	8.85	9.51
Pigs/litter after equalization[b]	9.22	8.48	9.36
Survival to weaning, %[c]	89.18	94.10	92.37
Pigs weaned/litter[b]	8.20	7.95	8.65
Pig Performance, lb			
Pig birth wt	2.82	2.84	26.87
Litter birth wt	25.56	24.67	26.87
Pig wt at weaning[b]	11.00	11.98	11.43
Litter wt at weaning	90.80	94.61	97.89
Sow wt gain during gestation, lb	99.02	94.15	97.74
Sow backfat change during gestation, in	-.01	.02	-.02
Sow wt d 108 gestation, lb	373.41	366.17	367.19
Sow backfat d 108 gestation, in[b]	.98	1.05	.96
Sow wt loss during lactation, lb[b]	24.54	18.32	24.44
Sow backfat loss during lactation, in[b]	.15	.19	.15

[a]Lactation length, 21 d.
[b]Quadratic effect of niacin ($P<.05$).
[c]Quadratic effect of niacin ($P<.10$).

Table 3. Effect of Niacin Intake during Gestation and Lactation on Sow and Litter Performance (Parity 2)[a]

	Niacin Intake mg, Gestation/Lactation		
Item	50/100	250/500	500/1000
No. of litters	27	25	28
Total pigs born	8.81	9.11	8.48
Pigs born alive	8.14	8.72	7.98
Pigs/litter after equalization[b]	7.94	8.48	7.64
Survival to weaning, %	97.66	95.45	98.66
Pigs weaned/litter	7.72	8.06	7.55
Pig Performance, lb			
Pig birth wt	3.27	3.26	3.32
Litter birth wt	26.19	28.13	25.57
Pig wt at weaning	12.37	12.43	12.83
Litter wt at weaning	95.39	99.20	95.59
Sow wt gain during gestation, lb	81.57	75.88	87.13
Sow backfat change during gestation, in	.15	.10	.12
Sow wt d 108 gestation, lb	406.39	403.73	405.38
Sow backfat d 108 gestation, in	.99	.96	.93
Sow wt loss during lactation, lb	21.91	20.08	23.21
Sow backfat loss during lactation, in	.17	.15	.16

[a]Lactation length, 21 d.
[b]Quadratic effect of niacin ($P<.05$).

EFFECT OF SUBSTITUTING SPRAY-DRIED PLASMA PROTEIN FOR MILK PRODUCTS IN STARTER PIG DIETS

J. A. Hansen, R. D. Goodband, J. L. Nelssen, K. G. Friesen, and T. L. Weeden[1]

Summary

Two growth trials utilizing 444 weaned pigs were conducted to determine the efficacy of substituting spray-dried porcine plasma protein (PP) for dried skim milk (DSM) and/or dried whey (DW) in starter pig diets. Trial 1 was a field study in which 240 pigs were fed either a control diet containing 20% DSM and 20% DW during phase I (0 to 14 d post-weaning) and 15% DW and 5% select menhaden fishmeal in phase II (14 to 28 d post-weaning) of the 28 d trial. Plasma protein was substituted on a lysine basis for DSM in the phase I diet and for DW in the phase II diet. Diets were isolactose in both phases. Pigs fed the diets containing PP grew faster and consumed more feed from d 0 to 7 than pigs fed the control. However, pigs fed the control diet compensated during wk 2 to achieve equal performance during phase I. No treatment differences were detected during phase II or in overall performance. In Trial 2, 204 pigs were allotted to one of the following treatments: 1) control diet containing 20% DSM and 20% DW, 2) as 1 with casein replacing soybean meal (lysine basis; all milk protein), 3) as 1 with PP and lactose replacing 20% DSM (lysine and lactose basis), 4) as 3 with starch replacing lactose (wt/wt), 5) as 1 with PP and lactose replacing DSM and DW (lysine and lactose basis), 6) as 5 with starch replacing lactose, 7) corn-soybean meal plus 20% DW. Pigs fed diets containing PP grew faster and consumed more feed than pigs fed the control, casein, or 20% DW diets from 0 to 14 d postweaning. Similarly, overall gains were significantly greater for pigs fed PP than pigs fed the control, casein, and DW diets. Also, pigs fed PP consumed greater quantities of feed over the entire trial than those pigs fed the control or casein diets. Serum was collected on d 13 and analyzed for blood urea nitrogen. Blood urea N was higher for pigs fed PP, indicating that the amino acids in PP are more available to the pig, but not all are utilized for protein synthesis. Skinfold thickness was measured on d 7 following intradermal injections of protein extracts of PP soybean meal and DSM; these data indicate that PP and DSM cause extremely small changes in skinfold thickness compared to soybean proteins. Based on the results of these experiments, PP has an equal, if not better, feeding value than milk protein.

(Key Words: Starter Performance, DSM, Whey, Plasma Protein.)

---

[1]Appreciation is expressed to American Protein Corporation, Ames, IA, for financial support and to Louis Russell, Feed Specialties, Inc., Des Moines, IA, for technical assistance. The author's also wish to thank Prince Agri. Products, Quincy, IL, for donating the monosodium phosphate used in this research and to Dale Keesecker and Keesecker Agribusiness, Washington, KS, for use of facilities and animals.

Introduction

Previous research has indicated that soybean proteins have several antinutritional factors that cause morphological and immunological changes to the small intestine of newly weaned pigs. This results in reduced nutrient uptake and significant reductions in growth rate and feed intakes of the weanling pigs. Milk protein is considered to be one of nature's most perfect proteins for new-born animals. For this reason, it is often included in starter pig diets to offset some of the detrimental effects of the soybean proteins typically added to those diets. Many researchers have demonstrated tremendous advantages to using milk products in swine diets, especially dried whey (DW) and dried skim milk (DSM). From 0 to 14 d postweaning Kansas State University recommends using 20% DSM and 20% DW in starter diets for pigs weaned at 3 weeks of age. The present trials were conducted to determine if spray-dried PP is a viable alternative to milk products in starter pig diets.

Procedures

Trial 1 was a field study utilizing 240 weaned pigs (16.5 lb initial wt; 25 d of age; 28 d trial) to determine the efficacy of substituting PP and lactose for DSM during phase I and for dried whey during phase II, on a lysine and lactose basis. Diets (Table 1) were formulated to contain 1.5% and 1.25% lysine in phase I and phase II, respectively, plus .9% calcium and .8% phosphorus. Pigs were blocked by weight and assigned by sex and ancestry to experimental treatments. Pigs were housed 15 per pen (8 pens per treatment) in an environmentally controlled nursery with woven wire flooring and allowed ad libitum access to feed and water. Individual pig weights and feed intakes per pen were obtained and recorded at weekly intervals. Feed conversions were calculated based on gains per pen and feed intakes. The pen was considered an experimental unit.

Skinfold thickness was determined at 7 d postweaning. Pigs were intradermally injected with .5 ml of sterile saline (physiological), soybean protein, milk protein, and PP extracts. Skinfold thickness was measured using a micrometer 24 hr postinjection. All test solutions contained equimolar quantities of the respective protein extracts to determine the immunological response to injection, as well as to determine dietary treatment by injection treatment interaction.

In Trial 2, 204 pigs were weaned at about 21 ± 2 d age (initial wt 12.9 lb; 35 d trial), blocked by weight and sex, then randomly assigned to experimental treatments within blocks according to ancestry. There were five replicate pens (6 pigs/pen) for all treatments, except the diet containing casein, which had only four replicate pens. Pigs were housed in 4 ft x 5 ft pens (woven wire floors) in an environmentally controlled nursery and allowed feed and water ad libitum. Pigs were weighed weekly and feed disappearance per pen was obtained for feed conversion analysis. Serum samples were obtained on d 13 of the trial and subsequently analyzed for blood urea nitrogen (BUN). Skinfold thickness was determined as in trial 1.

Experimental treatments (Table 2) were: 1) control (HNDD), corn-soybean meal + 20% DSM + 20% DW; 2) casein (CAS), as 1 with casein replacing soybean meal, 3) plasma-lactose-whey (PLW), as 1 with plasma and lactose replacing DSM; 4) plasma-starch-whey (PSW), as 3 with corn starch replacing lactose; 5) plasma-lactose (PL), as 1 with plasma and lactose replacing

DSM and DW; 6) plasma-starch (PS), as 5 with corn starch replacing lactose; 7) dried whey (DW), corn-soybean meal + 20% DW. All diets were formulated to contain similar amounts of lysine (1.4%), calcium (1.0%), phosphorus (.9%), sodium (.91%), and at least .39% methionine. All other amino acids were calculated to exceed National Research Council (NRC, 1988) and Kansas State Universities nutrient estimates for 12 lb pigs. The diets were pelleted through a 10/64 in x 1.5 in die with a conditioning temperature of 140 to 144° F, with the exception that the PS diet was pelleted with a conditioning temperature of 158 to 167° F, indicating a higher absorptive capacity for water by the starch.

Table 1. Trial 1 Diet Composition

	Phase I		Phase II	
Ingredient	Control	Plasma protein	Control	Plasma protein
Corn	25.06	24.05		
Sorghum			53.4	54.15
Soybean meal, (48.5% CP)	22.15	22.15	19.3	19.3
Dried whey	20	20	15	
Dried skim milk	20			
Fishmeal, select menhaden			5	5
Lactose		10		10.8
Plasma protein		10		2.9
Soybean oil	10	10	4	4
Monocalcium phosphate (21% P, 18% Ca)	1.1	2.05	1.3	1.8
Limestone	.5	.7	.5	.6
Lysine·HCl, 98%	.14		.2	.15
Salt			.3	.3
Premix[a]	.95	.95	.95	.95
Vitamin E[d]	.1	.1	.1	.1
Total	100	100	100	100
Calculated Analysis, %				
Crude protein	22.2	22.3	19.1	19.1
Lysine	1.55	1.55	1.25	1.25
Methionine	.42	.3	.34	.33
Sodium	.38	.89	.36	.34

[a] Premixes provided 5 g chlortetracycline; 5 g sulfathiazole; 2.5 g penicillin; vitamin A, 2,500 IU; vitamin D_3, 250 IU; vitamin E, 10 IU; menadione, 1 mg; riboflavin 2.5 mg; pantothenic acid, 6.25 mg; niacin, 13.75 mg; choline, 250 mg; and vitamin B_{12}, .5 µg; 4.5 mg Mn; 4.5 mg Fe; 4.5 mg Zn; 1.81 mg Ca; 115.7 mg Cu; .18 mg K; .14 mg I; .09 mg Na and .05 mg Co per lb of finished diet.
[b] Each lb of premix contained 20,000 IU vitamin E.

Table 2. Trial 2 Diet Composition

	Phase I[a]	Phase

Ingredient	HNDD	CAS	PLW	PSW	PL	PS	DW	II
Corn	33.4	42.2	33.1	33.1	34.7	34.7	36.4	55.3
Soybean meal, 48.5%	16.1		16	16	16	16	32	23.3
Dried whey	20	20	20	20			20	10
Dried skim milk	20	20						
Plasma protein			10.3	10.3	13.4	13.4		
Fishmeal, select menhaden								4
Lactose			10		24.4			
Corn starch				10		24.4		
Soybean oil	6	6	6	6	6	6	6	4
Monosodium phosphate (18.8% P, 26% Na)	1.6	1.63			.26	.26	2.03	
Monocalcium phosphate (21% P, 18% Ca)		.05	2.58	2.58	2.99	2.99		1.46
Limestone	1.24	1.31	.68	.68	.92	.92	1.7	.54
Salt	.3						.3	.25
Lysine·HCl, 98%	.14						.15	.15
Dl-methionine, 99%			.13	.13	.15	.15	.06	
Premix[b]	.95	.95	.95	.95	.95	.95	.95	.95
Selenium premix[c]	.05	.05	.05	.05	.05	.05	.05	.05
Cr_2O_3	.1	.1	.1	.1	.1	.1	.1	
Total	100	100	100	100	100	100	100	100
Calculated Analysis, %								
Crude protein	19.9	19.5	20.1	20.1	19.7	19.7	21.2	19.4
Lysine	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.25
Methionine	.39	.49	.39	.39	.39	.39	.39	.35
Lactose	24.4	24.4	24.4	14.4	24.4	0	14.4	7.2

[a] HNDD=control; CAS=casein; PLW=plasma-lactose-whey; PSW=plasma-starch-whey; PL=plasma-lactose; PS=plasma starch; DW=dried whey.
[b] Same as Table 1.
[c] Selenium premix provided 136.2 μg per lb complete diet.

Results and Discussion

Skinfold Thickness. Skinfold thickness data (Table 3) for both trials showed no injection by dietary treatment interactions, indicating that feeding casein, DSM or PP offers no potential for immunological changes past the intestinal level. All measurements were relative to saline, thus, negative values could be obtained, as indicated by DSM. Plasma protein caused slightly higher changes in skinfold thickness, which could be due to the different proteins and immunoglobulins that would be foreign to the pig. Because the composition of milk protein compared to PP would include large quantities of casein rather than functional circulating proteins, the possible antigenicity could be due to the proteins in plasma. There was a significant change in skinfold thickness from the soybean proteins, indicating that the anti-nutritional factors present in soybean meal cause significant immunological changes in the pig. These data are in agreement with previous data from this station.

Table 3. Skinfold Thickness Change Due to Protein Source for Trials 1 and 2

Item		Protein source			CV
		Plasma protein	Skim milk	Soybean meal	
Trial 1					72.5
	Skinfold thickness vs. saline[a], µm	.69	.58	1.28	
Trial 2					116.2
	Skinfold thickness vs. saline[a], µm	.33	-.1	1.37	

[a] Soybean meal vs others (P<.01).

Trial 1. Week one performance data (Table 4) indicate that the replacement of milk protein with PP and lactose increased daily feed intake (ADFI; .48 vs .39 lb/d; P<.10) and average daily gain (ADG; .49 vs .40 lb/d; P<.05). The response to added PP was not maintained, however, because pigs fed the control diet compensated during wk 2. Therefore, no net differences were detected for phase I (0 to 2 wk). A similar pattern was noticed in phase II and overall performance, in which no treatment differences were found. In general, these data suggest that PP plus lactose has an equal feeding value to DSM during the first 2 weeks postweaning. The PP may be more beneficial during the first 7 to 10 d postweaning when maximal stress is possible, whereas the DSM appears to be most beneficial when the pigs have overcome the postweaning stress.

Trial 2. In trial 2, wk 1 and 0 to 14 d gains (P<.05) and feed intakes (P<.05) of pigs fed PP (Table 5) were superior to those fed the control diet. The substitution of plasma and lactose for DSM (PLW diet) appeared to maximize the response in growth and intake. This could be the combined effect of adding lactose compared to starch (P<.10) and the low compared to high level of PP (P<.05) on both ADG and ADFI. Similarly, ADG for pigs fed the PSW diet was second only to the PLW diet, indicating the need for lactose and DW during the initial 7 d postweaning. The PL diet performed similarly to the PSW diet, indicating again that lactose has a profound positive effect on initial postweaning performance. It is important to note, however, that the PL diet had higher quantities of lactose than the PSW diet (24.4 vs 14.4%), indicating that the higher inclusion rate of PP is not essential to maximize growth response. In general, pigs fed diets containing PP grew faster because of an increased feed intake (P<.05) than pigs fed the HNDD, CAS, or DW diets.

Pigs fed the DW diet had poorer ADG (P<.05) than those fed the HNDD diet during week 1, but this effect was not observed throughout the 0 to 14 d period. These results indicate that the inclusion of only 20% DW would be adequate during the first 14 d postweaning, which is inconsistent with previous research evaluating these of diets. Pigs fed the DW diet tended to sort out unwanted particles in the trough, as indicated by average daily feed refusal (Table 5). Because all feeders were managed to allow the opportunity for pigs to consume fresh feed, the potential for poor performance on the DW diet could have been minimized, because the pigs could eat the most desirable components and leave the rest. From an economical standpoint, the DW diet was least desirable because pigs refused large quantities of feed.

Pigs fed the CAS diet performed as well as the pigs fed the HNDD or DW diets during the first week and 0 to 14 d postweaning. There was a clear trend for pigs fed the CAS diet to have reduced feed intakes during these periods as well. However, the reduction in feed intake was offset by a more efficient utilization of feed for gain. It appears that casein would be best utilized in diets for pigs weighing less than 15 lb.

Table 4. Effect of Substituting Plasma Protein and Lactose for Milk Products in Starter Pig Diets (Trial 1)[a]

Item	Control	Plasma protein	CV
<u>0-7 d</u>			
ADG, lb[b]	.40	.49	11.7
ADFI, lb[c]	.39	.48	8.6
F/G	.97	.98	6.4
<u>0-2 wk</u>			
ADG, lb	.58	.59	5.2
ADFI, lb	.67	.67	6.8
F/G	1.16	1.14	5.9
<u>2-4 wk</u>			
ADG, lb	1.16	1.12	3.3
ADFI, lb	1.9	1.86	2.8
F/G	1.63	1.65	3.1
<u>0-4 wk</u>			
ADG, lb	.87	.84	2.6
ADFI, lb	1.28	1.26	2.4
F/G	1.48	1.49	3.2

[a] Values are means of eight pens containing 15 pigs per pen (initial wt 16.5 lb; 28 d trial; 25 d of age).
[b] Means differ ($P<.05$).
[c] Means differ ($P<.10$).

Blood urea nitrogen data (Table 5) indicate that pigs fed the lower levels of plasma protein had significant excesses of amino acids that could be metabolized to urea. Similarly, pigs fed the higher level of PP had BUN levels higher than those of the HNDD pigs. These results suggest that the amino acids in PP are more available for use by the pig; therefore, some may be in excess. Blood urea nitrogen data parallel F/G data. Pigs fed the diets containing PP had slightly poorer F/G; therefore, higher BUN values would be anticipated. These factors are expected to be influenced at this age mainly by feed intake, because the pigs consuming more feed in this trial had somewhat poorer feed efficiencies.

During phase II, all pigs had similar weight gains and feed intakes, with the exception of pigs fed the CAS diet, which had poorer gains and feed intakes. In general, pigs fed the diets containing PP tended to have reduced performance during wk 3, possibly caused by such a significant change in diet, but compensated during wk 4 and 5 to have slightly better gains and much higher feed intakes (P<.05) for the 2 to 5 wk period. However, pigs fed the HNDD or DW diet showed very little difference in performance when the switch was made to a common phase II diet.

During the 0 to 5 wk period, pigs fed the diets containing PP had significantly faster rates of gain (P<.05) and greater feed intakes (P<.05) than pigs fed the HNDD diet. The PLW diet produced the highest ADG (11% greater than HNDD) and ADFI (14% greater than HNDD) of all experimental treatments.

Based on these results, spray-dried porcine plasma protein can be an effective alternative to DSM in starter pig diets. These data indicate that substituting PP on a lysine basis for DSM, with subsequent additions of 10% lactose during the first 7 to 14 d postweaning, can produce better growth rates and feed intakes than a diet containing 20% DSM plus 20% DW.

Table 5. Effect of Substituting Plasma Protein and Lactose or Starch for Milk Products in Starter Pig Diets (Trial 2)[ab]

Item	HNDD	CAS	PLW	PSW	PL	PS	DW	CV
<u>0-7 d</u>								
ADG, lb[cdef]	.67	.73	.89	.83	.82	.69	.57	9.8
ADFI, lb[cde]	.66	.65	.88	.76	.79	.67	.62	8.1
F/G[f]	.98	.89	.99	.93	.97	.97	1.08	7.5
Blood urea N, mg/dl[de]	4.24	3.42	6.09	6.56	4.99	4.65	5.42	41.4
<u>0-2 wk</u>								
ADG, lb[cde]	.69	.73	.98	.93	.91	.83	.72	8.9
ADFI, lb[cde]	.86	.82	1.18	1.07	1.06	.96	.92	8.2
F/G[e]	1.24	1.12	1.21	1.16	1.17	1.15	1.27	4.7
Feed refusal, lb/pen·d^{-1}	.18		.09		.27	.19	.98	
<u>2-5 wk</u>								
ADG, lb	1.30	1.19	1.34	1.30	1.34	1.33	1.33	6.4
ADFI, lb[e]	2.30	2.22	2.48	2.43	2.53	2.54	2.49	6.3
F/G[e]	1.77	1.86	1.86	1.88	1.90	1.90	1.88	5.6
<u>0-5 wk</u>								
ADG, lb[e]	1.05	1.01	1.19	1.15	1.17	1.13	1.09	6.1
ADFI, lb[e]	1.72	1.66	1.96	1.89	1.95	1.91	1.86	6.3
F/G	1.63	1.64	1.65	1.64	1.67	1.68	1.72	4.3

[a] Values are means of four (CAS) or five (others) pens with 6 pigs/pen (initial wt 12.9 lb; 35 d trial; 21 ± 2 d of age).

[b] HNDD=control; CAS=casein; PLW=plasma-lactose-whey; PSW=plasma-starch-whey; PL=plasma-lactose; PS=plasma starch; DW=dried whey.

[c] Main effect of lactose (P<.10).

[d] Main effect of plasma protein level (P<.05).

[e] Plasma protein vs control (P<.05).

[f] Control vs dried whey diet (P<.05).

EFFECT OF REPLACING DRIED SKIM MILK WITH SPECIALLY PROCESSED SOY PRODUCTS ON DIGESTIBILITY OF NUTRIENTS AND GROWTH PERFORMANCE OF NURSERY PIGS

D. B. Jones, J. D. Hancock, P. G. Reddy[1], R. D. Klemm[1] and F. Blecha[1]

Summary

One hundred twenty-eight pigs (21 d of age and 11.7 lb) were used to determine the effects of feeding specially processed soy products and lactose versus dried skim milk on growth performance and nutrient digestibility. For d 0-14, pigs received pelleted diets that were: 1) corn-soybean meal-whey control; 2) a high nutrient density diet (HNDD) containing 20% dried skim milk and 20% dried whey; 3 and 4) the HNDD with soy protein isolate[2] replacing 50% and 100% of the protein supplied by dried skim milk; 5 and 6) the HNDD with soy protein concentrate[3] replacing 50% and 100% of the protein supplied by dried skim milk; 7 and 8) the HNDD with modified soy flour[4] replacing 50% and 100% of the protein supplied by dried skim milk. For d 14-35, all pigs were fed a common diet. Average daily gain (ADG), average daily feed intake (ADFI), feed:gain ratio (F/G), and fecal scores were determined for d 7, 14, and 35 of the experiment. Apparent digestibilities of N and DM were determined from fecal samples collected on d 13. For d 0 to 7, pigs fed the HNDD had the best F/G, pigs fed the corn-soybean meal-whey control had the poorest F/G, and pigs fed diets with the specially processed soy products were intermediate in feed efficiency. Pigs fed the soy isolate had improved feed efficiency and less incidence of diarrhea compared to pigs fed the soy concentrate. For d 0 to 14, pigs fed the corn-soybean meal-whey control had the poorest performance and DM digestibility. When dried skim milk was replaced with the specially processed soy products, F/G was worse, but digestibility of N and DM were not decreased, especially at the 50% level of replacement. Pigs fed the soy isolate had performance more similar to pigs fed the HNDD than pigs fed the soy concentrate or modified soy flour. From d 0 to 35, ADG and ADFI were greater for pigs fed diets with soy products replacing the protein from dried skim milk than pigs given the HNDD. However, pigs fed the HNDD gained more efficiently. Our data indicate that replacing the protein from dried skim milk with the specially processed soy products tested in this experiment resulted in slight depressions in performance early in the nursery phase (i.e., d 0 to 14). However, as the processing techniques became more elaborate (i.e., isolate> concentrate> modified soy flour), utilization of the products was improved.

(Key words: Starter, Performance, Soybean, SBM, DSM.)

Introduction

Early weaning has resulted in the use of diets high in milk products, especially dried skim milk and dried whey, to increase the nutrient quality and to better match those diets to the pigs' digestive capabilities. Although performance of pigs fed these high milk-product diets is greater

---

[1]Dept. of Anatomy and Physiology.

[2]Ardex F, [3]Pig Pro 70, [4]Pig Pro 50, ADM Protein Specialties, Archer Daniels Midland Co., Decatur, IL.

than performance of pigs fed simple corn-soybean meal diets, the milk-product diets are more expensive. Thus, other feed ingredients need to be investigated as possible replacements for all or part of the milk products in high nutrient density diets (HNDD). Three potential replacement products are soy protein isolate, soy protein concentrate, and modified soy flour. Soy protein isolates are produced by using precipitation techniques to separate the large storage proteins of defatted soy flakes from the soluble and insoluble carbohydrates and smaller whey proteins. This leaves a high quality soy product that is approximately 90% crude protein. Soy protein concentrates are produced by extracting (usually with ethanol and/or water) the soluble carbohydrates from the defatted soy flakes, leaving a product of about 70% crude protein. Modified soy flour is produced by fine grinding dehulled soybean meal and then further processing it by methods such as toasting or extrusion that serve to deactivate the growth inhibitors and cause structural changes to the soybean proteins. An experiment was conducted to determine the effects of using these specially processed soy products to replace the protein from dried skim milk in diets for weanling pigs.

Procedures

One hundred twenty-eight crossbred pigs were weaned at 21 d of age (avg wt=11.7 lb) and used in a 5-wk growth assay to determine the effects of feeding specially processed soy products and lactose in place of dried skim milk in diets for newly weaned pigs. Pigs were housed (two barrows and two gilts per pen) in an environmentally controlled nursery equipped with 4 × 5 ft pens and woven wire flooring. Each pen had a self-feeder and nipple waterer so feed and water could be consumed ad libitum.

Pigs were fed the Phase 1 diets (Table 1) from weaning to d 14. Phase 1 treatments were: 1) corn-soybean meal-whey control; 2) a high nutrient density diet (HNDD) containing 20% dried skim milk and 20% dried whey; 3 and 4) the HNDD with soy protein isolate replacing 50% and 100% of the protein supplied by dried skim milk; 5 and 6) the HNDD with soy protein concentrate replacing 50% and 100% of the protein supplied by dried skim milk; 7 and 8) the HNDD with modified soy flour replacing 50% and 100% of the protein supplied by dried skim milk. All Phase 1 diets contained .25% chromic oxide as an indigestible marker for determination of apparent

Table 1. Diet Composition.

Ingredient, %	Corn-soy-whey	HNDD[a]
Corn	37.82	31.34
Soybean meal(48%)	33.20	20.60
Soy replacements	—	—
Dried skim milk	—	20.00
Dried whey	20.00	20.00
Lactose	—	—
Soy oil	5.00	5.00
Lysine-HCl	.23	.11
Vit/Min/Antibio.	3.50	2.70
Chromic oxide .25		.25
Total	100.00	100.00
<u>Calculated composition</u>[b]		
Lactose, %	14.80	25.00
g Lys/Mcal DE	4.20	4.10

[a]Soy isolate, soy concentrate or modified soy flour were used to replace 50% and 100% of the protein from dried skim milk in the HNDD. Lactose was added so that all HNDD's contained 25% lactose.
[b]Formulated to provide 22% crude protein, 1.5% lysine, .9% Ca, and .8% P.

digestibilities of N and DM. A common diet was fed to all pigs during Phase 2 (from d 14 to 35), based on corn-soybean meal with 20% dried whey, formulated to contain 1.25% lysine, .9% Ca, and .8% P.

Pigs and feeders were weighed on d 7, 14, and 35 of the experiment to determine average daily gain (ADG), average daily feed intake (ADFI), and feed:gain ratio (F/G). On d 13 of the experiment, fecal samples were collected from all of the pigs by rectal massage; pooled within pen, dried, and analyzed for N, DM, and Cr content. Apparent digestibilities of N and DM were calculated using the indirect ratio method.

Each pen of pigs was observed at approximately 8:00 a.m. and given a fecal score. Scores were assigned using the scale 1 = all pigs with normal feces to 5 = all pigs with diarrhea. Scores for d 7, 14, and 35 were calculated by averaging the scores for d 5, 6, and 7; d 12, 13, and 14; and d 33, 34, and 35, respectively. The pooled scores were transformed (square root transformation) prior to statistical analysis.

Results and Discussion

Growth data, digestibility data, and fecal scores are given in Table 2. From d 0 to 7 of the experiment, pigs fed the HNDD had the best F/G ($P<.05$). Pigs fed the corn-soybean meal-whey control were the least efficient ($P<.02$), and pigs fed the diets with soy products replacing the protein from dried skim milk were intermediate in efficiency of feed utilization. Pigs fed the soy isolate had improved F/G ($P<.01$) and less incidence of diarrhea ($P<.02$) compared to pigs fed the soy concentrate. Pigs fed the diets with soy isolate or soy concentrate ate more feed and had greater ADG as the level of soy products was increased from 50 to 100% replacement, whereas pigs given the modified soy flour ate less feed and had decreased ADG as the level of soy flour was increased in the diets ($P<.02$). Pigs fed diets with soy isolate had lower incidence of diarrhea ($P<.02$) than pigs fed soy concentrate.

From d 0 to 14 of the experiment, pigs given the corn-soy-whey control gained slower than pigs fed the other diets ($P<.11$). Also, ADG increased as the level of soy isolate or soy concentrate was increased in the diet, but ADG decreased ($P<.11$) as the level of modified soy flour was increased. Feed intake was affected by concentration of soybean product, with increased ADFI as more isolate and concentrate were added to the diets, but reduced ADFI as the inclusion rate of modified soy flour was increased ($P<.09$). Pigs fed the corn-soy-whey control diet had greater F/G ($P<.02$) than pigs fed the other treatments, and F/G was less ($P<.02$) for pigs fed the HNDD than for those fed diets with dried skim milk replaced by the soy products. Dry matter digestibilities were lower for pigs fed the control diet than for those fed the HNDD's ($P<.04$), and the diets containing modified soy flour had lower DM digestibility than diets with soy isolate or soy concentrate ($P<.09$). Nitrogen digestibilities followed a similar trend to DM digestibilities; however, the differences were not statistically significant ($P>.18$). On d 14 of the experiment, there was a reduction in the incidence of diarrhea as the level of soy isolate or soy concentrate was increased in the diet, but an increase in the incidence of diarrhea as the level of modified soy flour was increased in the diet ($P<.08$).

Overall (d 0 to 35), pigs fed diets with the specially processed soy products from d 0 to 14 consumed more feed ($P<.001$) and gained faster ($P<.03$) than those fed the HNDD. There was an increase in ADG as the concentration of the soy product replacements was increased ($P<.07$), and pigs given isolate or concentrate gained faster than those given modified soy flour (P<.05). Pigs given the HNDD were more efficient than pigs given the other treatments (P<.08). At d 35, there were no treatment effects (P>.18) on the incidence of diarrhea, which could be expected because all pigs received the same dietary treatment for the last 21 d of the experiment.

When compared to a simple corn-soybean meal-whey diet, HNDDs containing skim milk and(or) the soy products plus lactose were of greater nutritional value to the weanling pig for the first 14 d postweaning. The diets containing soy isolate and concentrate were highly digestible, and diets with soy isolate tended to cause less diarrhea than diets containing soy concentrate or modified soy flour. For the soy products, as the complexity of the processing methods increased (i.e., soy isolate> soy concentrate> modified soy flour), nutritional value tended to be improved. However, during the early nursery phase, HNDD's with the soy products replacing the protein from dried skim milk were of slightly less nutritional value than the HNDD with dried skim milk.

Table 2. Effects of Soybean Products on Performance and Nutrient Digestibility in Nursery Pigs

Item	Corn-soy whey	HNDD	Soy isolate 50%	Soy isolate 100%	Soy concentrate 50%	Soy concentrate 100%	Modified soy flour 50%	Modified soy flour 100%	CV
d 0 to 7									
ADG, lb[a]	.47	.55	.49	.54	.42	.49	.55	.43	15.6
ADFI, lb[b]	.48	.44	.40	.45	.40	.49	.48	.39	15.5
F/G[c]	1.03	.80	.83	.85	.94	1.00	.86	.90	10.5
d 0 to 14									
ADG, lb[d]	.50	.60	.56	.56	.54	.55	.58	.50	11.4
ADFI, lb[e]	.62	.60	.62	.63	.59	.63	.65	.58	11.3
F/G[f]	1.24	1.02	1.11	1.13	1.10	1.15	1.12	1.15	8.4
d 0 to 35									
ADG, lb[g]	.93	.82	.88	.96	.89	.93	.85	.87	6.7
ADFI, lb[h]	1.26	1.05	1.16	1.27	1.21	1.28	1.16	1.18	6.1
F/G[i]	1.35	1.28	1.32	1.32	1.36	1.37	1.36	1.35	5.4
Digestibility, %									
N[j]	76.4	80.5	81.9	79.5	79.4	78.4	76.5	78.3	5.2
DM[k]	81.6	84.7	86.8	84.0	85.0	85.8	82.5	84.1	3.2
Fecal Scores[l]									
d 7[m]	1.9	1.9	1.8	1.7	2.3	2.1	2.0	2.1	11.0
d 14[n]	3.7	3.1	3.5	3.1	3.5	3.3	3.0	3.8	12.1
d 35[o]	2.7	1.9	2.5	2.3	2.2	1.9	2.4	2.5	15.3

[a]Linear X Soy isolate & Soy concentrate vs Modified soy flour (P<.01).
[b]Linear X Soy isolate & Soy concentrate vs Modified soy flour (P<.02).
[c]Control vs others (P<.02), HNDD vs replacements (P<.05), Soy isolate vs Soy concentrate (P<.01).
[d]Control vs others (P<.11), Linear X Soy isolate & Soy concentrate vs Modified soy flour (P<.11).
[e]Linear X Soy isolate & Soy concentrate vs Modified soy flour (P<.09).
[f]Control vs others (P<.02), HNDD vs replacements (P<.02).
[g]HNDD vs replacements (P<.03), Linear effect of replacements (P<.07), Soy isolate & Soy concentrate vs Modified soy flour (P<.05).
[h]Control vs others (P<.07), HNDD vs replacements (P<.001), Linear effect of replacements (P<.04), Soy isolate & Soy concentrate vs Modified soy flour (P<.06).
[i]HNDD vs replacements (P<.08).
[j]No treatment effect (P>.18).
[k]Control vs others (P<.04), Soy isolate & Soy concentrate vs Modified soy flour (P<.09).
[l]Scale: 1= all pigs with normal feces to 5= all pigs with diarrhea.
[m]Soy isolate vs Soy concentrate (P<.02).
[n]Linear X Soy isolate & Soy concentrate vs Modified soy flour (P<.08).
[o]No treatment effect (P>.18).

EFFECT OF REPLACING DRIED SKIM MILK WITH SOY PRODUCTS ON FUNCTION AND MORPHOLOGY OF THE SMALL INTESTINE IN NURSERY PIGS

D. B. Jones, J. D. Hancock, P. G. Reddy[1], R. D. Klemm[1], and F. Blecha[1]

Summary

Sixty-six pigs (averaging 21 d of age and 11.8 lb) were used in a 7-d experiment to evaluate the effects of specially processed soy products on function and morphology of the small intestine. Treatments were: 1) corn-milk products control; 2, 3, 4, and 5) simple corn-based diets with either soybean meal, soy isolate[2], soy concentrate[3], or modified soy flour[4] as the major protein source; 6) a high nutrient density diet (HNDD) containing 20% dried skim milk and 20% dried whey; 7, 8, and 9) the HNDD with soy isolate, soy concentrate, or modified soy flour plus lactose replacing 100% of the dried skim milk. Xylose absorption was determined from plasma collected on d 6 post-weaning. On d 7 post-weaning, serum was collected for determination of antisoy titers, and four pigs/trt were sacrificed for collection of tissues to determine villus height and crypt depth. The milk diet was more digestible than the other treatments, and the complex diets were more digestible than the simple diets. Nitrogen from soy isolate and concentrate was more digestible than N from soy flour in the simple diets. Pigs fed diets with the specially processed soy products had lower antisoy titers than pigs fed diets with soybean meal. However, diets with the specially processed soy products resulted in lower xylose absorptions than the diet with soybean meal. Pigs fed the corn-milk products control tended to have longer villi and lower crypt depths than pigs fed the other treatments. In conclusion, it appears that the specially processed soy products were better utilized than soybean meal, but of lower nutritional value than milk products. Of the specially processed soy products, soy protein isolate had the greatest nutritional value in simple diets, but the soy products were of similar nutritional value in the complex diets.

(Key Words: Starter, Performance, SBM, Process, Soybean, Digestion.)

Introduction

Previous research indicates that the presence of dietary antigens is associated with villus atrophy and increased crypt cell mitosis (which increases the crypt depth), both of which affect the absorptive capability of the gut. The major storage proteins of the soybean (glycinin and β-conglycinin) are suggested as two such dietary antigens. Recent interest in replacing milk products in weanling pig diets with less expensive soy products has led to concern about mild allergic responses to soy proteins causing malabsorption in the small intestine. This experiment was designed to test the effects of replacing the protein from milk products with specially processed

---

[1]Dept. of Anatomy and Physiology.

[2]Ardex F, [3]Pig Pro 70, [4]Pig Pro 50 ,ADM Protein Specialties, Archer Daniels Midland Co., Decatur, IL.

soy products (i.e., soy isolate, soy concentrate, or modified soy flour) on the functional integrity of the small intestine in weanling pigs.

Procedures

Sixty six crossbred pigs were weaned at 21 d of age (avg wt=11.8 lb) and started immediately on the experimental diets. Pigs were housed (six per pen) in an environmentally controlled nursery (4 × 5 ft pens) equipped with woven wire flooring. Each pen had a self-feeder and nipple waterer so feed and water could be consumed ad libitum.

The experimental diets (Table 1) were fed for the duration of the 7-d experiment. Treatments were: 1) corn-milk products control; 2,3,4, and 5) simple corn-based diets with either soybean meal, soy isolate, soy concentrate or modified soy flour as the major protein source; 6) a HNDD with 20% dried skim milk and 20% dried whey; 7, 8, and 9) the HNDD with soy isolate, soy concentrate, or modified soy flour plus lactose replacing 100% of the dried skim milk. The diets were fed in mash form and contained .25 % chromic oxide as an indigestible marker for determination of apparent digestibility of N and DM.

Table 1. Diet Composition[a]

	Simple		Complex
Ingredient, %	Milk	Soybean meal	HNDD
Corn	17.14	17.09	35.49
Soybean meal (48% CP)	—	27.33	16.60
Dried skim milk	30.00	—	20.00
Dried whey	20.00	—	20.00
Lactose	—	30.10	—
Corn gluten meal	15.00	15.00	—
Cornstarch	10.00	—	—
Soy oil	5.00	5.00	5.00
Lysine-HCl	.20	.32	—
Vit/Min/Antibiotic	2.41	4.91	2.66
Chromic oxide	.25	.25	.25
Totals	100.00	100.00	100.00
Calculated composition, % [b]			
Lactose, %	30.10	30.10	25.00
g Lysine/Mcal DE	3.43	3.45	3.56

[a]Cornstarch, and either soy isolate, soy concentrate, or modified soy flour replaced the soybean meal in the simple diets. Lactose and either soy isolate, soy concentrate, or modified soy flour replaced the skim milk in the complex diets.
[b]Formulated to contain 23.5% crude protein for the simple diets and 21.0% crude protein for the complex diets, and all diets contained 1.5% lysine, .9% Ca, and .8% P.

On d 6 of the experiment, a solution of xylose and water (10% w/v) was infused into the stomach of each pig at the rate of .45 ml/lb body weight. The pigs were fasted for 12 h and denied water for 4 h prior to infusing to ensure an empty stomach and intestinal tract. Blood was collected 1 h post-infusion, and the plasma was analyzed for xylose concentration.

On d 7, serum samples were collected for determination of antisoy antibody titers using an ELISA procedure. Four pigs from each treatment were sacrificed, and tissue samples were obtained from the duodenum 6 in. from the pyloric valve. Villus height and crypt depth were determined by light microscopy. Also, fecal samples were collected from the distal colon for determination of apparent digestibility of N and DM.

Results and Discussion

Chemical composition of the protein sources used in the experiments is given in Table 2. The DM and CP values are those typical for the various protein sources, with the exception of the soy concentrate that was lower in CP than the expected 70% CP. The amino acid values are also those typical for the various protein sources, and as one would expect, as protein concentration of the products goes down (from 94.5 to 47.4 %) so does the concentration of lysine (from 5.9 to 3.1 %) and the other amino acids. Analyzed values for glycinin and β-conglycinin antigenic activity indicated that soybean meal had extremely high activity (i.e., too high to quantify), and the other products had little to no activity.

Table 2. Chemical Composition of Protein Sources

Item	Dried skim milk	Dried whey	Soybean meal	Soy isolate	Soy concentrate	Modified soy flour
DM, %[a]	94.0	93.0	90.0	94.0	94.0	93.0
CP, %[a]	34.3	13.3	47.4	94.5	58.7	55.3
Amino acids, %[b]						
Lysine	2.5	.9	3.1	5.9	3.8	3.4
Tryptophan	.4	.2	.7	.9	.8	.6
Threonine	1.6	.9	1.9	3.8	2.3	2.3
Glycinin titer, log2[a]	0	0	>10	0	0	0
β-conglycinin titer, log2[a]	0	0	>10	5	0	0
Lactose, %[b]	52.0	74.5	—	—	—	—
Ca, %[b]	1.28	.86	.26	.09	.45	.34
P, %[b]	1.02	.76	.64	.78	.87	.70

[a]Analyzed values.
[b]Values from NRC (1988) and ADM Technical Report (1989).

Data from the experiment are given in Table 3. The corn-milk products control had greater DM digestibility than the other diets (P<.02). The simple diets had lower N (P<.006) and DM (P<.07) digestibilities than the complex diets. Of the experimental soy products, the isolate and concentrate had higher N digestibility than the modified soy flour (P<.10), with this response being pronounced only in the simple diets.

Pigs fed the corn-soybean meal and HNDD diets had higher (P<.02) antibody titers for glycinin and β-conglycinin than pigs fed diets with soy isolate, soy concentrate, and modified soy flour. The trend for higher titers for pigs given the complex diets vs the simple diets suggests that the presence of soybean meal in the diets, even at low levels, still resulted in elevated anti-soy titers in blood serum. Pigs fed the corn-milk products diet had longer villi ($P<.11$) and tended to have lower crypt depths than pigs fed the other treatments. The xylose absorption test indicated that pigs fed the complex diets absorbed more xylose than pigs fed the simple diets ($P<.05$), suggesting a more functional gut wall.

In conclusion, it appears that the specially processed soy products were better utilized and less allergenic than soybean meal in simple diets, but were of lower nutritional value than milk products. The soy isolate and soy concentrate were better utilized than modified soy flour in the simple diets, but those differences were not apparent in the complex diets.

Table 3. Effects of Soy Products on Nutrient Digestibility and Intestinal Morphology in Nursery Pigs[a]

		Simple				Complex				
Item	Milk	Soybean meal	Soy isolate	Soy conc.	Modified soy flour	HNDD	HNDD + Isolate	HNDD + Conc.	HNDD + Flour	CV
Digestibility, %										
N[b]	71.2	52.1	68.1	63.0	54.1	74.6	65.3	68.0	65.3	13.0
DM[c]	85.1	72.3	81.5	79.0	76.1	82.8	78.9	80.9	79.1	5.8
Blood criteria										
Xylose absorption, $mmol \cdot l^{-1}$ [d]	.60	.64	.54	.60	.52	1.13	.53	.45	.85	43.4
Anti-soy titers, log^2 [e]	5.15	7.53	5.94	5.53	4.36	7.92	5.53	6.74	6.74	29.9
Morphology										
Villus height, µm[f]	252	209	223	216	222	232	195	213	197	20.4
Crypt depth, µm[g]	336	336	347	347	347	337	345	361	360	13.3
Height: Depth[h]	.75	.62	.64	.62	.64	.69	.57	.59	.55	22.1

[a] Pigs were 21 d of age at initiation of the experiment (11.8 lb) and were fed the dietary treatments for 7 d.
[b] Simple vs Complex (P<.006), Iso & Conc vs Flour (P<.10), SBM & HNDD vs Iso & Conc & Flour X Simple vs Complex (P<.02).
[c] Milk vs others (P<.02), Simple vs Complex (P<.07), SBM & HNDD vs Iso & Conc & Flour X Simple vs Complex (P<.02).
[d] Simple vs Complex (P<.05), SBM & HNDD vs Iso & Conc & Flour (P<.002), SBM & HNDD vs Iso & Conc & Flour X Simple vs Complex (P<.03), Iso & Conc vs Flour X Simple vs Complex (P<.05).
[e] SBM & HNDD vs Iso & Conc & Flour (P<.02).
[f] Milk vs others (P<.11).
[g] No treatment effect (P>.43).
[h] No treatment effect (P>.13).

INTERRELATIONSHIP BETWEEN HYPERSENSITIVITY TO SOYBEAN PROTEINS AND GROWTH PERFORMANCE IN EARLY-WEANED PIGS

D. F. Li, J. L. Nelssen, P. G. Reddy[1]
F. Blecha[1], R. Klemm[1], and R. D. Goodband[2]

Summary

One hundred twenty-five pigs were orally infused with 6 g/d of either dried skim milk, soybean meal (48% CP), soy protein concentrate, extruded soy protein concentrate, or experimental soy protein concentrate from 7 to 11 d of age and then fed a diet containing the corresponding protein sources from weaning (d 21) to 35 d of age. All pigs were fed a corn-soybean meal diet containing 10% dried whey, 1.25% lysine, and 3% soybean oil for the remaining 21 d of the experiment. Skin-fold thickness following intradermal injection of protein extracts, xylose absorption, and anti-soy immunoglobulin G (IgG) titers were measured on d 6 postweaning. A total of 25 pigs (five pigs/treatment) was euthanized on d 7 postweaning. Villus height and crypt depth from duodenum samples were measured. These measurements were obtained to elucidate a relationship between the hypersensitivity responses to soybean products and growth performance of baby pigs. Pigs fed diets containing soybean meal had a lower rate of gain (ADG), lower villus height, higher serum anti-soy IgG titers, and increased skin-fold thickness following intradermal injection compared to those fed dried skim milk. Pigs fed other soy proteins also had lower ADG from d 0 to 14 postweaning; however, pigs fed moist-extruded soy protein concentrate tended to have higher ADG and improved feed utilization when compared to those pigs fed soybean meal. Skin-fold thickness and anti-soy IgG titers were negatively correlated with ADG at d 14 postweaning. Results indicate that a model including skin-fold thickness and anti-soy IgG titers provided a good estimate of nursery pig growth performance (R^2=.33). Villus height was related to ADG at d 14 postweaning (R^2=.40). A combination of skin-fold thickness, anti-soy IgG titers, xylose absorption, villus height, and crypt depth provided the best estimate of growth performance (R^2=.65) for early-weaned pigs.

(Key Words: Starter, Piglet, SBM, Soybean, Process, Performance.)

Introduction

Research indicates that pigs fed diets containing commercially prepared soybean meal (SBM) have a transient hypersensitivity (allergy) response to soybean proteins. Sensitization and challenge by proteins present in SBM may lead to abnormalities in digestive processes, including disorders in digesta movement and an inflammatory response in the intestinal mucosa of the early-weaned pig.

---

[1]Dept. of Anatomy and Physiology.

[2]We thank Central Soya Co., Fort Wayne, Indiana, for providing the soybean products and partial finanicial support for this project.

Because it appears that the pig mounts an immune response to some of the detrimental antigens presented in conventially processed SBM, this study was designed to determine if immune response criteria might be an effective indicator of soy protein quality. Therefore, the objective of this study was to establish a relationship between gut morphology, immunological responses to dietary soy protein, and growth performance in starter pigs fed different soy proteins.

Procedures

One hundred twenty-five crossbred (Hampshire × Yorkshire × Duroc) pigs from 16 litters with an average birth weight of 2.9 ± .6 lb were utilized. Sows were fed a corn-corn gluten meal (14% CP, .65% lysine) diet from d 109 of pregnancy throughout lactation in order to limit passive transfer of maternal anti-soybean protein antibodies to the baby pigs via colostrum. The pigs were allotted randomly to one of five treatment groups (25 pigs/group). In order to sensitize the pigs to dietary proteins, they were infused through a stomach tube from d 7 to d 11 with 6 g.pig^{1}.d^{1} of either dried skim milk (control), soybean meal (48% CP), soy-protein concentrate, extruded soy-protein concentrate, or experimental soy protein concentrate. Pigs were housed in an environmentally controlled nursery (5 pigs/pen; 5 replications/treatments) with pen dimensions of 4 × 5 ft, with woven wire floors over a Y-flush gutter, and one nipple waterer and one, four-hole, self-feeder per pen. The room temperature was at 95°F for the first 7 d, and then was lowered 3°F each week thereafter. On d 6 postweaning, blood samples were taken from the jugular vein for determination of IgG titers to soybean proteins, glycinin, and β-conglycinin. All pigs were weaned on d 21 and until d 28 were reallotted by litter, sex, and weight to one of the five dietary treatments (Table 1) containing the same dietary protein sources that were infused during the preweaning period. Water and feed were available ad libitum. Postweaning diets were formulated to contain identical amounts of lysine, Ca, P, and ME. On d 7 postweaning, all pigs were fed the same corn-soybean meal diet (Table 2) containing 3% soybean oil and 1.25% lysine for the remaining 21 d of the experiment. Feed consumption and individual pig weights were measured at weekly intervals to determine average daily gain (ADG), average daily feed intake (ADFI), and feed/gain (F/G).

On d 7 postweaning, 25 pigs (5 pigs/treatment) were euthanized, and small intestines were immediately excised. Samples were collected, then sectioned at 6 mm thickness and stained with azur A and eosin. Intact villi were measured in four specimens for each pig within each group. Villus height was measured from the crypt mouth to the villus tip.

Cutaneous hypersensitivity to the corresponding protein to which the pigs were sensitized was tested on d 6 postweaning. Results were expressed as difference in skin-fold thickness (mm) obtained with protein compared to saline injections.

Small intestinal contents were obtained and mixed immediately after pigs were euthanized. Subsamples were prepared and plated in plate count agar (PCA) and violet red bile agar (VRB), followed by a standard plate count procedure.

Stepwise regression and simple correlations among villus height, crypt depth, anti-soy antibody titers, skin-fold thickness, and xylose absorption as related to ADG and F/G at d 14 postweaning were evaluated.

Table 1. Diet Composition (D 0 to 14 Postweaning)[a]

	Diets				
Ingredient, %	Milk protein	Soybean meal	Soy protein concentrate	Extruded soy protein concentrate	Experimental soy protein concentrate
Ground corn	9.82	7.50	7.50	7.50	7.50
Oat groats	29.13	11.69	27.08	27.08	27.08
Skim milk	35.00				
Dried whey	20.00				
Soybean meal (48%, CP)		38.13			
Soy protein concentrate			24.07		
Extruded soy protein concentrate				24.07	
Experimental soy protein concentrate					24.07
Dicalcium phosphate (18.5% P)	.24	2.26	2.29	2.29	2.29
Limestone	.26	.41	.39	.39	.39
Fat[b]	4.78	7.74	6.37	6.37	6.37
Trace mineral premix[c]	.12	.12	.12	.12	.12
Vitamin Premix[d]	.09	.09	.09	.09	.09
Lactose		31.50	31.50	31.50	31.50
L-lysine HCL (78%)	.10	.10	.13	.13	.13
$CuSO_4$[e]	.09	.09	.09	.09	.09
Salt	.35	.35	.35	.35	.35
Ethoxyquin	.02	.02	.02	.02	.02

[a]Calculated analysis of the diet: ME, 1.59 Mcal/lb; lysine, 1.35%, .8%; P, .7%.
[b]Fat was 2% soybean oil and remainder was lard.
[c]Provided the following per lb of the complete diet (mg): Zn, 32; Fe, 23; Mn, 12: Cu, 2.3; Co, .23, I, .32; Se, .14.
[d]Provided the following per lb of complete diet: vitamin A, 2000 IU; vitamin D_3, 200 IU; vitamin E, 6.7 IU; vitamin K, 1.3 mg; riboflavin, 2.0 mg; niacin, 12.6 mg; d-pantothenic acid, 8.0 mg; vitamin B_{12}, 8.0 µg.
[e]Suplied complete diet with 240 ppm supplemental Cu.

Table 2. Diet Composition (D 14 to 35 Postweaning)

Ingredient	%	Ingredient	%
Corn	59.32	Vitamin premix[a]	.25
Soybean meal (48%)	23.75	Trace mineral premix[b]	.25
Dried whey	10.00	Se premix[c]	.05
Soy oil	3.00	L-Lysine.HCL (78%)	.35
Dicalcium phosphate	1.51	CuSO4	.10
Limestone	.82	Antibotic[d]	.50
Salt	.25		

[a]Provided the following per lb of complete diet: vitamin A, 2000 IU; vitamin D_3, 200 IU; vitamin E, 6.7 IU; vitamin K, 1.3 mg; riboflavin, 2.0 mg; niacin, 12.0 mg; d-pantothenic acid, 8.0 mg; vitamin B_{12}, 8.0 µg.
[b]Provided the following per lb of the complete diet (mg): Zn, 32; Fe, 23; Mn, 12; Cu, 2.3; Co, .23; I, .32; Se, .14.
[c]Provided .3 ppm selenium.
[d]Provided the following per lb of complete diet: 50 mg chlortetracycline, 50 mg sulfamethazine and 25 mg penicillin.

Results and Discussion

At d 14 postweaning, pigs fed soybean meal had lower ADG and ADFI and poorer F/G ($P<.05$) than pigs fed the diet containing dried skim milk (Table 4). Pigs fed extruded soy protein concentrate tended to have higher ADG ($P<.09$) than those fed soybean meal and improved F/G ($P<.05$) compared with those fed other soybean products. There were no differences in ADG, ADFI, and F/G among the treatments from d 14 to 35 postweaning.

These results generally agree with previous reports. However, pigs fed milk gained the same as those fed soybean products from d 14 to 35 postweaning in the present study. Inclusion of soybean meal in starter pig diets may be responsible for shortened intestinal villus height and hypertrophy in the crypt. Moist-extruded soy protein concentrate improved F/G for starter pigs from d 0 to 14, when compared with other soybean products used in this experiment. With increasing villus height, ADG at d 14 postweaning increased ($R=.63$; $P<.05$), indicating a relationship between villus height in the small intestine and growth rate in starter pigs. This is not surprising, because the reduction of villus height could decrease total luminal villus absorption area and could result in inadequate digestive enzyme development and(or) transport of nutrients at the villus surface. Reduced enzyme content of cells of the intestinal mucosal barrier could also alter the capacity of the gastrointestinal tract to digest antigenic proteins.

Changes in skin-fold thickness following intradermal injection of the extracts of corresponding proteins are presented in Table 3. Pigs given dried skim milk had lower ($P<.05$) skin-fold thickness than pigs fed any of the soybean products. Pigs fed soybean meal had greater ($P<.05$) skin-fold thickness than pigs fed either milk protein or other soy proteins. Pigs orally infused with soybean meal preweaning and fed a diet containing soybean meal postweaning showed higher ($P<.05$) cutaneous hypersensitivity, coinciding with lower ($P<.05$) ADG during 14 d postweaning. Pigs fed soybean meal had higher serum ($P<.01$) IgG titers than pigs fed diets containing dried skim milk, soy-protein concentrate, extruded soy protein concentrate, or experimental soy-protein concentrate (Table 3). This clearly indicates that antigenicity of dietary proteins may be critical in influencing overall pig performance. Thus, it may be advantageous to predict the suitability of soybean products by determining titers of antigenic proteins by ELISA before including them in the diets of baby pigs. Because skin-fold thickness is relatively easy to measure, it also may be used as an indicator of antigenicity of the soybean products for baby pigs. A relationship ($P=-.54$; $P<.05$) was found between skin-fold thickness and ADG at d 14 postweaning. Also, pigs fed a diet containing soybean meal had lower ($P<.05$) xylose concentrations in plasma (Table 3) than pigs fed diets containing soy protein concentrate, experimental soy protein concentrate, or dried skim milk, suggesting a compromised absorptive ability of the small intestine. However, there were no differences ($P>.20$) in plasma xylose concentration of pigs fed soy protein concentrate, extruded soy protein concentrate, or experimental soy-protein concentrate.

Plate count agar counts represent total bacterial numbers present in the small intestinal contents, and VRB counts represent total number of coliforms present in the small intestinal contents. The percentage of coliforms in total bacteria (Table 3) was lower ($P<.05$) in pigs fed milk protein than in pigs fed soybean products. Among soybean products, pigs fed soybean meal had the highest percentage of coliforms, and those fed extruded soy protein concentrate and experimental soy protein concentrate were intermediate. This suggests that soybean meal protein may be unsuitable for baby pigs and may favor coliform proliferation.

Pigs fed soybean meal had shorter villus height, greater crypt depth ($P<.01$), and higher anti-soy IgG titers ($P<.05$) than pigs fed either milk protein or the other soybean products (Table 3). There were no differences in villus height among pigs fed soy-protein concentrate, extruded soy-protein concentrate, or the experimental soy-protein concentrate; however, villus heights of pigs on all soy treatments were lower than that of pigs fed milk protein.

Villus height was negatively correlated ($R=.67$; $P<.05$) with skin-fold thickness (Table 5). A stepwise model that included skin-fold thickness and anti-soy IgG titers provided an estimate of growth performance ($R^2=.33$; $P<.05$). Villus height provided a good estimate of ADG for pigs at d 14 of age ($R^2=.40$; $P<.01$). A combination of skin-fold thickness, anti-soy IgG titers, xylose absorption, villus height, and crypt depth provided the best estimate of growth performance ($R^2=.65$; $P<.05$) for the early-weaned pig fed various soy protin products. The best prediction model used to estimate ADG is listed below.

$$Y = 161.9 + .33X_1 + 81.4X_2 - .51X_3 + 16.76X_4 - 11.33X_5$$

Where, Y = ADG, lb
X_1 = villus height, micrometer
X_2 = xylose absorption, mg/100 ml
X_3 = crypt depth, micrometer
X_4 = anti-soy antibody titers, log 2
X_5 = skin-fold thickness, mm

This model can be used to differentiate the quality of various soybean products for utilization in formulating diets for nursery pigs. However, a model that includes non-invasive criteria (skin-fold thickness and antisoy IgG titers) may be more practical and cost effective in predicting soybean product quality.

Table 3. Effect of Feeding Different Soybean Products on Gut Morphology, Skin-Fold Thickness, Xylose Absorption, Anti-Soy IgG Titers, and Intestinal Bacteria of Starter Pigs

Criteria	Milk protein	Soybean meal	Soy protein concen.	Extruded soy prot. concen.	Exp. soy Prot. con.	CV
Residual antigens in products[a]						
Glycinin	ND*	2.4	.9	.8	.5	
Beta-conglycinin	ND*	3.6	1.5	1.3	1.2	
Anti-soy IgG titers (Log2)[a]						
D 7 preweaning	3.05	3.10	2.91	2.96	2.99	14.0
D 6 postweaning	3.12[c]	5.16[b]	2.94[c]	3.14[c]	3.26[c]	17.0
Skin-fold thickness, mm	.82[d]	3.33[b]	2.65[c]	2.50[c]	2.59[c]	37.0
Xylose absorption, mg/100 ml	.82[b]	.42[b]	.61[bc]	.67[bc]	.78[b]	31.8
Bacteria						
Total bacteria (10^6)	52	3	14	5	6	9
Coliform (10^6)	.89	1.11	3.4	.2	1.14	10
Coliform/total bacteria, %	1.7	37.0	24.3	4.0	23.3	15
Villus height, µm	364.2[b]	234.0[d]	309.0[c]	319.0[c]	280.0[c]	18.0
Crypt depth, µm	198.0[c]	222.4[b]	214.9[c]	195.7[c]	189.7[c]	16.5

[a]ELISA titers (Log2)
[bcd]Means within a row with unlike superscripts differ ($P<.01$). Five replications per treatment.
[*]ND=none detected.

Table 4. Effect of Different Soybean Products on Starter Pigs Performance[a]

	Treatment					
Criteria	Milk protein	Soybean meal	Soy protein concen.	Extruded soy prot. concen.	Exper. soy prot. concen.	CV
ADG, lb						
d 0 - 14	.72[b]	.40[c]	.46[c]	.50[c]	.46[c]	15.5
d 14 - 35	.98	1.18	1.15	1.12	1.16	8.1
d 0 - 35	.87	.86	.87	.89	.87	8.1
ADFI, lb						
d 0 - 14	.66[b]	.55[c]	.51[c]	.53[c]	.55[c]	13.1
d 14 - 35	1.72	1.91	1.86	1.74	1.84	11.0
d 0 - 35	1.29	1.33	1.50	1.31	1.29	10.2
F/G						
d 0 - 14	.99[b]	1.38[c]	1.14[c]	1.07[b]	1.18[c]	18.8
d 14 - 35	1.77	1.65	1.63	1.58	1.65	8.2
d 0 - 35	1.50	1.57	1.72	1.47	1.52	5.6

[a]Five pigs per pen, five replications per treatment, avg initial age of 21 d.
[bc]Means same row with different superscript differ (P<.05).

Table 5. Simple Correlations among Growth Performance and Immunological Criteria

	Correlation coefficient					
Item	ADG	F/G	Skin-fold thickness	Villus height	Xylose absorption	Anti-soy IgG titers
Skin-fold thickness	-.54	.30	—	-.67	-.11	.22
Villus height	.63	-.46	-.67	—	.43	-.56
Xylose absorption	.54	-.49	-.11	.43	—	-.53
Anti-soy titers	-.30	.40	.22	-.56	-.53	—

PROCESSING METHOD AFFECTS THE NUTRITIONAL VALUE OF LOW-INHIBITOR SOYBEANS FOR NURSERY PIGS

J. D. Hancock, A. J. Lewis[1], D. B. Jones, M. A. Giesemann[1], and B. J. Healy

Summary

One hundred weanling pigs (16.5 lb avg initial wt) were used in a 35-d growth assay to determine the effects of processing method (roasting in a Roast-A-Tron® roaster vs extrusion in an Insta-Pro® extruder) on the nutritional value of Williams 82 soybeans with (+K) and without (-K) gene expression for the Kunitz trypsin inhibitor. Treatments were: 1) soybean meal with added soybean oil, 2) +K roasted, 3) +K extruded, 4) -K roasted, and 5) -K extruded. All diets were corn-based and formulated to contain .92% lysine and 3.50 Mcal/kg DE for d 0 to 14 of the experiment and .76% lysine and 3.49 Mcal/kg DE for d 14 to 35 of the experiment. From d 0 to 14, pigs fed extruded soybeans (+K and -K) ate more feed (greater ADFI), grew faster (greater ADG), and were more efficient (better F/G) than pigs fed roasted soybeans. From d 14 to 35 and overall, the same effects were noted, i.e., pigs fed extruded soybeans had greater ADFI and ADG and better F/G than pigs fed roasted soybeans. Also, pigs fed -K soybeans were more efficient than pigs fed +K soybeans. The average performance of all pigs fed diets containing the roasted and extruded soybeans was not different from that of pigs fed diets with soybean meal and added soybean oil, although diets with -K extruded soybeans consistently supported numerically greater rates and efficiencies of gain. Extrusion processing yielded soybean products of greater nutritional value than roasting, and -K soybeans were of greater nutritional value than +K soybeans when roasted or extruded.

(Key Words: Soybean, SBM, Processing, Starter, Performance, Trypsin.)

Introduction

The major constituent that limits the nutritional value of raw soybeans is a group of small proteins collectively called trypsin inhibitors. In last year's KSU Swine Day Report, we reported data that indicated improved nutritional value of soybeans lacking gene expression for the Kunitz soybean trypsin inhibitor. As roasting temperature was increased to full-roast, utilization of both conventional and low-inhibitor soybeans was increased. Although full-roasting was necessary to optimize performance of pigs fed conventional and low-inhibitor soybeans, even with full-roasting, the low-inhibitor soybeans were still of greater nutritional value than conventional soybeans for growing and finishing pigs. Considering those results and with the current interest in on-farm soybean processing, an experiment was designed to determine the effects of roasting and extruding on the nutritional value of low-inhibitor soybeans for nursery pigs.

Procedures

[1]University of Nebraska, Department of Animal Science.

Williams 82 soybeans with (+K) and without (-K) gene expression for the Kunitz trypsin inhibitor were either roasted or extruded and incorporated into corn-based diets with 20% dried whey (Table 1). Treatments were: 1) soybean meal with added soybean oil, 2) +K roasted, 3) +K extruded, 4) -K roasted, and 5) -K extruded. The roasting and extrusion treatments were those deemed usual for soybean processing, i.e., a throughput of approximately 1,000 lb/h and an average exit temperature of 245°F in a Roast-A-Tron® roaster versus a throughput of approximately 1,500 lb/h and an average barrel temperature of 290°F in an Insta-Pro® dry-extruder. All diets were formulated to contain .92% lysine and 3.50 Mcal/kg DE for d 0 to 14 of the experiment, and .76% lysine and 3.49 Mcal/kg DE for d 14 to 35 of the experiment. The diets were formulated to be slightly deficient in lysine to ensure that differences in protein quality would be detected.

Table 1. Diet Composition for Phase I (d 0 to 14)[a]

Ingredient, %	Soybean meal	+K roasted[b]	-K roasted[b]
Soybean meal	20.06	—	—
Soybean oil	2.50	—	—
Whole soybeans	—	24.55	24.85
Cornstarch	2.21	.30	—
Corn	51.38	51.38	51.38
Dried whey	20.00	20.00	20.00
Vitamins and minerals	3.25	3.17	3.17
Copper sulfate	.10	.10	.10
CSP-250	.50	.50	.50
Total	100.00	100.00	100.00

[a]Soybean treatments, cornstarch, monocalcium phosphate, and limestone were adjusted so that all diets contained .92% lysine, 3.50 Mcal/kg DE, .9% Ca and .8% P for Phase 1, and .76% lysine, 3.49 Mcal/kg DE, .8% Ca, and .7% P for Phase 2 (d 14 to 35).
[b]Extruded soybeans were added to replace the roasted soybeans on a protein basis.

One hundred weanling pigs (16.5 lb avg initial wt) were fed the treatment diets. The pigs were housed (four pigs per pen and five pens per treatment) in an environmentally controlled nursery equipped with a woven-wire floor. Each pen had a self-feeder and nipple waterer so feed and water could be consumed ad libitum. On d 14 of the experiment, fecal samples were collected by rectal massage, pooled within pen, dried, and analyzed for DM, N, and chromium contents. Apparent digestibilities of DM and N were calculated using the indirect ratio method. Response criteria were ADG, ADFI, F/G, and digestibilities of DM and N.

Results and Discussion

Chemical composition of the soybean preparations is given in Table 2. Dry matter content was similar among all soybean preparations. The protein content of the soybean meal was higher than that of the roasted and extruded soybeans. Trypsin inhibitor activities were lower for the -K soybeans than for the +K soybeans. Soybean antigenic activity (i.e., glycinin activity and β-conglycinin activity) was reduced by extrusion processing compared to roasting and soybean meal.

Table 2. Effect of Roasting and Extrusion on Chemical Composition of Conventional (+K) and Low-Inhibitor (-K) Soybeans

Item	Soybean meal	+K roasted	+K extruded	-K roasted	-K extruded
Dry matter, %	92.2	92.7	93.7	93.7	93.5
Protein, %	49.4	37.4	38.9	37.8	40.1
Trypsin inhibitor, mg/g	.5	2.2	1.8	1.1	1.4
Glycinin activity, log 2	>10[a]	>10	4	>10	3
β-Conglycinin activity, log 2	>10	>10	7	>10	>10

[a]Activity was too high to quantitate.

Performance of nursery pigs fed the soybean preparations is given in Table 3. For d 0 to 14, pigs fed the extruded soybeans (+K and -K) ate 15% more feed (.86 vs .75 lb/d), grew 29% faster (.66 vs .51 lb/d), and were 11% more efficient (1.30 vs 1.46 F/G) than pigs fed the roasted soybeans. Similar responses were observed from d 14 to 35, so that overall, pigs fed the extruded soybeans ate 13% more feed (1.78 vs 1.58 lb/d), gained 21% faster (1.04 vs .86 lb/d), and were 6% more efficient (1.73 vs 1.85 F/G) than pigs fed the roasted soybeans. The improved performance of pigs fed the extruded soybeans compared to roasted soybeans corresponds with the 6% improvement in DM digestibility and 5% improvement in N digestibility for diets with extruded soybeans. It is unlikely that the difference seen for extrusion processing can be attributed to trypsin inhibitor content, because all of the values were acceptably low (i.e., 2.2 or less). However, the improvements in nutrient digestibility and performance of pigs fed the extruded soybeans may have resulted from the disruption and structural changes in soybean proteins that are normally attributed to extrusion processing, thus increasing their susceptibility to enzymatic hydrolysis. Also, disruption of the soybean proteins reduced their antigenicity (i.e., reduced glycinin and β-conglycinin activities), which could have contributed to improved gut function and nutrient digestibility.

From d 14 to 35, pigs fed the -K soybeans grew 8% faster (1.23 vs 1.14 lb/d) and were 7% more efficient (1.86 vs 1.99 F/G) than pigs fed the +K soybeans. Overall, pigs fed the -K soybeans were 6% more efficient (1.73 vs 1.85 F/G) than pigs fed the +K soybeans. Apparent digestibilities of DM and N were also improved for -K soybeans compared to +K soybeans (i.e., 86.9 vs 82.9% and 84.7 vs 82.0% for DM and N, respectively). Also, the improved nutritional value of the -K soybeans was consistent when roasted or extruded, as indicated by a lack of interaction between soybean type and processing method for any of the response criteria ($P>.11$).

Performance of pigs fed the soybean meal plus soybean oil control was not different than the average performance of pigs fed all other treatments ($P>.24$). However, pigs fed diets with roasted +K and -K soybeans had consistently lower performance than pigs fed soybean meal plus soybean oil, and pigs fed -K extruded soybeans had consistently greater performance than pigs fed the other treatments, including those fed soybean meal plus soybean oil.

In conclusion, extrusion processing yielded soybean preparations of greater nutritional value than roasting, and -K soybeans were of greater nutritional value than +K soybeans when roasted or extruded.

Table 3. Performance of Nursery Pigs Fed Conventional (+K) or Low-Inhibitor (-K) Soybeans either Roasted or Extruded[a]

Item	Soybean meal	+K roasted	+K extruded	-K roasted	-K extruded	CV
d 0 to 14						
ADG, lb[b]	.60	.50	.66	.52	.66	13.8
ADFI, lb[c]	.82	.75	.87	.74	.84	16.6
F/G[d]	1.37	1.50	1.32	1.42	1.27	9.3
d 14 to 35						
ADG, lb[e]	1.18	1.07	1.21	1.10	1.36	9.0
ADFI, lb[f]	2.25	2.19	2.32	2.08	2.47	7.6
F/G[g]	1.91	2.05	1.92	1.89	1.82	5.2
d 0 to 35						
ADG, lb[h]	.95	.84	.99	.87	1.08	9.0
ADFI, lb[i]	1.68	1.62	1.74	1.54	1.82	8.2
F/G[j]	1.77	1.93	1.76	1.77	1.69	4.7
Apparent digestibility (d 14)						
DM, %[k]	85.6	80.5	85.3	84.5	89.3	4.1
N, %[l]	82.0	80.5	83.5	81.7	87.6	2.6

[a]Four pigs per pen, six pens per treatment, avg initial wt=16.5 lb.
[b]Extruded vs roasted (P<.001).
[c]Extruded vs roasted (P<.09).
[d]Extruded vs roasted (P<.02).
[e]-K vs +K (P<.08), extruded vs roasted (P<.001).
[f]Extruded vs roasted (P<.004).
[g]-K vs +K (P<.02), extruded vs roasted (P<.03).
[h]Extruded vs roasted (P<.001).
[i]Extruded vs roasted (P<.006).
[j]-K vs +K (P<.02), extruded vs roasted (P<.004).
[k]-K vs +K (P<.02), extruded vs roasted (P<.008).
[l]-K vs +K (P<.02), extruded vs roasted (P<.001).

EFFECT OF L-CARNITINE ON STARTER PIG PERFORMANCE AND FAT UTILIZATION

T. L. Weeden, J. L. Nelssen, J. A. Hansen, G. E. Fitzner, R. D. Goodband, D. F. Li, and S. A. Blum[1]

Summary

Three hundred early-weaned pigs with average initial weights of 12.3 and 13.2 lb, respectively, were utilized in two 5-wk experiments to determine the effect of L-carnitine on growth performance. Diets contained 20% dried skim and 20% dried whey in phase 1 (0 to 14 d) for both experiments and 20 and 10% dried whey, respectively for experiments 1 and 2 in phase 2 (15 to 35 d). In experiment 1, L-carnitine at levels of 0, 500, and 1000 ppm was combined with 0 or 10% soybean oil in phase 1, levels were reduced by 50% in phase 2 to 0, 250, and 500 ppm L-carnitine and 0 or 5% soybean oil. There was no improvement in pig performance from addition of either L-carnitine or soybean oil in phase 1. In phase 2 and for the cumulative 5 wk experiment, soybean oil addition improved average daily gain (ADG) but had no effect on feed intake (FI) or feed/gain (F/G). Feed efficiency was improved linearly as the level of L-carnitine was increased in phase 2, however, there was no effect on ADG or FI. In experiment 2, L-carnitine levels in phase 1 were 0 and 1000 ppm, combined with levels of 0, 250, and 500 ppm in phase 2. Addition of L-carnitine improved ADG and increased FI, but had no effect on F/G the first 2 wk postweaning. In phase 2, increasing the level of L-carnitine resulted in improved F/G. Feed intake was decreased as L-carnitine level increased. There was no effect on ADG in phase 2 or during the cumulative 5 wk experiment from level of L-carnitine fed. Feed efficiency improved and FI decreased over the 5 wk trial as the level of L-carnitine increased. Based on the results of these experiments, addition of L-carnitine shows the potential to improve F/G by 11 to 16% in phase 2 and 7 to 9 % for the overall starter phase.

(Key Words: Starter, Performance, Carnitine, Soybean Oil.)

Introduction

The common practice of weaning pigs at 3 weeks of age or less has increased the problems with postweaning lag in many swine operations. Early weaning results in many lightweight pigs (< 11 lb), which require highly palatable and highly digestible diets. A high nutrient density diet (high in fat and milk products) has been researched vigorously in recent years at Kansas State University and developed as a specialty diet for the early-weaned pig. Typical high nutrient density diets contain 40% milk products and 10% added fat (soybean oil or choice white grease). Recent research has shown early-weaned pigs to have difficulty in utilizing the fat in these diets. This is somewhat surprising because the pig does quite well on sow's milk, which is 35% fat on a dry matter basis. However, one nutrient quite high in sows milk is carnitine, which is normally

[1]These experiments were sponsored in part by Lonza, Fair Lawn, NJ 07410.

quite low in the diets fed early-weaned pigs. Therefore, the present studies were designed to determine the effect of L-carnitine on performance and fat utilization of the early weaned pig.

Procedures

Experiment 1. A total of 120 crossbred pigs was weaned at 19 ± 2 d with an average wt of 12.3 lb and utilized in a 5-wk growth trial. Pigs were housed in an environmentally controlled nursery in 4 × 5 ft pens. Feed and water were supplied ad libitum, and pig and feed weights were recorded weekly. Pigs were allotted to one of the six dietary treatments by litter, sex, and weight. Five replications per treatment with four pigs per pen were used. The experimental treatments were in a 2 × 3 factorial arrangement with two levels of soybean oil (0 or 10%) combined with three levels of L-carnitine (0, 500, or 1000 ppm) in phase 1 (0 to 14 d). In phase 2 (15 to 35 d), additions were cut in half resulting in soybean oil levels of 0 and 5% combined with L-carnitine levels of 0, 250, and 500 ppm. Phase 1 diets were formulated to contain at least 1.3% lysine with a constant calorie/lysine ratio of 250 kcal ME/g lysine. Compositions of experiment 1 diets are shown in Table 1. All diets were pelleted.

Experiment 2. A total of 180 pigs was weaned at 22 ± 2 d with an average initial wt of 13.2 lb and utilized in a 5-wk growth trial. Facilities, method of allotting pigs, method of diet preparation, and methods of feeding were identical to those in experiment 1. The soybean oil level was decreased to 5% for the entire 5 wk experiment, because no response to soybean oil addition was shown in phase 1 of exp. 1. A 2 × 3 factorial arrangement was used again with two levels of L-carnitine (0 or 1000 ppm) in phase 1 combined with three levels (0, 250, or 500 ppm) of L-carnitine in phase 2. Phase 1 diets were formulated to contain 1.45% lysine and phase 2 diets 1.25% lysine. Compositions of experiment 2 diets are shown in Table 2.

Results and Discussion

Experiment 1. Growth performance data are reported as interaction means in Table 3. Because there was no L-carnitine × soybean oil interaction ($P>.12$), main effects for L-carnitine and soybean oil will be discussed. There was a numerical trend for higher ADG and improved F/G for pigs fed the high levels of L-carnitine in combination with soybean oil. Pig performance in phase 1 was similar among all treatments, with no response to addition of either L-carnitine or 10% soybean oil (Table 3). However, in phase 2, feed efficiency was improved linearly ($P<.05$) as the level of L-carnitine was increased. There was no L-carnitine effect on pig performance for the cumulative 5 wk experiment. Addition of soybean oil improved ($P<.05$) ADG in phase 2 and for the cumulative 5 wk trial.

Initially, most of the response to L-carnitine would have been expected to be in phase 1, because this is when carnitine synthesis by newly weaned pigs is lowest. The high nutrient density diets fed were analyzed to contain 100 ppm L-carnitine without additional supplementation. This is considerably higher than diets without milk products and may partially explain why the response to L-carnitine was somewhat variable in phase 1. In phase 1 there was a numerical trend for 1000 ppm L-carnitine to decrease FI and ADG in combination with no soybean oil, whereas addition of 500 ppm L-carnitine gave an improved response in ADG and FI. This suggests that the carnitine requirement was met at the intermediate level and that the requirement was exceeded with the higher level, resulting in lowered performance. For pigs receiving diets with soybean oil added, the highest ADG and feed efficiency levels were achieved at the highest level of L-carnitine supplementation, suggesting that pigs fed fat may have higher carnitine requirements than those no fed fat.

Feeding of fat in phase 1 gave no improvements in pig performance; however, before fat is totally eliminated from the phase 1 diet, several other factors need to be considered. High milk product diets need to contain at least 3% fat to be pelleted and have acceptable pellet quality and mill throughput. Secondly, previous research has shown that pigs require an adjustment period to utilize fat. Consequently, improved performance from fat addition in phase 2 requires at least some fat to be fed in phase 1.

Experiment 2. Main effects of L-carnitine addition on growth performance in phase 1 are shown in Table 4. Pigs fed 1000 ppm L-carnitine had higher ($P<.02$) feed intakes and improved ($P<.08$) ADG in phase 1. Dietary treatment fed in phase 1 had no effect on pig performance in phase 2 nor for the cumulative 5 wk of the experiment.

Pig performance data are reported as interaction means for the combination of L-carnitine level fed in phase 1 and phase 2 and are shown in Table 5. Phase 1 growth data can be compared only as the main effect of L-carnitine level fed in phase 1, because carnitine level fed in phase 2 could not affect performance of pigs in phase 1. Contrary to the increased FI response of L-carnitine addition in phase 1, FI decreased linearly ($P<.05$) as the level of L-carnitine was increased in both phase 2 and for the cumulative 5 wk trial. Feed efficiency was improved linearly ($P<.03$) and quadratically ($P<.02$) as levels of L-carnitine were increased in phase 2. A similar linear improvement ($P<.06$) in F/G with increasing level of carnitine was also found over the cumulative 5 wk trial.

In this experiment with fat added to all diets, addition of 1000 ppm L-carnitine improved FI and ADG in phase 1, suggesting that we were correct in our thoughts that pigs fed fat-added diets have higher carnitine requirements than those not fed fat. This improved performance in phase 1 did not carry through to phase 2, which may be explained partly by the fact that very little postweaning lag was observed in either experiment. The improved FI from L-carnitine addition may prove to be more beneficial in operations where pigs don't eat well immediately following weaning and postweaning lag is a major problem.

In phase 2, in agreement with experiment 1, L-carnitine addition again improved feed efficiency; however there was an equal improvement regardless of whether the pigs received L-carnitine in phase 1 or not. Carnitine has several roles in nutrient metabolism in pigs. Our experiments indicate that tissue synthesis of carnitine may not be sufficient to optimize pig performance.

Based on the results from these two experiments, pigs apparently do have a requirement for more carnitine than they are capable of synthesizing, because the results consistently show L-carnitine improving F/G by 10 to 15% in phase 2. However, the exact requirement cannot yet be determined based on the data from these two experiments. Further investigation into other possible roles of carnitine in metabolism will be needed before a carnitine requirement for nursery pigs can be offered.

The data from these experiments show that addition of L-carnitine to starter diets offers the potential to substantially improve feed efficiency.

Table 1. Composition of Diets (Experiment 1)

	Phase 1[a]		Phase 2[b]	
Ingredient	Control	Fat added	Control	Fat added
Corn	41.65	31.50	45.15	40.05
Soybean meal (44% CP)	15.00	15.00	31.00	31.00
Dried skim milk	20.00	20.00	—	—
Dried whey	20.00	20.00	20.00	20.00
Soybean oil	—	10.00	—	5.00
L-lysine HCL	.10	.25	.10	.15
D-L methionine	.10	.10	—	—
Monocalcium phosphate	.90	.90	1.51	1.51
Limestone	.60	.60	.82	.82
Salt	.10	.10	.25	.25
Copper sulfate	.10	.10	.10	.10
Selenium premix[c]	.05	.05	.05	.05
Trace mineral premix[d]	.15	.15	.15	.15
Vitamin premix[e]	.25	.25	.25	.25
Antibiotic[f]	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00

[a]All diets formulated to contain at least 1.3% lysine, .9% Ca, .8% P, and 250 Kcal ME/g lysine.
[b]All diets formulated to contain at least 1.25% lysine, .9% Ca, and .8% P in a constant calorie/lysine ratio.
[c]Each lb contains 272.4 mg Se.
[d]Contains 10% Mn, 10% Fe, 10% Zn, 4% Ca, 1% Cu, .4% K, .3% I, .2% Na, and .1% Co.
[e]Each lb contains: vitamin A, 1,000,000 IU; vitamin D_3, 100,000 IU; vitamin E, 4,000 IU; menadione, 1.32 mg; riboflavin, 2 mg; niacin, 12 mg; d-pantothenic acid, 8 mg; vitamin B_{12}, 8 mg.
[f]Carbadox added at 20 lb/ton.

Table 2. Composition of Diets (Experiment 2)

Ingredient, %	Phase 1[a]	Phase 2[b]
Corn	33.16	47.00
Soybean meal, (44% CP)	18.20	33.10
Dried skim milk	20.00	—
Dried whey	20.00	10.00
Soybean oil	5.00	5.00
L-lysine HCL	.22	.10
D-L methionine	.10	—
Monocalcium phosphate	1.23	1.85
Limestone	.44	.80
Salt	.10	.30
Vitamins/minerals[c]	.55	.55
Antibiotic[d]	1.00	1.00
Total	100.00	100.00

[a]All diets formulated to contain 1.45% lysine, .9% Ca, and .8% P.
[b]All diets formulated to contain 1.25% lysine, .9% Ca, and .8% P.
[c]Same as experiment 1 diet; See Table 1.
[d]Supplied the following per lb of diet: 10 mg furazolidine, 50 mg oxytetracycline, and 45 mg arsanilic acid.

Table 3. Effect of L-Carnitine on Pig Performance (Experiment 1)

	Control			Soybean oil[b]			
	Carnitine, ppm[c]						
Item	0	500	1000	0	500	1000	CV
ADG, lb							
0-2 wk	.65	.70	.61	.69	.68	.70	13.2
3-5 wk[d]	.83	.98	.96	1.02	.98	1.11	15.7
0-5 wk[d]	.76	.87	.83	.90	.87	.94	12.1
Feed Intake, lb/d							
0-2 wk	.65	.70	.66	.71	.69	.70	13.8
3-5 wk	1.69	1.83	1.77	1.88	1.85	1.84	10.5
0-5 wk	1.27	1.38	1.33	1.41	1.38	1.38	9.8
F/G							
0-2 wk	1.03	1.02	1.13	1.08	1.07	1.02	8.6
3-5 wk[df]	2.22	2.00	2.00	2.04	2.00	1.71	14.4
0-5 wk	1.74	1.65	1.67	1.67	1.66	1.48	10.7

[a]A total of 120 weanling pigs, 4 pigs/pen, 5 pens/trt; avg initial wt 12.3 lb, avg final wt 42.5 lb.
[b]Soybean oil levels were reduced by 50% in phase 2.
[c]L-carnitine levels were reduced by 50% in phase 2.
[d]Soybean oil effect (P<.05).
[e]L-carnitine effect linear (P<.05).

Table 4. Main Effects of Feeding L-Carnitine in Phase 1 (Experiment 2)[a]

	Carnitine (ppm)	
Item	0	1000
0-14 d		
ADG, lb[b]	.62	.69
FI, lb/d[c]	.68	.75
F/G	1.23	1.16
15-35 d		
ADG, lb	1.03	1.02
FI, lb/d	1.81	1.90
F/G	1.84	1.96
0-35 d		
ADG, lb	.87	.89
FI, lb/d	1.36	1.44
F/G	1.61	1.66

[a]A total of 180 weanling pigs, 6 pigs/pen, 15 pens/trt; avg initial wt 13.2 lb, avg final wt 43.9 lb.
[b]Carnitine effect (P<.08).
[c]Carnitine effect (P<.02).

Table 5. Effect of L-Carnitine on Pig Performance (Experiment 2)[a]

	Carnitine (ppm)[b]						
Item	0/0	0/250	0/500	1000/0	1000/250	1000/500	CV
ADG, lb							
0-2 wk	.62	.63	.62	.70	.73	.63	13.1
3-5 wk	1.07	.95	1.07	1.06	1.00	1.00	13.7
0-5 wk	.89	.83	.88	.92	.90	.85	11.4
Feed intake, lb/d							
0-2 wk	.67	.72	.66	.78	.77	.69	9.9
3-5 wk[c]	1.98	1.67	1.78	1.95	2.01	1.73	11.6
0-5 wk[d]	1.45	1.29	1.33	1.49	1.52	1.32	9.7
F/G							
0-2 wk	1.24	1.30	1.13	1.17	1.13	1.19	12.2
3-5 wk[de]	1.96	1.88	1.70	1.92	2.19	1.78	9.7
0-5 wk[f]	1.68	1.62	1.54	1.66	1.72	1.59	6.9

[a]A total of 180 weanling pigs, 6 pigs/pen, 5 pens/trt; avg initial wt 13.2 lb, avg final wt 43.9 lb.
[b]Carnitine levels as fed phase 1/phase 2.
[c]Carnitine effect linear (P<.05).
[d]Carnitine effect linear (P<.03).
[e]Carnitine effect quadratic (P<.02).
[f]Carnitine effect: Linear (P<.06).

EFFECT OF ACIDIFICATION ON STARTER PIG PERFORMANCE AND NUTRIENT DIGESTIBILITY

T. L. Weeden, J. L. Nelssen, J. A. Hansen, and K. L. Richardson

Summary

One hundred ninety-six pigs (21 d of age and 12.3 lb initial wt) were used to evaluate the effect of adding an organic acid blend (OAB)[1] to starter diets on growth performance and nutrient digestibility. The four dietary treatments consisted of a control diet and the OAB replacing corn at 3, 4.5, and 6 lb/ton in both phases 1 and 2. In phase 1 (0 to 14 d) diets, contained 20% dried skim milk, 20% dried whey, and 5% soybean oil. Phase 2 diets (15 to 35 d) contained 10% dried whey and 5% soybean oil. There was no response in ADG, FI, or F/G to the addition of OAB to starter diets in either phase 1 or phase 2. Fecal samples were collected on d 12 (phase 1) of the experiment via rectal massage, and apparent digestibility of nitrogen and dry matter were calculated using chromic oxide (.25%) as an indigestible marker. Nitrogen and dry matter digestibility decreased linearly with increasing levels of OAB. This trial demonstrates that addition of OAB has no effect on performance when pigs consumed high milk-product diets.

(Key Words: Starter, Performance, Digestion, Acid.)

Introduction

The early-weaned pig has an immature digestive system and is somewhat limited in digestive capability; therefore, lowering the pH of the diet by feeding combinations of organic acids may improve digestibility and growth performance of early weaned pigs. Previous research has concentrated on addition of fumaric, hydrochloric, citric, or phosphoric acids to simple corn-soybean meal diets at levels of 1 to 4%, resulting in 5 to 10% improvements in feed efficiency only in the first 2 wk postweaning. The objective of this experiment was to determine the effect on pig performance and nutrient digestibility from addition of lower inclusion rates of an organic acid blend (OAB) to high nutrient density starter diets during phase 1 (0 to 14 d) and more simple diets during phase 2 (15 to 35 d).

Procedures

A 5-wk growth trial was conducted to evaluate the effects of various levels of OAB on pig performance and apparent nutrient digestibilities. Dietary treatments included OAB levels of .150, .225, and .300% of the diet. These levels were attained by replacing corn from the control diet with 3, 4.5, or 6 lb/ton of OAB, respectively. One hundred ninety-six

---

[1]The authors express appreciation to SmithKline Animal Health Products, which donated the Stacidem® for testing.

crossbred pigs weaned at 21 ± 2 d, with an average weight of 12.3 lb were utilized. Pigs were housed in an environmentally controlled nursery with feed and water supplied ad libitum throughout the experiment. Pigs were allotted by litter and sex within weight blocks to the four dietary treatments. There were seven replications per treatment with seven pigs per pen. Feed intakes per pen and individual pig weights were recorded weekly. On d 12 postweaning (phase 1) fecal samples were collected via rectal massage and frozen for later analysis. Apparent digestibilities of dry matter and nitrogen were calculated using chromic oxide (.25%) as an indigestible marker.

Compositions of the control diets are shown in Table 1. A pelleted diet containing 40% milk products and 5% soybean oil was fed during phase 1 (0 - 14 d) containing 1.45% lysine, .90% Ca, and .80% P. In phase 2 (15 to 35 d), pigs were fed a meal diet containing 10% dried whey, 5% fish meal, and 5% soybean oil and formulated to contain 1.25% lysine, .90% Ca and .80% I?

Results and Discussion

The effect of OAB on growth performance is shown in Table 2. Pigs fed the OAB diets showed no improvement over the control diet for ADG, FI, or F/G in phase 1, phase 2, or the cumulative 5-wk experiment.

In phase 1, a linear ($P<.07$) decrease in the digestibilities of N and DM occurred as levels of OAB increased (Table 3).

These results indicate that the digestibility of high milk product diets (phase 1) do not benefit from addition of organic acids to the diet. These complex diets are highly digestible, thus the addition of acid did not improve protein digestibility, as often occurs with simple corn-soy diets. Although this decrease in digestibility is commonly found with organic acid addition to complex diets, the reason is unclear. One reason may be a slight problem with acidosis from organic acid addition to high milk diets, since research at Illinois has shown increased performance with acid-treated complex diets when sodium bicarbonate was added. Previous research with organic acid additions to starter diets has shown that most of the improved digestibility of simple corn-soybean meal was due to the lowered pH denaturing the protein. The low level additions of OAB ranging from .15 to .30% may not decrease pH enough to improve digestibility. By 6 to 8 wk of age, the digestive system of the pig has matured enough to digest most corn-soybean meal diets quite satisfactorily. This may explain why addition of organic acids to phase 2 diets did not improve pig performance, regardless of whether a complex or simple diet was fed. Based on the results of this experiment, the addition of low levels of OAB to complex starter-pig diets is not justified.

Table 1. Composition of Diets

Ingredient, %	Phase 1[a] (control)	Phase 2[b] (control)
Corn[c]	32.91	56.12
Soybean meal (44% CP)	18.20	
Soybean meal (48% CP)	—	20.05
Fish meal		5.00
Dried skim milk	20.00	
Dried whey	20.00	10.00
Soybean oil	5.00	5.00
Monocalcium phosphate	1.23	1.35
Limestone	.44	.48
Salt	.10	.25
L-lysine, HCL	.22	.20
D-L methionine	.10	—
Copper sulfate	.10	.10
Chromic oxide	.25	—
Selenium premix[d]	.05	.05
Trace mineral premix[e]	.15	.15
Vitamin premix[f]	.25	.25
Antibiotics	1.00	1.00
Total	100.00	100.00

[a]Calculated analysis for phase 1: 1.45% lysine, .9% Ca, .8% P.
[b]Calculated analysis for phase 2: 1.25% lysine, .9% Ca, .8% P.
[c]An organic acid blend (Stacidem®) replaced corn at the rate of 3, 4.5, and 6 lb/ton in phase 1 and phase 2.
Each lb contains 272.4 mg Se.
[e]Contains 10% Mn, 10% Fe, 10% Zn, 4% Ca, 1% Cu, .4% K, .3% I, .2% Na, and .1% Co.
[f]Each lb contains: vitamin A, 1,000,000 IU; vitamin D_3, 100,000 IU; vitamin E, 4,000 IU; menadione, 1.32 mg; riboflavin, 2 mg; niacin, 12 mg; d-pantothenic acid, 8 mg; vitamin B_{12}, 8 mg.
[g]Supplied the following per lb of diet: 10 mg furazolidone, 50 mg oxytetracycline, 45 mg arsanilic acid.

Table 2. Effect of and Organic Acid Blend (OAB)[a] on Starter Pig Performance[b]

Item	Control	.15% OAB[b]	.225% OAB	.3% OAB	CV
O-2 wk					
ADG, lb	.73	-69	.66	.71	9.2
FI, lb/d	.76	.75	.70	.73	10.6
F/G	1.15	1.15	1.13	1.08	11.1
3-5 wk					
ADG, lb	1.27	1.28	1.26	1.28	6.8
FI, lb/d	2.34	2.31	2.23	2.35	7.5
F/G	1.95	1.83	1.86	1.92	8.0
O-5 wk					
ADG, lb	1.05	1.04	1.02	1.05	6.7
FI, lb/d	1.70	1.69	1.62	1.70	7.5
F/G	1.67	1.64	1.64	1.66	4.2

[a]OAB was Stacidem®

[b]Tota1 of 196 weanling pigs, 7 pigs/pen with 7 pens/treatment; avg initial wt 12.3 lb, ave final wt 48.7 lb.

Table 3. Effect of an Organic Acid Blend (OAB)[a] on Nutrient Digestibility

Item	Control	.15% OAB	.225% OAB	.30% OAB	CV
Apparent nitrogen digestibility, %[b]	88.20	87.49	84.54	86.57	2.3
Apparent dry matter digestibility, %[c]	88.95	87.53	87.14	87.68	1.7

[a]OAB was Stacidem®.

[b]Stacidem® effect: linear decrease in digestibility (P<.02).

[c]Stacidem® effect: linear decrease in digestibility (P<.07).

COMPARISON OF TWO ATROPHIC RHINITIS VACCINES FOR YOUNG PIGS

D. A. Schoneweis[1] and R. H. Hines

Summary

Two farrowing groups (340 pigs) were used to evaluate two atrophic rhinitis vaccines (Atrobac III® and Toxivac®) for the young pig. Both vaccines were effective, because no clinical evidence of atrophic rhinitis was observed for either treatment during the experiment. Although the swine herd had been observed in previous farrowing do have various degrees of conjunctivitis, none was observed in the pigs vaccinated with either vaccine. Weight gains of pigs at 14 d and 35 d postweaning were the same for each treatment.

(Key Words: Starter, Performance, Disease, Rhinitis.)

Introduction

Atrophic rhinitis continues to be a challenging and perplexing problem in the swine industry. Research has indicated that the primary causes of this complex are Bordetella bronchiseptica and/or Pasteurella multocida type D. The combination of these organisms in a susceptible animal and poor facilities can cause severe economic losses from retarded growth. Clinical signs of atrophic rhinitis are primarily twisted and/or shortened noses, which may result in pigs failing to grow even when management is excellent. This experiment was conducted to evaluate two commercially available bacterin-toxiods that may be used for the prevention of atrophic rhinitis.

Procedures

Two farrowing groups of pigs (340 pigs) were used. Half of each litter (odd no. pigs) received one injection of Atrobac III® at 5 to 7 d of age and a booster injection at the time of weaning (age at weaning varied from 19 to 28 d). The second group of pigs (even no. pigs) received one injection of Toxivac® at the time of weaning. The weights at weaning and at 14 d and 35 d postweaning were evaluated. There was no opportunity for a slaughter check to determine whether there was a difference in lung and turbinate scores. No unvaccinated controls were used.

Discussion

None of the pigs showed evidence of discomfort, swelling, or injection reaction following vaccination, either at 1 wk or 3 wk. There was no clinical evidence of atrophic rhinitis in any of

[1]Department of Surgery and Medicine, Kansas State University.

the pigs up to the conclusion of the 35-d postweaning period when the pigs were 8 to 9 wk of age. Various degrees of conjunctivitis had been a problem in previous farrowing; however, none of the pigs in this experiment showed any marked evidence of conjunctivitis. CSP-250 was added to the nursery rations. All sows had been vaccinated prior to farrowing with Toxivac®.

Table 1 presents the pig weight data for the two treatment groups at weaning (age at weaning varied from 19 to 28 d within each farrowing) and at 14 d and 35 d postweaning. No postweaning differences in pig weight were observed for either treatment.

Table 1. Pig Weights of Pigs Vaccinated with either Atrobac III® or Toxivac®

Vaccine[a]	Atrobac III®	Toxivac®
No. pigs	175	165
Weaning wt, lb	13.07	13.06
14 d postweaning, lb	22.66	22.42
35 d postweaning, lb	42.08	41.83

[a]Atrobac III - Smith, Kline, Beecham, Lincoln, NE.
[a]Toxivac AD - Noble lab, Sioux Center, IA.

LOW-TEST WEIGHT SORGHUM FOR GROWING-FINISHING SWINE

J. A. Hansen, R. D. Goodband, R. C. Thaler[1], J. D. Hancock, J. L. Nelssen, and R. H. Hines

Summary

Two growth studies were conducted to determine the effects of substituting lower test-weight sorghum (35 lb/bu as LOW or 45 lb/bu as MED) for normal test-weight sorghum (55 lb/bu NORM), in growing and finishing swine diets. One-hundred twelve pigs (50 lb initial wt) were fed for 28 d in the grower study and 80 pigs (120 lb initial wt) were fed for 51 d in the finisher study. Diets were formulated to contain .80 and .65% lysine for the grower and finisher trials, respectively, using NORM and soybean meal; LOW and MED were substituted on a wt/wt basis for NORM. The fourth treatment evaluated was a 50:50 (wt:wt) blend of LOW/NORM. Apparent dry matter and nitrogen digestibility were determined on d 14 of the grower trial using chromic oxide as a nondigestible marker. In the grower study, pigs fed the NORM or MED had similar growth rates, daily feed intakes, and feed conversions. However, pigs fed the LOW diet tended to grow slower and convert feed to gain less efficiently than pigs fed either the NORM or MED diets. Similarly, pigs fed the LOW/NORM blend tended to perform at a level intermediate to pigs fed the MED and LOW diets. Dry matter and N digestibilities paralleled the numeric trends noticed in the performance data, and significant differences were detected between NORM or MED and the LOW or LOW/NORM. In the finishing trial, pigs fed the NORM or MED gained at similar rates and had similar feed efficiencies, but pigs fed the LOW or blend had poorer feed/gain and slightly poorer growth rates. In a companion study, chicks fed the sorghums had linear reductions in growth rate and feed conversions when fed diets containing reduced test-weight sorghum. Overall, LOW sorghum can be expected to cause a 5 to 7% reduction in gains and a 7 to 12% reduction in feed/gain when fed to growing and finishing pigs. Similar reductions are observed for chicks (6 to 7% reduction in growth rate; 4 to 5% reduction in feed/gain). Medium sorghum has an equal feeding value to NORM sorghum for both growing and finishing swine and a slightly lower feeding value for chicks.

(Key Words: Sorghum, Test Weight, Damaged, GF, Performance.)

Introduction

Sorghum grains grown under normal agronomic conditions should obtain test weights of greater than 50 lb/bu. In general, test weights can be affected by several factors including a late seeding, early frost, or drought. Unfortunately, drought conditions over the past few years have resulted in less than optimal test weights for sorghum. The sorghum generally contains a slightly higher percentage crude protein, however, smaller seed size indicates a significantly reduced starch content, resulting in a larger fraction of protein. This would seem beneficial from a nutritional

[1]In cooperation with South Dakota State University, Brookings, SD.

standpoint, but the opposite is generally the case. Therefore, the present research was needed to further evaluate the use of reduced test-weight sorghum in growing and finishing swine diets.

Procedures

A total of 112 crossbred (Hampshire x Yorkshire x Duroc) pigs (initial wt 50 lb; 28 d trial) and 80 crossbred (Large White × Landrace × Duroc × Hampshire) pigs (initial wt 120 lb; 51 d trial) were utilized in grower and finisher trials, respectively, to determine the efficacy of substituting MED or LOW sorghum for NORM sorghum in standard growing and finishing swine diets. Pigs were blocked by weight and randomly allotted to dietary treatments within each block to obtain four replicate pens per treatment. Sexes were represented equally across treatments. There were five or seven (finisher and grower, respectively) pigs per pen. Apparent digestibility of dry matter (DMD) and nitrogen (ND) were determined on d 14 using a non-digestible marker (Cr_2O_3).

The chemical composition of the sorghum is presented in Table 1. It is important to note that the sorghums were not cleaned before use in the studies. Basal diets (Table 2) were formulated to contain .80 and .65% lysine, .75 and .65% calcium, and .65 and .55% phosphorus in the grower and finisher studies, respectively. Experimental treatments were: 1) basal diet, 2) MED substituted for NORM (wt/wt basis), 3) LOW substituted for NORM (wt/wt basis), 4) 50:50 blend of LOW/NORM substituted for NORM (wt/wt basis). Pigs were allowed feed and water ad libitum.

Table 1. As Fed Composition of Sorghum

Nutrient, %	Norm	Med	Low
Protein	9.7	10.2	11.5
Ca	.02	.04	.07
P	.28	.30	.37
Fiber[a]	3.20	6.00	10.40
Lysine	.20	.26	.31
Methionine	.15	.15	.16
Threonine	.35	.39	.44
Tryptophan	.10	.13	.12

[a]Acid detergent fiber analysis.

In a companion study, a 14-d assay was conducted using 7-d-old chicks to further evaluate the reduced test-weight sorghum for monogastric animals. Diets were evaluated using six cages (four birds per cage) per treatment. The basal diet was formulated to contain 24% crude protein, 1.1% calcium, and .9% phosphorus and fortified to meet or exceed the chicks estimated requirements. Chick wt and feed intakes were measured weekly, and feed efficiency was calculated.

Results and Discussion

Pigs grew at similar rates (Table 3) when fed diets containing NORM, MED, or LOW/NORM in the grower trial. There was a numerical difference between gains for pigs fed the LOW diet as compared to all other treatments. Most notably, there was a tendency for reduced efficiency of feed utilization by pigs fed diets containing LOW (including the blend). There was a significant reduction ($P<.05$) in DMD for pigs fed the LOW diet as compared to all other diets. Similarly, ND was reduced for both LOW and LOW/NORM diets when fed to grower pigs, indicating that the availability of amino acids in the low test-weight sorghum is reduced. In the finishing trial, no differences were detected in ADG or in feed intake (Table 3). There was a tendency for pigs fed the LOW or LOW/NORM diets to have poorer feed conversions; however, these differences were not statistically significant.

Chick performance (Table 4) followed a similar trend to the pig performance, with chicks fed LOW growing slowest. Blending the LOW with NORM resulted in growth and feed/gain similar to LOW. Chicks fed MED had intermediate performance to chicks fed NORM and LOW. Feed conversion ratios were similar to those observed in the swine trials, with respect to dietary treatment. Linear reductions in the efficiency of feed utilization were observed with reducing test weight.

Table 2. Composition of Basal Diets

	Amount, %		
Ingredient	Grower	Finisher	Chick
Sorghum	75.00	81.15	53.28
Soybean meal (44% CP)	21.65	16.20	
Soybean meal (48% CP)			38.12
Soybean oil			3.50
Monocal phos (21% P)	1.45	1.05	2.45
Limestone	1.05	1.00	1.40
Salt	.25	.25	.40
Vitamin premix	.25	.25	.50
Trace mineral mix	.10	.10	.05
Dl-methionine			.25
Chromium oxide	.25		
Antibiotic[a]			.05
Total	100	100	100

[a]Provided .025% amprolium.

In summary, these data indicate that monogastric animals, pigs and chicks, utilize reduced test-weight (45 lb/bu or 35 lb/bu) sorghum less efficiently for gain than normal test- weight sorghum. Although feed intake patterns are not altered significantly, the reduced ability to utilize the grain results in reduced growth rates. It appears that the reduced test- weight sorghums have a lower availability of total dry matter as well as amino acids, as indicated by nitrogen digestibility. Overall, one can expect to observe a 5 to 7% reduction in growth rate in both species and a 7 to 12% (swine) or 4 to 5% (chicks) reduction in feed/gain. Thus, when considering the use of low test-weight sorghum in swine or poultry diets, one should weigh the expected reductions in performance against the price of the sorghum. Simply stated, a producer should not pay more than 90 to 93% the present value of normal test-weight sorghum for sorghums testing less than 45 lb/bu.

Table 3. Effect of Sorghum Test Weight on Growing and Finishing Pig Performance[a]

Item	NORM	MED	LOW	LOW/NORM	CV
Grower trial					
ADG, lb	1.30	1.30	1.22	1.30	10.1
ADFI, lb	3.73	3.55	3.70	3.73	5.0
Feed/gain	2.75	2.72	3.14	2.88	12.7
Apparent digestibility, %					
DM[b]	71.7	71.7	65.2	68.8	2.7
N[c]	82.2	81.0	72.0	78.8	1.9
Finisher trial					
ADG, lb	2.10	2.05	2.02	2.01	7.0
ADFI, lb	7.30	7.07	7.45	7.45	6.6
Feed/gain	3.50	3.46	3.71	3.73	4.5

[a]Values are means of four replicate pens containing seven (grower; initial wt 50 lb) or five (finisher; initial wt 120 lb) pigs per pen.
[b]LOW vs others (P<.06).
[c]LOW vs others (P<.01), NORM or MED vs blend (P<.05).

Table 4. Effect of Sorghum Test Weight on Chick Performance

Item	NORM	MED	LOW	LOW/NORM	CV
Total gain, lb[a]	1.07	1.00	1.00	1.01	4.8
Total feed, lb	1.50	1.44	1.45	1.48	3.7
Feed/gain[a]	1.40	1.44	1.46	1.47	3.1

[a]Linear effect of test weight (P<.05).

POSTFINISHING MINERALIZATION OF SKELETAL TISSUE IN REPLACEMENT GILTS

R. I. Nicholson, R. H. Hines, G. E. Fitzner, J. D. Hancock, and R. D. Goodband

Summary

Thirty-two crossbred gilts averaging 250 lb were selected for the experiment at the conclusion of the finishing phase. Eight of the gilts were slaughtered on d 0 to serve as a pretreatment control group. The remaining 24 gilts were assigned to three dietary treatments to provide daily 100% (14 g/d Ca and 11.3 g/d P), 150% (22.5 g/d Ca and 16.6 g/d P), and 200% (29.9 g/d Ca and 22.0 g/d P) of the Ca/P level consumed per d during the finishing phase. These gilts were slaughtered 35 d later at 291 lb. Gilts receiving 29.9 g/d Ca and 22.0 g/d P yielded ribs that had the highest values for percent ash, bending moment, and modulus of elasticity. Femurs did not differ in any bone characteristics because of treatment; however, the 3rd metacarpal bone showed the highest percent ash and greatest bending moment at the intermediate level of Ca/P.

(Key Words: GF, Performance, Calcium, Phosphorus, Sow.)

Introduction

The current NRC (1988) recommendations for Ca and P for finishing pigs are .50% and .40%, respectively, for growth rate and feed efficiency. However, to maximize bone parameters (wall thickness, modulus of elasticity, and percent ash) the recommendations for Ca and P are .90% and .75%, respectively. Research has shown that compensatory bone mineralization can occur between the growing phase (115 lb) and the conclusion of finishing (205 lb). Therefore, the objective of this study was to determine the effect of different levels of dietary Ca and P on bone mineralization of gilts after the finishing phase.

Procedures

Thirty-two crossbred gilts averaging 250 lb were selected at the conclusion of the finishing phase. Eight gilts were randomly selected for slaughter on d 0 to determine bone characteristics. The remaining 24 gilts were assigned by weight and ancestry to three dietary treatments. During the final 2 wk of the finishing period, the average daily feed intake had been determined to be 5 lb per d of a diet containing .65% Ca and .50% P. At this level of feed intake, the gilts were consuming 14.7 g of Ca and 11.3 g of P daily. Based on the daily feed intake of 5 lb/gilt, the dietary treatments were formulated to provide 100, 150, and 200% g of Ca and P received in the finishing phase. This resulted in daily Ca/P treatment levels of 14.7 g/11.3 g, 22.5 g/16.6 g, and 29.9 g/22.0 g, respectively. Monocalcium phosphate (21% P) was used as the source of P in a milo-soybean meal diet (Table 1). Limestone was used to provide Ca in a calculated 1.3:1 Ca:P ratio.

The 24 gilts were housed in a modified open front building. Eight gilts were maintained in each pen measuring 6 ft × 16 ft. The concrete floors of the pens were partially slatted (50%). The gilts were fed twice a day on the floor to reduce feed wastage and behavior problems. The gilts remained on trial for 35 d.

At the conclusion of the trial, the gilts were weighed and slaughtered. The 3rd metacarpal, 1st rib, and femur from the right side of each carcass were collected for determining bone characteristics.

Table 1. Composition of Diets

			Percent of control diet		
		Initial	100	150	200
	Ca, g :	14.7	14.7	22.5	29.9
Ingredient, %	P, g :	11.3	11.3	16.6	22.0
Milo		80.30	81.50	79.68	77.87
Soybean meal[a]		17.00	15.68	16.03	16.35
Monocalcium phosphate		.90	.82	1.93	3.08
Limestone		.95	1.15	1.52	1.84
Salt		.50	.50	.50	.50
Vitamin premix		.25	.25	.25	.25
Trace mineral premix		.10	.10	.10	.10

[a]The control diet was formulated with 44% CP soybean meal; treatment diets were formulated with 48.5% CP soybean meal.

Results and Discussion

The calculated and analyzed compositions of the diets are presented in Table 2. After 35 d on trial, the average slaughter weight of the gilts was 291 lb. No difference in average daily gain because of treatment was observed. No differences were observed in carcass data (avg backfat thickness, carcass length, and longissimus muscle area) from treatment.

The mechanical properties and percentage ash of the bones are shown in Table 3. Although the Ca/P levels of the control diet were continued as a treatment, there was a tendency for the bone mechanical properties of this treatment to be lower than those observed in the gilts slaughtered initially. It should be noted that the feed intake was estimated at 5 lb/d while the gilts were still in the finishing phase. However, the gilts were being fed with barrows ad libitum, which could have resulted in an underestimation of actual feed intake of the gilts because of the estimated correction for barrows in the pen. The actual daily feed intake based on analyses of the diets (Table 2) shows the original gilts were receiving 3 g more P/d than those gilts with the continued treatment based on the same feed intake.

Table 2. Analyses of Diets

			Percent of control diet	
	Initial	100	150	200
Ca, g :	14.7	14.7	22.5	29.9
Item P, g :	11.3	11.3	16.6	22.0
Calculated, %				
Crude protein	14.70	14.70	14.70	14.70
Ca	.65	.65	.99	1.32
P	.50	.50	.73	.97
Analyzed, %				
Crude protein	16.48	15.19	15.57	13.95
Ca	.79	.78	1.00	1.33
P	.62	.49	.68	.91
Actual daily intake[a], g				
Ca	17.9	17.7	22.7	30.2
P	14.1	11.1	15.4	20.7
Actual ratio of Ca:P[b]	1.3:1	1.6:1	1.5:1	1.5:1

[a]Based on 5 lb of feed intake per gilt per day. Control diet was fed ad libitum in finishing phase.
[b]Ratio based on diet analyses.

The postfinishing levels of Ca and P in the diet did not influence any mechanical properties or the percentage ash of the femur. Effects of treatment on bone mechanical properties are given in Table 3. Modulus of elasticity, or the rigidity of the bone, was highest at the end of the finishing phase but appeared to decrease during the 35-d postfinishing period. Of the three bones evaluated, the rib was the most responsive. A linear increase ($P<.05$) in modulus of elasticity was observed with increased Ca/P levels. Gilts receiving the highest treatment (29.9 g Ca and 22 g P) had the highest values for bending moment, modulus of elasticity, and percentage ash. Percentage of ash also tended to increase linearly ($P<.16$). Maximum bending moment values were obtained from metacarpals of gilts fed 22.5 Ca and 16.6 g P. The highest level of Ca/P (29.9 g and 22.0 g) resulted in the highest percent of ash. The gilts slaughtered initially yielded metacarpals that had the highest modulus of elasticity compared to those from gilts slaughtered 35 d later. Table 4 shows the data for serum P, Ca, and alkaline phosphatase (AP). The overall final values of P were significantly lower ($P<.01$) than the overall initial values. There was a reduction within treatment between the initial and final P levels for the highest two dietary treatments of Ca and P. Although final levels of calcium were slightly elevated compared to initial values, the differences were not significant. In general, serum P tended to decrease from the initial bleeding to the final period, whereas Ca tended to increase. This inverse relationship of Ca and P has been reported by other researchers working with growing swine, but does not appear to exist for mature animals such as sows. There were no differences in serum AP. Maximum calcification was associated with low AP levels.

Table 3. Bone Mechanical Properties and Mineralization of Gilts Fed Different Levels of Calcium and Phosphorus

			Percent of control diet		
	Initial	100	150	200	
Ca, g :	14.7	14.7	22.5	29.9	
Item P, g :	11.3	11.3	16.6	22.0	CV
Femur[a]					
Bending moment, kg	424	393	426	409	18.9
Modulus of elasticity, kg/cm^2	1,363	1,348	1,180	1,217	44.6
Wall thickness, cm	.42	.40	.42	.39	12.0
Stress, kg/cm^2	32.0	274	278	278	
Ash, %	71.40	71.10	71.10	71.25	1.1
Rib					
Bending moment, kg[d]	125[b]	137[bc]	149[bc]	158[c]	19.6
Modulus of elasticity, kg/cm^2	8,659[bc]	6,605[b]	9,130[bc]	10,606[c]	39.3
Stress, kg/cm^2	695[bc]	567[b]	747[c]	776[c]	
Ash, %[de]	56.47[b]	58.21[bc]	59.20[c]	59.51[c]	3.2
3rd Metacarpal					
Bending moment, kg	235[b]	248[b]	291[c]	258[bc]	15.3
Modulus of elasticity, kg/cm^2	2,615	2,045	2,387	1,926	39.4
Stress, kg/cm^2	714	625	779	716	
Ash, %	60.84	60.77	61.35	61.58	1.9

[a]Control treatment represents the right femur; remaining treatments and CVs represent the pooling of the right and left femur.
[bc]Means with unlike superscripts differ (P<.05).
[d]Linear effect of treatments (P<.05).
[e]Contrast of control vs treatments is significant (P<.01).

Table 4. Serum Blood Values of Gilts Fed Different Levels of Calcium and Phosphorus[a]

			Percent of control diet		
	Initial	100	150	200	
Ca, g :	14.7	14.7	22.5	29.9	
Item P, g :	11.3	11.3	16.6	22.0	CV
P (g/dl)[b]					
Initial	7.03	6.50	7.01[c]	7.07[e]	10.4
Final		5.82	5.97[d]	5.73[f]	16.3
Ca (mg/dl)					
Initial	13.41	12.93[c]	13.82	12.35	13.8
Final		14.46[d]	14.17	13.66	11.1
Alkaline phosphatase (Sigma units)					
Initial	1.35	1.32	1.28	1.42	21.9
Final		1.21	1.25	1.22	19.0

[a]Eight gilts per treatment; controls were slaughtered on d 0.
[b]Final values differ from initial (P<.001).
[cd]Means in columns with unlike superscripts differ (P<.05).
[ef]Means in columns with unlike superscripts differ (P<.01).

EFFECT OF EXTRUSION ON THE NUTRITIONAL VALUE OF SOYBEANS AND SORGHUM GRAIN IN FINISHING PIGS

R. H. Hines, J. D. Hancock, G. E. Fitzner, T. L. Weeden, and T. L. Gugle

Summary

A total of 112 finishing pigs (avg initial wt of 139 lb) was used to determine the effects of adding extruded soybeans and/or sorghum grain to diets for finishing pigs. Treatments were: 1) sorghum-soybean meal control (sorghum-SBM), 2) extruded soybeans and ground sorghum, 3) SBM and extruded sorghum, and 4) extruded soybeans and sorghum. All diets were isocaloric and isolysinic. Using extruded soybeans and/or sorghum improved efficiency of gain compared to the sorghum-SBM control. This response was apparently related to the improved digestibilities of dry matter and nitrogen with the use of extruded ingredients. Optimum digestibility of dry matter and nitrogen was achieved when just the sorghum was extruded, but optimum growth performance (i.e., efficiency of gain) was achieved when extruded sorghum and soybeans were added to the diet.

(Key Words: GF, Performance, Process, Sorghum.)

Introduction

Extrusion involves heating and compressing simultaneously by a screw type auger. Heat is generated when feedstuffs are augured through the screw chamber under extreme pressure that creates friction. This friction can result in product temperatures of up to 360°F, which is more than adequate to destroy the trypsin inhibitor present in soybean. The pressure and heat rupture the oil cells, which allows the oil to be reabsorbed into the soybean residue.

Extrusion of cereal grains disorganizes the semicrystalline structure of the starch granules. This makes the starch more easily attacked by digestive enzymes and may enhance efficiency of utilization of the cereal grain by the finishing pigs.

Therefore, the objectives for this finishing pig study were to determine the effect of extrusion in the nutritional value of milo and soybeans and to determine if the increased feeding value of the individual ingredients is additive when they are added to diets in combination.

Procedures

One hundred twelve finishing pigs, averging 139 lb, were allotted to one of four dietary treatments based on initial weight, sex, and ancestry. There were seven pigs per pen and four pens per treatment. Pigs were housed in a modified, open fronted building, with 50% solid concrete and 50% concrete slat flooring. Each pen (6 × 16 ft) contained one, two-hole self-feeder and a nipple waterer.

The treatments used in the study were as follows: 1) control (ground milo, soybean meal, and soy oil); 2) ground milo and extruded soybeans; 3) extruded milo, soybean meal and soy oil; 4) extruded milo and soybeans. Diets were formulated to be isocaloric and isolysinic, with the same ratio of g lysine to Kcal of metabolizable energy.

Three weeks after initiation of the trial, chromic oxide was added to the diets (.25%). After a 4-d adjustment period, fecal samples were collected from eight pigs on each treatment. The samples were dried, ground, and analyzed for chromium, DM, and N contents, so that apparent DM and N digestibilities could be determined.

Results and Discussion

Growth performance of pigs fed the experimental diets is given in Table 2. Rate of gain was not affected by dietary treatment (P>.19). However, pigs fed the sorghum-SBM control ate more fed (P<.003) and were less efficient (P<.02) than pigs fed diets with extruded soybeans and/or extruded sorghum. A comparison of F/G values indicated that using extruded soybeans or sorghum improved efficiency of gain by 5% (3.11 vs 3.27), but using extruded soybeans and sorghum improved efficiency of gain by 9% (2.96 vs 3.27).

Apparent digestibility values (Table 2) also indicated that extrusion processing of soybeans and/or sorghum improved the nutritional value of the diets. Dry matter digestibility was 6% higher (85.8 vs 81.2%) with extruded soybeans and/or sorghum compared to the sorghum-SBM control diet. Extrusion of sorghum improved dry matter digestibility more than extrusion of the soybeans, as might be expected because sorghum accounted for 76% of the diet and extruded soybeans accounted fro only 21% of the diet. Extruding the sorghum also had a greater positive effect on nitrogen digestibility than extruding the soybeans, even though the soybeans supplied more of the total dietary crude protein.

In conclusion, using extruded soybeans and/or sorghum in diets for finishing pigs improved performance and nutrient digestibility compared to a simple sorghum-SBM diet. Although optimum digestibility was achieved by extruding only the sorghum, optimum efficiency of gain was achieved when both sorghum and soybeans were extruded and used in the diet.

Table 1. Diet Composition

Ingredient, %	Control (SBM)	Extruded soybeans
Sorghum	80.70[a]	76.09[a]
Soybean meal (48% CP)	14.90	—
Extruded soybeans	—	21.09
Soy oil	1.50	—
Monocalcium phosphate	1.08	1.00
Limestone	1.02	1.02
Salt, vit-mix, tm-mix, se-mix, antibiotic	.80	.80
Calculated analysis:		
Crude protein, %	14.41	14.51
Lysine, %	.65	.65
Ca, %	.65	.65
P, %	.55	.55
ME, Kcal/lb	1482	1482
g Lysine/Kcal ME	2.00	2.00

[a]For diets with extruded milo, ground milo was replaced on a lb for lb basis.

Table 2. Effect of Extrusion on the Nutritional Value of Soybeans and Sorghum in Finishing Pigs

		Extrusion treatment			
Item	Control	Soybeans	Sorghum	Soybeans and sorghum	CV
Growth performance[a]					
ADG, lb[b]	2.24	2.27	2.17	2.21	4.7
ADFI, lb[c]	7.33	7.07	6.72	6.55	3.4
F/G[d]	3.27	3.11	3.11	2.96	4.0
Apparent digestibility, %[e]					
DM[f]	81.2	83.1	88.0	86.4	3.0
N[g]	68.5	73.1	84.2	84.6	5.2

[a]A total of 112 finishing pigs, avg initial wt of 139 lb, avg final wt of 246 lb. There were seven pigs per pen and four pens per treatment.
[b]No treatment effect (P>.19).
[c]Control vs others (P<.003); extruded soy or extruded sorghum vs extruded soy and sorghum (P<.04); extruded soy vs extruded sorghum (P<.07).
[d]Control vs others (P<.02); extruded soy or extruded sorghum vs extruded soy and sorghum (P<.08).
[e]A total of eight pigs per treatment.
[f]Control vs others (P<.001); extruded soy vs extruded sorghum (P<.001).
[g]Control vs others (P<.001); extruded soy or extruded sorghum vs extruded soy and sorghum (P<.003); extruded soy vs extruded sorghum (P<.001).

PROTEIN SPARING EFFECT OF A FERMENTATION PRODUCT IN PIG DIETS FROM WEANING TO MARKET

J. D. Hancock and J. A. Swanson

Summary

One hundred eighty pigs (avg wt of 21.1 lb) were used in an experiment to determine if a fermentation product[1] improves performance and reduces last rib fat thickness in pigs when added to a low-protein diet regimen. Treatments were: 1) positive control (19-16-14% crude protein regimen during the nursery-growing-finishing phases); 2) positive control plus 2.50 lb/ton fermentation product; 3) low-protein regimen (17-14-12% crude protein during the nursery-growing-finishing phases); 4) low-protein regimen plus 1.25 lb/ton fermentation product; 5) low-protein regimen plus 2.50 lb/ton fermentation product; and 6) low-protein regimen plus 5.00 lb/ton fermentation product. As addition of fermentation product was increased from 0 to 5.00lb/ton in the low-protein regimen, average daily feed intake (ADFI) of nursery pigs decreased linearly. However, average daily gain (ADG) and feed to gain ratio (F/G) tended to be best for pigs fed 1.25 lb/ton of fermentation product compared to other treatments. During the growing and finishing phases, feeding the low-protein regimen reduced performance compared to the positive control. Compared to pigs fed the positive control, feeding 2.50 lb/ton of fermentation product tended to decrease ADFI and ADG but improved F/G. Feeding 2.50 and 5.00 lb/ton fermentation product reduced ADG and ADFI, and worsened F/G for pigs fed the low-protein regimen. Overall (from 21 to 220 lb), feeding the fermentation product at more than 1.25 lb/ton in the low-protein diet regimen tended to reduce performance, and pigs fed the low protein diets with or without the fermentation product had poorer performance (ADG, ADFI, F/G, and last rib fat thickness) than pigs fed the 19-16-14% crude protein diets.

(Key Words: Starter, GF, Performance, Probiotic, Carcass, Additive.)

Introduction

The gastro-intestinal tracts of pigs are continually challenged by antinutritional factors, abrasive materials, and potentially pathogenic microorganisms present in feed and feces. Both antibiotics and probiotics have been investigated by the authors (see 1989 KSU Swine Day Report) as feed additives that might improve growth performance of pigs by inhibiting the proliferation of pathogenic microorganisms in the intestine. However, feeding antibiotics and probiotics in combination is generally discouraged because of the negative effects that antibiotics have on the probiotic organisms. An experiment was designed to investigate the efficacy of a microbial fermentation product that can be added to diets with antibiotics. In particular, the ability of this fermentation product to increase performance and decrease last rib fat thickness of pigs fed a low-protein diet was determined.

---

[1]Fermacto®, Pet-Ag. Inc., Elgin, IL 60120.

Procedures

One hundred eighty pigs were allotted to six treatments based on sex, weight, and ancestry. The pigs were housed, six pigs/pen and six pens/treatment, in an open-front building with a solid concrete floor. At weaning, the pigs were fed a common diet (a high nutrient-density diet with 1.5% lysine, 10% added fat, and 40% milk products) to an average weight of 21.1 lb. The pigs were fed the treatment diets (Table 1) from 21.1 lb until the end of the finishing phase. Treatments were: 1) positive control (19-16-14% crude protein regimen for the nursery-growing-finishing phases); 2) positive control plus 2.50 lb/ton fermentation product; 3) low-protein regimen (17-14-12% crude protein for the nursery-growing-finishing phases); 4) low-protein regimen plus 1.25 lb/ton fermentation product; 5) low-protein regimen plus 2.50 lb/ton fermentation product; and 6) low-protein regimen plus 5.00 lb/ton fermentation product. Calculated lysine concentrations for the 19-16-14% crude protein regimen were 1.16, .83, and .66%, and for the 17-14-12% crude protein regimen were 1.01, .69, and .52%, respectively. Feed and water consumption was ad libitum. All feed additions were recorded, and pig and feeder weights were collected at 4 wk to end the nursery phase, at 117 lb to end the growing phase, and when pigs in the first pen in a weight block averaged 230 lb to end the finishing phase. At the end of the feeding experiment, the pigs were ultrasonically scanned[2] for fat thickness at the last rib. Response criteria were ADG, ADFI, F/G, and last rib fat thickness. Orthogonal contrasts were used to separate treatment means, and final weight was used as a covariable in the analysis of fat thickness data.

Table 1. Composition of Diets, %[a]

	----------- Diet CP, % -----------		
Ingredient	19	16	14
Corn	43.73	73.24	79.86
Soybean meal	23.05	20.93	14.78
Dried whey	20.00	—	—
Fish meal	4.00	—	—
Choice white grease	5.00	2.00	2.00
Vit and Min	2.52	3.23	2.81
Antibiotics[b]	1.20	.10	.05
Trt premix[c]	.50	.50	.50

[a]Diets were formulated to supply .90% Ca and .80% P in the nursery phase, .75% Ca and .65% P in the growing phase, and .65% Ca and .55% P in the finishing phase. Ratios of corn and soybean meal were adjusted to give the low-protein regimen (17-14-12% CP).

[b]Provided 50 g/ton carbadox, 96 g/ton pyrantel tartrate and 250 ppm Cu in the nursery phase, 100 g/ton chlortetracycline in the growing phase, and 50 g/ton chlortetracycline in the finishing phase.

[c]Provided 0 or 2.50 lb/ton fermentation product in the 19-16-14% crude protein diets, and 0, 1.25, 2.50 and 5.00 lb/ton fermentation product in the 17-14-12% crude protein diets.

Results and Discussion

Samples of ingredients were analyzed for crude protein content before the diets were formulated. Crude protein percentages for the "48% soybean meal" ranged from 44.9 to 48.5%.

[2]Scanoprobe.

Crude protein percentages for the corn ranged from 7.9 to 8.8%. From these analyses, it is apparent that "book values" for nutrient composition of feedstuffs should not be assumed correct in experiments designed to test the consequences of nutrient concentrations in diets.

Results from the growth assay are given in Table 2. In the nursery phase, there were no differences (P>.42) in ADG, ADFI, or F/G for pigs fed the 19 or 17% crude protein diets. The lack of difference when the low-protein regimen was fed probably resulted from the addition of good lysine sources (i.e., dried whey and fish meal) to the diets. Although the daily lysine intakes were still lower than those recommended by British scientists (i.e., ARC guidelines) and Australian scientists, lysine intakes were calculated to be roughly adequate according to the National Research Council guidelines (i.e., intakes of 8.5 to 9.7 g/d for pigs fed the low-protein regimen diets vs the NRC recommendation of 9.0 g/d).

As the concentration of fermentation product was increased from 0 to 5.00 lb/ton in the low-protein diets, ADG was reduced from 1.21 to 1.13 lb (a 7% reduction), an effect that corresponds to the 12% reduction (P<.05) in feed intake. However, it should be noted that pigs fed the 17% crude protein diet with the lowest level of inclusion (1.25 lb/ton) of fermentation product gained as well and were 10% more efficient than pigs fed the 19% crude protein diet without fermentation product (F/G of 1.61 vs 1.78, respectively).

Decreasing the crude protein concentration in the grower diet from 16 to 14% resulted in a 9% decrease in ADG (P<.001), a 4% decrease in ADFI (P<.10), and a 6% poorer F/G (P<.05). Increasing the concentration of fermentation product from 0 to 5.00 lb/ton resulted in a linear decrease in ADG and ADFI; however, the reduced performance resulted from the two greatest levels of addition (2.50 and 5.00 lb/ton).

In the finishing phase, decreasing the crude protein concentration of the diet resulted in a 13% reduction in ADG (P<.01), a 5% reduction in ADFI (P<.05), and a 9% poorer F/G (P<.001). Feed intake was reduced when 2.50 lb/ton of the fermentation product was added to the 14% crude protein diet (P<.05). The reduced feed intake was probably responsible for the 5% reduction in ADG and the 5% improvement in F/G, responses that are common with restricted feed intake. For pigs fed the low-protein diets (12% crude protein), ADG and ADFI were reduced by 11 and 9% as concentration of the fermentation product was increased from 0 to 5.00 lb/ton. However, as in the growing phase, the two greatest levels of inclusion (2.50 and 5.00 lb/ton) were responsible for the reduced growth performance. When pigs were fed the lowest level of inclusion (1.25 lb/ton), ADFI was reduced by 4% and ADG was reduced by 2%, but F/G was improved by 2%. This slight improvement in F/G cannot be explained by a restriction of feed intake, because with the low protein diets, a reduction in feed intake would intensify the protein deficiency. It is possible that a protein sparing effect may have occurred at the lowest level of fermentation-product inclusion.

Overall (from 21 lb to market weight), the reduced protein regimen (17-14-12%) resulted in reduced ADG and ADFI, and poorer F/G compared to the 19-16-14% protein regimen (P<.05). Adding 2.50 lb/ton of fermentation product to the 19-16-14% regimen reduced ADFI by 8% (P<.05). The fermentation product tended to reduce ADG but improved F/G by 5% (P<.05). Increasing the concentration of fermentation product in the low-protein diets from 0 to 5.00 lb/ton reduced ADG and ADFI (P<.05). However, at the lowest level of inclusion (1.25 lb/ton), ADG was not affected and F/G was improved by 2%. Last rib fat thickness was increased by 11% by feeding the low-protein regimen. Adding fermentation product to the diets did not affect fat thickness (P>.16).

In conclusion, feeding the low-protein regimen (17-14-12% crude protein) reduced growth performance and increased carcass fatness compared to feeding the 19-16-14% crude protein regimen. Adding 2.50 lb/ton of fermentation product to diets with 19-16-14% crude protein tended to depress feed intake, resulting in small reductions in ADG but small improvements in F/G. Increasing concentration of fermentation product from 0 to 5.00 lb/ton in the 17-14-12% crude protein regimen reduced growth performance, although this effect was due primarily to the 2.50 and 5.00 lb/ton additions. Finally, adding fermentation product to the low-protein diets did not result in growth performance or last rib fat thickness comparable to those of pigs fed the positive control.

Table 2. Growth Response of Pigs fed Low Protein Diets and a Fermentation Product[a]

	19-16-14% regimen		17-14-12% regimen				
Item	0	2.50	0	1.25	2.50	5.00	CV
Nursery phase (21 to 54 lb)							
ADG, lb[b]	1.19	1.15	1.21	1.22	1.14	1.13	11.0
ADFI, lb[i]	2.12	1.96	2.11	1.96	2.02	1.85	8.5
F/G[j]	1.78	1.70	1.74	1.61	1.77	1.64	8.9
Growing phase (54 to 117 lb)							
ADG, lb[f,i]	1.81	1.76	1.67	1.69	1.56	1.55	6.6
ADFI, lb[c,h]	4.31	4.15	4.15	4.17	3.94	3.94	5.8
F/G[d]	2.38	2.36	2.49	2.47	2.53	2.54	4.9
Finishing phase (117 to 220 lb)							
ADG, lb[e,i]	1.94	1.85	1.75	1.72	1.56	1.56	9.8
ADFI, lb[d,g,i]	6.75	6.15	6.47	6.24	5.78	5.91	6.6
F/G[f]	3.48	3.32	3.70	3.63	3.71	3.79	5.6
Overall (21 to 220 lb)							
ADG, lb[f,i]	1.73	1.66	1.61	1.60	1.46	1.47	6.2
ADFI, lb[d,g,i]	4.98	4.56	4.79	4.66	4.38	4.41	5.5
F/G[f,g]	2.88	2.75	2.98	2.91	3.00	3.00	2.7
Last rib fat thickness, in[e]	.90	.87	.95	1.03	.96	.98	17.0

[a]Five pens/treatment, six pigs/pen. Fermentation products added at 0, 1.25, 2.50 and 5.00 lb/ton.
[b]No treatment effect (P>.21).
[c,d,e,f]Effect of protein concentration (P<.10, P<.05, P<.01, and P<.001, respectively).
[g]19-16-14% regimen with vs without fermentation product (P<.05).
[h,i]Linear effect of fermentation product concentration (P<.10 or P<.05, respectively).
[j]Cubic effect of fermentation product concentration (P<.10).

EFFECTS OF DAILY ADMINISTRATION OF PORCINE SOMATOTROPIN ON PERFORMANCE OF GROWING PIGS (55 TO 130 LB)

G. E. Fitzner, R. H. Hines, J. L. Nelssen, D. H. Kropf, T. L. Weeden, R. D. Goodband, J. D. Hancock, B. J. Healy, and B. R. Schricker[1]

Summary

Sixty crossbred barrows initially weighing 55.7 lb were used to evaluate six experimental treatments during a 5-wk growth trial. Pigs received one of three levels of dietary lysine (1.0, 1.5, or 2.0%) and were injected daily with either 3 mg porcine somatotropin (pST) or placebo. During the first 2 wk of the trial, there was no effect from either pST injection or increasing level of dietary lysine on average daily gain (ADG) or average daily feed intake (ADFI). Also, there was no effect of pST injections on feed conversion (F/G), but those pigs fed diets containing higher levels of lysine showed improved F/G. During the entire 5-wk period, pigs administered pST gained faster than placebo-injected pigs. During the 5-wk trial, there was a nonsignificant reduction in ADFI for pigs injected with pST compared with those receiving placebo injections. Increasing the level of dietary lysine also resulted in a nonsignificant reduction in ADFI. Pigs injected daily with pST showed a 10% improvement in (F/G) when compared with placebo-injected pigs. Increasing the dietary lysine level from 1.0 to 2.0% resulted in a 10% improvement in F/G for both pST- and placebo-injected pigs. Tenth rib fat depth and average backfat thickness were both reduced in pST-treated pigs compared with placebo-injected pigs.

(Key Words: GF, Repartition, Performance, Lysine.)

Introduction

Porcine somatotropin (pST) has been shown to be effective as a growth promotant in finishing swine, with daily injections improving growth performance and carcass characteristics. However, the lysine requirement of finishing pigs injected daily with pST is approximately twice that recommended by the NRC. Porcine somatotropin also has been effective as a growth promotant in growing pigs, but some work indicates that the improvements in carcass quality, growth, and feed efficiency begin to diminish 10 d after cessation of pST administration. However, researchers have not yet evaluated the effects of pST administration on the lysine requirement of growing swine. This experiment was designed to do that.

Procedures

Sixty crossbred barrows initially weighing 55.7 lb were allotted by weight and ancestry to one of six experimental treatments. Treatments included three corn-corn gluten meal-soybean meal diets (Table 1) formulated to contain either 1.0, 1.5, or 2.0% lysine in combination with daily injections of either placebo or 3 mg pST. L-Lysine HCl was substituted for corn in those diets

[1]Pitman-Moore, Inc., Terre Haute, IN 47808.

containing 1.5 and 2.0% lysine. Diets were formulated to provide 200% of NRC recommended levels for all other essential amino acids, vitamins and minerals. Feed and water were provided ad libitum. There were two pigs per pen and five pens per treatment. Pigs were housed in a modified open front building with solid concrete floors. All pigs and feeders were weighed weekly and all feed additions were recorded for calculations of average daily gain (ADG), average daily feed intake (ADFI), and feed conversion (F/G). At the end of the 5 wk experiment, six pigs from each treatment were slaughtered for evaluation of carcass characteristics.

Table 1. Diet Composition

	Percentage Lysine		
Ingredient	1.0	1.5	2.0
Corn	55.31	54.67	54.03
Soybean meal (48% CP)	24.65	24.65	24.65
Corn gluten meal (60% CP)	8.95	8.95	8.95
Soybean oil	5.00	5.00	5.00
Monocalcium phosphate (21% P)	3.02	3.02	3.02
Limestone	1.38	1.38	1.38
L-lysine HCl	0.00	.64	1.28
L-threonine	0.09	0.09	0.09
Salt	0.30	0.30	0.30
Vitamin premix[a]	0.50	0.50	0.50
Trace mineral premix[b]	0.20	0.20	0.20
Antibiotic[c]	0.50	0.50	0.50
Copper sulfate	0.05	0.05	0.05
Selenium premix[d]	0.05	0.05	0.05
Calculated analysis, %			
CP	22.1	22.1	22.1
Lysine	1.00	1.50	2.00
Ca	1.20	1.20	1.20
P	1.10	1.10	1.10

[a]Each lb of vitamin premix contains: vitamin A, 1,000,000 IU; vitamin D_3, 100,000 IU; vitamin E, 4,000 IU; menadione, 400 mg; riboflavin, 1000 mg; pantothenic acid, 2,500 mg; niacin, 5,500 mg; choline, 100,000 mg; and vitamin B_{12}, 5mg.
[b]Contains 10% Mn, 10% Fe, 10% Zn, 4% Ca, 1% Cu, 0.4% K, 0.3% I, 0.2% Na, and 0.1% Co.
[c]Each lb of antibiotic contained 10 g chlortetracycline, 10 g sulfathiazole, and 5 g penicillin.
[d]Each lb of selenium premix contains 272.4 mg Se.

Results and Discussion

There was no effect of either pST injection or percentage dietary lysine on ADG or ADFI of pigs during the first 2 wk of the experiment (Table 2). However, feeding increased levels of dietary lysine improved ($P<.01$) F/G during the first 2 weeks.

During the entire 5-wk, pigs injected daily with pST demonstrated increased ($P<.05$) ADG compared to the placebo-injected pigs (Table 2). There was no effect of either pST injection or dietary lysine level on ADFI during 5 wk, but there was an improvement ($P<.05$) in F/G caused by both daily pST administration as well as increasing levels of dietary lysine. Pigs injected daily with pST showed a 10% improvement in F/G at all three levels of dietary lysine. Increasing the dietary lysine level from 1.0 to 2.0% resulted in a similar, 10% improvement in F/G. The effect of daily pST injection on ADG was not as great as the 30% improvement shown by finishing pigs treated with pST and fed diets containing high (200% of NRC) levels of dietary lysine. The non-significant reduction (P>.27) in ADFI was not expected, because results observed with finishing swine showed a dramatic reduction in ADFI which, combined with the improvement in ADG, resulted in a large improvement in F/G.

The reduction (P<.05) in tenth rib backfat and average backfat (Table 2) in pST-treated pigs compared to placebo-injected pigs demonstrates one of the major results of pST administration normally observed in finishing pigs, i.e., the improvement of carcass leanness.

Table 2. Performance and Carcass Characteristics of Pigs Injected with Placebo (0) or 3 mg/d pST.

	1.0% lysine		1.5% lysine		2.0% lysine	
pST (mg/d):	0	3	0	3	0	3
Growth Performance[a]						
Wk 0-2						
ADG, lb	1.96	1.90	1.97	1.98	1.94	2.07
ADFI, lb	3.64	3.51	3.42	3.26	3.31	3.19
F/G[b]	1.86	1.85	1.74	1.65	1.71	1.54
Wk 0-5						
ADG, lb[c]	2.00	2.15	1.95	2.10	2.06	2.19
ADFI, lb	4.71	4.50	4.46	4.34	4.36	4.13
F/G[bc]	2.35	2.09	2.28	2.07	2.12	1.89
Carcass Characteristics[d]						
Fat depth, 10th rib, in[c]	0.71	0.47	0.68	0.54	0.75	0.48
Average backfat, in[ce]	0.86	0.69	0.84	0.74	0.87	0.72

[a]A total of 60 growing pigs initially weighing 55.7 lb, 2 pigs/pen, 5 pens/treatment.
[b]Lysine effect P<.01.
[c]pST effect P<.05.
[d]A total of 36 pigs, 6 pigs/treatment.
[e]Mean of measurements taken over the first rib, the last rib, and the last lumbar vertebrae.

These results indicate that administration of 3 mg/d pST in growing pigs caused some improvements in carcass leanness and performance although they were not as dramatic as those reported in finishing pigs. The diminished effect of pST injection in growing pigs suggests that the level of naturally occurring somatotropin in this size pig may be higher than in older pigs. The improvement in ADG and F/G combined with the reduction in carcass backfat demonstrates the improved efficiency of converting feed to lean tissue rather than fat. The combined effect of pST on F/G resulting in 20% total improvement at all levels of dietary lysine suggests that the effects are additive.

EFFECTS OF PORCINE SOMATOTROPIN AND DIETARY LYSINE LEVEL ON GROWTH PERFORMANCE AND CARCASS CHARACTERISTICS OF FINISHING SWINE FED TO 280 LB

M. E. Johnston, J. L. Nelssen, R. D. Goodband, D. H. Kropf, R H. Hines, and B. R Schricker[1,2]

Summary

One hundred twenty barrows with an initial wt of 130 lb were utilized to determine the effects of dietary lysine level and porcine somatotropin (pST) injection on growth performance and carcass characteristics of finishing pigs fed to heavy market weights (280 lb). Pigs were injected daily in the extensor muscle of the neck with either 4 mg pST or a placebo and fed diets containing either .8, 1.0, 1.2, or 1.4% dietary lysine. Performance data were collected and evaluated for three weight ranges : 130 to 230 lb, 230 to 280 lb, and 130 to 280 lb. Two pigs from each pen were slaughtered to determine carcass measurements. The first pig was slaughtered at 230 lb and the second pig at 280 lb. Average daily gain (ADG) was maximized at the 1.0% lysine level for the pigs fed from 130 to 230 lb and for those fed from 130 to 280 lb. From 230 to 280 lb, ADG was improved for pigs fed the 1.0 and 1.4% lysine levels. Pigs injected with pST had a significant improvement in ADG compared to control pigs at all weight ranges. There was a linear decrease in average daily feed intake (ADFI) with increasing dietary lysine levels from 130 to 230 lb and from 130 to 280 lb. Feed conversion (F/G) improved as dietary lysine levels increased for pigs from 130 to 280 lb and was improved in response to PST-treatment. No pST x lysine interactions were observed for either ADG, ADFI, or F/G. Percent carcass muscle increased with increasing dietary lysine level and pST-treatment at both slaughter weights. A pST x lysine interaction was seen for percent muscle when pigs were slaughtered at 230 lb. Backfat thickness, kidney fat, and longissimus muscle area (LEA) were unaffected by dietary lysine level, but did show a pST response for pigs slaughtered at 230 lb. Longissimus muscle area was also increased with PST-treatment but was unchanged by changing lysine level for pigs killed at 280 lb. Kidney fat and backfat thickness decreased with pST-treatment and as lysine level increased in 280-lb pigs. There was no pST x lysine interaction at either slaughter weight for backfat thickness, kidney fat, or LEA At slaughter weights of 230 and 280 lb, there was an increase in trimmed ham weight with increasing dietary lysine level and PST-treatment, but no pST x lysine interaction. Organ weights were unaffected by lysine level, but were heavier with PST-treatment. These data indicate that growth performance was maximized at 1.0% dietary lysine, and carcass traits were optimized at dietary lysine of 1.2 to 1.4%. These results further demonstrate that pigs fed to 280 lb, when injected daily with pST, are more efficient, grow faster, and are leaner than control pigs.

(Key Words: Repartition, Lysine, GF, Performance, Carcass, Heavy, Weight.)

---

[1]Pitman-Moore, Inc., Terre Haute, IN 47808

[2]We would like to acknowledge Nutri-Quest, St. Louis, MO for partial support of this research.

Introduction

The ideal market weight of finishing swine often has been governed by the efficiency of the animal and the quality of the carcass. Pigs fed to heavier weights start to deposit more fat and less protein and are less efficient than those slaughtered at the more conventional weight of 230 lb. Also, with health-conscious consumers looking for leaner meat, the swine producer cannot afford to market an overly fat hog. Even if it would be more desirable to market a heavier pig, the producer has been unable to do so.

Research with PST-treated pigs has shown an improvement in gain and feed conversion, reduced carcass lipid content, and an increase in protein deposition. When given daily injections of pST, finishing pigs appear to have a delay in the fattening phase of their growth curve and, thus, a leaner carcass. If pST treatment would delay the fattening phase long enough, producers could market a leaner, much heavier hog that would meet consumer standards and still be efficient to raise. The accelerated growth rate of the pST-treated pigs requires that their nutritional requirements be reevaluated when they are fed to the heavier market weight of 280 lb.

Therefore, the objective of this experiment was to determine the effects of lysine level and pST administration on growth performance and carcass characteristics of finishing swine fed to 280 lb.

Procedures

One hundred twenty crossbred barrows (Duroc x Yorkshire x Hampshire) averaging 130 lb were allotted on the basis of weight and ancestry to one of eight treatments. Treatments included either a daily injection of 4 mg pST or placebo in combination with a corn-soybean meal diet (Table 1) containing either .8, 1.0, 1.2, or 1.4% lysine. All diets were formulated to contain at least 200% of NRC (1988) recommendations for other amino acids. There were three pigs per pen and five replicates per treatment. Pigs were weighed at 14-d intervals until the pen mean weight reached 230 lb. At this time, one pig per pen was slaughtered for recording carcass measurements and organ weights. The other two pigs remained on experimental treatment and were weighed at 7 d intervals until they reached a final mean weight of 280 lb. One of the two remaining pigs was then slaughtered for carcass measurements and recording of organ weights. Pigs slaughtered at 230 and 280 lb had the right ham removed for evaluation. A whole ham weight was recorded; then the ham was trimmed and trimmed weight also was recorded. Each ham was also evaluated for color, firmness, and marbling. Production measurements taken included average daily gain (ADG), average daily feed intake (ADFI), and feed conversion (F/G).

Results and Discussion

Average daily gain for pigs fed from 130 to 230 lb was maximized at the 1.0% dietary lysine level (Table 2). Pigs fed 1.0% dietary lysine and receiving pST gained 15% more than the control pigs at the same dietary lysine level ($P<.01$) and 5% more than the PST-treated pigs at the other three lysine levels. There was a decrease (linear, $P<.01$) in ADFI with increasing dietary lysine levels. Control pigs consumed more feed than PST-treated pigs, with an average increase of 21% in daily feed intake across all dietary lysine levels. Feed conversion was improved (P<.0l) for PST-treated pigs by 42% compared to the control pigs at the 1.4% lysine level. Porcine somatotropin-treated pigs fed to 230 lb had an average improvement of 29% in F/G (P<.0l) over the control pigs across the remaining three lysine levels.

When performance was evaluated from 230 to 280 lb, ADG was highest (P<.04) for pST-treated pigs at the 1.0 and 1.4% lysine levels. This was a 19% improvement over the control pigs fed the same dietary lysine levels. Feed intake averaged across all lysine levels numerically decreased 4% for pST-treated pigs compared to the control animals. Feed conversion was optimized (quadratic, P<.07) at the 1.4% lysine level for pigs treated with pST. Pigs treated with pST had a 15% improvement (P<.0l) in F/G compared to placebo-injected pigs.

Looking at performance for the entire trial (130 to 280 lb), those pigs treated with pST had an improvement of 12% in ADG (P<.0l) compared to control pigs. There was a numerical advantage in gain for PST-treated pigs at the 1.0% dietary lysine level, with a 7% increase in gain over the other three lysine treatments. Control pigs fed to 280 lb consumed 17% more feed than PST-treated pigs taken to the same weight (P<.01). There was a trend (linear, P=.07) toward decreasing feed intake with increasing lysine levels. Increasing dietary lysine levels resulted in improved F/G (linear, P<.0l) for PST-treated pigs. Feed conversion showed the most improvement at the 1.0 and 1.4% lysine levels; with PST-treated pigs being 36% more efficient than the control pigs.

Backfat thickness of pigs slaughtered at 230 lb was unaffected by dietary lysine level in the diet. However, PST-treated pigs did have 30% less backfat (P<.01) than control pigs (Table 3). Increasing lysine level also had no effect on longissimus muscle area (LEA), but there was a 22% increase (P<.01) in LEA at the 1.4% lysine level for PST-treated pigs compared to control pigs. Percent carcass muscle increased (linear, P<.02) with increasing dietary lysine levels. Porcine somatotropin-treated pigs had 8% more muscle than control pigs (P<.0l) slaughtered at 230 lb. Whole ham weight was not affected by pST or lysine level, but trimmed ham weight increased (quadratic, P<.03) with increasing levels of lysine. Kidney fat showed a numerical decrease (linear, P<.08) with increasing dietary lysine levels, with pST treated pigs having 34% less kidney fat than control pigs (P<.01). Subjective evaluations of ham firmness and marbling were unaffected by lysine level. However, PST-treated pigs had a 57% decrease (P<.01) in marbling compared to control pigs. Ham color showed an improvement (linear, P<.02) with increasing dietary lysine level.

Evaluation of the same carcass measurements for pigs slaughtered at 280 lb shows a decrease (linear, P<.05) with increasing dietary lysine levels in backfat thickness, with control pigs having 36% more backfat than PST-treated pigs (P<.0l). Longissimus muscle area was not affected by dietary lysine level, but it was maximized numerically at the 1.2% lysine level. Pigs injected daily with pST showed a 28% increase (P<.01) in LEA over control pigs slaughtered at 280 lb. Percent carcass muscle showed an increase (linear, P<.03) with increasing lysine levels. Pigs slaughtered at 280 lb exhibited a trend (linear, P<.06) toward increased whole ham weight with increasing lysine levels, but there was no effect (P>.2) on whole ham weight from pST treatment. Trimmed hams from 280 lb pigs also showed an increase (linear, P<.02) in weight with increasing dietary lysine levels. Pigs injected with pST had 8% heavier trimmed hams than control pigs (P<.01). Kidney fat decreased (linear, P<.02) with increasing lysine levels for pigs slaughtered at 280 lb. Ham firmness and marbling scores showed a decrease (linear, P<.01) with increasing lysine level, but ham color was unaffected by pST treatment or lysine level.

Weights of heart, liver, spleen, and lungs were not affected by dietary lysine level. However, organ weights of pST-treated pigs were significantly heavier (P<.0l) than those of control pigs slaughtered at 230 lb (Table 4). Kidney weight of these pigs increased (linear, P < .02) as dietary lysine level increased. Liver weight of pigs slaughtered at 280 lb showed an increase (linear, quadratic, P<.0l) with increasing lysine levels as did kidney weight (linear, P<.01). Weights of heart, lungs, and spleen were again unaffected by dietary lysine level.

The results of this study indicate that growth performance of PST-treated pigs fed to 230 or 280 lb was maximized at a dietary lysine level of 1.0%. Carcass traits were optimized at dietary lysine levels of 1.2 to 1.4%. Although control pigs showed some improvement with increasing lysine level, PST-treated pigs showed a greater magnitude of response. Porcine somatotropin-treated pigs fed to 280 lb proved to be 27% more efficient than control pigs fed to 230 lb and had a 13% improvement in ADG. The carcasses of these 280 lb PST-treated pigs yielded 36% larger LEA while showing a 26% decrease in backfat thickness in comparison to the control pigs at 230 lb. These results demonstrate that with injections of pST finishing pigs can be fed to a heavier market weight with no loss of efficiency or desirable carcass characteristics.

Table 1. Composition of Experimental Diets

	Lysine level, %			
Ingredients	.8	1.0	1.2	1.4
Corn	68.48	61.32	54.55	47.80
Soybean meal (48%)	20.00	27.20	34.10	41.02
D-L methionine	.05	.05	.05	.05
Soybean oil	6.00	6.00	6.00	6.00
Monocalcium phosphate	3.22	3.15	3.05	2.92
Limes tone	1.00	1.03	1.00	.96
Vitamin premix[a]	.50	.50	.50	.50
Trace mineral premix[b]	.20	.20	.20	.20
Selenium premix[c]	.05	.05	.05	.05
Salt	.50	.50	.50	.50
Calculated Analysis				
Crude protein, %	15.33	18.14	20.84	23.55
ca, %	1.23	1.26	1.26	1.25
P,%	1.06	1.07	1.08	1.07

[a]Each lb of premix contains the following: l,000,000 million IU vitamin A, 100,000 IU vitamin D,, 4000 IU vitamin E, 1000 mg riboflavin, 400 mg menadione, 2500 mg d-pantothenic acid, 5,500 mg niacin, 100,000 mg choline chloride, 5 mg vitamin B_{12}
[b]Each lb of premix contains: 25 g Mn, 45.4 g Fe, 5 g Cu, 91 g Zn, .7 g I, and .45 g co.
[c]Each lb of premix contains 272 mg Se.

Table 2. Effect of PST and Lysine Level on Growth Performance

	0 pST+ Dietary lysine level, %				4 mg/d pST+ Dietary lysine level, %			
Item	.8	1.0	1.2	1.4	.8	1.0	1.2	1.4
ADG, lb								
130-230 lb[a]	1.95	1.84	1.87	1.79	2.02	2.12	2.02	2.01
230-280 lb[a]	2.09	1.93	1.90	2.11	1.97	2.43	2.13	2.51
130-280 lb[a]	1.95	1.84	1.86	1.90	1.95	2.22	2.04	2.18
ADFI, lb								
130-230 lb[ab]	7.30	6.74	6.86	6.81	6.16	5.73	5.75	5.37
230-280 lb	7.77	7.48	7.64	7.59	6.31	8.02	7.28	7.58
130-280 lb[aC]	7.42	6.99	7.13	6.98	6.20	6.21	6.20	5.80
F/G								
130-230 lb[a]	3.76	3.68	3.67	3.82	3.05	2.71	2.85	2.68
230-280 Ib[ad]	3.79	3.96	4.04	3.64	3.28	3.33	3.43	3.01
130-280 lb[ab]	3.81	3.80	3.83	3.68	3.19	2.80	2.99	2.67

[a]Effect of PST (P<.05).
[b]Effect of lysine (linear, P<.01).
[c]Effect of lysine (linear, P<.07).
[d]Effect of lysine (quadratic, P<.07).

Table 3. Effect of PST and Lysine Level on Carcass Characteristics

	0 pST+ Dietary lysine level, %				4 mg/d pST+ Dietary lysine level, %			
Item	.8	1.0	1.2	1.4	.8	1.0	1.2	1.4
Backfat, in								
230 lb[a]	1.45	1.34	1.35	1.37	1.07	1.07	1.03	1.06
280 lb[ad]	1.60	1.46	1.49	1.42	1.13	1.15	1.06	1.04
Longissimus muscle, in^2								
230 lb[a]	4.52	5.14	5.17	4.73	5.32	5.45	5.45	5.80
280 lb[a]	5.52	5.49	5.53	5.82	6.06	6.89	7.10	6.62
Percent Muscle								
230 lb[ac]	50	53	53	52	55	55	57	58
280 lb[ad]	49	51	51	52	56	57	57	58
Kidney fat, g								
230 lb[a]	1672	1431	1389	1539	1210	1277	1048	972
280 lb[ac]	2636	2398	2235	2179	1554	1483	1353	1091
Whole ham weight, lb								
230 lb	20.98	21.60	21.36	20.62	21.18	21.62	21.72	21.42
280 lb[e]	24.36	24.84	25.94	26.20	25.92	25.64	25.96	25.96
Trimmed ham weight, lb								
230 lb[af]	16.42	17.36	17.10	16.28	17.54	17.72	18.34	17.90
280 lb[ac]	18.88	19.62	20.72	20.94	21.46	21.66	21.78	21.90
Ham color scores								
230 lb[bc]	2.8	2.8	3.0	3.0	2.4	2.4	2.6	3.0
280 lb	2.8	2.8	3.0	2.8	3.0	2.8	3.0	2.6
Ham firmness score[h]								
230 lb[b]	2.2	2.4	2.2	2.4	2.0	2.0	2.0	2.0
280 lb[ac]	2.8	2.4 .	2.4	2.0	2.2	2.0	2.0	1.8
Ham marbling score[i]								
230 lb[a]	1.8	1.6	1.6	1.6	1.2	1.0	1.0	1.0
280 lb[ac]	2.6	2.0	2.2	1.6	1.4	1.6	1.2	1.2

[a]Effect of PST (P<.01).
[b]Effect of PST (P<.03).
[c]Effect of lysine (linear, P<.02).
[d]Effect of lysine (linear, P<.O5).
[e]Effect of lysine (linear, P<.O6).
[f]Effect of lysine (quadratic, P<.05).
[g]Based on a scale with l=extremely pale, 3=uniformly grayish pink, 5=dark
[h]Based on a scale with l=soft and watery, 3=moderately firm and dry, 5=very firm and dry
[i]Based on a scale with l=trace, 3=small, 5=abundant

Table 4. Effect of PST and Lysine Level on Organ Weight

	0 pST+				4 mg/d pST+			
	Dietary lysine level, %				Dietary lysine level, %			
Item	.8	1.0	1.2	1.4	.8	1.0	1.2	1.4
Heart, g								
230 lb[a]	372	382	358	370	418	403	462	452
280 lb[a]	402	393	414	465	474	476	474	443
Liver, g								
230 lb[a]	1500	1453	1592	1614	1931	1967	1793	2040
280 lb[abc]	1427	1532	1569	1618	1748	2269	2226	2108
Kidney, g								
230 lb[ab]	371	348	386	402	426	461	451	493
280 lb[ab]	345	344	377	466	440	535	519	523
Lungs, g								
230 lb[a]	779	715	720	764	959	923	824	1226
280 lb[a]	942	975	790	977	1341	1077	1121	1107
Spleen, g								
230 lb[ac]	182	154	179	207	228	210	204	274
280 lb[a]	190	241	212	201	263	270	238	275

[a]Effect of PST (P<.01).
[b]Effect of lysine (linear, P<.02).
[c]Effect of lysine (quadratic, P<.02).

THE EFFECTS OF DIETARY THREONINE AND PORCINE SOMATOTROPIN DOSAGE ON NITROGEN BALANCE IN FINISHING SWINE

J. A. Swanson, R. D. Goodband, J. L. Nelssen, B. R. Schricker[1], D. F. Li, and J. A. Hansen[2]

Summary

Fifteen crossbred barrows were utilized to determine the effects of porcine somatotropin (pST) administration in combination with increasing dietary threonine levels on nitrogen retention and growth performance. Barrows averaging 147.3 lb were allotted in a split-plot arrangement with pST dosage (0, 4, or 8 mg/d) as the whole plot, and dietary threonine level (.45, .55, .65, .75, and .85%) as the subplot. These threonine values ranged from 112 to 212% of the dietary threonine estimate for finishing pigs (NRC 1988). All pigs within each pST dosage treatment received each diet for an 8-d period in a Latin square design. Diets were fed for a 4-d adaptation period followed by a 4-d total collection of feces and urine. Pigs were also weighed and bled at the end of each 8-d period. Increasing threonine level increased average daily gain (ADG), reduced feed intake (ADFI), and improved feed efficiency (F/G). Porcine somatotropin had no effect on ADG; however, pigs injected with 4 or 8 mg/d had numerical increases in ADG as threonine level increased. Feed efficiency improved as pST dosage increased. Daily threonine intake increased as dietary threonine level increased. However efficiency of threonine utilization for gain became poorer for control pigs as threonine intake increased, but pST-treated pigs had little change in efficiency of threonine utilization up to the .75 and .85% threonine levels for 4 and 8 mg/d pST dosages, respectively. There was a threonine x pST interaction for plasma urea concentrations, with control pigs having little change in urea concentrations, whereas pigs injected with 4 mg/d pST had a decrease then an increase in urea concentrations and pigs injected with 8 mg/d had continual decrease in urea concentrations. Nitrogen retention (g/d) and percent nitrogen retention increased as dietary threonine level increased. However, pigs injected with either 4 or 8 mg/d pST had greater increases in nitrogen retention than control pigs. Biological value also improved as dietary threonine level increased, but again showed a greater improvement for pST-treated pigs than control pigs. These results indicate improvements in growth performance and nitrogen retention for finishing pigs fed increasing threonine levels. However, the data also indicated that the magnitude of response to added threonine was greater for pST-treated pigs, suggesting a possible threonine requirement of approximately .65% or 18 g/d.

(Key Words: Repartition, GF, Performance, AA, Nitrogen.)

[1]Pitman Moore, Inc., Terra Haute, IN 47808.

[2]We would like to acknowledge Nutri-Quest, St. Louis, MO for partial support of this research.

Introduction

Previous studies at Kansas State University have focused on determining the interactive effects of porcine somatotropin (pST) administration and nutrient density on growth performance and carcass characteristics of finishing pigs. These studies have suggested that pST administration and the associated increases in lean gain are optimized with a diet containing between 1.0 and 1.2% dietary lysine. Therefore, the objective of this study was to determine if pST administration increases the dietary threonine requirement of finishing pigs as measured by nitrogen retention.

Procedures

Fifteen crossbred barrows (Duroc x Yorkshire x Hampshire x Chester White) averaging 147.3 lb were placed in metabolism crates, which allowed for separate collection of urine and feces. Pigs were allotted in a split-plot arrangement with pST dosage as whole plot treatments (0,4, and 8 mg/d pST). Subplot treatments consisted of 5 dietary threonine levels (.45, 55, .65, .75 and 85%; Table 1) administered in a Latin square design with each pig within a pST dosage receiving each of the diets. Diets were formulated to contain at least 200% of the pig's requirement for amino acids, vitamins and minerals with the exception of threonine (Table 2). This was to ensure that any change in response criteria was due to dietary threonine. Dietary treatments were fed for 8 d, with a 4-d adaptation period and a 4-d total collection of feces and urine. Pigs were fed a diet containing 1.2% lysine and injected with their respective pST dosage for a 7-d adaption period prior to the start of the experiment. Pigs were weighed at the end of every 8-d period, and feed intake was recorded. Feed and water were offered ad libitum. In addition, at 4 h postinjection and 3 h postprandial, pigs were bled for serum urea concentrations.

Results and Discussion

Increasing level of dietary threonine resulted in an increase (linear, $P<.05$) in ADG (Table 3). Although there was no effect of pST or pST x threonine interaction on ADG, control pigs appeared to show no improvement in ADG (avg 2.01 lb), whereas pigs injected with 4 or 8 mg/d pST had increasing ADG, which was maximized at .65 and .75% dietary threonine, respectively (2.48 and 2.36 lb/d). Average daily feed intake tended to decrease (linear $P<.10$) as dietary threonine increased and to decrease as pST dosage increased by 13 and 23% for pigs injected with 4 or 8 mg/d, respectively. Feed conversion was improved as dietary threonine level increased (linear, $P<.05$) and as pST dosage increased (linear and quadratic, $P<.05$). Control pigs had an 11% improvement in F/G as dietary threonine level increased; however, pigs injected with 4 or 8 mg/d pST had 21 and 34% improvements in F/G. Calculated daily threonine intakes (feed intake x % dietary threonine) increased as dietary threonine level increased (linear, $P<.05$ and quadratic, $P<.l0$) but decreased as pST dosage increased (linear $P<.05$). When expressed as efficiency of threonine utilization for gain (g threonine/lb gain), increasing dietary threonine level resulted in poorer efficiency of gain (linear, $P<.05$), but as pST dosage increased, efficiency of threonine utilization for gain improved (linear and quadratic, $P<.05$). Although there was no pST x threonine interaction ($P>.30$), with each increasing threonine level, control pigs had poorer threonine utilization.

Pigs injected with 4 and 8 mg/d pST had similar threonine utilization until .75 and .85% dietary threonine, respectively, when threonine utilization then became poorer.

There was a pST x threonine interaction for plasma urea concentrations (P< .05). This appeared to be the result of very little change in urea concentrations of control pigs compared to a decrease then increase in 4 mg/d PST-treated pigs and a continued decrease in urea concentrations of 8 mg/d PST-treated pigs. High urea concentrations indicate that excess amino acids are being oxidized to produce urea, whereas low values indicate that amino acids are being incorporated into protein synthesis. In pigs treated with 4 or 8 mg/d pST, as dietary threonine level increased, threonine was no longer limiting protein synthesis, and other amino acids were no longer being deaminated into urea synthesis.

Table 1. Diet Composition

Ingredient	%
Milo	65.05
Peanut meal, solvent	20.03
Soybean oil	7.00
Monocalcium phosphate (21% P)	3.31
Limestone	1.13
L-lysine	1.47
Vitamin premix[a]	.50
Trace mineral premix[b]	.20
DL-methionine	.34
Salt	.25
L-Isoleucine	.21
L-Tkyptophan	.06
Selenium premix[c]	.05
Sucrose/Threonine[d]	.40
	100.00

[a]Each lb of vitamin premix contains: vitamin A, 1,000,000 IU; vitamin D_3, 100,000 IU; vitamin E, 4,000 IU; menadione, 400 mg; riboflavin, 1000 mg; pantothenic acid, 2,500 mg; niacin, 5,500 mg; choline, 100,000 mg; and vitamin B_{12}, 5 mg.
[b]Contains 10% Mn, 10% Fe, 10% Zn, 4% Ca, 1% Cu, 0.4% K, 0.3% I, 0.2% Na, and 0.1% Co.
[c]Provided .3 ppm Selenium.
[d]Sucrose was replaced by threonine to provide levels of .55, .65, .75, and .85%.

Table 2. Chemical Analysis of Control Diet[a]

Item	%
DM	89.60
CP	15.90
Ca	1.10
P	1.00
Essential and semi essential amino acids	
Arginine	1.32
Cystine	.23
Histidine	.37
Isoleucine	.76
Leucine	1.45
Lysine	1.60
Phenylalanine	.80
Threonine	.45
Tryptophan	.24
Tyrosine	.55
Valine	.71

[a]Analyzed values are expressed on an as-fed basis.

Table 3. Effect of Dietary Threonine and pST on Growth Performance of Finishing Pigs

	% Threonine					
Item	.45	.55	.65	.75	.85	CV
ADG, lb[a]						
Control	1.98	2.10	1.91	2.10	2.15	18.3
4 mg pST	2.00	2.18	2.47	2.08	2.36	
8 mg pST	1.50	2.02	2.03	2.37	2.13	
ADFI, lb[bc]						
Control	6.69	7.05	6.74	6.57	6.66	8.0
4 mg pST	5.93	6.01	6.23	5.72	5.46	
8 mg pST	5.20	5.27	5.07	5.35	5.00	
F/G[acd]						
Control	3.38	3.36	3.53	3.13	3.10	18.5
4 mg pST	2.97	2.76	2.52	2.75	2.31	
8 mg pST	3.47	2.61	2.50	2.26	2.35	
Threonine intake, g/d[acef]						
Control	13.55	17.56	19.82	22.4	25.76	8.4
4 mg pST	12.1	15.03	18.41	19.53	21.22	
8 mg pST	10.54	13.27	14.99	18.21	19.28	
Threonine efficiency, g threonine/lb gain[acd]						
Control	7.38	8.52	10.35	10.92	12.33	3.4
4 mg pST	6.08	7.18	7.49	9.47	9.12	
8 mg pST	7.09	6.70	7.68	7.74	9.17	

[a]Linear threonine effect (P<.05).
[b]Linear threonine effect (p<.10).
[c]Linear effect of pST (P<.05).
[d]Quadratic effect of pST (P<.05).
[e]Quadratic threonine (P<.10).
[f]Threonine × pST interaction (P<.15).

Nitrogen intake decreased as dietary threonine level increased (linear and quadratic, P<.05) and decreased as pST dosage increased (linear P<.05). Nitrogen retention (g/d) increased then decreased (quadratic, P<.05) as dietary threonine level increased. As pST dosage increased, there were 72 and a 38% increases in nitrogen retention for pigs injected with 4 and 8 mg/d, respectively. Similar trends were observed for nitrogen retention when expressed as a percentage of nitrogen intake. For pigs injected with 4 or 8 mg/d pST, nitrogen retention appeared to be maximized at .65% dietary threonine; however, control pigs maximized their nitrogen retention at .75% dietary threonine. This response is in disagreement with the other response criteria observed for the control pigs. Biological value of the diets tended to increased (linear and quadratic, P<.10) as dietary threonine level increased. As pST dosage increased, there were 90 and 81% increases in biological value for pigs treated with 4 or 8 mg/d pST (linear and quadratic, P<.05). Biological value is an indicator or protein quality, or how closely a protein comes to meeting all the pig's amino acid requirements. The higher BV of pST-treated pigs compared to control-treated pigs fed the same diets, indicated that amino acids were utilized more efficiently.

Porcine somatotropin had no effect on digestibility of nitrogen or dry matter. Threonine level had no effect on nitrogen digestibility, but dry matter digestibility increased with increasing threonine level (linear, P<.05).

In conclusion, these data suggest that approximately .65% dietary threonine maximized growth performance of pigs injected daily with 4 mg pST. However, pigs injected with 8 mg/d pST tended to have better performance when fed a diet containing .75% threonine. Pig performance appeared to plateau and be optimized with the 4 mg pST dosage; however, there were some improvements in feed conversion and nitrogen balance with the 8 mg/d dosage. Increasing threonine level appeared to give little or variable improvement in performance and nitrogen balance of control pigs. Pigs injected with pST tended to show a greater magnitude of response in nitrogen balance and growth performance to dietary threonine.

Table 4. Effect of Dietary Threonine and pST on Nitrogen Balance in Finishing Pigs[a]

	% Threonine					
Item	.45	.55	.65	.75	.85	CV
Plasma urea concentration, mg/dl[bcde]						15.0
Control	26.69	29.42	29.34	27.14	25.32	
4 mg pST	18.36	15.03	12.78	13.31	14.41	
8 mg pST	16.51	12.05	10.72	10.72	8.90	
Nitrogen digestibility, %						
Control	79.19	81.65	81.59	82.07	79.24	3.7
4 mg pST	80.64	81.48	81.49	80.88	82.44	
8 mg pST	77.92	79.32	80.19	81.13	80.54	
Dry matter digestibility, %[b]						
Control	82.78	84.31	84.45	84.86	83.24	2.2
4 mg pST	83.74	83.76	84.44	84.21	85.61	
8 mg pST	81.85	83.20	84.07	84.46	84.70	
Nitrogen intake, g/d[bcf]						
Control	78.11	81.64	80.31	79.31	76.05	8.4
4 mg pST	71.87	73.78	73.85	65.01	64.12	
8 mg pST	58.07	60.21	59.56	62.74	56.91	
Nitrogen retention, g/d[cdf]						
Control	18.38	12.91	23.84	32.12	21.56	13.0
4 mg pST	35.06	38.82	44.47	33.79	34.85	
8 mg pST	17.43	28.35	38.47	36.43	29.46	
Nitrogen retention, %[cdg]						
Control	26.24	16.79	31.39	36.57	28.25	36.3
4 mg pST	48.31	53.57	59.99	50.83	54.62	
8 mg pST	34.14	46.79	62.93	55.79	50.00	
Biological value, % [cdg]						
Control	33.29	20.77	37.87	43.91	35.92	35.4
4 mg pST	59.69	65.58	73.38	62.72	65.99	
8 mg pST	43.92	59.25	78.15	68.87	61.79	

[a]Each mean represents five observations. Average initial wt = 147.3 lb. Each collection period was 4 d in length.
[b]Linear effect of threonine (P<.05).
[c]Linear effect of pST (P<.05).
[d]Quadratic effect of pST (P<.05).
[e]Threonine × pST interaction (P<.05).
[f]Quadratic effect of threonine (P<.05).
[g]Linear and quadratic effect of threonine (P<.10).

PRICE DISCOVERY AND BASIS RISK FOR LIVE HOGS

T.C. Schroeder[1] and B.K. Goodwin[1]

Summary

The short- and long-run daily price relationships between cash and futures markets for live hogs were examined over the 1975-89 period. Price discovery generally originates in the futures market with about 65% of new information being passed from the futures to the cash market. However, at times, especially during large price moves that are not necessarily anticipated in the futures market, the cash market price relies less on the futures market. The very short-term basis for hogs is fairly stable, with approximately 85% of yesterday's nearby-basis persisting today. Generally, little can be gained by speculating on basis from day to day. The farther from futures contract delivery they are, the more the futures and cash price diverge from each other, reflecting the fact that they represent different markets. Hedgers liquidating futures positions prior to the contract delivery month face larger basis risk than those liquidating positions in the contract month.

(Key Words: Marketing, Economics, Contract.)

Introduction

A major role of futures markets is their contribution to price discovery. Price discovery in futures markets refers to the use of futures prices in determining cash market prices. That is, the futures price may serve as the market's expectation of the cash price in a subsequent delivery period. The share of price discovery originating in the futures market and the degree to which futures price changes are reflected in the cash market and vice-versa have important implications for hedgers using these markets.

The price discovery relationship between cash and futures prices is directly related to the basis (cash price minus futures price). The stability or predictability of the basis is critical for successful hedging. An unpredictable basis results in an unpredictable expected price from hedging. Therefore, determination of the stability and predictability of the short-run basis is important for judging the level of basis risk associated with hedging. Basis risk refers to the chances of unfavorable basis at the time a hedger liquidates a hedge. The objectives of this study were to determine the short-term price leadership roles and basis stability for live hog cash and futures prices.

---

[1]Assistant professor, Department of Agricultural Economics, Kansas State University. Helpful comments from Michael Langemeier are acknowledged.

Procedures

Daily cash and Chicago Mercantile Exchange (CME) futures market prices for hogs were collected over the 1975-89 period. Cash price data were daily slaughter hog prices from the Omaha market (midpoint of the daily range). Cash prices for different weight ranges of hogs during the period were used because of changing price reporting practices by the Agricultural Marketing Service (AMS) and to reflect changes in weights of the largest volume of hogs marketed. The weight ranges used were as follows: 1975-78, 200-220 lb; 1979-84, 200-230 lb; 1985-87, 210-240 lb; and 1988-89, 230-240 lb. The Omaha market was selected as the cash price location because of its fairly high volume and because it is a par delivery point for the CME's live hog futures contract. The analysis was performed using the nearby futures contract prices. The nearby contract period was defined as the 16th d of the previous contract month through the 15th d of the contract expiration month.

To evaluate the price discovery role of the live hog cash and futures markets and to obtain a measure of basis risk, a statistical procedure using regression analysis was used. The regression model essentially amounted to regressing the cash price on the futures price (and vice-versa) and examining the properties of the models. The analysis was conducted on each of the 15 yr (1975-89) separately to allow us to determine the degree of annual variation present in the cash-futures price relationship.

Results and Discussion

Over all 15 yr, the regression estimates provided strong evidence that the futures price leads the cash price in reflecting new information. However, the magnitudes of price leadership varied from year to year, and no general trend was detected over the time period. The live hog futures price was found to discover price independently of the Omaha cash hog price. No definitive trend in the degree of cash price feedback to the futures price was detected.

Table 1 shows the percentages of market information (price discovery) originating in the futures market relative to the cash market. For example, in 1989, 71% of the new information entering the live hog markets originated in the futures market and was subsequently passed to the cash market. The remaining 29% (100%-71%) of new cash price information was determined independent of the futures market. With a few exceptions, at least 60% of the market information was discovered first in the live hog futures market and then transferred to the cash market. During 5 of the 15 yr (1975, 1978, 1980, 1981, and 1983), the Omaha cash hog price appeared to be discovering the majority of new information more rapidly than the live hog futures market (i.e., the percentage was less than 50). In 4 of these 5 yr (1978 perhaps as the exception), cash hog prices exhibited relatively large swings during the year. For example, in 1975, the Omaha cash hog price ranged from \$37/cwt to nearly \$65/cwt, a greater than 75% change in price. Similarly, during 1980 and 1983 the high to low range of hog cash prices exceeded \$22/cwt. Thus, during these years, the new information entering the market may well have originated in the cash market, because the futures market apparently did not anticipate the magnitude of price changes as rapidly as they occurred in the cash market.

Table 1. Percentage of Daily Price Discovery Originating in the Live Hog Futures Market and Daily Omaha Basis Persistance (1975-89)

Year	Percentage of live hog price discovery originating in the futures market	Percentage of Omaha basis persisting from day to day
1975	30	81
1976	64	81
1977	78	91
1978	39	81
1979	77	91
1980	28	88
1981	24	72
1982	100	100
1983	39	78
1984	65	85
1985	65	91
1986	81	83
1987	100	95
1988	100	100
1989	71	93
Average	64	87

Table 1 also shows the percentage of basis stability from day-to-day, which was generally 72% to 100% of the previous day's basis. Thus, the previous day's live hog cash to futures price basis persists and is similar to the current day's basis. In the very short-run, from day-to-day, little basis fluctuation occurs and the cash and futures prices do not necessarily converge rapidly. This suggests that there would be generally little gain for a hedger in speculating on day-to-day basis on the nearby contract. Likewise, it suggests that very short-term basis risk for hogs in Omaha, as measured by daily fluctuations in basis, is not large on average.

An evaluation of the basis across a longer time period (i.e., over weeks rather than days) suggests that basis risk increases. As we examine the nearby contract basis from the expiration of the previous contract through the expiration of the nearby contract, basis risk becomes more important. Large price swings often occur in live hog markets within fairly short periods of time. For example, over the 1975-89 period, the average absolute value of the daily price change in the Omaha cash hog market was approximately $.70/cwt. Accumulated across several days or weeks, during periods in which no delivery option is available on the futures market (i.e., during months that have no corresponding hog futures contract expiring), this price movement creates relatively large basis risk. Figure 1 shows the relationship between basis risk and weeks until futures contract expiration for 1989 (the remaining 14 yr have patterns similar to those of 1989). The plot indicates that the farther from contract expiration they are, the more the cash and futures prices tend to diverge from each other. Figure 1 suggests that hog producers liquidating hedges during non-contract months face nearly three times the basis risk of those who liquidate the hedge early in the contract delivery month.

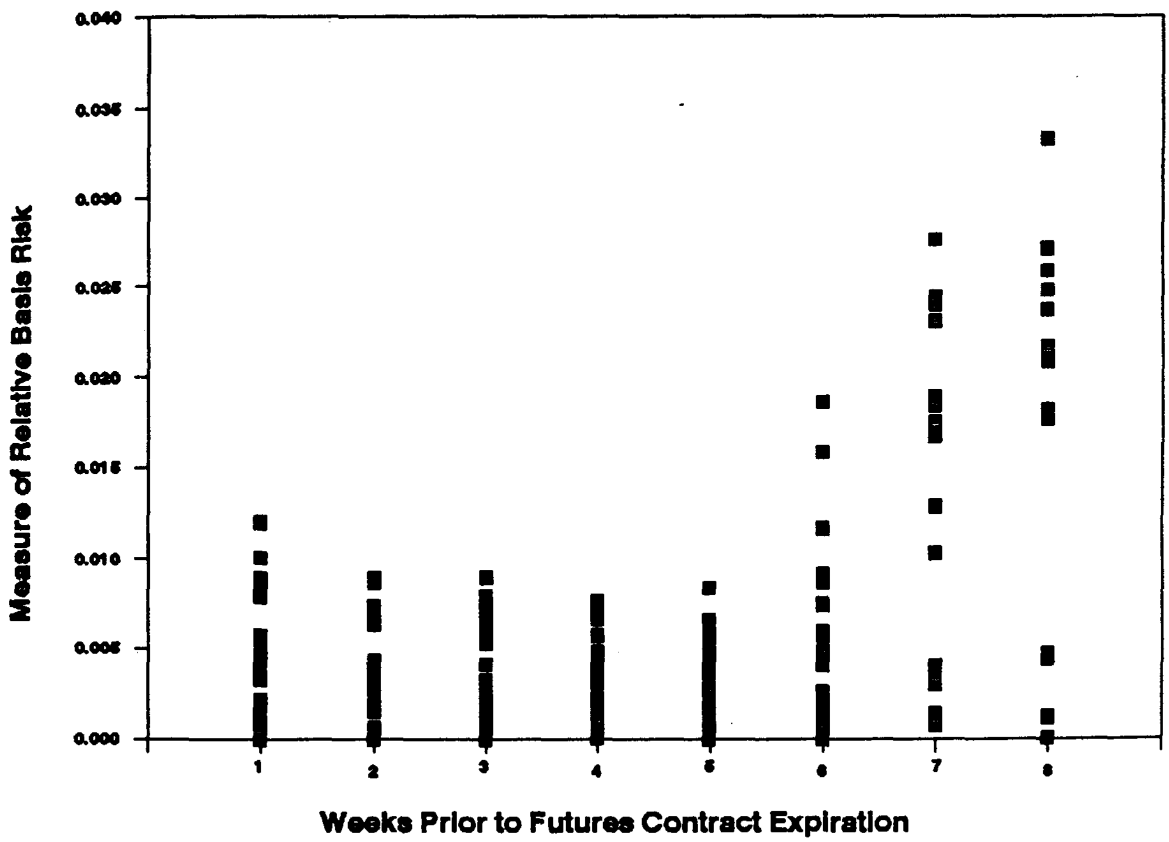

Figure 1. Relationship between daily basis variation and weeks to futures contract expiration, 1989.

THE COSTS AND RETURNS ASSOCIATED WITH CORN-, MILO-, AND WHEAT-BASED SWINE DIETS

Michael R. Langemeier[1]

Summary

Feed costs per hundred weight for farrow-to-finish operations in Kansas were generally lower for a milo-based diet than for corn-based or wheat-based diets. Use of corn and wheat in the diet was economical for short periods of time only. Feed costs were found to be consistently higher and returns per head consistently lower when corn and wheat were fed over the entire farrowing to market period.

(Key Words: Grain, Economics, Marketing.)

Introduction

Feed costs represent a major portion of the total costs required to produce hogs. One of the largest components of feed costs is the cost of grain. Kansas is somewhat unique in that three different types of grain (milo, corn, and wheat) are commonly utilized in swine diets. For most of the state, milo-based diets predominate. The objective of this study was to determine the costs and returns in Kansas from 1981 to 1990 associated with corn, milo, and wheat-based swine diets for farrow-to-finish operations.

Procedures

Cash prices for market hogs, cull sows, corn, milo, soybean meal, vitamins, and minerals were obtained from various publications of the Kansas Agricultural Statistical Service for the period starting with the first quarter of 1981 and ending with the second quarter of 1990. Input costs for feed processing, labor, veterinarian costs, supplies, utilities, repairs, and interest on operating expenses were obtained from budgets developed by Extension Agricultural Economists at Kansas State University.

Whole farm feed conversion was assumed to be about 3.75 for the corn-based diet. This level of feed conversion was representative of current information obtained from record keeping systems in Nebraska and Iowa. Whole-farm feed conversion for milo- and wheat- based diets was assumed to be 5% higher than that of the corn-based diet. Wheat is usually considered to be a more valuable feed grain than corn because it contains a higher percent of protein and lysine. The savings or increased value associated with feeding wheat are derived from the reduced amount of soybean meal that is required in wheat diets and not from any increase in rate or efficiency of gain.

[1]Assistant Professor, Department of Agricultural Economics, Kansas State University.

Returns per head were calculated by subtracting total costs (which included annual charges for investment in buildings, equipment, and breeding stock) from the gross returns obtained through market hog and cull sow sales. A charge for management and the risk associated with producing hogs were not included in cost calculations. Thus, the returns per head represent the returns to management and risk.

Results and Discussion

Table 1 presents the average, variation, and range of feed costs per hundred weight for milo-, corn-, and wheat-based swine diets for the 38 quarters from January 1981 to June 1990. Each diet was utilized over the entire feeding period (farrowing to market). The feed costs per hundred weight for the milo-based diet were about $1 lower than feed costs for the corn-based diet and about $3 lower than feed costs for the wheat-based diet. Feed costs for the milo based diet ranged from about 96 to 99% of the feed costs for the corn-based diet and about 89 to 99% of the feed costs for the wheat-based diet.

Information on returns per head for the three alternative diets are presented in Table 2. Returns per head for the milo-based diet are about $2.25 higher than the returns per head for the corn-based diet and about $7.00 higher than the returns per head for the wheat-based diet. Downside risk, measured as the percentage of quarters that returns per head was below the break-even value, was lower for the milo-based diet than the corn- and wheat-based diets.

These results show that generally feed costs are lower and returns per head are higher for a milo-based diet. This does not mean that corn or wheat cannot beeconomically used in swine diets. Feeding corn or wheat is economical for short periods of time. However, the results do imply that feeding corn or wheat over the entire farrowing to market period is seldom economical in Kansas. If the feed costs associated with feeding corn or wheat are lower than the feed costs associated with feeding milo at a particular time, this situation could be expected to change rapidly.

Table 1. Feed Costs per Hundred Weight for Alternative Farrow-to-Finish Diets for 1981-1990 Period

Variable	Feed costs for milo-based diet	Feed costs for corn-based diet	Feed costs for wheat-based diet
Mean	24.59	25.63	27.62
Standard deviation	3.70	3.88	2.93
Coefficient of variation	15.03	15.15	14.25
Minimum	17.63	18.28	20.67
Maximum	30.51	31.53	33.13
Percent of quarters below			
feed costs for milo	---	0.00	0.00
Percent of quarters below			
feed costs for corn	100.00	---	15.79

Table 2. Returns Per Head for Alternative Farrow-to-Finish Diets for the 1981-1990 Period

Variable	Returns per head for milo-based diet	Returns per head for corn-based diet	Returns per head for wheat-based diet
Mean	17.78	15.40	10.84
Standard deviation	18.15	18.40	18.44
Coefficient of variation	102.12	119.54	170.06
Minimum	-11.53	-12.78	-18.66
Maximum	54.56	53.37	51.26
Percentage of quarters			
below break-even value	15.79	18.42	23.68

ANALYSIS OF KANSAS HOG ENTERPRISE RETURNS FROM 1981-1990

Michael R. Langemeier[1]

Summary

Estimated historical return distributions for farrow-to-finish, feeder pig finishing, and feeder pig producing operations in Kansas from 1981-1990 were examined. Average returns per head were the highest and downside risk was the lowest for farrow-to-finish operations over this period. However, the required investment in buildings, equipment, and breeding stock per head was also higher for this operation. Thus, a tradeoff exists between returns per head and capital requirements per head.

(Key Words: Enterprise, Records, Economics.)

Introduction

A distribution of potential returns is important information to have when developing long-term plans. In particular, expansion or contraction decisions can be made more readily with this information.

Using just the current return information to make these decisions may cause an inadequate result. Using several alternative return scenarios enables the producer to determine potential profitability for alterative situations.

The objectives of this study were to determine estimated historical return distributions for farrow-to-finish, feeder pig finishing, and feeder pig producing operations in Kansas from 1981-1990 and to discuss how this information can be used.

Procedures

Data pertaining to market hog prices, sow prices, feeder pig prices, fixed costs, feed costs, and other variable costs were collected for the 38 quarters from January 1981 to June 1990. Cash prices for market hogs, sows, milo, soybean meal, and other feed ingredients were obtained from various publications of the Kansas Agricultural Statistical Service. Feeder pig prices for 40 pound feeder pigs in Southern Missouri were obtained from data collected by the Agricultural Marketing Service. Other variable and fixed costs were obtained from representative farrow-to-finish, feeder pig finishing, and feeder pig production budgets developed by Extension Agricultural Economists at Kansas State University. The fixed costs of production include annual charges needed to recover the investment in buildings, equipment, and breeding stock. These costs would be incurred

[1]Assistant Professor, Department of Agricultural Economics, Kansas State University.

even if no hogs were produced. Variable costs include milo, soybean meal, vitamins, minerals, pig starter, feed processing, labor, veterinarian costs, supplies, utilities, repairs, and interest on operating expenses. These costs vary with the level of production.

Returns per head for farrow-to-finish, feeder pig finishing, and feeder pig producing operations were estimated by subtracting variable and fixed costs from gross returns obtained through market hog and cull sow sales. Charges for management and risk were not included in cost calculations. Thus, the estimated return distributions represent the returns to management and the risk associated with hog production.

Results and Discussion

Table 1 presents the estimated return distribution for farrow-to-finish production in Kansas from the first quarter of 1981 to the second quarter of 1990. The average return over the 10-yr period was $17.78 per head. Quarterly returns per head ranged from a loss of $11.53 to a profit of $54.46. Returns per head exceeded $50 about 10.5% of the time. Returns per head exceeded $20 about 31.6% of the time. Returns per head were below the break-even value about 15.8% of the time.

The estimated return distribution for feeder pig finishing in Kansas from the first quarter of 1981 to the second quarter of 1990 is presented in Table 2. The average returns per head over the 10-yr period was $8.30. Quarterly returns per head ranged from a loss of $11.58 to a profit of $40.65. Returns per head exceeded $20 about 18.4% of the time. Returns per head were below the break-even value about 31.6% of the time. Thus, returns per head were relatively lower and downside risk was relatively greater for feeder pig finishing operations.

Table 3 presents the estimated return distribution for feeder pig producing operations in Kansas from the first quarter of 1981 to the second quarter of 1990. The average return per head over the 10-yr period was $.30, or about $17 and $8 lower than the average return per head for farrow-to-finish production and feeder pig finishing. None of the quarters had returns per head greater than $20. Returns per head were below the break-even value about 52.6% of the time. Thus, there was a considerable degree of downside risk in feeder pig production over this period.

These results indicate that potential returns per head are higher for farrow-to-finish operations than for feeder pig finishing and feeder pig producing operations. Also, downside risk is relatively lower for farrow-to-finish operations. However, investment per head is relatively higher for farrow-to-finish operations. Thus, there is a tradeoff between returns per head and capital intensity. The return distribution above can be used by producers along with information pertaining to limits on available capital to choose the appropriate mode of production.

Table 1. Estimated Distribution of Farrow-to-Finish Hog Returns in Kansas from 1981-1990

Returns per head	Percent of quarters
Returns greater than $50/head	10.5
Returns greater than $40/head	13.2
Returns greater than $30/head	26.3
Returns greater than $20/head	31.6
Returns greater than $10/head	60.5
Returns greater than break-even value	84.2
Returns less than break-even value	15.8
Loss greater than $10/head	2.6

Table 2. Estimated Distribution of Feeder Pig Finishing Returns in Kansas from 1981-1990

Returns per head	Percent of quarters
Returns greater than $50/head	0.0
Returns greater than $40/head	2.6
Returns greater than $30/head	5.3
Returns greater than $20/head	18.4
Returns greater than $10/head	39.5
Returns greater than break-even value	68.4
Returns less than break-even value	31.6
Loss greater than $10/head	7.9

Table 3. Estimated Distribution of Returns for Feeder Pig Production Operations in Kansas from 1981-1990

Returns per head	Percent of quarters
Returns greater than $50/head	0.0
Returns greater than $40/head	0.0
Returns greater than $30/head	0.0
Returns greater than $20/head	0.0
Returns greater than $10/head	23.7
Returns greater than break-even value	47.4
Returns less than break-even value	52.6
Loss greater than $10/head	15.8

BONE-IN PORK LOINS: MODIFIED ATMOSPHERE PACKAGING TO EXTEND SHELFLIFE

K. E. Warren, M. C. Hunt, C. L. Marksberry, O. Sörheim, and D. H. Kropf

Summary

Modified atmosphere packaging with 100% carbon dioxide was used to investigate changes in daily gas composition, as well as the influence of fat trim level and location of loin in the box on shelflife characteristics. Length of storage was the primary factor influencing shelflife of whole loins and their retail chops. Although microbial qualities was acceptable in loins stored up to d 19, sirloin and blade discoloration was obvious at 11-13 d. Storage for more than 11 d reduced the display life of retail chops to 1-2 d. Shelflife characteristics of bone-in pork loins were superior with this packaging system compared to more traditional systems.

(Key Words: Pork, Packaging, CO_2, Shelflife, Color.)

Introduction

Modified atmosphere packaging (MAP) is a packaging system in which the normal atmosphere in the package is removed and replaced with gases that help extend shelflife of meat. Carbon dioxide is the most commonly used gas in the United States because of its anti-microbial properties. If not used properly, carbon dioxide in MAP can cause undesirable meat discoloration even though bacterial growth is controlled. However, the causes of this problem are not fully known. For example, will trimming pork loins to 0 to 1/4 in. fat affect MAP shelflife? Thus, this experiment was conducted to determine the effects of subcutaneous fat trim level, location of the loin in the box, and daily gas changes in MAP on shelflife of bone-in loins and retail chops.

Procedures

Paired pork loins (110 pairs) were obtained from a commercial pork plant. Subcutaneous fat of one loin of each pair was trimmed to 1/4 in., whereas fat on the companion loin was trimmed to 1/8 in. Loins were weighed to calculate weight losses. Bone, fat, sirloin, and blade color were evaluated, and bone bacterial counts were taken. Five loins of the same trim level were then packaged in a box containing a MAP plastic bag. Loins were oriented with two in the top layer, one in the middle, and two in the bottom layer locations. The five companion loins of the second trim level were packaged in another box with the same location orientation, thus, creating a set of paired boxes. All bags were evacuated of air and flushed with 100% carbon dioxide. Initial gas composition was determined on all boxes using a gas analyzer, and the boxes were shipped to Kansas State University where they were stored up to 19 d at 33°F.

During storage (3-19 d), oxygen and carbon dioxide levels were determined daily. Two sets of paired boxes were opened on d 3, 4, 5, 6, 7, 9, 11, 13, 15, 17, and 19 of MAP for evaluation of shelflife characteristics. Loins were evaluated for weight loss; discoloration of bone, fat, and blade and sirloin lean surfaces; off-odors; and microbial quality. Rib and sirloin chops were removed to determine display color stability. Chops were individually placed in styrofoam trays overwraped with PVC, and displayed for three d at 38°F under 100 ft-candles of "natural" fluorescent lighting.

Results and Discussion

Length of MAP storage was the primary factor influencing gas composition and shelflife characteristics of whole loins and their retail chops. Carbon dioxide concentration (Fig. 1) was lower at d 3 of MAP and continued to decrease through d 19. Oxygen concentration (Fig. 1) was higher at d 3, decreased through d 15, and then increased through d 19. The initial rapid change in gas composition (d 3) was due to the absorption of carbon dioxide into the meat surface. Whole loin weight loss (data not shown) increased with increasing lengths of MAP storage from 1.7% at d 3 to 4.3% at d 19. Off-odors were not detectable through 7 d of MAP and had only a slight intensity at d 19.

Microbial counts increased with increasing storage, but at d 19, counts were still acceptable (log 4.5), and loins were free from spoilage. More importantly, the microbial counts through 9 d of MAP were lower than initial counts (pre-packaging). This reduction was due to the bacteriostatic action of carbon dioxide. The increase in counts above initial levels may have been due to the simultaneous decrease in carbon dioxide concentration or the adaptation of the microflora to the carbon dioxide environment.

Discoloration was the limiting factor in the shelflife of the whole loins. Bone discoloration increased with increasing length of MAP storage, with the most rapid increase at d 5. However, even after 19 d of storage, discoloration of bone surfaces was still at an acceptable level. Blade and sirloin lean discoloration (Fig. 3) increased rapidly between 5 and 7 d of MAP and continued to increase through 19 d. Discoloration was obvious and probably objectionable between d 9 and 11 for the sirloin lean and at 13 d for the blade lean. Longissimus (loin eye) muscles discolored less during display than the sirloin and tenderloin muscles. Discoloration of the muscles increased as display time increased. Storage in MAP for 13 d or more reduced the display life of longissimus muscles from 3 to 2 d. Eleven d in MAP reduced display life for the sirloin and tenderloin muscles to 1 d.

Level of fat trim and location of loins in the box had negligible effects on most wholesale loin or retail chop characteristics. However, loins in the middle and bottom location trimmed to 1/8 in. had greater ($P<.05$) discoloration of the fat than their counterparts trimmed to 1/4 in. Discoloration of fat did not differ between loins in the top location.

Conclusions

Packaging pork loins in 100% carbon dioxide produces a dynamic gas environment, which can extend the microbial shelflife of bone-in pork loins up to 19 d. However, discoloration of the whole loin lean surface will result in discrimination between 11-13 d of MAP. Initial color of discoloration of the whole loin lean surface will result in discrimination between 11-13 d of MAP. Initial color of retail chops from loins stored 19 d in MAP is acceptable, but chops will have only 1 to 2 d of display life after MAP storage of 11 d.

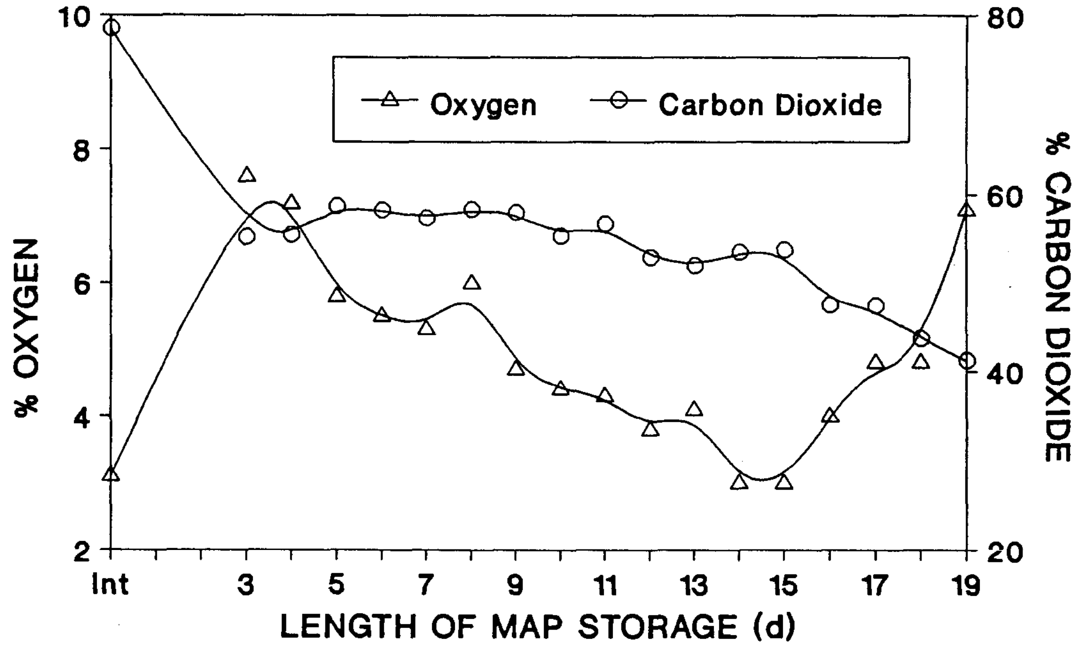

Figure 1. Changes in gas composition.

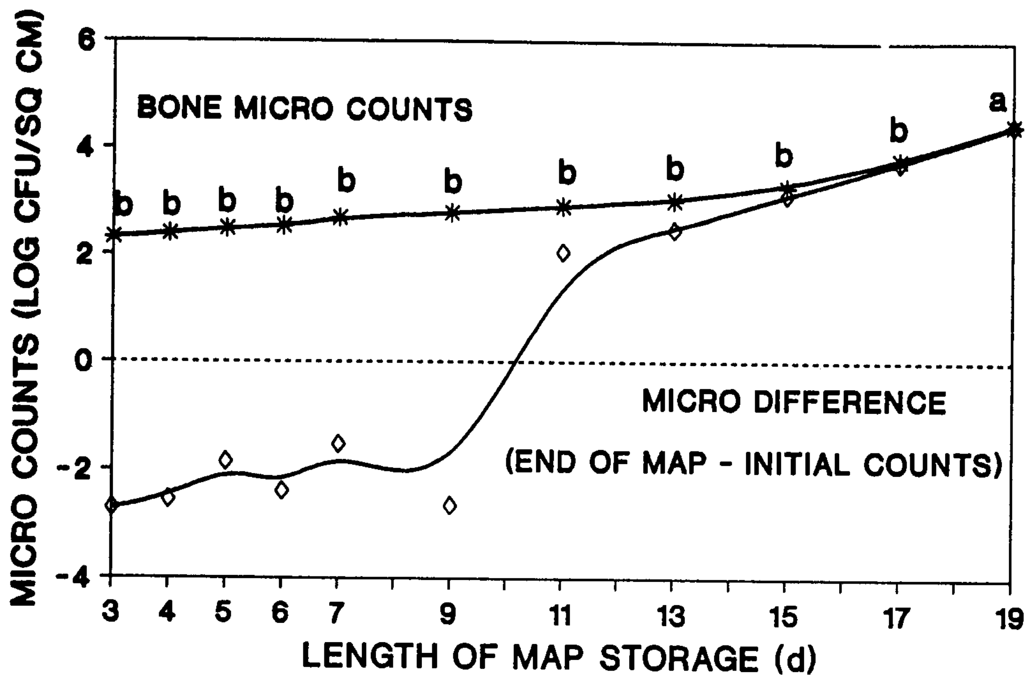

Figure 2. Microbial growth.

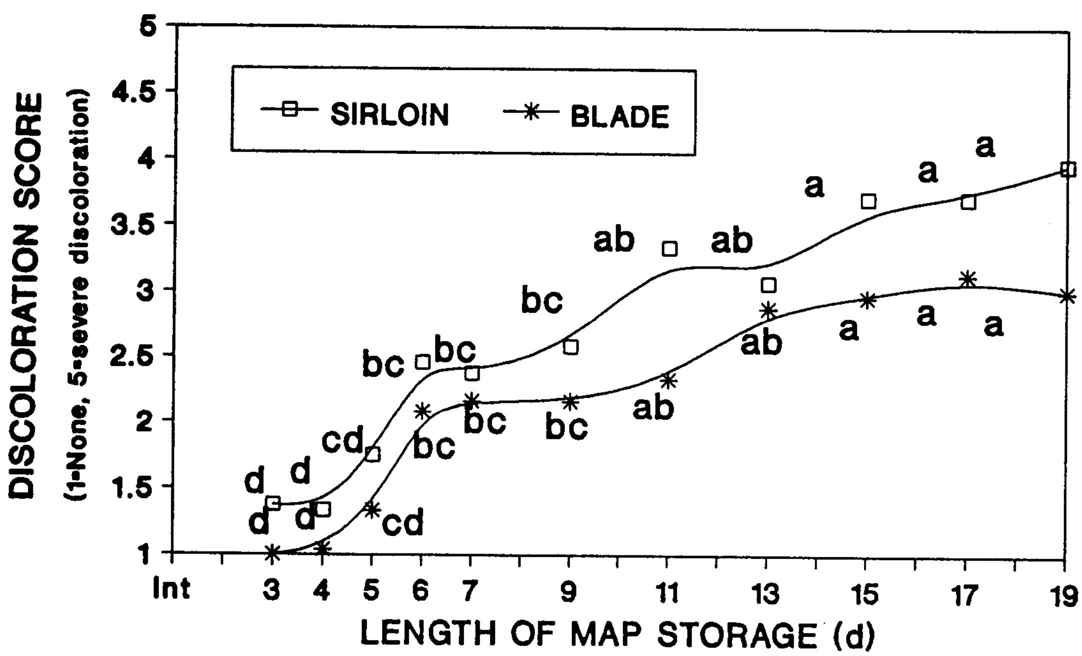

Figure 3. Whole loin discoloration.

EFFECTS OF MODIFIED ATMOSPHERE PACKAGING AND CARCASS CHILL RATE ON PORK LOINS[1]

D. H. Kropf, O. Sörheim[2], M. C. Hunt, M. Menninen, and K. E. Warren

Summary

Use of 10% oxygen in a modified gas atmosphere package resulted in more off-odor, higher microbial counts, and a less desirably colored loin and loin chops. Furthermore, it reduced chop display life and is not recommended.

(Key Words: Pork, Shelflife, Packaging, Quality, Oxygen.)

Introduction

Modified gas atmosphere packaging offers a longer product life for fresh pork cuts, including loins. Use of 100% carbon dioxide is common but may cause suboptimal loin appearance. Low oxygen levels in the gas mix may reduce this problem, but green discoloration of retail chops may result.

This study investigated use of various carbon dioxide/nitrogen gas mixes plus one with 10% oxygen on loin and retail chop color, weight loss, aroma and storage, and/or display life for both conventionally and ultra-chilled pork sides.

Experimental Procedures

Twenty conventionally slaughtered pork carcasses were split, and sides were assigned to either conventional chill at 34°F or ultra chill at -30°F with rapid air movement for 1 h. Then temperature equilibration was allowed at 34°F, and both sides were cut at 24 ± 2 h postmortem.

At cutting, loins were divided into five sections, each covering a three-vertebrae part of the loin, and closely trimmed of fat (overtrimmed) to maximize muscle exposure. Because loin sections vary anatomically, sections were assigned to packaging treatments so that each anatomical loin section was assigned equally to each treatment.

Immediately after cutting and trimming, loin pieces were placed in a gas barrier film bag, which was flushed and then filled with the appropriate gas mixture using a Corr-Vac Mark III snorkel-type packager, or vacuum packaged and stored at 34 to 40°F. The four gas packaging treatments included the following proportions (%) of carbon dioxide (CO_2), nitrogen (N), and

[1]Study supported by Pork Check-off funds.

[2]Guest scientist from Norwegian Food Research Institute, As, Norway.

oxygen (O_2), respectively, in the gas mixture: 100, 0, 0; 50, 50, 0; 25, 75, 0; and 25, 65, 10. Packages were monitored for percentage CO_2 and O_2 during storage.

Loins from 10 carcasses were stored for 22 d and those from the other 10 carcasses for 14 d before opening; evaluating aroma, purge loss; and microbial standard plate count; and preparing chops for retail display.

Retail chops (1 in. thick) from each loin section were individually placed on a tray, over-wrapped with oxygen permeable polyvinylchloride film, and placed under standardized display temperature and lighting. Color was evaluated by a color scoring panel and also instrumentally before display (d 0) and after 1, 2 and 3 d of display. At the end of the 5-d display, product aroma, standard plate count, and display weight loss (or gain) were determined.

Results and Discussion

Ultra-chill versus conventional chill reduced carcass shrink but did not result in other differences. Differences between 14 and 22 d of storage of loin pieces in modified gas atmospheres were not consistent. Therefore, data were combined (Table 1).

Oxygen in the treatments with only CO_2/N in the gas mix remained below 0.3%. All gas packages were double-flushed, i.e., a vacuum, flush, vacuum, fill cycle. The treatment with 10% O_2 initially had 9.5% O_2, which gradually was reduced to below 6% as O_2 was used for muscle metabolism.

Weight loss for loin pieces in 100% CO_2 was greater than for those in vacuum packages, which lost slightly more weight during 3-d display than the other treatments.

Off-odor for loins immediately after the modified atmosphere (gas) package was opened was greatest for the two treatments with 25% CO_2 and least for those with 100 or 50% CO_2. This odor dissipated 15 min after the package was opened, but the treatment with 10% O_2 still had slightly more off-odor. This treatment and vacuum packaged showed most off odor after a 3-d display. A higher microbial count for the 10% O_2 treatment was related to the greater off-odor.

Average loin color for the 10% O_2 treatment tended to be less desirable ($P<.05$) at 15 min after opening gas packs. Discoloration score showed a rather general off-color for the treatment with 10% O_2. Color evaluation of chops before display and after 1 or 3 d of display showed least desirably colored chops when 10% O_2 was added to the gas mix. When 100% CO_2 was used, the loin was more discolored than for other gas atmospheres 15 min after the package was opened, but the chop appearance was equal or superior to that of chops in other treatments.

Table 1. Loin Gas Packaging Effects on Loin and Chop Traits (Chill and Storage Treatments Combined)

Trait	100% CO_2	50% CO_2 50% N_2	25% CO_2 75% N_2	25% CO_2 65% N_2 10% O_2	Vacuum
Weight loss, %					
Loins	4.3[a]	3.8[ab]	3.8[ab]	3.9[ab]	3.2[b]
Chops (3 d)	2.6[ab]	2.5[ab]	2.5[b]	2.5[ab]	2.7[a]
Off-odor[e]					
Loins, 0 min	1.0[c]	1.1[c]	2.1[a]	2.2[a]	1.5[b]
Loins, 15 min	1.0[b]	1.0[b]	1.0[b]	1.3[a]	1.0[b]
Chops (3 d)	1.7[c]	1.9[bc]	2.1[b]	3.2[a]	2.9[a]
Microbial					
CFU/cm^2, log	3.3[b]	3.7[b]	4.1[b]	5.1[a]	3.9[b]
Color[f]					
Loin, 15 min	2.6	2.5	2.1	3.7	2.2
Chops, d 0	1.25[b]	1.22[b]	1.28[b]	1.37[a]	1.28[b]
Chops, d 3	3.40[ab]	3.32[b]	3.32[b]	3.45[a]	3.34[b]
Color, Worst Spot[f]					
Chops, d 0	1.26[a]	1.22[a]	1.28[a]	2.50[b]	1.34[a]
Chops, d 1	2.17[a]	2.06[a]	1.94[a]	3.03[b]	2.09[a]
Chops, d 3	3.47[a]	3.40[a]	3.37[a]	4.11[b]	3.49[a]
Discoloration[g]					
Loin, 15 min	3.2[b]	2.6[c]	1.9[d]	4.7[a]	1.9[d]
Chops, d 0	1.0[b]	1.0[b]	1.0[b]	1.6[a]	1.1[b]
Chops, d 1	1.4[b]	1.3[b]	1.1[b]	1.9[a]	1.2[b]
Chops, d 3	3.5[c]	3.6[bc]	3.5[c]	3.9[a]	3.7[b]

[a-d]Means in same row with same or no superscript letter are not different (P>.05).
[e]Off-odor scale: 1 = none, 2 = slight, 3 = small, 4 = moderate, 5 = extreme.
[f]Color scale: 1 = bright pink, 3 = slightly gray or tan, 5 = extremely gray or tan.
[g]Discoloration scale: 1 = none, 2 = slight (0-10%), 3 = small (11-20%), 4 = moderate (21-60%) and 5 = severe (>60%).

UTILIZATION OF SURIMI-LIKE PRODUCTS FROM PORK WITH SEX-ODOR IN RESTRUCTURED, PRECOOKED PORK ROASTS

C. M. Garcia Zepeda, C. L. Kastner, D. H. Kropf, M. C. Hunt, P. B. Kenney, J. R. Schwenke[1], and D. S. Schleusener

Summary

Surimi-like materials from boar and sow muscle and Alaska pollack surimi were evaluated at a 5% inclusion level in a restructured, precooked (158°F) pork roast. Meat batches were formulated to contain 95% chunked ham muscles and either 5 or 0% surimi-like or surimi binder, either 0.2 or 1.0% NaCl, and 0.5% phosphate. The surimi washing process did not remove or decrease boar taint intensity of the binder or enhance instrumental and sensory textural characteristics of the finished product. Products without binder were comparable or superior in textural and microbial characteristics to those with binders. Increasing salt content had detrimental effects on TBA (rancidity) and color but enhanced product textural attributes. Fish surimi did not have greater structural integrity than washed boar counterparts.

(Key Words: Boar, Odor, Pork, Quality.)

Introduction

Increasing marketing alternatives for pork is an important goal for the swine industry. Enhancing quality of restructured pork products offers significant economic opportunities for this industry by maximizing value of pork and creating palatable, convenient, nutritious, and profitable products from low-cost, pork, raw materials. The utilization and value of meat from some hogs is limited by the prevalence of sex odor. Approximately 65% of all boar carcasses and up to 5% of all barrows and females exhibit sex odor. The manifestation of sex odor can cause carcasses to be put into restrictive use categories or even condemned. Additionally, consumer acceptance can be influenced by marketing carcasses with marginal sex odor problems. Fat contains the sex odor, which has been described as onion-like, perspiration-like, and urine-like. Thus, removing fat from the lean fraction could minimize and potentially eliminate the odor.

Fish surimi has been proposed as an alternative to salt-extracted proteins as the binding mechanism in restructured meats. Fish surimi, in both dried and frozen forms, has been used successfully as a binder to restructure red meat products, but the pork industry should determine if a comparable or better and economically competitive surimi-like material could be produced from pork skeletal muscle. Therefore, the objective of this study was to develop a surimi-like material by using a refining process that removes the undesirable odors and flavors from these otherwise less than optimun value carcasses, while providing a highly functional myofibrillar component. Use of this refined material as a binding agent could produce a restructured pork product with enhanced characteristics.

---

[1]Department of Statistics.

Procedures

Six sow carcasses were conventionally slaughtered at the Kansas State University Meat Laboratory. The carcasses were chilled in a 36°F cooler for 24 h and fabricated. Major muscles were excised from the hams and from four additional hams purchased frozen from a commercial sow processor. Frozen boar meat trimmings (50/50 and 75/25 lean to fat ratio) were obtained from a commercial boar processor. All muscles were manually trimmed of exterior fat and connective tissue and frozen (-4°F) until experimentation began.

Sow muscles were thawed in a 36°F cooler and chunked through a 24 x 48 mm, kidney-shaped, grinder plate. Chunks were thoroughly mixed to ensure that muscles from different animals and sources were uniformly distributed. The pork chunks were then refrozen (-4°F).

To prepare the binders sow muscles and lean boar trimmings were ground twice through a 3.2 mm plate. Unwashed binders were collected at this time. For binders to be washed, fat content of both raw materials was standardized to 12% to evaluate the efficacy of the washing process to remove boar odor. Boar and sow ground meat was washed twice. A 1:5 meat to water ratio was used; water and ground meat were moderately agitated for 15 min at 39°F. The slurry was rested for 30 min; water was decanted; and meat particles were placed in cheese cloth (2 mm openings), and manually pressed to remove excess water. The amount of water removed from the meat particles was added to the pressed particles in the second washing procedure to approximate the meat:water ratio of the first washing. Wash water was again decanted; the particles were filtered, pressed, and centrifuged at 2000 x g (2800 rpm) for 15 min; and the supernatant was discarded. Cryoprotectants (0.15% sodium tripolyphosphate (STPP), 0.15% tetrasodium polyphosphate (TSPP), 4% sorbitol, and 4% sucrose) were added to unwashed and washed binders at levels present in fish surimi. Alaska pollack surimi was purchased frozen. All binders were vacuum packaged and stored at -4°F until product manufacture.

The pork chunks and binders for each replication were thawed overnight at 36°F and the pork chunks were thoroughly mixed with 0.51% TSPP. This chunk preblend was stored for 12 h until binder addition and stuffing. Each standardized binder, washed boar muscle (WBM), unwashed boar muscle (UBM), washed sow muscle (WSM), unwashed sow muscle (USM) or fish surimi (FS), was mixed with 4% NaCl for 15 min, activated by one pass through an emulsifier, and stored for 12 h. Then, 10-lb batches were formulated to contain 95% chunks and 5% finely (3.2 mm) ground, unwashed material or ground, washed surimi-like material or fish surimi corresponding to each treatment outlined previously, with the exception of the non-binder treatment formulation (0/0.2). This latter treatment consisted of 100% sow chunks and the same percentage of cryoprotectant present in each binder in order to minimize confounding ingredients effects. After addition of the appropriate ingredients, each batch was mixed for 15 min, vacuumized, and stuffed into a No. 6 fibrous, prestuck casing. Roasts were cooked to an internal temperature of 158°F, then chilled. Roasts were dried, weighed, vacuum packaged, and frozen for subsequent analyses.

The vacuum-packaged roasts were thawed and tested or stored for 14 d at 36°F. Then slices (0.29 in) from the roasts were overwrapped with oxygen permeable PVC Resinite packaging film and placed under lighting at 1076 lux in a 37°F display case for 6 or 12 h. Slices taken from the center of the roasts an external face (F) slice were evaluated before display (0 h) and rancidity (TBA) and color measurements were determined. A professional, trained, seven-member panel evaluated each treatment within each replication in triplicate before and after 14 d of vacuum storage. Panelists were selected also for their ability to detect boar and fish odor. They evaluated tensile strength, firmness, off flavor, boar flavor/aroma fishy flavor/aroma, and uniformity of appearance. The Instron Universal Testing Machine was used to measure tensile strength, hardness, and cohesiveness of the roasts. Microbial counts were conducted on meat samples before and after heat processing and during the display period (before and after vacuum storage of roasts for 14 d including external face samples) at 0, 6, and 12 h.

Results and Discussion

Washing boar muscle did not alter (P>.05) the compositional, physicochemical, instrumental, and sensory textural measurements of finished restructured pork roasts relative to those containing unwashed muscle, fish surimi, or no added binder. Bind did not increase with the increased percentage of myofibrillar proteins after removal of sarcoplasmic proteins during the surimi washing process. Washing increased (P<.05) the lightness and decreased (P<.05) the yellowness of external face samples. Washing did not affect TBA (rancidity) numbers at 0 and 6 h of display but decreased (P<.05) the 12 h values compared to the unwashed counterparts, which had the only TBA value above the threshold level of 1.0 of all treatment combinations throughout the retail display period. From the microbial standpoint, washing tended to decrease mesophilic and psychrotrophic bacterial counts of center slices and significantly decrease (P<.05) both mesophilic and psychrotrophic counts for uncooked roasts. Microbial counts did not reach spoilage or deterioration levels in any treatment combination. Washing did not improve (P>.05) product yields or conclusively remove or reduce the intensity of boar taint.

In regard to compositional, functional, yield, color, TBA, microbial, instrumental, and sensory measurements, products formulated to contain 0.2% NaCl and no binder were comparable or superior to products containing washed or unwashed adjuncts. Redness of pork roast was increased (P<.05) with the addition of unwashed boar muscle; however, addition of washed material did not affect (P>.05) redness values. Unwashed boar muscle tended to have higher TBA (rancidity) values. Uncooked products without binder were more (P<.05) microbiologically stable than those formulated with washed or unwashed binders.

Sensory and instrumental textural responses agreed that higher salt products had greater (P<.05) tensile strength and sensory firmness than lower salt products. Also, there was a tendency for higher salt products to be harder and more cohesive (P>.05) than lower salt counterparts. Products containing 1% NaCl had higher (P>.05) yield. The high-salt treatment adversely affected (P<.05) color, TBA (rancidity), and uniformity of appearance values of cooked pork products. Exterior and center slices were (P<.05) darker with higher salt concentration. In addition, increasing salt content had noticeable effects on 12 h TBA numbers (P<.05); warmed over flavor; and metallic, sour, and fishy off-flavor notes of cooked roasts. Salt adversely affected consumer acceptance of restructured meat products by increasing oxidation and causing off-colors and flavors.

Products containing washed boar binder were comparable to or had greater structural integrity than fish counterparts. Two factors may have influenced these results. First, binder emulsification and product temperature were higher ($P<.05$) for fish surimi, which could have affected the heat stability of the fish proteins. Secondly, the amount of fish used may have been insufficient to enhance overall textural properties of the roasts. Warmed over and fishy flavor notes were intensified by the addition of fish binder in the formulation. However, TBA values were not different ($P>.05$) between treatments throughout retail display.

Conclusions

The surimi washing process did not improve physicochemical, instrumental, and sensory textural measurements of finished restructured pork roasts nor remove or decrease boar odor intensity of binders. Functional, temperature, yield, color, TBA, microbial, instrumental, and sensory measurements indicated that products formulated to contain 0.2% NaCl and no binder were comparable or superior to those with binder and the same salt content. Increasing salt content had detrimental effects on TBA and color but enhanced product sensory and instrumental texture attributes. Fish surimi products did not have greater structural integrity than counterparts containing boar muscle.

CONSUMER EVALUATION OF RETAIL HAMS FROM DIFFERENT PRODUCTION PROCESSES

D. N. Waldner, M. E. Dikeman, D. H. Kropf, S. L. Stroda, and R. E. Campbell

Summary

Consumers evaluated hams from the four minimum protein-fat-free categories labeled; 1) ham (H), 2) ham with natural juices (HNJ), 3) ham-water added (HWA) and 4) ham and water product (HWP), for juiciness, flavor, and overall acceptability. Shear force and cooking loss data were also obtained. The HNJ product was rated higher for flavor and overall acceptability, whereas the H and HWP were found to be the least desirable. The HWP was rated the most juicy; the H product was scored the least juicy. Peak shear force was lower for the HWP than for the other ham types; however, all hams were acceptably tender. The HWA and HWP had the least amount of cooking loss.

(Key Words: Ham, Pork, Consumer, Evaluation.)

Introduction

New regulations were adopted in 1985 to monitor ham production according to minimum levels of protein rather than water content. Prior to the new regulations, processors had three categories in which to effectively market their product. One was a product labeled "ham", which could contain no added water. The other two categories were required to be labeled with a statement as to the amount of water that had been added to the product. A ham containing up to 10% added water was labeled "ham-water added", and those containing more than 10% added water but less than 20% were labeled "ham and "X" percent added water". The new regulations specify a minimum meat protein content on a fat-free basis (PFF), instead of water content, with each class of pork product having a minimum protein requirement. The USDA labeling and minimum PFF regulations for protein percentage of ham products now read as follows: ham, 20.5%; ham with natural juices, 18.5%; ham-water added, 17.0%; ham and water product, <17.0%. These new regulations allow processors to produce numerous products ranging from the more expensive dry cured hams to the high added-water, 95% fat-free hams that are relatively inexpensive.

With the wide variety of ham products resulting from the new regulations, recognizing consumer preferences for them is important. Currently, some products contain up to 35% added water, which results in an economical product to consumers. However, consumer preference for these products when compared to the more "traditionally" cured ham products is not known. This study was designed to evaluate consumer preference for juiciness, flavor, and overall acceptability of hams from the four minimum PFF categories and to possibly identify those segments of the population that have differing attitudes about these products.

Procedures

On six different days of sampling, one ham from each of the PFF categories was purchased at a retail market and prepared for consumer evaluation, cooking-loss determination, and shear force analysis.

Samples for sensory analysis were sliced 3/8 in. thick, cut into 3/4 x 3/4 in. squares, and refrigerated at 40°F until evaluated. During the six sampling periods at two retail markets, consumers (n=301) were asked to evaluate each of the four ham products; 1) ham (H), 2) ham with natural juices (HNJ), 3) ham - water added (HWA), and 4) ham and water product (HWP). Samples were served in random order, and panelists were asked to evaluate hams for juiciness, flavor, and overall acceptability (Table 1).

Table 1. Sensory Evaluation Scoring Scale

Juiciness	Flavor	Overall Acceptability
1 very juicy	1 like very much	1 like very much
2 moderately juicy	2 like moderately	2 like moderately
3 slightly juicy	3 like slightly	3 like slightly
4 slightly dry	4 dislike slightly	4 dislike slightly
5 moderately dry	5 dislike moderately	5 dislike moderately
6 very dry	6 dislike very much	6 dislike very much

Shear force samples 3/4 in. thick were removed after every fourth sensory slice. Six 1/2 in. diameter cores were removed from each slice, perpendicular to the slice surface, and peak force was measured using the Instron Universal Testing Machine (model 4201, Instron Corp, Canton, MA 02621) with a Warner-Bratzler shear attachment.

Cooking losses were determined on 2 lb butt portions and whole hams. Samples were weighed, cooked to 135°F in a gas oven and reweighed to determine cooking loss by difference.

Results and Discussion

The ham with natural juices (HNJ) product was rated highest ($P<.05$) for flavor and overall acceptability, whereas the ham (H) and ham and water product (HWP) were found to be the least desirable (Table 2). The HWP was rated the most ($P<.05$) juicy of all hams; the H was scored the least ($P<.05$) juicy.

Table 2. Means for Juiciness, Flavor, and Overall Acceptability of the Four Ham Types

Ham type	Juiciness	Flavor	Overall Acceptability
Water added	2.60[a]	2.36[a]	2.37[a]
Water product	2.12[b]	2.59[b]	2.62[b]
Natural juices	2.83[c]	2.02[c]	2.08[c]
Ham	3.40[d]	2.70[b]	2.74[b]

[a,b,c,d]Means within the same column with different superscripts differ significantly (P<.05).

Table 3. Means and Standard Deviations for Shear Force and Cooking Losses of the Four Ham Types

	Peak Force(lb)		Cooking Loss(%)	
Ham type	Mean	Std Dev.	Mean	Std Dev.
Water added	2.42[a]	1.63	6.70[a]	1.34
Water product	1.89[b]	1.39	7.70[a]	1.12
Natural juices	3.52[a]	1.56	10.2[b]	2.78
Ham	4.64[c]	2.38	14.3[c]	3.11

[a,b,c]Means within the same column with different superscripts differ significantly (P<.05).

Peak shear force was lowest (P<.05) for the HWP among all ham types (Table 3). The HWA and HNJ hams were intermediate in shear force values, whereas the H product had the highest (P<.05) values. It should be noted that shear values for all hams were quite low, indicating that they were all acceptably tender. Many consumers suggested that the HWP ham was too soft and that a little more texture would be desirable. Although the HWP is an economical product, there appears to be a limit to the amount of water that can be added before producing an undesirable mouthfeel. The HWP apparently had reached that limit.

Cooking losses were significantly lower for the HWA and HWP than the other two ham types. This indicates, that although these products do contain a considerable amount of moisture, it is tightly bound within the product and is not released to any great extent during cooking. On the other hand, those products that have not been extensively processed, i.e, tumbled, massaged, defatted, or deboned, will tend to lose more weight in the cooking process. These products will more than likely be less moist and may seem more salty, as comments have suggested.

In summary, it appears that, although no single segment of the population can be targeted for a specific ham product, the ham with natural juices is the product of choice for most consumers when evaluating for flavor and overall acceptability. Although the more moist products may be perceived as desirable from an economical standpoint, the ham and water product not only rated poorly for flavor and overall acceptability, but also received comments that it was too soft and too bland. On the other hand, the dry and more expensive ham product received similar ratings and was described as being too dry or salty and containing too much fat. Therefore, it appears that such products as the ham with natural juices and ham-water added optimize flavor and juiciness, low fat, and low salt, which will meet consumers needs for an economical, tasty, and healthy alternative in the meat case.

ACKNOWLEDGEMENTS

Appreciation is expressed to these organizations for assisting with swine research at Kansas State University:

ADM Protein Specialties, Decatur, IL
American Livestock Equipment, Clay Center, KS
American Proteins Corporation, Ames IA
Ark City Packing Co., Arkansas City, KS
BioKyowa, Inc., St. Louis, MO
Central Confinement Service, LTD., Columbus, NE
Central Soya, Fort Wayne, IN
CIL, Inc., Ontario, Canada
Cryovac Division, W. R. Grace & Co., Duncan, SC
DeKalb Seed Co., Dekalb, IL
Elanco Products Company, Indianapolis, IN
Excel Corp., Wichita, KS
Feed Specialties Inc., Des Moines, IA
Finnfeeds International LTD, Surrey, U.K.
Heartland Lysine, Inc., Chicago, IL
Hoffman-LaRoche, Inc., Chicago, IL
ICI, PLC, London, England
Iowa Limestone Co., Des Moines, IA
Kansas Pork Producers Council, Manhattan, KS
Kansas State Board of Agriculture, Topeka, KS
Keesecker Enterprises, Washington, KS
Livestock and Meat Industry Council, Manhattan, KS
Lonza, Inc., Fair Lawn, NJ
M-TEK Inc., Elgin, IL
McCullough & Co., Kansas City, MO
Merrick Foods, Union Center, WI
Monsanto Ag. Co., St. Louis, MO
Morrison Grain Co., Salina, KS
Pfizer, Inc., Terre Haute, IN
Pet Ag, Inc., Elgin, IL
Pitman-Moore, Inc., Terre Haute, IN
Prince Agri. Products, Inc., Quincy, IL
Protein Technologies International, St. Louis, MO
SmithKline Animal Health Products, West Chester, PA
Syntex Animal Health, Inc., West Des Moines, IA
United States Department of Agriculture, Science and Education, Washington, D.C.
Zapata Haynie Corporation, Reedville, VA

We especially appreciate the assistance and dedication of John Blaske, Joe Carpenter, Steve Hargrave, Melanie Krause, Mark Nelson, Dianna Reves, and Kris Richardson.

We gratefully acknowledge Eileen Schofield for editorial assistance, Val Stillwell for word processing, and Fred Anderson for cover design for this publication.

Swine Industry Day Committee

Jim Nelssen, Chairman	Joe Hancock
Duane Davis	Bob Hines
Bob Goodband	Dave Nichols

Contribution 91-189-S from the Kansas Agricultural Experiment Station.

Agricultural Experiment Station, Kansas State University, Manhattan 66506

Report of Progress 610 November 1990

2M