The Prairie Swine Centre is pleased to present our 1996 Annual Research Report

HIGHLIGHTS

Highlights of the 1996 Research Report:

- **A factorial approach to predicting lysine and energy requirements of growing-finishing pigs (p.25)**
- **Removal of supplemental vitamins and trace minerals in finisher diets could provide savings of $1.50 per pig (p.29)**
- **Five different varieties of hulled barley are being tested in the Centre (p.33)**
- **Dehulled canola meal represents a new alternative to increasing the digestible energy content of this popular supplemental protein source (p.35)**
- **Feeding plasma diets is more beneficial to pigs in a continuous-flow compared with an all in - all out nursery (p.40)**
- **Human responses are used as criteria to evaluate the Centre's oil-sprinkling technology to reduce respirable dust (p.44)**
- **A negative ionization system reduces respirable and inhalable dust in the short-term (p.49)**
- **A balloon-type lagoon cover reduces odour emission at a very low cost (p.54)**
- **Different strains of *Streptococcus suis* share common proteins which could be used to develop a vaccine (p.62)**
- **Wet/dry feeders increase weight gain and feed intake by 5% compared with dry feeders (p.65)**
- **Stalls and farrowing crates (narrow and wide) are compared with pens regarding the behavioural response of gilts during gestation, farrowing and lactation (p.70)**
- **Important concepts in selecting and locating water sources for pigs (p.74)**

"The mission of Prairie Swine Centre Inc. is to provide a centre of excellence in research, technology transfer and education, all directed at the enhancement of efficient, sustainable pork production in Canada."

CONTENTS

THE PRAIRIE SWINE CENTRE

The Prairie Swine Centre focuses on issues of efficiency and sustainability. While much of the research program seeks to improve the individual pork producer's net income, through nutrition, management and housing, there is also a need to deal with issues that have less direct economic impact but clearly influence the future success of our industry. Currently, the issues of animal welfare and human health are two important focuses of the Centre's research, technology transfer and teaching programs.

Funding

The Centre must attract funding in order to survive. This is one of the corporation's strengths. It ensures that the Centre is responsive to industry needs and input. This is clearly demonstrated by the make-up of its Board of Directors. In addition, the Centre was established with a view to attracting funds from a wide variety of sources; this reduces dependency on any one source and at the same time reduces the cost to any one participant in the Centre's various programs. About one-third of total revenues are derived from sale of stock; this encourages the Centre to be a good pork producer, which many producers tell us is critical to our being a good research facility. The subject of funding is covered in greater detail in the President's Report.

Staffing

The strength of any organization is its staff. While the Centre is proud of its modern, practical research facilities, its greatest resource is its people. There are a total of 38 people currently employed by the Centre in a variety of professional and support positions.

Graduate Studies

Graduate students bring a new perspective to the Centre. Their intense interest often leads to new questions being asked and traditional ideas being challenged. The Centre currently has three graduate students - two in ethology and one in engineering. Further expansion of graduate training is expected in the future.

Facilities

The Prairie Swine Centre is the largest swine production research facility in Canada. With more than 77,000 ft^2 of barn and office space, it maintains a unique array of research capability on one site.

Original Facilities

The original 250 sow farrow-to-wean unit was built in 1980 by the University of Saskatchewan. It consists of two 100-sow and one 50-sow units, each with its own gestation, farrowing and weanling areas. A small feeder barn was also built at that time consisting of 24 pens capable of holding 10 pigs each.

Grower-Finisher Research Unit

In May, 1992, pigs were first introduced into the new Grower-Finisher Research Unit. This unique facility was designed by a commercial engineer and constructed using the same materials and methods employed by the commercial pig industry. The cost of the new unit, at about $\$35/ft^2$, is only moderately higher than the \$20 to $\$25/ft^2$ experienced by commercial units. Yet, this includes a wide array of specialized research equipment and facilities; this cost also includes office facilities for the expanded research staff. The unit can be divided into 5 functional areas: basic, intensive, semi-intensive, commercial and proprietary.

Basic

The basic research area includes a fully-equipped surgery, related prep areas, two small experimental rooms designed for flexible research use, and a very sizable metabolism room that can accommodate up to 20 metabolism crates for large-scale digestibility studies.

Intensive

The intensive research area includes two rooms of 76 individual pens each. These rooms are designed for use in experiments where individual animals are the focus of research or where only small quantities of test materials are available for nutrition experiments. The pens are designed to be modified, to convert from one pig in a pen up to 5 pigs in a pen, depending on the needs of the experiment.

Semi-intensive

Oftentimes, research requires facilities that are mid-way between commercial scale and intensive. The semi-intensive rooms were designed to fulfill this need. Four rooms each contain 20 pens designed for 5 pigs each. Again, the penning is flexible, allowing groupings larger than 5 pigs when desired.

Commercial

The commercial area actually includes two types of facilities. In one area, there are three rooms of partially-slatted floor pens; each room consists of 12 pens housing 12 pigs each. Although somewhat smaller than the typical commercial group size of 20 to 30, the commercial rooms allow research to be conducted in facilities that in most respects resemble recently constructed commercial barns.

A second area of the commercial wing includes two engineering rooms. These consist of 12 pens of 12 pigs each, housed in fully-slatted floor pens. However, the rooms are designed for maximum flexibility so that they can be converted to partially-slatted or even totally-solid floors. The ventilation system can be completely changed to incorporate a wide array of options in both inlet and exhaust design.

Proprietary

The proprietary area includes 4 semi-intensive rooms and one metabolism room, similar to that in the basic area. This provides Prairie Swine Centre with unique facilities to serve the commercial sector; indeed, companies from across the United States and from as far away as Europe have contracted with the Centre to conduct research on their behalf. This not only helps the financial situation of the Centre, but places it firmly in the “big leagues” of swine research worldwide.

Other Facilities

In addition to the above, the Centre maintains an office building complete with offices for the research and administrative staff as well as graduate students. It also has a simple laboratory and reading room. By employing modern communication technology, the Centre is linked through computer networks to researchers on campus and around the world. Prairie Swine Centre Inc. employs research and support staff to ensure that all research and technology transfer objectives are met. Each member of the Executive Management Team brings a wealth of research and practical pork production experience.

BOARD OF DIRECTORS

Left to right seated: Terry Scott, John Patience, Weldon Newton, Jim Smith
Left to right standing: Wayne Vermette, Florian Possberg, Mac Sheppard, Cam Henry, George Lee
(Missing: John Stewart)

Board of Directors:

The Centre's Board of Directors has 10 members as of June 30, 1996. They represent the diverse interests of the western Canadian swine industry, including:

Mr. Weldon Newton, Chairman, Prairie Swine Centre Board of Directors, Manitoba pork producer,

Mr. Jim Smith, Alberta pork producer,

Mr. Wayne Vermette, Saskatchewan pork producer,

Mr. Florian Possberg, Saskatchewan pork producer,

Dr. George Lee, Agricultural Research Coordinator, U of S,

Dr. John Patience, President Prairie Swine Centre,

Mr. Cam Henry, Manitoba grain producer,

Mr. Terry Scott, Assistant Deputy Minster of Agriculture, Saskatchewan Agriculture and Food

Mr. Mac Sheppard, controller (recently retired), U of S,

Dr. John Stewart, Dean of Agriculture, U of S.

STAFF AND ASSOCIATES

Executive Management Team
Left to right seated; Dr. John Patience, President/CEO, Mr. Lee Whittington, Manager-Information Services
Left to right standing; Dr. Harold Gonyou, Research Scientist-Ethology, Mr. Brian Andries, Operations Manager, Dr. Yuanhui Zhang, Research Scientist - Engineering.

President

Dr. John Patience is President and Chief Executive Officer of the Corporation. He brings 13 years of experience in extension, the feed industry and research to the Centre. Raised on a hog and beef farm in southern Ontario, he obtained both his Bachelor and Master degrees from the University of Guelph and his Ph.D. from Cornell University, the latter in 1985.

Research Scientist - Engineering

Dr. Yuanhui Zhang is Research Scientist - Engineering. Dr. Zhang obtained his Ph.D. in Agricultural Engineering at the University of Saskatchewan before joining the College of Engineering at the University of Illinois to work on NASA-funded projects on space travel. Dr. Zhang has particular expertise in air quality and environmental control and chairs the sub-committee Environmental Control for Plants and Animals, American Society of Heating, Refrigeration and Air Conditioning Engineers.

Research Scientist - Ethology

Dr. Harold Gonyou is Research Scientist - Ethology (Behaviour). Raised on a farm in southern Ontario, Dr.Gonyou obtained his Bachelors degree from the University of Guelph, his Masters degree from the University of Alberta and his Ph.D. from the University of Saskatchewan. He joined the faculty of the University of Illinois and rose to the position of Professor before leaving to join the Centre. Currently, Dr. Gonyou is President of the International Society of Applied Ethology, the first North American to hold this position. He has also been invited to participate in an international committee focusing on swine equipment design.

Manager - Information Services

Mr. Lee Whittington is Manager - Information Services. Originally from Ontario, he obtained his Bachelors degree from the University of Guelph before joining Shur Gain where he remained for 13 years. In addition to his animal science background, Mr. Whittington has extensive training and experience in marketing and communication, making him ideally suited to his current responsibilities at the Centre.

Manager - Operations

Mr. Brian Andries is Manager - Operations. He hails from southern Saskatchewan and obtained his Bachelors degree from the University of Saskatchewan. Mr. Andries has over 10 years experience in swine production and has risen through the ranks of the Centre to his current position.

In addition to the staff noted above, the Centre is very well served by support staff in a variety of accounting, clerical, production and technical positions. Their combination of training and experience in pork production as well as research methodologies provides the essential support needed in any successful research program.

Post Doctoral

Dr. Mark Lorschy
Citizenship - Australia
Degree - PhD Nutrition
Last appointment - University of Minnesota
Area of research - Amino acid/energy interaction in growing-finishing pigs

Dr. Aki Tanaka
Citizenship - Japan
Degree - PhD Engineering
Last appointment - Ichinoseki Agricultural High School
Area of research - dust control

Dr. Zhensheng Lou
Citizenship - Canadian
Degree - PhD Behaviour
Last appointment - University of Guelph
Area of research - animal/equipment interaction

Graduate Students

Renée Bergeron
Degree earned:
Ph.D. in Ethology

Guangzhi Zhao
Degree earned:
M.Sc. in Engineering
Continuing PhD studies

Moira Harris
Degree sought:
M.Sc. in Ethology

Shawn Fairbairn
Degree sought:
M.Sc. in Nutrition

Administration Staff
Left to right:
Christine Wakabayashi (Financial Manager),
Audrey McFarlane (Secretary).

Proprietary Research Group
left to right; Ms. Alison Bzowey, research technician, Dr. Eduardo Beltranena, Manager-External Research, Ms. Raelene Petracek, research technician.

Kelly Sauder,
Farm worker

Standing (L-R) John Meier, Darryl Wurtz, T. J. Hanson, Doug Gillis, Garth McDonald, Karen Wurtz, Marnie Korchinski
Seated (L-R) Joe Jobin, Colin Peterson, Troy Donauer, Alison Bzowey, Raelene Petracek

SCIENTISTS, UNIVERSITY OF SASKATCHEWAN

Dr. Ernie Barber
Professor
Dept. Agricultural and Bioresource Engineering
Research Emphasis: ventilation control and air quality

Dr. Milt Bell
Professor Emeritus
Dept. Animal & Poultry Science
Research Emphasis: evaluation of canola meal, peas, barley and wheat

Dr. Bernard Laarveld
Professor
Dept. Animal & Poultry Science
Animal Biotechnology Group
Research Emphasis; endrocine control of metabolism, growth and lactation; immune castration, immune enhancement, neonatal management.

Dr. Iain Christison
Professor
Dept. Animal & Poultry Science
Research Emphasis; sow and litter mngt; piglet and weaning behavior; flooring, crate and pen design

Dr. Al McCurdy
Professor
Dept. Appl. Micro. and Food Science
Research Emphasis; meat processing; extended shelf-life; lipid chemistry

Dr. Chuck Rhodes
Professor
Dept. Herd Med. & Theriogenology
Research Emphasis; swine production medicine

Dr. Phyllis Shand
Research Associate
Dept. Appl. Micro. and Food Science
Research Emphasis; meat processing; product development; sensory properties of meat

Dr. Joseph Stookey
Associate Professor
Dept. Herd Med. & Theriogenology
Research Emphasis; animal behaviour and welfare

Dr. Phil Thacker
Professor
Dept. Animal & Poultry Science
Research Emphasis; improving sow fertility; evaluation of new feeds; gilt management

Research Technicians U of S

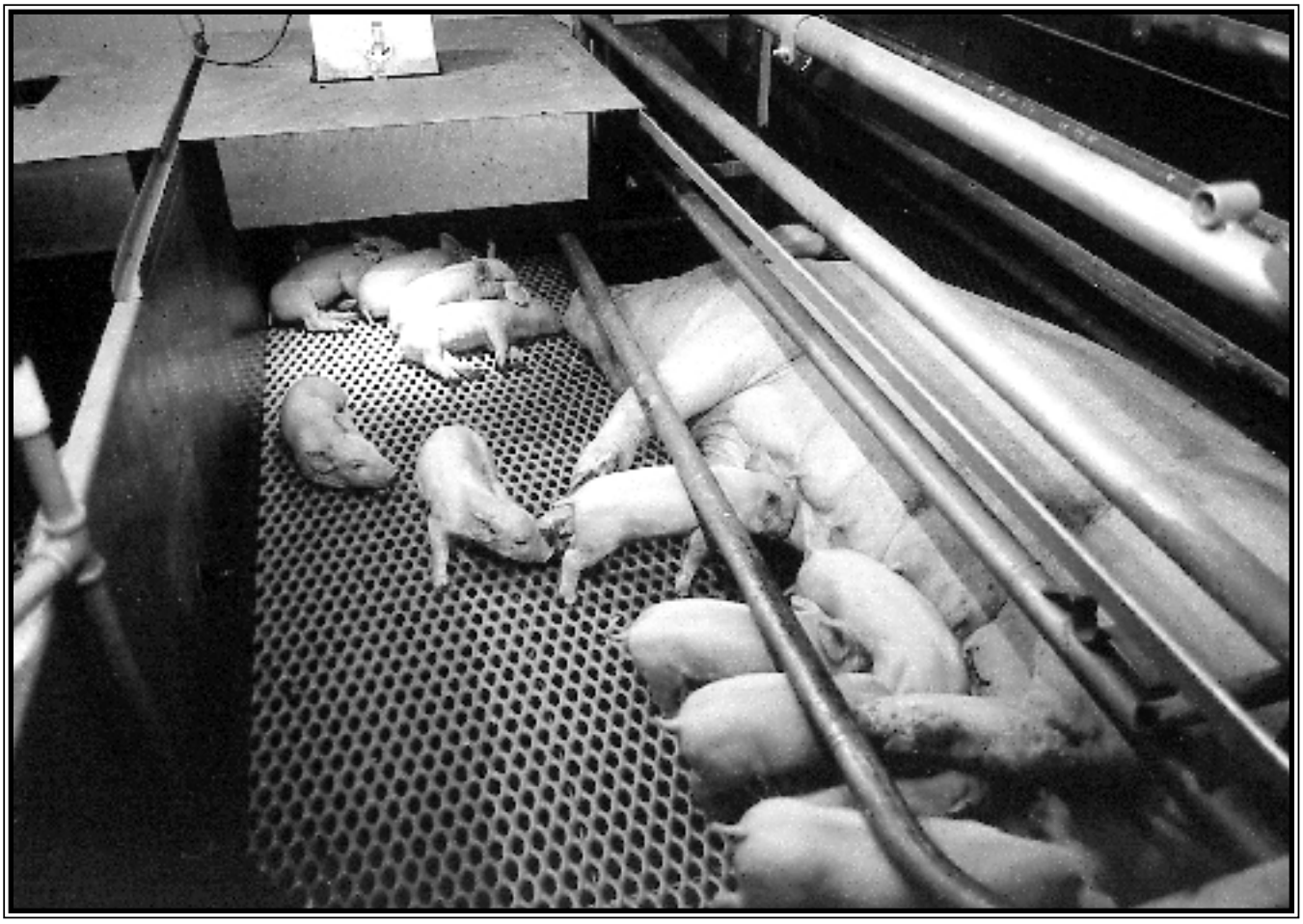
Bing Li
Carmen Engele
Anita Lemke
Wayne Morley, Ag. Eng.
Lewis Roth, Ag. Eng.
Charlotte Hampton
Joyce Nordick
Blair Goldade
Susan Francis
Ron Korchinski

Graduate Students U of S

Colleen Christensen
Wenyin Li

Cooperating Scientists

Dr. K. Rajkumar, Reproductive Biology Unit, Obstetrics and Gynecology, Royal University Hospital, Saskatoon, Saskatchewan
Dr. Shin-ichi Urano, Hokkaido University, Japan
Dr. John Feddes, University of Alberta, Edmonton
Dr. Laurie Conner, University of Manitoba, Winnipeg
Dr. Jim Dosman, Centre for Agricultural Medicine, U of S.
Dr. A. Senthilselvan, Centre for Agricultural Medicine, U of S.
Mr. J. Strom, National Institute for Agricultural Engineering, Denmark
Dr. P. Willson, VIDO
Prof. W.T. Martin, Royal University Hospital, Saskatoon, Saskatchewan
Dr. M. Sheridan, Steinbach, Manitoba



Farrowing crate at Prairie Swine Centre showing movable creep hoover

FINANCIAL SUPPORT

Pork production research is entering a new phase in Canada, with increasing emphasis on producer driven and funded programs. Prairie Swine Centre Inc. wants to acknowledge the many individuals and agencies that supported the dynamic research and technology transfer programs this past year. This support is essential to the ongoing developments that will keep Canadian pork producers at the forefront of applied technology.

In addition to industry and government funding, the University of Saskatchewan contracts the facilities and services of PSCI for research and teaching. This ongoing agreement provides income for the Centre in return for the use of modern production and research facilities.

The following organizations have provided funding or donations in kind to support public research at the Centre for the 1995/1996 year. Their support is greatly appreciated.

Pork Producers of Saskatchewan
SPI Marketing Group
Swine Improvement Services Co-op

Pork Producers of Alberta
Alberta Pork Producers Development Corporation

Pork Producers of Manitoba
Manitoba Pork Est.

Government
Alberta Agricultural Research Institute
Agricultural Development Fund
Canada-Saskatchewan Green Plan Agreement
Western Economic Diversification Program
Natural Sciences and Engineering Research Council of Canada (NSERC)
Industrial Research Assistance Program (IRAP)

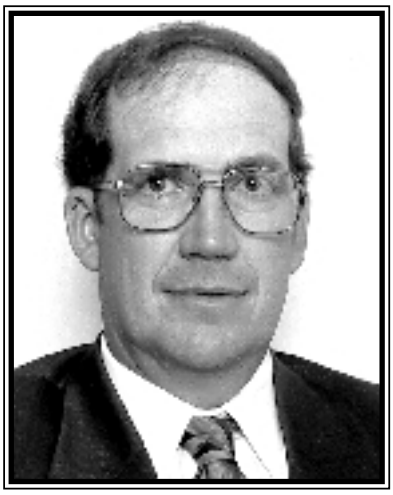
Institutions outside Canada
United States Department of Agriculture (USDA)
University of Maryland

Industry Donations
Feed Flavors Incorporated
Canola Council of Canada
Pig Improvement (Canada) Ltd.
Saskatchewan Canola Development Commission
ADM Bioproducts
Del Air Systems Ltd.
Canodev Research
Degussa Corporation
TDK Corporation of America
Hillcrest Farms, Ltd.
Master Feeds
Shamrock Feed Ltd.
Kenpal Farm Products, Inc.

Many corporations provide funding in support of technology transfer programs conducted by the Centre. We wish to acknowledge their contribution for assisting the Centre in encouraging the adoption of new technologies by Canadian pork producers.

Agricultural Credit Corporation, Swift Current, SK
Alberta Swine Genetics, Leduc, AB
Betker Livestock Equipment Sales, Saskatoon, SK
B.C. Hog Marketing Commission, Abbotsford, BC
Can-Win Specialty Products, Winnipeg, MB
Coop Feeds, division of CFL, Saskatoon, SK
Cotswold Western, Winnipeg, MB
DGH Engineering, Winnipeg, MB
Elanco Animal Health, Guelph, ON
Hillcrest Farms Ltd., Bruno, SK
Merick AgVet, Mississauga, ON
National Pig (Canada) Co. Ltd., Regina, SK
Nutrena Feeds, Lethbridge, AB
Phason, Winnipeg, MB
Pig Improvement (Canada) Ltd., Acme, AB
Prairie Pride Enterprises, Winnipeg, MB
Pro-Ag Products, Winnipeg, MB
Sheridan and Heuser, Steinbach, MB
SPI Marketing Group, Saskatoon, SK
Unipork Genetics, division of UGG, Okotoks, AB

CHAIRMAN'S REPORT



Weldon Newton
Chairman of the Board

This is my first report as Chairman of the Board of Directors of the Prairie Swine Centre. As the first Chairman from outside of Saskatchewan it is very gratifying to see the continued financial support from producers across the prairie provinces for the research program at the Centre. It is with this substantial base of support that new, aggressive research talent can be attracted and maintained.

Indeed the Centre has gained a very positive profile amongst producers throughout Canada for developing and delivering relevant information. The findings from the last four years are particularly relevant this year as we search for ways to stretch our feed dollar further in the barn. The research community throughout other parts of the world has also recognized the abilities of our Centre and the technical expertise of researchers and support staff. This support is critical to continued progress and membership in the world community of pork production. Knowledge is a critical component of progress.

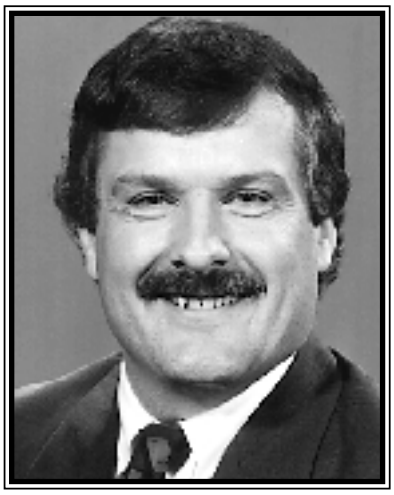
The swine industry continues to change at a rapid pace. This challenge will continue to keep leading edge research a key ingredient in the development of the Prairie swine industry.

The support of producers must continue to be earned and can never be taken for granted. This can only be achieved by continuing to provide sound new research results to producers on relevant issues for our industry. Economics and paybacks are two important considerations in the business of swine research.

We must continue our efforts to keep the Centre on a sound financial structure to ensure the strength of the research program can be maintained into the future. With that in mind the management will continue to seek out new partners who share the philosophy of progress through co-operation and are willing to contribute financially to working toward improved production technologies.

As we look toward the 21st century, the research and technology transfer programs will continue with its emphasis on the reduction in production costs. This will encompass the nutrition, animal behaviour, engineering and air quality programs. Our challenge as pork producers is to use these developments with an enthusiasm for progressive change.

PRESIDENT'S REPORT



Dr. John Patience
President

This is the fourth Annual Research Report published by Prairie Swine Centre Inc. since its restructuring in 1992. On behalf of all of the staff and students at the Centre, I am pleased to present this summary of experiments completed during the past year. We hope that the information is useful and practical, helping the industry to address issues of economic efficiency and sustainability as defined in our mission statement.

As in previous years, we are pleased to welcome contributions from faculty and students at the University of Saskatchewan, who report on research they carried out at the Centre during the previous year. This year, the Annual Report covers topics in nutrition, engineering, ethology and ethology.

Collaboration

In a world where capital is in short supply, no one organization can operate as an island. In the business world, companies respond by forming strategic alliances. In research, we call them collaborations. Whatever the name, joining forces and working in concert to achieve a common goal makes sense in every way. With the global pig industry advancing at an incredible rate, maximizing the industry's benefit from research is essential if we are to maintain our dominant position in the export market. As a research organization, we are very fortunate to be part of an industry that values technology and has an almost insatiable thirst for new information to increase profitability, improve product quality and safety and address such issues as animal welfare and the environment. In turn, we have a responsibility to use our resources as effectively as possible to provide information which can be utilized by the industry.

Research and technology transfer partners are critical to the success of Prairie Swine Centre Inc. For example, our relationship with the University of Saskatchewan is an important one; we are able to share resources and enhance each other's teaching and research programs. During the past year, the Prairie Swine Centre has been involved in collaborative activity with 7 of the University's 14 Colleges.

However, our partnerships go well beyond the local community, with formal arrangements with universities and federal research stations in other parts of Canada, the U.S., Europe and Australia. In every case, each institution brings to the collaboration its own strengths and capabilities. The concept of working together reminds me of the old saying "None of us is as smart as all of us!"

Funding

Because the Centre receives no "core" government funding, it is dependent on the grants received from various sources. The most critical to our success is that obtained from the pork producers. While government grants represent a substantial portion of our total funding, their support is often founded, directly or indirectly, on the demonstrated support of the pork industry.

The Saskatchewan pork producers, in particular, had the vision to support the renewal of the Prairie Swine Centre in the late 1980's; their ongoing support has allowed us to grow with support from pork producers in Alberta and Manitoba and from various government agencies. Almost one in four research dollars earned by the Centre now accrues from outside Canada.

New sponsors of our research and technology transfer efforts this year included the Alberta Agriculture Research Institute, the B.C. Hog Marketing Commission, Hillcrest Farms, Masterfeeds, Shamrock Feeds, Kenpal Farm Products and the TDK Corporation from Japan.

All of the staff at the Centre thank you for your support.

Staff changes

The past year has seen some important changes in our staff. Dr. Yuanhui Zhang, Research Scientist - Engineering, left the Centre to join the College of Engineering at the University of Illinois. As one of the top engineering colleges in the U.S., this was a tremendous opportunity for Yuanhui. Yuanhui brought to the Centre a strong work ethic, enthusiasm and humour; we wish him well in his new endeavours.

Dr. Stéphane Lemay, a graduate of Laval University, will join our staff as Research Scientist -Engineering, starting July 1, 1996. With a strong background in ventilation technology, particularly in expert systems design, Stéphane will bring new vision and ideas to our research program in engineering. One of his first functions will be to consult with the industry on the direction of our research program in engineering over the next 5-10 years.

In other movements, graduate students Allan Zhao and Xinlei Wang moved with Yuanhui to the University of Illinois to continue their graduate work there. Dr. Aki Tanaka, Post Doctoral Fellow completed his term at the Centre and accepted a post doctoral fellowship at Iowa State University.

Technicians Darryl Wurtz, Dave Junor and Heather Hockley also left the Centre during the past year. We wish them all well in their new positions. Term employees Tonia Ballantyne (secretary) and Yvonne Cranna and T.J. Hanson (technicians) filled important rolls at the Centre, helping to cover temporary demands in our work load. Each summer, the Centre recruits university students to assist with specific experiments or cover for our regular staff who take holidays. Last summer, Ryan Sullivan and Bryce Coutts helped out in many areas. At this time, I would like to recognize the important roll these staff members played in the success of the Centre over the past year.

During the past year, we welcomed four new employees to the Centre. Marney Korchinski and Scott Neis accepted positions as technicians, while Dr. Mark Lorschy joined the Centre as a post doctoral fellow, working on our amino acid project. Richard Scmidt was hired as a weekend casual.

Wim Gakeer, an engineering visiting student from the Netherlands, was instrumental in the design and testing of our new balloon-type manure lagoon cover.

Research

The Centre's research program maintains its focus on issues of economic efficiency and industry sustainability. A five year plan, developed by the original advisory board, has been the framework within which we work. Industry input into our research program is an important aspect of the management of the Centre.

Over the past year, research at the Centre has included nutrition studies aimed at reducing the cost of production, defining amino acid requirements more precisely and in a more globally-applied manner and in defining the true feeding value - and thus economic value - of local feed ingredients. Studies in ethology looked at feeder design and management, effective floor space utilization and the behaviour of gilts at the time of farrowing. Engineering research continued its focus on dust control management and the impact of such strategies on human health. The study of an inflatable slurry storage cover was also completed.

Production

One of the recommendations of the Advisory Board was that the Centre must be an efficient producer of pigs if it is to be a successful research organization. Brian Andries, Manager - Operations, and his staff have responded to this challenge by recording consecutive record increases in herd output. This year was no different, as more than 6,800 pigs were produced during the year. The fact that PSC used to produce less than 5,000 pigs per year during the late 1980's is testimony to the success of our production staff. The rapid advancement of the pig industry in Canada demands that the Centre keep pace in order to sustain its relevance.

The affect of the TGE outbreak in late March, 1995 worked its way through the Centre well into the current fiscal year. This was all carefully recorded and documented in a 12 page monograph published in the Spring, 1996. Copies of this report are available on request.

Technology transfer

Technology transfer is a very important component of the Centre's overall activities. Lead by Lee Whittington, Manager - Information Services, two new events initiated in 1995 were expanded in 1996. The highly successful Satellite Conference went national and the charter trip to the World Pork Expo was expanded, from 3 days to 4 and from one plane to two. The second edition of the Swine Nutrition Guide was also released. It was another busy year in technology transfer.

The central role of technology transfer projects at the Centre is not a coincidence. Not only does it ensure that research results are communicated to the farming community, but it also fills a second, equally important roll; Ongoing contact with the pork industry provides feed-back on our existing research program and on future needs. Thus, technology transfer, as practiced at PSCI, is a form of *two-way* communication that seeks to keep information moving from the Centre to the industry, as well as from the industry to the Centre.

Consulting

Following a study on fee-for-service consulting completed last year, the Centre initiated consulting services to the pork industry. It was done in a relatively simple manner with little fanfare. However, it was clear that on occasion, pork producers, agribusiness or government would like to access the Centre's expertise to address very specific issues of direct importance to their particular situation. Whereas our technology transfer program is responsible for communicating the results of our research to the industry, consulting focuses on more situation-specific questions.

Fees earned from consulting are used by the Centre to enhance its research and technology transfer efforts. For example, the funds may be used to purchase or lease research equipment, hire temporary staff or fund graduate students. Thus, consulting will hopefully benefit our research program. It helps in other ways as well. Such one-on-one consulting provides our scientists with the opportunity to become more familiar with the industry, which in turn contributes to a more relevant, dynamic research program. While there are only so many hours in a day, increased contact between the Centre and the industry benefits everyone.

Strategic plan

As reported last year, the Centre embarked on a review of its Strategic Plan. The original plan, developed by the Advisory Board in 1989, was due for review, to determine its current relevance and to identify necessary changes in the operation of the Centre. Following consultation with the industry, a revised plan has now been adopted by our Board of Directors.

No major changes were identified, but the new Strategic Plan places renewed or increased emphasis on the depth and breadth of our research program and on maintaining the kind of research herd and facilities needed to achieve our research objectives. Technology transfer will remain a key part of the Centre, but more emphasis will be placed on the adoption of new technology as opposed to simply communicating research results. Participation in the development of human resources for the pig industry is maintained, as is our internationally active and contract research program. The Plan directs us to ensure a strong and healthy financial position for the Centre. Last but certainly not least, the Strategic Plan directs us to maintain a strong team approach to our organization, to ensure that we maximize the contribution of all of our staff to the achievement of our goals and objectives in research, education and technology transfer.

Board of Directors

The Board of Directors represents a key link between the Centre and the people and organizations we serve. Their role can never be under-estimated, so it is only appropriate that we recognize their volunteer contribution to the Prairie Swine Centre.

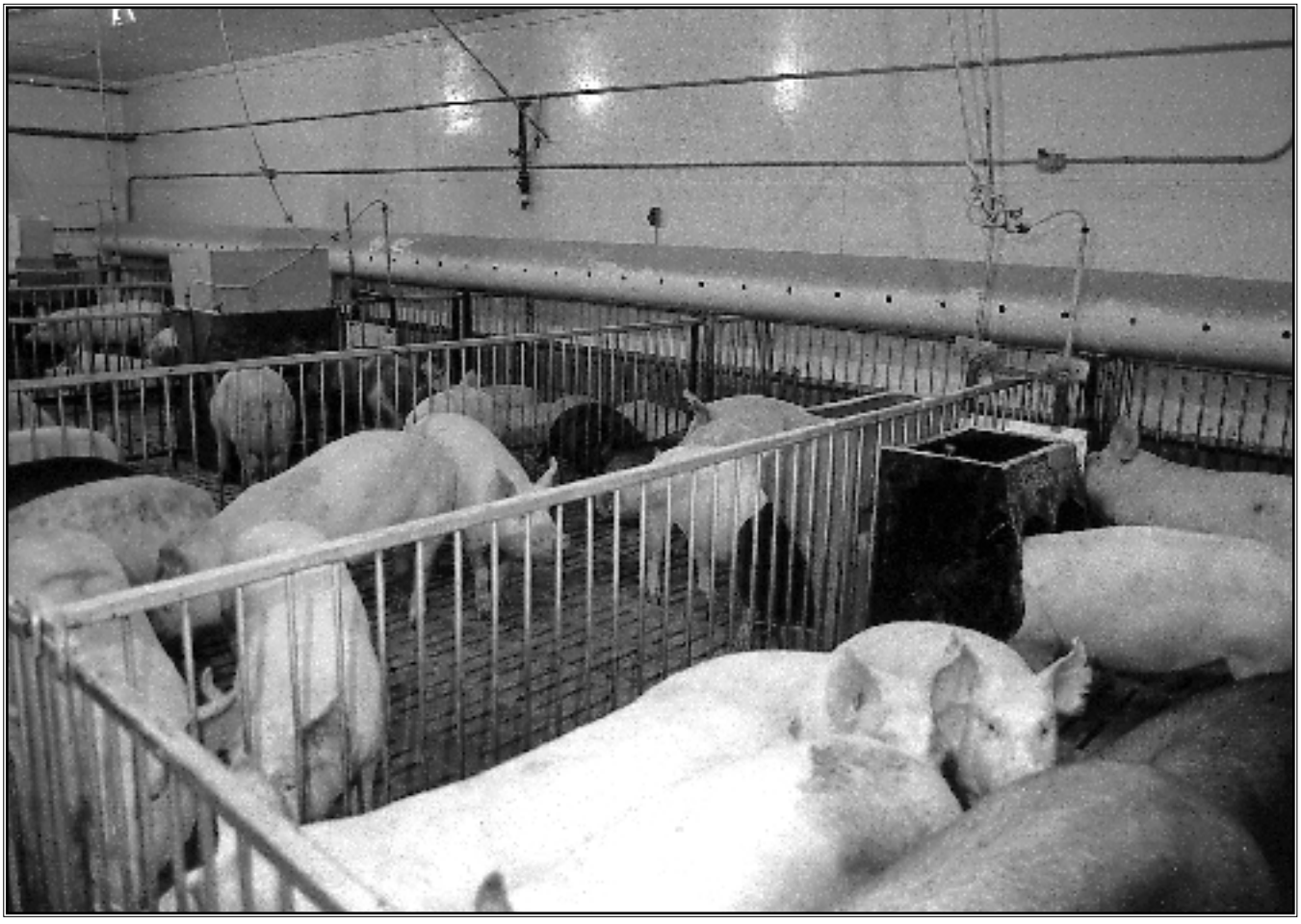
During the past year, we welcomed three new Directors. Mr. Wayne Vermette replaced Dr. Harold Fast as one of the 4 producers on our Board. Wayne has been associated with the Saskatchewan pork industry for more than 20 years and most recently is a partner in Quadra Management, Outlook, SK.

Mr. Jim Smith replaced Mr. Bill Devereux. Jim also has a long and distinguished career in the Alberta and Canadian pig industry, having served as Chairman of the Alberta Pork Producers Development Corporation and is currently Chairman of the Canadian Pork Council. Jim farms near Innisfail, AB.

The third new Director is Mr. Cam Henry, a certified seed grower from Oak River, MB. He replaces Mr. Roy Piper of Elrose, SK. Cam is active in many farm organizations, including the Western Grains Research Foundation. As such, he brings to our Board a strong background in the grains industry and its research needs.

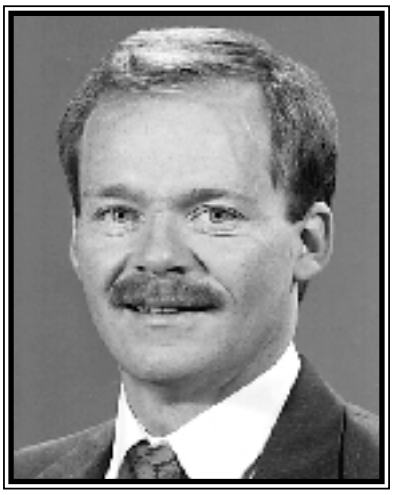
Mr. Weldon Newton was elected to Chair the Board of Directors, replacing Harold Fast who had been Chair since the Board's inception.

Because the Directors all serve as volunteers, and are very busy people in their own right, I would like to recognize their contribution to the Centre and thank them for their input.



Market hogs in one of the 'engineering' rooms at Prairie Swine Centre

INFORMATION MANAGER'S REPORT



Lee Whittington
Manager-Information Services

The past year has seen an expansion of technology transfer activities across western Canada and beyond. This year marks the third year of publication of the quarterly newsletter Centred on Swine. This 6 page newsletter goes out free to pork producers in western Canada as an on-going reminder of how research can be applied on the farm. Many supplier businesses and extension personnel also get the newsletter to use as part of their efforts to improve the profitability and sustainability of commercial pork producers. The newsletter is also available on a subscription basis and is read by producers and the industry across Canada and in many other parts of the world. Since the newsletter's inception it has grown to a circulation of nearly 5000.

This fourth Annual Research Report focuses on the details of various research programs carried out at the Centre during the past year. The easy reading style combined with the author's ideas for present and future applications provides producers with an insight on how to transfer this new technology to their farm.

Personal contact is still the preferred method of technology transfer in the industry. This is accomplished through daily phone contact between myself or the research scientist and pork producers. This year electronic mail via the Internet has become a more important method of communication within the industry. The Centre launched its first home page on the world wide web in January 1996. This has spawned a number of inquiries from within Canada and beyond. We receive about one e-mail a day as a direct result of the home page. Come and visit us at www.lights.com/psc

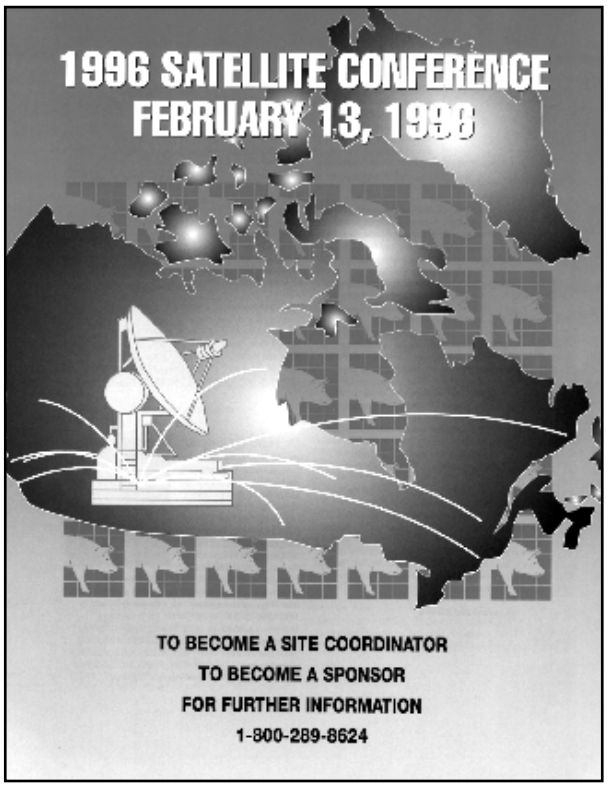
In February 1996 the second annual Satellite Conference went national. With over forty conveniently located sights across Canada the conference became the largest one day swine conference in Canada with over 800 participants. The conference has become our flagship event, introducing the newest research available to commercial pork producers. The satellite conference has also become an effective forum for discussing issues relevant to the industry that are shared in all areas of the country. This year three farm manager/owners shared their views on personnel management. Following the presentations the phone lines were opened and participant views were added to the mix.

The coming year will see all of these activities continued. The continual evolution of the industry is being addressed with an increased emphasis on the application and not just the transfer of technology. By working closely with the various agencies and corporations in the industry the Centre attempts to have new technologies adopted by the largest possible number of producers. Through the development of written materials and the sponsorship of special events such as the World Pork Expo Tour, the Centre hopes to increase the speed of adoption of new technologies that improve the profitability and sustainability of the industry.

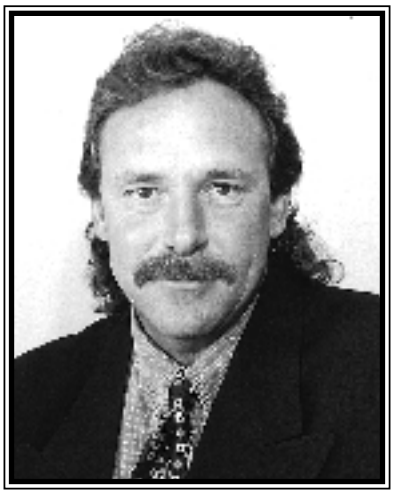
Thanks to the Following Cooperators and Volunteers

British Columbia Ministry of Agriculture, Fisheries and Food
British Columbia Hog Commission
Alberta Agriculture, Food and Rural Development
University of Alberta
Alberta Pork Producers Development Corporation
Saskatchewan Department of Agriculture and Food
Pork Implementation Team
SPI Marketing Group (Saskatchewan
Manitoba Pork Est.
Manitoba Department of Agriculture
Ontario Pork Producers Marketing Board
Ontario Ministry of Agriculture, Food and Rural Affairs
Universite Laval, Quebec
Centre de Developpement du Porc du Quebec Inc.
P.E.I. Department of Agriculture
P.E.I. Hog Commodity Marketing Board
Nova Scotia Department of Agriculture
Newfoundland Department of Fisheries, Food and Agriculture

We would also like to thank all the individuals and businesses that helped to organize a local site.



OPERATION MANAGER'S REPORT



Brian Andries
Operation Manager

Production is an important part of my responsibility as Manager -Operations at the Prairie Swine Centre. The Centre's production, however, is viewed by myself and all staff as a means to an end. It is there to ensure that an abundance of quality animals are on hand at all times for research purposes.

To gain the respect of the industry, however, we have to strive for productivity that is comparable to the top herds in Western Canada. Good production assists in demonstrating that ongoing research carried out at the Centre is relevant to our industry.

The scheduling of animals and rooms in preparing start up procedures for Internal, External, and Contract Research is an important part of my daily activities. This maximizes the utilization of animals and physical facilities and the amount of quality research that can be carried out at the Centre. Animal schedules are updated weekly, so that at a glance, we are able to look at any farrowing group (sows to farrow in a weekly period and their progeny), and know exactly to whom, and what project animals should be assigned. Room schedules are handled similarly. Each room is assigned to a particular researcher and experiment for a period of time according to the type of trial (sows, nursery, growing - finishing).

Daily time summaries are used to determine the exact amount of time staff spend on any particular research project or on a production activity. With this information, we can more properly estimate the length of time it will take to complete any activity for a particular type of research project. Thus, this helps in estimating costs of future experiments.

As technical support staff and production personnel assist each other on certain projects, time summaries also assist the Researcher in determining how much labor each one of the projects is taking to complete.

Regarding animal production, in the new fiscal year, we will focus on improving certain production parameters such as conception and farrowing rates. Production staff will be trained, with the help of staff at the Western College of Veterinary Medicine, to evaluate boar semen. Every six months, we will be looking at concentration rates, motility, and morphology, on semen samples taken from all boars at the Centre. As we dual mate, it is hard to evaluate boar performance from observed matings, so this will assist in boar evaluations.

Finally, the table below summarizes the production averages for this fiscal year and the previous:

	95/96	94/95
Number of sows farrowed	712	634
Farrowing rate %	89.7	86.7
Average pigs born alive/litter	11.0	11.1
Number of litters weaned	702	648
Total pigs weaned	7060	6310
Pigs weaned/female inventory	24	22.9

FIVE YEAR OBJECTIVES

The five year research program of Prairie Swine Centre Inc. has five main objectives, and broadly covers the areas of nutrition, engineering and behaviour. In detail the objectives are as follows:

Objective 1:

To define optimum feeding and management procedures to reduce the cost of feeding out grower-finisher pigs (20 kg to market) by at least $2.00 per head. Feed is the single largest expense in commercial pork production; there is tremendous opportunity to significantly reduce the cost of production by defining cost-effective feeding strategies that focus on the biology of the pig. Optimum nutrition at the least cost occurs when we are neither overformulating nor underformulating diets. Projects in this area include investigation into phase feeding, split sex feeding and defining requirements based on lean tissue growth rates (genetics).

The underlying objective here is the development of feeding programs that focus on maximizing net profit as opposed to maximizing average daily gain or achieving the best index.

Objective 2:

To increase the value and use of opportunity feeds in swine diets. In order to increase the use of locally grown commodities as ingredients in practical swine diets, the feeding value or the levels of available nutrients in these opportunity ingredients will be determined in digestibility studies. The maximum inclusion rate of opportunity ingredients in swine diets will also be determined using feed intake and animal performance studies. Again, the objective is to maximize net income. The central question will be "how can these ingredients be used effectively to reduce the overall cost of production?" rather than "how much can be added to the diet without affecting performance?"

Objective 3:

To develop animal care guidelines through consideration of animal behaviour. The evolving science of animal behaviour will be used to determine how the physical and social environment affects the productivity and well-being of the pig. The underlying objective is to define management procedures that are good for both pigs and people.

Objective 4:

To improve the air quality of hog barns for both pigs and people. Air quality within swine building airspaces is important in establishing the productivity, health and well-being of animals and the health and well-being of operators. The contaminant concentration within the barn will be measured, the rates of generation and spatial distribution of contaminants will be modeled, and control strategies to improve the air quality will be developed.

Objective 5:

To reduce the costs of production by optimizing the physical environment in commercial barns. Currently, pork producers spend large amounts of money to build and operate facilities in order to achieve a certain interior barn environment. Optimizing this physical environment will avoid the cost of over-building while at the same time identifying weaknesses in our current designs. These studies will help to bring together the true needs of the pig (e.g. temperature, humidity, space, etc.) and the construction and operating specifications of the barn.

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BIOLOGICAL VARIABILITY & CHANCES OF ERROR

Variability among 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 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 "1 chance in 20" or 5%. If two averages are said to be "significantly different", the probability is less than "1 chance in 20" (5%) that the difference is from chance, or the probability exceeds 95% that the difference resulted from the treatments applied.

Some papers contain 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 correlation the relationship 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.

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Technician Colin Petersen weighs feed into feeder in one of the 'engineering' rooms

A FACTORIAL APPROACH TO PREDICTING ENERGY AND LYSINE REQUIREMENTS BASED ON WHOLE BODY PROTEIN DEPOSITION RATES

Mark L. Lorschy and John F. Patience.

SUMMARY

By partitioning the pig's requirements for energy and amino acids into meaningful components, for example, into those associated with the digestion of food and the deposition of carcass protein, it is possible to make accurate predictions about whole body energy and amino acid requirements.

This simple approach enables quick calculations of requirements on a computer spreadsheet which will reduce over-formulation, thus reducing feed costs and reducing nitrogen wastage.

To employ this useful technique on individual farms, it is necessary to gain information about the potential carcass protein deposition rates and the degree to which a minimal amount of fat is inevitably deposited in the carcass. Current research both at the PSCI and at other research stations is addressing these issues for genotypes used in Canada.

In this paper, an example is given which details the calculations involved in estimating requirements for lysine and energy for barrows and for gilts grown from 24 to 120 kg liveweight. In this example, it is shown that differences in protein deposition between barrows and gilts change the requirements for lysine and energy. For a given feed intake, it is important to adjust the concentration of lysine and energy to meet the requirements for this growth.

INTRODUCTION

There are two methods used to defining nutrient requirements. The traditional method, often called the "empirical" method, involves the use of many experiments to identify the level of nutrient which maximizes performance. The "factorial" approach, on the other hand, employs a deeper understanding of how nutrients are used by the pig, breaking it down into individual components.

For example, we know that energy is used by the growing pig to maintain basic body functions (maintenance) as well as support growth. By summing the energy required for maintenance with that required for growth, one can estimate to total quantity of energy required by the pig.

The factorial approach has been around for many years and is gaining greater acceptance for a number of reasons. For example, the empirical approach may only provide information useful under conditions used in the experiments. If conditions on the farm differ from the experimental conditions, the results may not hold. If sufficient information is available, the factorial approach generates information that can be adapted to a wide range of conditions, including different genetics. Also, the factorial approach is complementary to growth simulation models, which will become more common in the future. Thus the factorial approach is more adaptable, but will only be as accurate as the data used to generate the final requirements.

In this paper, we will give an example of how lysine and energy requirements can be estimated for growing and finishing pigs. Five weight categories (24 to 56 kg, 56 to 72 kg, 72 to 88 kg, 88 to 104 kg and 104 to 120 kg) will be included, to provide examples of how phase feeding programs are developed. These factorial estimates of the energy and lysine requirements of growing and finishing pigs are derived through a knowledge of protein and lipid deposition rates.

Lysine Requirements

Dietary lysine is used for both maintenance and for growth. Maintenance refers to the lysine used for normal daily protein turnover plus inevitable losses from the intestinal tract due to normal digestive processes. The lysine required for maintenance is generally expressed on the basis of the body weight of the pig.

The lysine required for growth will be dependent on the rate of protein deposition, and is based on the portion of body protein deposited which is lysine, adjusted for the efficiency with which lysine is used

for this purpose. Accordingly, the digestible lysine (Lys_i) requirements can be expressed using the following function:

$$Lys_i = Lys_m + \frac{(PD.Lys_p)}{e}$$

Parameters:

Lys^m - The quantity of lysine used for daily maintenance, calculated as 0.036 g/kg $LW^{0.75}$

PD - The rate of protein deposition, expressed in grams per day (g/d)

Lys_p - The lysine content of body protein, calculated as 6.6% (0.066 g/g)

e - The efficiency with which lysine is used to produce body protein, estimated to be 58% (0.58)

Notice that body weight is expressed as a fraction of metabolic body weight (LW0.75) rather than simple body weight (LW). This is quite common in such calculations, because many studies have shown that it provides a better estimate of metabolic function of the body.

Energy requirements

Energy is used for maintenance needs, such as activity and respiration, and to drive the many metabolic functions that keep the pig alive. Maintenance energy requirements are typically calculated as being 109 kilocalories divided by the metabolic bodyweight (i.e. liveweight to the power 0.75).

Production energy needs are based on the quantities of protein and lipid deposited and the respective efficiencies with which energy is used for each. Accordingly, the metabolizable energy (ME) requirements of the growing pig can be expressed using the following function:

$$ME_i = ME_m + \frac{1}{k_p}.PD.GE_{PD} + \frac{1}{k_f}.LD.GE_{LD}$$

Parameters:

ME_i - The level of metabolizable energy (ME) required per day, expressed in kilocalories (kcal/d)

MEm - The maintenance energy requirement, calculated as 109 kcal ME/kg LW0.75 and expressed in kilocalories per day (kcal /d)

kp - The efficiency with which energy is used to deposit body protein. Estimated to be 54% (0.54)

kf - The efficiency with which energy is used to deposit body fat. Estimated to be 74% (0.74)

GEPD -The gross energy contained in body protein, estimated to be 5.67 kcal/g

GELD -The gross energy contained in body lipid, estimated to be 9.46 kcal/g

RESULTS AND DISCUSSION

Predicted Requirements for Lysine and Energy in a Case Study

The energy and lysine requirements were calculated according to the above equations for each of the five different weight classes (Table 1). The lysine requirement closely resembled the rate of protein deposition, reflecting the fact that most of the amino acids in the diet are used for growth as opposed to maintenance. It therefore is no surprise that the differences in lysine requirement between genders was predominately due to differences in protein deposition rate. As the animals became heavier, the maintenance requirement became larger.

The barrows had higher energy requirement due to their higher rates of protein and lipid deposition.

For pigs below 50 to 60 kg live weight, the Lysine:Energy ratio is often used as a basis for diet formulation, because energy intake is limiting the rate of protein deposition. This ratio was estimated to be 2.60 and 2.87 g/kcal for barrows and gilts, at 24 kg liveweight, respectively.

Above 50 to 60 kg, it is generally understood that the pig can adjust feed intake enough to meet its energy requirements. The digestible lysine requirement changed from 15.9 to 11.2 g/d for barrows and 15.7

to 12.4 g/d for gilts, when grown from 56 to 120 kg liveweight. At the liveweight range where the pigs deposited their highest levels of protein (56 to 72 kg), the digestible lysine requirement was estimated to be 15.9 g/d for barrows and 15.7 g/d for gilts.

These estimated lysine requirements were compared to those determined following a detailed literature review by Dr. Brian Kerr (Biokyowa). As illustrated in Figure 1, both approaches revealed very similar requirements.

Variation in feed intake has a profound impact on the percentage of digestible lysine required in the diet in order to meet the pig's daily requirement (Table 2). For example, for barrows at 56 kg liveweight, when feed intake varies from 80 to 110% of that predicted by the NRC (1988), lysine (%) changes from 0.79 to 0.57%! The difference in the cost of these two diets is enormous, in the range of 10% or $20 per tonne at current feed prices. A difference of $20 per tonne is equivalent to about $5 per pig sold. It is therefore emphasized that an actuate estimate of feed intake is needed to ascertain the inclusion level of lysine (and other amino acids) in the diet.

IMPLICATIONS

Lysine and energy requirements may, and indeed, should be estimated based on protein deposition rates. While such information is not yet readily available, the trends in the pig industry suggest that it will become more common in the future. As progress in this area is achieved, diet formulation will become more precise and net income maximized.

Acknowledgments

This authors wish to acknowledge that funding for this project was provided by the Archer Daniels Midland Company who also kindly provided crystalline amino acids and amino acid analysis for this project.

Table 1. Factorial approach to estimating daily digestible lysine (g/d) and energy requirements (Mcal ME/d) to meet the observed liveweight (kg), protein (g/d) and lipid (g/d) deposition for barrows and gilts grown between 24 and 120 kg liveweight (kg).

Liveweight	Lysine for maintenance	Protein deposition rate	Lysine for protein deposition	Total lysine need	Maintenance energy need	Lipid deposition rate	Energy needs	Ratio of lysine and energy needs
Barrows								
24-56	0.57	138	15.70	16.28	1.74	225	6.27	2.60
56-72	0.81	140	15.93	16.75	2.48	341	8.61	1.95
72-88	0.96	128	14.57	15.53	2.93	398	9.71	1.60
88-104	1.10	115	13.09	14.19	3.36	405	10.11	1.40
104-120	1.24	98	11.15	12.39	3.77	382	10.06	1.23
Gilts								
24-56	0.57	128	14.57	15.14	1.74	158	5.27	2.87
56-72	0.81	138	15.70	16.52	2.48	262	7.53	2.19
72-88	0.96	133	15.13	16.10	2.93	317	8.68	1.85
88-104	1.10	119	13.54	14.65	3.36	368	9.66	1.52
104-120	1.24	109	12.40	13.64	3.77	411	10.56	1.29

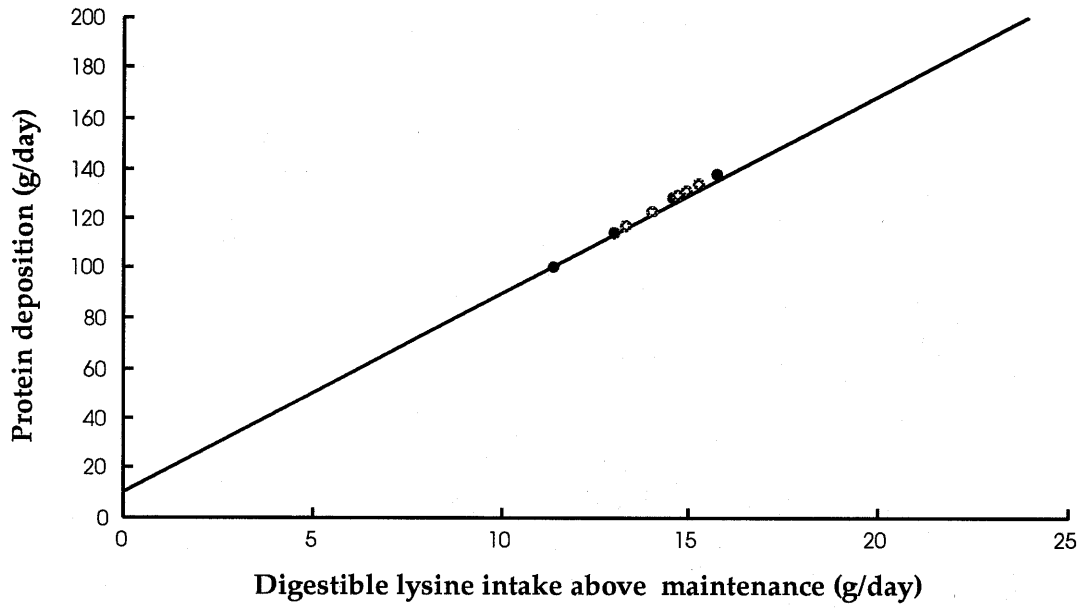
Table 2. Percentage of digestible lysine required in the diet to meet the requirements for protein deposition and maintenance as observed for pigs grown between 24 and 120 kg liveweight (kg) when feed intake is between 80 and 110% of that predicted by National Research Council (1998)

Liveweight (kg)	Feed intake (% NRC, 1988)			
	80	90	100	110
Barrows				
24-56	1.05	.93	.84	.76
56-72	.79	.70	.63	.57
72-88	.65	.58	.52	.48
88-104	.55	.49	.44	.40
104-120	.46	.41	.37	.39
Gilts				
24-56	.97	.87	.78	.71
56-72	.78	.69	.62	.56
72-88	.68	.60	.54	.49
88-104	.57	.51	.46	.42
104-120	.50	.45	.40	.37

Energy content of diet fed is 3421 kcal DE/kg.

Figure 4 Comparison of information for a literature survey (B.J. Kerr, 1992, Optimizing lean tissue deposition in swine. Biokyowa Technical Reviews - 6) and estimated relationships between digestible lysine requirements (g/d) and whole body protein deposition. Relationship for barrows (●) and gilts (❍) for the case study in this paper are included.

Regression line given by:
Protein deposition = 7.905 (s.d. 2.547) x lysine needs above maintenance + 10.499 (s.d. 16.331)



IMPACT OF PRE-SLAUGHTER WITHDRAWAL OF VITAMIN SUPPLEMENTS ON PIG PERFORMANCE AND MEAT QUALITY

John F. Patience and Doug Gillis

SUMMARY

Research reported in last year's Annual Report indicated that withdrawal of vitamin and trace mineral supplements 35 days before marketing had no impact on animal performance or carcass merit. The present experiment was conducted to further investigate the opportunity of increasing net income through revised diet supplementation strategies.

Three pens of barrows and three of gilts were assigned to one of three treatments: a control diet with "normal" levels of vitamin supplements, the same diet with vitamin supplements removed or the same diet with vitamin supplements tripled. Pigs received these diets for 35 days prior to marketing, during which time, performance was monitored, and after which, carcass merit was recorded and muscle vitamin levels determined.

Withdrawing vitamins had no impact on animal performance or carcass merit. However, muscle thiamine content was reduced and intramuscular lipid content was increased. Tripling vitamin supplementation had no impact on performance or carcass merit, but increased muscle riboflavin content.

The withdrawal of vitamins and trace minerals appears to be a viable commercial practice, at least in some circumstances. Savings in the range of $0.80 to $1.80 per pig may be achieved, depending on the current cost of supplementation. However, caution is advised when replacement breeding stock are involved. Withdrawal of vitamins and trace minerals under these conditions was not addressed in the present study.

INTRODUCTION

Financial success in pork production requires attention to all aspects of the production budget, with feed being by far the largest single component. Situation-dependent feed formulation, wherein feeding programs are designed to achieve success under specific environmental, genetic, health and economic conditions, represents one approach to maximizing net income. In this scenario, nutrients are supplied to the pig in quantities that, as much as possible, meet, but do not exceed, its requirements. Adding additional quantities as a "safety margin" represents an additional cost that may not be necessary, at least not in the size and scale that has often been practiced in the past.

The pig's requirement for vitamin and trace mineral supplementation has received less attention in recent years, following a flurry of activity in the four decades following the second World War. It is now time to reconsider supplementation strategies, in light of a rapidly changing pig industry and a more sophisticated approach to diet formulation. The current experiment had three objectives: 1) to further investigate the impact on pig performance and production economics of the removal of supplemental vitamins and trace minerals during the late growout period, 2) to determine the impact of withdrawing supplemental vitamins during the late growout period on carcass and meat quality, and 3) to determine if increased vitamin supplementation will result in improved performance or pork quality.

EXPERIMENTAL PROCEDURES

The three dietary treatments are summarized in Table 1. The estimated vitamin supplementation levels are summarized in Table 2. The control treatment provided a basic level of vitamin and trace mineral supplementation. In Treatment 2, all vitamin supplements were removed for the final 35 days before marketing; trace mineral supplementation was maintained as per the control treatment. In Treatment 3, vitamin supplementation levels were tripled, relative to the control treatment for the final 35 days prior to marketing; trace mineral supplementation was maintained as per the control treatment.

There were three pens of five barrows and three pens of five gilts on each diet, for a total of 30 pigs per treatment.

All pigs were housed in a confinement-type barn with fully-slatted concrete floors and PVC planking pen

dividers. Pigs were maintained in groups of five in pens providing 0.8 m^2 floor space per pig. The pigs had ad libitum access to feed from a single-space dry feeder; water was continuously available via a nipple drinker. Individual body weights and pen feed intake were recorded weekly for the full 35-day test period, at which time all pigs were marketed. Federal grading carcass measurements were recorded by sex and by treatment for all pigs marketed.

A subsample of 15 pigs (five per treatment) were processed at a smaller abattoir to facilitate collection of longissimus dorsi muscle samples, which were subsequently assayed for moisture, fat, pantothenic acid, thiamine, riboflavin and niacin content.

RESULTS AND DISCUSSION

The removal of vitamin supplements from the diet of market hogs for the last five weeks before marketing had no adverse effect on performance (Table 3) or on carcass merit (Table 4). Tripling the levels of vitamin supplements had no effect on animal performance or on carcass merit. As expected, gilts grew at the same rate as barrows, but had a lower feed intake and better feed conversion (Table 5). Compared with barrows, gilts also had less fat and a higher percent lean yield (Table 6).

Altering vitamin supplementation rates did affect selected muscle vitamin levels (Table 7). The removal of supplemental vitamins lowered L. dorsi muscle thiamine content ($P < 0.05$); conversely, increasing vitamin supplementation rates did not elevate muscle thiamine ($P > 0.05$), but did cause muscle riboflavin to rise. Lowering vitamin supplementation rates resulted in an increase in intramuscular lipid ($P < 0.05$); elevating vitamin levels, however, did not reduce muscle lipid content.

Based on these results, as well as those reported previously, the removal of supplemental vitamins and trace minerals has no impact on performance or on the standard indices of carcass merit.

The impact of vitamin supplementation on such quality traits as drip loss and shelf life was not evaluated. While there is considerable interest in extending shelf life of pork through vitamin E supplementation, the levels generally employed to achieve success are much higher than those used in the commercial pig industry. We would consider the use of vitamin E supplements to achieve increased shelf life to be a separate and specific topic which should be addressed on its own merit.

With respect to the implementation of this strategy into commercial practice, there is one note of caution. If animals are being kept for breeding purposes, the removal of vitamins and trace minerals is not recommended presently.

IMPLICATIONS

The exact savings achieved by implementing the results of this experiment, will, of course, depend on the current level and cost of supplementation. We estimate that vitamin and trace mineral supplementation typically costs $8 to $15 per tonne of finished feed; therefore, assuming pigs consume 100 to 120 kg of feed during the final five weeks before marketing, savings in the order of $0.80 to $1.80 can be expected.

Table 1. Experimental diets

	Control	No vitamin supplementation	3 x vitamin supplementation
Ingredients, % as fed			
Wheat	38.00	38.00	38.00
Barley	45.70	46.00	45.10
Soybean meal - 47%	8.00	8.00	8.00
Canola meal	5.00	5.00	5.00
Limestone	1.00	1.00	1.00
Dicalcium phosphate	0.70	0.70	0.70
Salt	0.40	0.40	0.40
Lysine HCl	0.08	0.08	0.08
Vitamin premix	0.30	-	0.90
Mineral premix[1]	0.30	0.30	0.30
Pellet binding agent	0.02	0.02	0.02
Oil	0.50	0.50	0.50
Nutrients, estimated			
D.E., kcal/kg	3210	3210	3210
Lysine - total, %	0.76	0.76	0.76
Lysine - digestible, %	0.59	0.59	0.59
Threonine - digestible, %	0.38	0.38	0.38
Tryptophan - digestible, %	0.15	0.15	0.15
TSAA - digestible, %	0.50	0.50	0.50
Calcium, %	0.60	0.60	0.60
Phosphorus - total, %	0.52	0.52	0.52
Phosphorus - available, %	0.27	0.27	0.27
Sodium, %	0.18	0.18	0.18
Chloride, %	0.32	0.32	0.32

[1] Provided per kg of diet: copper, 30 mg; iron, 48 mg; manganese, 15 mg; zinc, 60 mg; iodine, 0.3 mg; selenium, 60 μg.

Table 2. Estimated vitamin supplementation levels employed

	Control	No vitamin supplementation	3 x vitamin supplementation Control
Vitamin A, IU/kg	4950	0	14,850
Vitamin D3, IU/kg	495	0	1,485
Vitamin E, IU/kg	24	0	72
Menadione, mg/kg	2.4	0	7.2
Thiamine, mg/kg	0.6	0	1.8
Riboflavin, mg/kg	3	0	9
Niacin, mg/kg	21	0	63
Panthothenic acid, mg/kg	9	0	27
Vitamin B12, μg /kg	15	0	45
Biotin, μg /k g	120	0	360
Folic acid, mg/kg	1.2	0	3.6

Table 3. Impact of vitamin supplementation level on pig performance

	TREATMENT			SEM	P value
	Control	No vitamin supplementation	3 x vitamin supplementation		
Initial weight, kg	79.9	80.1	79.4		
Days on test	35	35	35		
Ave. daily gain, kg	0.897	0.915	0.880	0.023	0.96
Ave. daily feed, kg	3.220	3.203	3.157	0.053	0.71
Feed conversion	0.282	0.303	0.275	0.008	0.09

Table 4. Impact of vitamin supplementation level on carcass merit

	TREATMENT			SEM	P value
	Control	No vitamin supplementation	3 x vitamin supplementation		
Dressed wt., kg	90.8	89.1	88.0	1.6	0.48
Estimated yield, %	58.8	60.0	59.2	0.5	0.18
Fat thickness, mm	23.4	21.0	21.9	1.1	0.30
Loin thickness, mm	59.4	62.2	58.9	1.2	0.13

Table 5. Impact of gender on pig performance

	Barrows	Gilts	SEM	P value
Ave. daily gain, kg	0.899	0.895	0.023	0.89
Ave. daily feed, kg	3.356	3.030	0.043	0.01
Feed conversion	0.283	0.330	0.009	0.02

Table 6. Impact of gender on carcass merit

	Barrows	Gilts	SEM	P value
Dressed wt., kg	89.5	89.1	1.4	0.82
Estimated yield,%	58.6	60.1	0.4	0.008
Fat thickness, mm	24.2	20.0	0.9	0.002
Loin thickness, mm	59.2	61.0	1.0	0.19

Table 7. Effect of vitamin supplementation on the levels of selected vitamins

	TREATMENT			SEM	P value
	Control	No vitamin supplementation	3 x vitamin supplementation		
Water, %	73.49	73.34	73.76	0.32	0.66
Lipid, %[1]	2.03[a]	3.27[b]	2.47[ab]	0.34	0.04
Fresh weight basis, mg/100g					
Thiamine[1]	1.90[a]	1.52[b]	2.05[a]	0.10	0.01
- Riboflavin[1]	0.14[a]	0.13[a]	0.16[b]	0.01	0.02
- Niacin	9.57	8.52	10.16	0.67	0.27
- Pantothenic acid	0.86	0.80	0.89	0.06	0.59

[1] Means within a row with different superscripts differ, $P < 0.05$.

ESTIMATION OF THE ENERGY CONTENT IN BARLEY

IMPROVING THE CHARACTERIZATION OF ENERGY VARIABILITY IN WESTERN CANADIAN BARLEY

Shawn L. Fairbairn and John F. Patience

SUMMARY

Barley is the main cereal grain used by the pork industry in western Canada and thus is a primary source of energy in the pig's diet. However, the level of digestible energy (DE) in barley can vary by as much as 8 - 12%, due to genetic, nutritional and environmental factors. This degree of variation complicates feed formulation, particularly when one considers that most commercial diets are formulated, theoretically, to within 50 kcal DE, or about 1.5%! A better understanding of this variability will improve the accuracy of feed formulation.

A digestibility study is underway to determine the levels of DE provided by 20 different barley samples; five varieties were chosen for this project. We conducted an industry survey to determine which varieties should be represented. Differences in feed vs. malt, two- vs. six-row and importance in the swine industry across the Prairies were all considered. Four samples of each variety were obtained from Alberta, Saskatchewan and Manitoba in an effort to obtain a cross-section of the selected cultivars. Factors which influence nutritional quality, such as soil zone, climate and test weight were also used as criteria to select individual barley samples.

Extensive chemical and statistical analyses will be employed to develop a method to accurately estimate the DE of a particular barley sample. This knowledge will enhance the most effective utilization of barley in swine diets and facilitate the marketing of barley on a more value-based system instead of bushell weight alone.

EXPERIMENTAL PROCEDURE

This study is currently in progress. The following is a summary of the procedures which have or will be utilized to achieve our objective. Table 1 shows the five barley varieties chosen for this experiment. All varieties are hulled and found throughout the Prairies except Bedford. This six-row variety is only grown in Manitoba, but is still used extensively in swine feeding and was therefore included in this project.

A total of 60 barrows were selected at an average live weight of 35 kg for use in the digestibility trial. The pigs were housed in metabolism crates to allow for sample collection. All twenty varieties were fed five times to different pigs to provide a total of 5 observations per treatment. Feed intake was maintained at a constant level for all pigs to achieve an energy intake equal to 2.5 x maintenance. Feed, faecal, and urine samples were collected over five day periods.

Feed, faecal and urine samples were collected in order to determine gross, digestible, and metabolizable energy contained in each barley sample. Feed and faecal samples will also be used to determine the digestibility of certain nutrients contained in the barley grain, such as protein, lipids, starch, sugars and several different types of fibre.

Statistical analysis will be required to derive prediction equations which will relate energy content to other more easily measured quality characteristics. These prediction equations can then be utilized by the pig industry to achieve value-based pricing systems for the trading of feed barley.

IMPLICATIONS

An improved understanding of, and ability to estimate, the energy variability in barley will make it possible to more precisely formulate pig diets, avoiding costly over-formulation while at the same time ensuring minimum requirements are met. This increased accuracy in feed formulation will result in a reduction in feed costs, improved carcass uniformity and decreased amounts of wasted nutrients in the slurry.

Table 1. Sample location, soil zone, and official grading results of the barley varieties selected for analysis.

Barley Variety	Location of Sample	Soil Zone	Official Grade[a]	Dockage (%)a	Test Weight (Kg/hl) [a]	Official Bushel Weight (lb/bu) [a]	Unclean Bushel Weight (lb/bu) [b]
AC Lacombe #1	Lacombe, AB	black	1 CW	0.3	61.3	49.2	49.7
AC Lacombe #2	Melfort, SK	black saline	2 CW	1.0	55.7	44.7	39.6
AC Lacombe #3	Melfort, SK	black	Extra 1 CW	0.4	65.1	52.2	51.6
AC Lacombe #4	Binscarth, MB	black	1 CW	0.3	60.0	48.0	48.0
B 1602 #1	Lacombe, AB	black	Extra 1 CW	0.3	65.5	52.5	51.2
B 1602 #2	Milden, SK	dark brown	Extra 1 CW	0.3	63.8	51.2	50.9
B 1602 #3	Medstead, SK	grey black	Extra 1 CW	1.1	65.1	52.2	49.0
B 1602 #4	Morden, MB	black	2 CW	1.4	57.4	46.0	44.4
Bedford #1	Durban, MB	black	Extra 1 CW	0.3	63.6	51.0	51.0
Bedford #2	Dauphin, MB	black	1 CW	0.4	60.7	48.7	48.5
Bedford #3	Altona, MB	black	Extra 1 CW	2.6	63.2	50.7	50.9
Bedford #4	Crystal City, MB	black	2 CW	0.4	56.3	45.2	44.7
Harrington #1	Lacombe, AB	black	Extra 1 CW	0.4	67.4	54.0	53.5
Harrington #2	Carrot River, SK	grey	Extra 1 CW	0.8	67.0	53.7	51.6
Harrington #3	Pennant, SK	brown	2 CW	5.4	54.2	43.5	39.6
Harrington #4	Binscarth, MB	black	1 CW	4.7	60.0	48.0	47.4
Manley #1	Lacombe, AB	black	Extra 1 CW	0.5	69.7	55.9	54.9
Manley #2	Milden, SK	dark brown	Extra 1 CW	1.4	65.7	52.7	50.4
Manley #3	Kindersley, SK	brown	2 CW	3.3	57.8	46.3	41.6
Manley #4	Binscarth, MB	black	Extra 1 CW	0.6	64.2	51.5	50.9

[a] Official grading of the barley samples was completed by the Canadian Grains Commission

[b] Uncleaned bushel weights were completed on farm

THE EVALUATION OF DEHULLED CANOLA MEAL IN THE DIETS OF GROWING AND FINISHING PIGS

John F. Patience and Doug Gillis

SUMMARY

The major restriction to the expanded use of canola meal in swine diets is its low level of energy digestibility. There are many approaches that one might take to address this problem, but in this experiment, mechanical dehulling was considered as one possible alternative. This experiment was conducted to evaluate the performance of growing and finishing pigs using dehulled canola meal to replace at least half of the soybean meal in their diet.

In this two-phase experiment (growing phase, 24 - 56 kg; finishing phase, 71 - 100 kg), the diets were formulated to contain 15% (growing phase) or 10% (finishing phase) dehulled canola meal. In all cases, the diets were formulated to be of theoretical equal value to canola meal and soybean meal controls, at least in terms of digestible energy, digestible essential amino acids and macro minerals.

During the growing phase, growth rate, averaged 0.82 kg/day and feed conversion averaged 2.33:1 across all treatments. During the finishing phase, growth rate averaged 0.97 kg/day and feed conversion averaged 3.01:1. Carcass index averaged 109.4. None of the production parameters were affected by diet.

It was concluded that substantial quantities of dehulled canola meal could be successfully used in swine diets, provided the diets were carefully formulated according to digestible energy and digestible amino acid composition. Ultimately, the success of dehulled canola meal will be determined by consistency of supply and price, both of which are closely linked to the practicality of the dehulling process.

INTRODUCTION

Canola has achieved enormous success in Canadian agriculture, now ranking as the number 2 agricultural export. However, canola meal has not yet achieved the stature of soybean meal in swine diets, due in large part to its relatively low concentration of digestible energy. Its low energy content is related in large part to the presence of the hull which constitutes about 16% of the seed and about 25% of the meal; the hull fraction has a very low digestibility.

Dehulling is one option available to improve the digestibility of energy in canola meal. Indeed, most of the soybean meal used in Canada has been dehulled, and the primary reason is to enhance its nutritive value. However, dehulling soybean meal is much easier than dehulling canola seed, in part due to the size of the kernel. Therefore, while dehulling of canola seed has been considered for more than a decade, it has not yet achieved commercial practice.

Research was requested by the canola industry to determine if newer approaches to dehulling could overcome this issue and provide an opportunity to increase canola meal utilization in swine. Therefore, the objective of this study was to determine the performance of pigs fed dehulled canola meal as a replacement for soybean meal, when the diets are formulated to be equal in estimated nutrient composition.

EXPERIMENTAL PROCEDURES

This experiment consisted of two phases, the first, to evaluate pigs in the growing phase and the second to evaluate pigs in the finishing phase. Four experimental diets were used for the study with growing pigs (Table 1) and four different diets were used for the study with finishing pigs (Table 2). In each instance, the control diet contained soybean meal as the sole protein supplement. In the second test diet, canola meal was used to replace 95% of the soybean meal (growing phase) or 50% of the soybean meal (finishing phase). Dehulled canola meal was incorporated into the final two test diets at the rate of 15% (growing phase) or 10% (finishing phase). The second dehulled canola meal diet contained supplemental energy (100 kcal/kg) and amino acids, to determine if energy and(or) amino acids were possibly limiting animal performance. The first three diets were formulated to contain equal quantities of digestible energy, digestible amino acids and macrominerals.

There were two blocks of males and three blocks of females in the each of the growing and finishing phases. In the growing phase, each weight block started on test when the block average weight was 25 Ò 3 kg; pigs were then weighed biweekly until the pen average weight was 60 kg at which time the pen was removed from the experiment. In the finishing phase, each weight block started on test when the block average weight was 70 Ò 3 kg; pigs were then weighed biweekly until the heaviest pen within the block reached a minimum average weight of 105 kg, at which time the block was considered to be "off test" for the performance portion of the study. However, the pigs remained on the experimental diets until they were marketed at a body weight of approximately 106 kg.

The dehulled canola meal was analyzed by Dr. Sandy McCurdy, POS Pilot Plant, Saskatoon for phytate, sinapine and glucosinolate content (Table 3).

RESULTS AND DISCUSSION

The pigs responded very well to the dehulled canola meal, with no reduction in average daily gain, average daily feed or feed efficiency during the finishing period ($P > 0.05$) and only a trend ($P < 0.10$) towards reduced average daily gain in the growing period (Table 4).

It is also interesting to note that pigs fed the diet based on canola meal grew at the same rate as those pigs fed the soybean meal control. Feed conversion was somewhat poorer than on the soybean meal diet, suggesting that the energy content of the canola meal had been overestimated. In any case, it demonstrated once again that canola meal can be used in total replacement of soybean meal, when the diets are properly formulated.

There was no suggestion that energy or protein quality had been underestimated in the dehulled canola meal, as the performance on the two diets based on the dehulled canola meal were similar, whether DE was boosted or not.

Similarly, there was no effect of dietary treatment on carcass traits, such as leanness, fatness or predicted yield (Table 5). Based on overall index, animals on all treatments produced high quality carcasses. Fat thickness averaged 20.2 mm, yield averaged 59.8% and index averaged 109.4 across all treatments.

IMPLICATIONS

On the basis of this experiment, it appears that dehulled canola meal offers some potential to enhance the nutritional value of canola meal. Excellent performance can be achieved with this product. However, certain antinutritional factors, such as sinapine and glucosinolates, appear to concentrate in the low fibre fraction, so care must be taken to minimize this effect if the dehulled product is to be successfully used by the pig industry. Ultimately, the success of dehulled canola meal will be determined by consistency of supply and price, both of which are closely linked to the practicality of the dehulling process.

Acknowledgements

Funding for this project was provided by the Canola Council of Canada, under its Canola Utilization Assistance Program.

Table 1. Formulation of diets offered in the performance trial with growing pigs

Ingredient	Diet 1	Diet 2	Diet 3	Diet 4
Barley	57.35	44.68	57.33	52.21
Wheat	22.60	22.60	22.60	22.60
Soybean meal - 47%	15.54	0.85	0.85	4.55
Canola meal	-	26.93	-	-
Dehulled canola meal	-	-	15.00	15.00
L-lysine HCl	-	-	0.14	0.14
DL-methionine	-	-	0.04	0.08
L-threonine	0.03	-	0.06	0.09
Mono - dicalcium phosphate	1.15	0.45	0.45	0.43
Limestone	1.04	1.07	1.21	1.20
Salt	0.42	0.44	0.45	0.43
PSCI vitamin premix[a]	0.50	0.50	0.50	0.50
PSCI mineral premix[b]	0.50	0.50	0.50	0.50
Canola oil	0.88	1.99	0.88	2.28
Nutrients, calculated				
DE, Kcal/kg	3,200	3,200	3,200	3,300
Protein, %	16.54	18.34	15.44	16.73
Lysine, %	0.81	0.87	0.82	0.91
dlysine, %	0.64	0.64	0.64	0.73
dT.S.A.A., %	0.48	0.65	0.45	0.52
dthreonine, %	0.45	0.48	0.45	0.52
dtryptophan, %	0.16	0.16	-	-
dTSAA:dLYS	0.76	1.00	0.70	0.52
dTHR:dLYS	0.70	0.75	0.70	0.72
dTRP:dLYS	0.26	0.24	-	-
Calcium, %	0.70	0.70	0.70	0.70
Phosphorus, %	0.60	0.60	0.60	0.60
Sodium, %	0.19	0.19	0.20	0.19
Chloride	0.34	0.33	0.35	0.34

[a] Provided per kg of diet: Vitamin A, 8,250 IU; Vitamin D3, 825 IU; Vitamin E, 40 IU; menadione, 4 mg; thiamine, 1 mg; riboflavin, 5 mg; niacin, 35 mg; d-panthothenic acid, 15 mg; Vitamin B12, 25 μg; d-biotin, 200 μg; folic acid, 2 mg.

[b] Provided per kg of diet: copper, 50 mg; iron, 80 mg; manganese, 25 mg; zinc, 100 mg; iodine, 0.5 mg; selenium, 100 μg.

Table 2. Formulation of diets offered in the performance trial with finishing pigs

Ingredient	Diet 13	Diet 14	Diet 15	Diet 16
Barley	53.58	47.68	51.43	49.53
Wheat	22.60	22.60	22.60	22.60
Soybean meal - 47%	18.89	9.42	11.45	11.45
Canola meal	-	15.00	-	-
Dehulled canola meal	-	-	10.00	10.00
L-lysine HCl	-	-	-	0.12
DL-methionine	-	-	-	0.09
L-threonine	0.04	-	0.02	0.10
Mono - dicalcium phosphate	1.61	1.24	1.11	1.15
Limestone	1.05	1.07	1.17	1.16
Salt	0.43	0.43	0.43	0.43
PSCI mineral premix	0.50	0.50	0.50	0.50
PSCI vitamin premix	0.50	0.50	0.50	0.50
Canola oil	0.81	1.55	0.80	2.39
Nutrients, calculated				
DE, Kcal/kg	3,200	3,200	3,200	3,300
Protein, %	17.7	18.24	17.76	17.82
Lysine, %	0.90	0.90	0.90	0.99
dlysine, %	0.72	0.69	0.71	0.80
dT.S.A.A., %	0.51	0.59	0.48	0.70
dthreonine, %	0.49	0.48	0.48	0.56
dtryptophan, %	0.18	0.48	-	-
dTSAA:dLYS	0.71	0.86	0.68	0.70
dTHR:dLYS	0.69	0.69	0.69	0.70
dTRP:dLYS	0.25	0.24	-	-
Calcium, %	0.80	0.80	0.80	0.80
Phosphorus, %	0.70	0.70	0.70	0.80
Sodium, %	0.19	0.19	0.19	0.19
Chloride	0.34	0.33	0.34	0.33

[a] Provided per kg of diet: Vitamin A, 8,250 IU; Vitamin D3, 825 IU; Vitamin E, 40 IU; menadione, 4 mg; thiamine, 1 mg; riboflavin, 5 mg; niacin, 35 mg; d-panthothenic acid, 15 mg; Vitamin B12, 25 μg; d-biotin, 200 μg; folic acid, 2 mg.

[b] Provided per kg of diet: copper, 50 mg; iron, 80 mg; manganese, 25 mg; zinc, 100 mg; iodine, 0.5 mg; selenium, 100 μg.

Table 3. Phytate, sinapine and glucosinolate content of canola meal and meal fractions with various fiber contents (POS pilot)

Fraction	Yield, %	Phytate, %	Sinapine, %	Glucosinolate
Canola meal	100	3.82	2.38	14.6
Fibre reduced material	39	4.70	2.75	16.9
Fibre enriched material	61	3.19	2.22	13.3

Data provided by Dr. McCurdy, POS Pilot Plant

Table 4. Effect of dehulled canola meal on pen average daily weight gain, feed disappearance and feed conversion of pigs for the growing and finishing phases

Item	Treatment[a] 1	2	3	4	S.E.M.	Significant Effect[b]
Growing phase						
Initial weight, kg	23.8	24.0	23.9	24.1		
Final weight, kg	56.6	56.0	55.1	58.1		
Daily weight gain, kg	0.82	0.82	0.79	0.84	0.01	NSc
Daily feed, kg	1.98	1.84	1.89	1.90	0.05	NS
Gain:feed	0.41	0.45	0.42	0.44	0.01	NS
Finishing phase						
Initial weight, kg	71.1	70.9	70.6	71.3		
Final weight, kg	96.8	101.4	104.0	102.5		
Daily weight gain, kg	0.89	0.89	0.97	0.91	0.04	NS
Daily feed, kg	2.61	2.78	2.86	2.78	0.13	NS
Gain:feed	0.34	0.32	0.34	0.32	0.01	NS

[a] Treatment 1:control diet based on soybean meal; Treatment 2: negative control based on standard canola meal replacing 95% (growing phase) or 50% (finishing phase) of soybean meal; Treatment 3: dehulled canola meal at 15% (growing phase) or 10% (finishing phase) of the total diet; Treatment 4: the same as Treatment 3 except energy and amino acids were elevated relative to treatments 1 - 3.

[b] Treatment effect significant, $P < 0.05$

[c] Treatment effect significant, $P < 0.10$

Table 5. Effect of dehulled canola meal on the carcass traits of finishing pigs

Item	Treatment[1] 1	2	3	4	S.E.M.	Significant Effect[2]
Market wt., kg	106.5	105.7	105.6	106.4		
Dressed wt., kg	85.8	82.0	83.1	83.4	0.6	0.05
Lean, mm	59.3	56.5	58.7	57.9	1.4	NS
Fat, mm	19.0	19.8	20.9	21.1	1.0	NS
Yield, %	60.3	59.8	59.6	59.6	0.4	NS
Index	109.8	110.1	109.1	108.6	0.9	NS

[a] Treatment 1:control diet based on soybean meal; Treatment 2: negative control based on standard canola meal replacing 95% (growing phase) or 50% (finishing phase) of soybean meal; Treatment 3: dehulled canola meal at 15% (growing phase) or 10% (finishing phase) of the total diet; Treatment 4: the same as Treatment 3 except energy and amino acids were elevated relative to treatments 1 - 3.

[b] Treatment effect significant, $P < 0.05$

[c] Treatment effect significant, $P < 0.10$

FEEDING SPRAY-DRIED PLASMA IN CLEAN AND DIRTY ROOMS

THE EFFECT OF SPRAY-DRIED PLASMA INCLUSION IN PHASE I DIETS OFFERED TO WEANLING PIGS REARED IN AN ALL IN-ALL OUT OR CONTINUOUS-FLOW NURSERY

Nichole E. Lesperance, Andrew G. Van Kessel, Alberto Estrada, and G. Iain Christison

SUMMARY

A 28-day trial investigated the effects of feeding diets containing spray-dried porcine plasma to 60 weanling pigs (21±3 days of age) in two environments designed to compare disease challenge. Environments were characterized by all in-all out or continuous-flow, on-site nurseries. From day 0 to 14 (Phase I) pigs were offered diets containing either 6% spray-dried porcine plasma and 2.3% blood cells or 10% dried skim milk and 7% fish meal followed by appropriate Phase II diets containing either 2.27% blood cells or 5% dried skim milk and 2.5% fish meal, respectively.

From days 0 to 14, pigs offered the spray dried plasma diets showed improved average daily weight gain in both environments. The improvements were greater as a percentage in the continuous flow nursery vs. the all in-all out nursery. As expected, average daily weight gain was greater in the all in-all out than in the continuous-flow nursery from days 0 to 21.

Average daily feed disappearance was higher in pigs offered spray dried plasma from days 3 to 7. Average daily feed disappearance was also higher in the all in-all out vs. the continuous-flow nursery up to day 21.

There was no effect of diet in gain:feed ratios for any period. However, gain to feed ratios were higher in the continuous-flow nursery from days 3 to 28.

Insulin-like growth factor 1 levels were higher in the all in-all out nursery on days 3 and 14. Mean body temperatures of pigs offered spray dried plasma tended to be lower 3 days post-weaning, however, this trend did not continue. Neither environment nor diet affected health score, fecal score, total serum immunoglobulin or the humoral response to vaccination against KLH at weaning.

The results of this experiment showed that feeding spray dried plasma improved growth performance in pigs reared in a slow growing, continuos-flow environment and also in faster growing pigs in an all in-all out environment.

INTRODUCTION

Increasingly complex starter diets are required as the trend in the swine industry is toward reduced weaning age. Spray-dried porcine plasma has shown to be a superior protein source for piglets during the first two weeks post-weaning. Nursery pigs offered spray-dried porcine plasma diets show superior weight gain, higher feed disappearance and sometimes improved feed to gain compared with traditional protein sources.

Antibodies present in spray-dried porcine plasma are believed to protect newly weaned pigs against intestinal infections. Previous studies have shown that spray-dried porcine plasma improved weanling pig performance in a continuous flow (pen housed) environment but not in an all in-all out (individually housed) environment. The degree of improvement in growth performance when feeding spray-dried porcine plasma, however, has not been a consistent finding.

Thus it was the objective of this study to compare the effects of offering a complex diet containing spray-dried porcine plasma and blood cells with a conventional diet containing skim milk and fish meal to weanling pigs housed in two different environments designed to compare disease challenge.

EXPERIMENTAL PROCEDURE

Pigs were offered a Phase I diet containing either 6% spray-dried plasma and 2.3% blood cells or 10% dried skim milk and 7% fish meal followed by a Phase II diet containing either 2.27% blood cells or 5% dried skim milk and 2.5% fish meal, respectively (Table 1).

Pigs were housed at the same site in either an all in-all out or continuous flow nursery. The all in-all out nursery was power washed twice prior to piglet exposure. In contrast, pens were not washed between weanling groups in the continuous-flow nursery. Sixty commercial crossbred pigs were weaned at

Table 1. Experimental diets

	Phase I		Phase II	
	Conventional Plasma	Complex Control	Conventional Plasma	Complex Control
Ingredients, %				
Wheat	43.93	46.01	52.26	54.23
Soybean meal	15.00	15.00	23.00	23.00
Spray-dried whey	15.00	15.00	10.00	10.00
Dried skim milk	10.00		5.00	
Prolac		5.00		2.50
Spray-dried plasma		6.00		
Spray-dried blood cells		2.27		2.27
Fish meal	7.00		2.50	
Limestone / glass rock	1.00	1.70	1.20	1.50
Mono-dicalcium phosphate	0.60	1.50	1.10	1.50
Salt	0.25	0.25	0.35	0.35
Vitamin premix[a]	0.50	0.50	0.50	0.50
Mineral premix[b]	0.50	0.50	0.50	0.50
Tallow	2.50	2.50	2.50	2.50
Canola oil	2.50	2.50	2.50	2.50
Aureo SP250G	0.70	0.70		
Terramycin 50			0.30	0.30
Pellet binder	0.20	0.20	0.10	0.10
L-lysine HCl	0.15	0.10	0.10	0.10
L-threonine	0.08	0.08	0.05	0.05
DL-methionine	0.04	0.15	0.02	0.08
Choline chloride 60%	0.05	0.05	0.03	0.03
Calculated analysis				
DE Kcal/kg	3513	3487	3371	3365
Crude protein, %	22.19	22.50	21.69	20.94
Lysine, %	1.30	1.25	1.26	1.12
Methionine, %	0.48	0.43	0.43	0.40

[a] Provided the following per kg of premix: vitamin A 1,650,000 IU, vitamin D 165,000 IU, vitamin E 8,000, menadione 800 mg, thiamin 200 mg, riboflavin 1,000 mg, niacin 7,000 mg, d-pantothenic acid 3,000 mg, vitamin B12 5 mg, biotin 40 mg and folic acid 400 mg

[b] Provided the following per kg of premix: copper10 g, iron16 g, manganese 5 g, zinc 20 g, iodine 100 mg, selenium 20 mg

approximately three weeks of age. The pigs were then stratified by weight and randomly assigned to treatments. Treatment groups were balanced for litter of origin, but not sex. Thirty pigs were placed in each room, three pens per treatment, five pigs per pen.

The pigs had ad libitum access to the diet from self-feeders. Pigs also had ad libitum access to water from nipple drinkers.

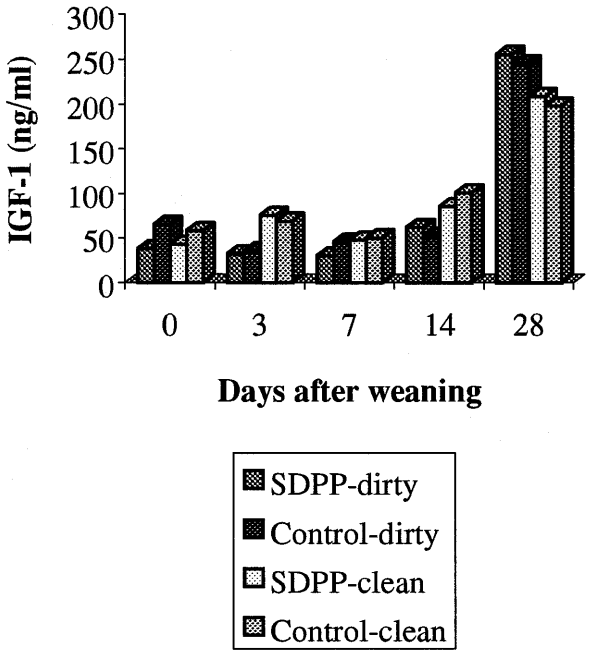
Room temperature was maintained at 28°C until day 15 when it was reduced to 26°C.

Pig weights and feed disappearance (consumed plus unknown spill) were recorded on days 3, 7, 14, 21, 28. Average daily weight gain, average daily feed disappearance and gain to feed ratios were calculated for periods 0 - 3, 3 - 7, 7 - 14, 14 - 21 and 21 - 28.

Rectal temperatures were taken on days -1, 3, 7, 14, 21, and 28. To measure specific antibody responses to a new antigen, all pigs were vaccinated with keyhole limpet hemocyanin (KLH) on days 0 and 14.

Serum samples were taken on days 0, 3, 7, 14, and 28 by jugular venipuncture. Serum samples were analyzed by ELISA for total immunoglobulin levels and anti-KLH antibody levels, and by radioimmunoassay for Insulin-like growth factor 1 (IGF-1) levels.

Figure 1. Mean serum IGF-1 levels in a subsample of the piglets on trial



RESULTS AND DISCUSSION

Table 2 summarizes the performance results. From days 0 to 14 pigs offered the spray dried plasma diets showed improved average daily weight gain in both environments. The improvements were greater as a percentage in the continuous flow nursery vs. the all in-all out nursery (24% vs. 16%, respectively). However, there was no significant diet x environment interaction ($P < 0.05$).

As expected, average daily weight gain was greater in the all in-all out than in the continuous-flow nursery from days 0 to 21. Unexpectedly, this higher rate of gain reversed on days 21 to 28. A possible explanation for this may lie in the fact that both nurseries were housed on the same site. The all in-all out nursery would have a reduced pathogen exposure at first, resulting in improved performance in the early post-weaning period. Because the nurseries were on the same site, there was opportunity for disease transmission through personnel and equipment. As the pigs reared in the all in-all out nursery were exposed to disease challenge their growth performance decreased. These results differ from those in the continuous-flow nursery where there was a reduction in growth immediately post-weaning. Once the pigs (housed in the continuous-flow nursery) had overcome the disease challenge (developed specific immunity) they were protected resulting in uninhibited growth.

Average daily feed disappearance was not available for days 0 to 3. Average daily feed disappearance was higher in pigs offered spray dried plasma from days 3 to 7.

Average daily feed disappearance was also higher in the all in-all out vs. the continuous-flow nursery up to day 21. However, there were no differences between nurseries from days 21 to 28. The lack of superior performance of the all in-all out pigs during this period agrees with the growth data. Previous research has shown that activation of the immune system reduced feed intake. This along with re-partitioning of nutrients towards fighting disease would decrease growth.

There was no effect of diet in gain:feed ratios for any period. However, gain to feed ratios were higher in the continuous-flow nursery from days 3 to 28.

Figure 1 shows serum insulin-like growth factor-1 (IGF-1) levels. IGF-1 is involved in increasing postnatal growth. IGF-1 levels were higher in the all in-all out nursery on days 3 and 14. There was a trend towards lower IGF-1 levels in the all in-all out nursery on day 28 ($P < 0.08$). This is consistent with lower weight gain of these pigs at the end of the trial.

Mean body temperatures of pigs offered spray dried plasma tended to be lower 3 days post-weaning, however, this trend did not continue.

Neither environment nor diet affected health score, fecal score, total serum immunoglobulin or the humoral response to vaccination against KLH at weaning.

IMPLICATIONS

The inclusion of spray dried plasma in the nursery diet improved piglet performance immediately post-weaning, however, this effect declined with time.

The inclusion of spray dried plasma improved performance to a greater extent in the continuous-flow nursery.

Piglets had greater weight gain in the all in-all out nursery for the first three weeks post-weaning. In the last week of the trial piglets in the continuous-flow nursery grew better, possibly due to disease challenge in the all in-all out nursery.

Table 2. The effects of nursery environment and diet on daily weight gain, daily feed disappearance and gain to feed ratios of weanling pigs

	Continuous-flow		All in-all out		SEM	P value	
	Conventional Control	Complex Plasma	Conventional Control	Complex Plasma		Nursery	Diet
Weight gain, kg							
3 - 7 d	0.169	0.161	0.150	0.194	0.024	0.77	0.45
7 - 14 d	0.270	0.350	0.362	0.383	0.025	0.02	0.05
14 - 21 d	0.469	0.451	0.517	0.496	0.025	0.07	0.46
21 - 28 d	0.647	0.675	0.568	0.626	0.029	0.03	0.14
Feed disappearance, kg							
3 - 7 d	0.167	0.204	0.210	0.284	0.011	0.00	0.00
7 - 14 d	0.297	0.373	0.365	0.396	0.028	0.14	0.09
14 - 21 d	0.588	0.604	0.721	0.715	0.030	0.00	0.88
21 - 28 d	0.920	0.892	0.864	0.910	0.031	0.55	0.78
Gain:feed ratios, kg:kg							
3 - 7 d	0.985	0.792	0.715	0.676	0.088	0.06	0.22
7 - 14 d	0.910	0.937	0.995	0.958	0.041	0.23	0.90
14 - 21 d	0.798	0.747	0.716	0.694	0.020	0.01	0.11
21 - 28 d	0.704	0.757	0.657	0.689	0.024	0.04	0.12

AIR QUALITY AND RESPIRATORY RESPONSES OF HUMAN SUBJECTS IN A SWINE BUILDING

Ambikaipakan Senthilselvan, Yuanhui Zhang, James.A. Dosman, Larry Holfeld , Shelley Kirychuk, Ernie M. Barber, Tom Hurst and Chuck Rhodes.

SUMMARY

The advent of environmentally controlled animal housing has had many helpful repercussions in improving livestock yields. However, this system also has drawbacks, particularly regarding the indoor air environment of the housing area. Confinement livestock buildings have shown potential for dramatically increased concentrations of dust particles, odours, and gases. Furthermore, worker satisfaction and performance are affected by dusty and odorous work environments.

Although the characterization of dust and the pathology of the health problems caused by air quality in swine building airspaces are unclear, there is little argument that dust, at typical concentrations, has an adverse effect on the health and comfort of animals and humans. Different dust control methodologies have been researched world-wide. In this study a canola sprinkling program was implemented in an attempt to reduce airborne particles and determine the effect this reduction in airborne particles would have on human subjects.

It was the objectives of this study to determine if (1) air quality control strategies can be directly evaluated measuring responses of human subjects, and if (2) improved air quality can alter the human response in swine building environments.

In this study 20 human subjects naive to hog barn confinement facilities, were exposed to two different hog confinement building air environments. The control group experienced a typical animal housing air environment, whereas the treatment group experienced an animal housing environment sprinkled with canola oil. Measurements were taken on the environment in each room for each study day and the human response attributes measured were Forced Expiratory Volume in one second (FEV_1), Forced Vital Capacity (FVC), white blood count (WBC), methacholine challenge (MC) and nasal cell counts (NL).

The results of this experiment indicate that human responses can be used to evaluate air quality conditions within animal housing environments.

EXPERIMENTAL PROCEDURE

The study was conducted at the research facilities of Prairie Swine Centre Inc. over 11 days in the winter month of December, 1995. The study as well as the consent form was approved by the University of Saskatchewan Advisory Committee on Ethics in Human Experimentation.

Animal Facilities and Management

The study utilized two identical swine grower/finisher rooms located at the Prairie Swine Centre Inc. A total of 288 pigs were housed in two rooms, 144 pigs for each. The average body weight of the animals was 25 ± 5 kg per pig. Pellet feed was filled daily to a single space dry feeder in each of 12 pens. Management for the two rooms was similar to commercial conditions and kept constant and equal for both rooms during the study period.

The control room attempted to duplicate a typical swine confinement environment. The treatment room implemented the dust control technology of canola oil sprinkling.

Oil Sprinkling

The following sprinkling schedule was maintained: 40 mL/m^2 per day for the first two days, 20 mL/m^2 per day for the second two days, and 5 mL/m^2 per day for the following days. Subsequently, on every fifteenth day each room was treated with an oil surge of 20 mL/m^2 per day. During the days when human subjects were in the rooms, the oil sprinkling rate was 5 mL/m^2 per day.

A backpack sprayer designed for chemical spraying was used in this study. Sprinkling was conducted at 07:00, one-half hour before the human subjects entered the room. When sprinkling, the nozzle was maintained at approximately 0.8 m above the floor (pen partition level). The entire floor area was sprinkled including the pen (both sleeping and

dunging areas), pig body and operator walkways. Spray was administered such that the amount of oil settling on the walls and the pen partitions was minimal.

Recruitment and Screening

Twenty lifetime non-smoking male subjects aged 23.9 ± 4.6 years met the screening protocol and were chosen for further study.

Screening consisted of a questionnaire inquiring about any previous swine barn exposure, medical history and allergy history. Subjects were also administered a skin prick tests of reaction against 28 common aeroallergens including ragweed, mixed grasses, trees (box elder, birch, poplar, willow, mixed) and mixed weeds; foods (milk, eggs, peanut, shell fish), dust mites; dusts from house, grain and wheat; and animals (feathers, cat, dog, cattle, horse, hog hair).

Subjects with previous smoking history, history of asthma or allergies, positive reaction (>3mm) to any of the aeroallergens in skin prick testing, history of previous hog barn exposure or any adverse medical history were excluded from further study.

Training Day

The twenty subjects chosen for the study attended a training session. In addition to a consent form, they completed a questionnaire on previous occupational exposures, current respiratory symptoms and past illnesses. In an attempt to minimize a learning curve, the subjects practiced pulmonary function tests and nasal lavage procedures. The subjects were also instructed on proper barn entry procedures at the Prairie Swine Centre Inc.

Baseline

The duration between baseline (laboratory) day and training day was at least seven days. Baseline measurements were taken at the Royal University Hospital. The subjects arrived at the hospital at 07:00 for pulmonary function tests. Subjects returned to the hospital at 11:00 for pulmonary function tests, a blood sample and nasal lavage. At 16:00 methacholine challenge tests were performed at the hospital.

Cross-over Design for Barn Exposure

There were two subjects per day per room. Subjects were randomly assigned to one of the rooms then following a minimum seven days break, they were placed in the alternate room. A randomization list was prepared for assigning the subjects to the traditional or oil control rooms.

Barn Day 1

Subjects arrived at the swine barn at 07:00. Pre-exposure pulmonary function test measurements were taken, personal air samplers were attached to each subject and they were randomly assigned to the traditional or oil control room. The subjects spent a total of five hours in the room. In order to simulate the usual work load encountered in a typical swine barn, the subjects were asked to ride a stationary bike for 3 km at 18 km/hour each hour during their stay in the barn. In addition to taking an oral temperature, subjects recorded the severity of cough, phlegm, shortness of breath, chest tightness, nasal irritation, eye irritation, chills and headache (done hourly until 10:00 PM) using a Likert scale. The scale ranged from 0 to 5, zero being representative of no symptoms and 5 indicative of severe symptoms. Subjects left the barn room every two hours for a ten minute period to perform pulmonary function tests, which were conducted in a common room adjacent to the barn rooms. At the end of the exposure (approximately 12:30), pulmonary function was measured, blood was drawn and nasal lavage was conducted. Subjects then returned to the hospital at 16:00 for methacholine challenge studies.

Barn Day 2

After a minimum period of seven days, subjects were assigned to the opposite room from that of Barn Day 1. The procedures on Barn day 2 were the same as on Barn day 1.

Lung Function

A Sensormedics volume displacement spirometer was used for lung function measurement and tests were performed according to American Thoracic Society

recommendations. Subjects performed the lung function tests in the sitting position. The pulmonary test variables, forced vital capacity (FVC), forced expiratory volume in the first second (FEV_1), FEV_1 /FVC ratio, and maximum mid-expiratory flow (FEF_{25-75}) were measured. The percentage changes in pulmonary function from the first measurement and last measurement on laboratory day (baseline) and on barn exposure days were calculated and defined as shift change in lung function. See figure 1 for description of shift change calculation.

Methacholine Challenge

Methacholine challenge tests were performed using a Medical Graphic Spirometer and the method of Juniper, Cockroft and Hargreave to determine changes in lung reactivity. The test was performed with inhalation of the diluent followed by inhalation of increasing doses of methacholine starting at 1 mg/mL with each increment representing doubling of the dose to a maximum final concentration of 256 mg/mL. The FEV_1 was measured at 30 and 90 seconds following the 2 minute inhalation of methacholine. Results are presented as the last dose of methacholine to produce a PC20, or the amount of methacholine required to reduce the FEV_1 by 20% from the control.

Nasal Lavage Procedure and Analysis:

Nasal lavage was used as an indicator of the airway inflammatory response to the indoor environment. A cell count was performed on a 10ml sample of expelled nasal washings. The cell count was calculated on hemocytometer with cells divided by original fluid volume to give number of cells/ml.

White Blood Count Methodology

White blood count was measured to determine the inflammatory response of the body to the differing environmental conditions. Blood samples were drawn using a vacutainer and 20¼ gauge needle. Cell counts are given in cells x 10^{-9}/mL.

Measurements of Air Quality and Environment
Dust mass concentration (mg/m^3) was measured daily using a personal aerosol sampler carried with each subject. Means of dust particle counts taken at 08:00 and 12:30 during the study period were used as indicators of dust in the control and treatment rooms. Hydrogen sulphide concentrations were continuously measured using a gas monitor.

Room temperatures and pressures across the exhaust fans and air inlets were measured and recorded continuously. Relative humidity was measured using a psychrometer at the center of the operator alley. Air velocity was measured using an anemometer at animal levels in three pens located at the center and both ends of the room. Ventilation rates were calculated from room temperature, fan schedule, pressure and fan curves. As an additional indicator of ventilation rate, carbon dioxide concentration was also measured in the two experimental rooms.

RESULTS AND CONCLUSIONS

Demographic Characteristics

Twenty non-smoking male subjects participated in the study. Their mean ± standard deviation (range) age, weight and height were 23.9 ± 4.6 (18 to 34) years, 83.5 ± 18.4 (60 to 129) kg and 177.2 ± 7.0 (165 to 194) cm respectively.

Thermal Environmental Conditions
Since the experiment was conducted between December 06 - 21, the mean outside temperature was -17.6 ± 7.6°C at which the room temperatures were maintained near the lower critical temperatures (LCT) of 14°C. At the LCT, the ventilation was consistently maintained near the minimum rate of 350 L/s. Thus, the thermal environments for both rooms were similar.

Air Quality

Table 1 shows the mean dust concentration in the treated and control rooms over the five hour exposure period for 11 days of the experiment. Two personal samplers were carried daily by two subjects during the experimental period. As shown in Table 1, means of respirable and inhalable dust, ammonia, hydrogen sulphide and carbon dioxide concentrations in the

treated room were significantly lower than that in the control room. Dust mass concentration was reduced by 93.5 ± 2.3%. The small standard error indicates that the reduction was very consistent. Dust particle count concentrations were reduced by 81.0 ± 11.0% and 84.9 ± 9.1% for modified respirable and modified inhalable dust respectively. The differences in mean values and variations of the mass and the count concentrations were due to the sampling methods and the sampling efficiencies. Mass concentration measured by personal samplers were operated continuously for five hours during the in-barn experimental period. Because oil was sprinkled right before the sampling, the dust reduction was higher than the daily average. The count concentration were measured twice a day at 09:00 and 16:00, which were during and after the in-barn experiment and each measurement lasted 100 seconds.

Hydrogen sulphide and ammonia concentrations in the treatment room were reduced by 26.7% and 29.6%, respectively. It was assumed that the oil film prevented the emission rates of gases into the airspace, but the mechanical and chemical reasons for the gas reduction need to be investigated. Carbon dioxide was reduced by 12.5%, which is much less than the reductions of hydrogen sulphide and ammonia. This was because that carbon dioxide was primarily produced by animal respiration on which oil sprinkling had little effect.

Responses of Human Subjects

As shown in Table 2, mean percent shift change in FEV_1 for the 20 subjects was -9.9% in the treated barn room in comparison to the smaller mean percent shift change of -1.94% in the control room and a mean shift change of +1.1% on the laboratory day (baseline). The differences in mean shift change in FEV_1 were statistically significant. A graphic illustration of the loss in FEV_1 is found in Graph 1.

Shift changes in forced vital capacity (FVC) of the subjects were monitored as were white blood count (WBC), methacoline challenge (MC), and nasal lavage (NL). The FEV_1, FVC, WBC, MC and NL are summarized in Table 2. There were significant levels of differences in responses among the baseline, treatment and controls and are stated at the bottom of the table.

IMPLICATIONS

It was confirmed that sprinkling a small quantity (6 mL/m^2 daily on average) of canola oil substantially reduced dust concentrations, producing an improved change in lung function measurements, white blood count and nasal cell count, when compared to a traditional barn environment. This suggests that implementing an air quality control strategy (oil sprinkling) will reduce the health effects on naive subjects produced from hog barn confinement housing work.

ACKNOWLEDGEMENTS

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Figure 1
Shift Change in FVC= FVC at the End of Exposure X 100
FVC at Beginning of Exposer

Graph: 1

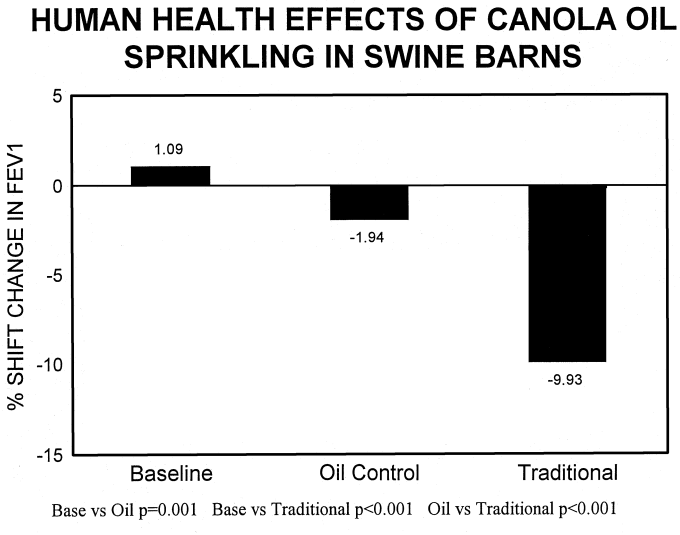


Table 1. Dust and gaseous concentrations in the treatment and control rooms

	Control	Treatment	% Change
Dust concentration (mg/m^3)	2.41 ± 0.38	0.15 ± 0.04	-93.5 ± 2.3
Modified respirable dust concentration (particles/ml)	50.5 ± 12.1	9.9 ± 8.1	-81.0 ± 11.0
Modified inhalable dust concentration (particles/ml)	69.5 ± 14.9	10.7 ± 8.8	-84.9 ± 9.1
Hydrogen Sulfide (ppm)	0.38 ± 0.06	0.27 ± 0.04	-26.7 ± 18.5
Ammonia (ppm)	26.0 ± 2.0	18.3 ± 1.7	-29.6 ± 5.3
Carbon Dioxide (ppm)	3736 ± 610	3300 ± 727	-12.5 ± 7.9

Table 2. Respiratory responses of human subjects

	Baseline	Treatment	% Change
	(n=20)	(n=20)	(n=20)
FEV percent shift change	1.09 ± 2.82★■	-1.94 ± 2.80◆	-9.93 ± 5.01
FVC percent shift change	-0.26 ± 3.34❖■	-2.25 ± 3.03*	-4.35 ± 3.77
Methacholine last dose (mg)	256 ± 0✱✧	181 ± 108	140 ± 113
White blood count (cells X 10^{-9})	6.18 ± 1.36✧	6.35 ± 1.39◆	8.75 ± 3.02
Nasal cell count (cells X 10^{-3})	15.63 ±28.84✪	10.17± 15.26✿	42.90 ± 36.37

* Continuous variables are expressed as mean ± standard deviation

Significance:
Baseline vs. treatment: ★p=0.001, ❖p=0.01, ✱p=0.006
Baseline vs. control: ■p=0.001, ✧p<0.001, ✪p<0.0001
Treatment vs. control: ◆p<0.001, *p=0.03, ✿p<0.0001

DUST SETTLING USING A NEGATIVE IONIZATION SYSTEM

Dust Settling using a Negative Ionization System in a Confinement Swine Building

Akihiro Tanaka, Yuanhui Zhang

SUMMARY

Dust is one of the main contaminants in barn air. Dust not only reduces pig performance and contributes to the deterioration of building and barn equipment, but more importantly, affects the health status of people working in confined buildings. Negative ionization constitutes a new technology promising to aid in controlling respirable dust levels in swine barn. A negative ionization system was installed and tested at Prairie Swine Centre Inc. The objectives of this study were to examine the effect of ionization on dust removal in a swine house and to evaluate the potential side effects of the electrostatic charge on building and equipment surfaces.

Two identical semi-intensive (20 pens, 5 pigs per pen) growing - finishing rooms were compared. One was fitted with the negative ionization system while the other served as control room.

It was confirmed that ionization reduced the modified respirable and inhalable dust counts by as much as 46%. The efficiency of the modified respirable and inhalable dust reduction decreased as the ventilation increased, and decreased with time, due to the accumulation of dust on surfaces. The mean electrostatic voltage of walls, ceiling and floor in the experimental room was 319 V compared with 137 V in the control room. The high voltage in the experimental room did not present a hazard to operators, but had an adverse effect on the dust settling.

It is concluded that the negative ionization is an effective technology for reducing dust levels in swine barns in the short-term and with low ventilation rates.

INTRODUCTION

A predominate problem within swine building environment is the high dust concentration. Airborne contaminants can make environmental conditions unpleasant and unhealthy for workers. Lung functions of workers in swine confinement buildings can be decreased by the polluted environment. Airborne contaminants may also increase disease and reduce the performance of pigs. Swine building dust also contributes to the rapid deterioration of buildings and equipment.

The objectives of this study were to examine the effect of ionization on dust removal in a swine house and to evaluate the potential side effects of the electrostatic charge on building and equipment surfaces.

EXPERIMENTAL PROCEDURE

Two identical swine growing - finishing rooms were used in this study: an experimental room fitted with the negative ionization system (Figure 1), and a control room (without ionization system). Each room measured 19.8 m (7.0 m (3.0 m and housed 100 pigs in 20 pens located in two adjacent rows along the centre of the room, leaving walkways along the side walls. Each pen measured 2.5 m (1.7 m and housed 5 pigs on a fully slatted floor. Single-space aluminum feeders in each pen were filled manually with dry-pelleted feed. Water was available ad libitum from water nipples located at the back of the pens. Body weight and number of pigs in each room were approximately the same. Pigs were admitted into each room at an average body weight of 25 kg and went to market at approximately 105 kg. The management for the two rooms was similar.

A negative ionization system (Model 300, Bionaire) was installed. The system consisted of an ion generator and ten sets of ion emitters (Figure 1).

Room temperature, relative humidity and pressure difference between the rooms and outside were measured every 10 minutes. Dust particles were categorized into two groups: modified respirable dust (0.5 to 5.0 (m in aerodynamic diameter) and modified inhalable dust (greater than 0.5 μm in aerodynamic diameter and usually smaller than 50 μm). Dust counts were measured at 0.2 m, 1.6 m and 2.8 m

above the floor at the centre of one alley at 9:00 and 15:30 daily using a laser particle counter (Model 227B, Met-One). The reduction of dust counts was compared between the two rooms. The electrostatic voltage on the surface of walls, ceilings, floors, feeders and feed was measured using a static sensor (Model 709, 3M).

A statistical analysis was used to establish the difference between the environmental conditions in one room compare with the other.

RESULTS AND DISCUSSION

Environmental Conditions of Rooms
There were no significant differences between two rooms in room temperature, relative humidity and ventilation rate ($P > 0.05$).

Dust reduction

The weekly mean dust count and reductions are summarized in Table 1. Dust reduction during the first two weeks was almost constant, 44.5% for modified respirable dust and 46.4% for modified inhalable dust. The reduction of modified respirable and inhalable dust decreased after the third week, which was assumed to be due to: (1) the ionization system did not have enough capacity to balance the high ventilation; (2) the dust accumulation on building surfaces reduced the efficiency of the ionization system.

Effect of Electrostatic Voltage

The modified inhalable dust count reduction versus the electrostatic voltage difference between the two rooms and the regression lines are shown in Figure 2. The electrostatic voltage in the control room was caused by dust particles which charged by the contact charging and ions from the atmosphere. In the surface of the earth, there are usually more positive ions because the earth itself is negatively charged and it tends to repel the negative ions and act as a magnet to positive ions. When the electrostatic voltage difference increased, the modified respirable and inhalable dust reductions were gradually decreased because the particles were charged with negative ions. When the negative charged dust particles settled onto surfaces due to the Coulomb force, they lost their negative charge by electrostatic induction. The electrostatic voltage is related to the thickness of the accumulated dust on the surface and the electrical resistance of dust. It is suspected that the high electrostatic voltage difference, i. e., accumulated dust on the surfaces insulate the grounded walls from the charged dust particles which in turn reduce the attraction of the aerial dust to building surfaces.

The settling efficiency of the modified respirable and inhalable dust could be reduced by the high electrostatic voltage. The overall mean value of electrostatic voltage in the experimental room was 182 V higher than the control room. A peak value of 859 V was observed on day 33. This high electrostatic voltage did not present uncomfortable sparks or hazard to operators. Due to the low values of correlations, it appears that the high electrostatic voltage had an adverse effect on dust reduction but this is not conclusive.

Effect of Ventilation Rate

The weekly dust count reduction versus weekly average ventilation rate of two rooms is plotted in Figure 3. The reductions of modified respirable and inhalable dust counts decreased with the increase of ventilation rate. When the ventilation rate increased, the efficiency of the ionization system was reduced because the numbers of ions and their time standing in the room were reduced. Thus, the dust reduction, which is related to the dust counts in both rooms, was reduced.

It is concluded that the negative ionization is an effective technology for reducing dust levels in swine barns in the short-term and with low ventilation rates.

IMPLICATIONS

1. It was confirmed that ionization can reduced dust counts. Dust reduction efficiency decreased with the time due to the accumulation of dust on surfaces.

2. Dust reduction using this ionization system was largely affected by the ventilation rate. The reductions for modified respirable and inhalable dust counts were effective (as much as 46%) when the ventilation rate was low and not effective (as low as 3%) when the ventilation rate was high.

3. Electrostatic voltage in the experimental room was 319 V compared with 137 V in the control room. This high voltage did not present a hazard to operators but likely had an adverse effect on dust concentration.

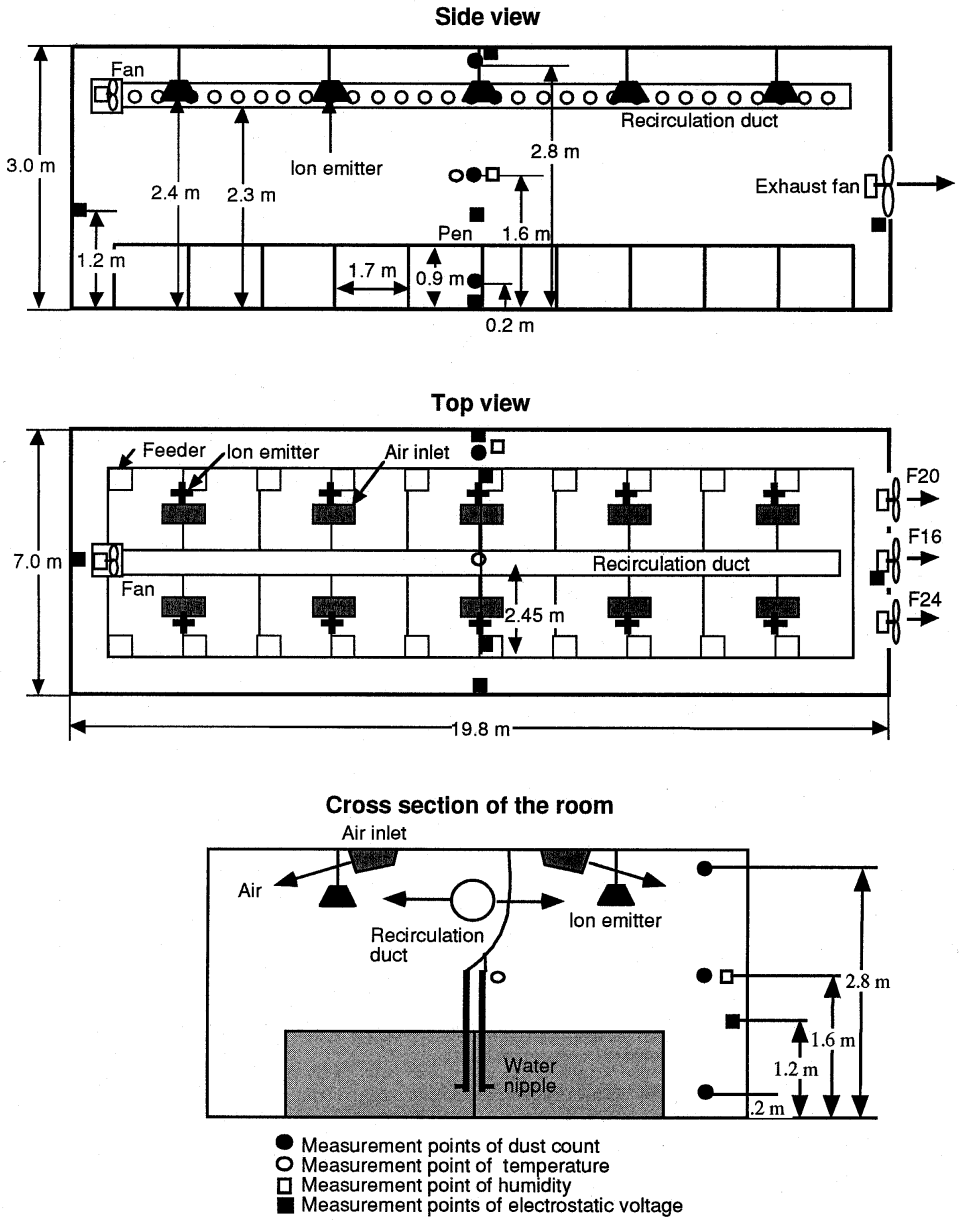


Figure 1. Sketch of the experimental room and measurement points.

Table 1. Weekly mean values of dust counts per unit pig body mass and electrostatic voltage

Treat	Week		Diminished dust			Modified respirable dust			Modified inhalable dust			Electrostatic voltage	
			Control (count/L/kg)	Experiment (count/L/kg)	Reduction (%)	Control (count/L/kg)	Experiment (count/L/kg)	Reduction (%)	Control (count/L/kg)	Experiment (count/L/kg)	Reduction (%)	Control (V)	Experiment (V)
	1	Mean	0.5	0.4	24.5	9.6	5.1	46.0	13.2	6.8	47.7	72	129
		S.D.	0.6	0.4	17.5	1.6	0.7	9.2	2.2	0.8	9.1	68	150
	2	Mean	0.4	0.3	21.4	9.8	5.5	43.0	13.9	7.5	45.1	198	381
		S.D.	0.4	0.3	19.3	2.0	1.3	13.9	3.1	1.8	14.5	73	157
1		S.D.	0.4	0.3	7.7	2.1	1.5	5.5	3.1	2.1	5.6	85	416
	4	Mean	0.3	0.2	19.2	5.4	3.7	28.3	7.9	5.4	29.1	54	179
		S.D.	0.3	0.2	12.2	0.9	0.5	15.1	1.4	0.8	15.7	51	176
	5	Mean	0.2	0.2	18.6	3.8	2.8	24.6	5.4	4.1	25.2	134	134
		S.D.	0.2	0.2	11.8	0.6	0.8	11.9	0.8	1.1	13.1	67	404
	6	Mean	0.2	0.2	14.7	2.5	2.4	1.7	3.4	3.3	1.9	226	246
		S.D.	0.2	0.2	14.5	0.6	0.5	20.8	0.9	0.8	22.4	196	431
2	7	Mean	0.2	0.2	11.8	2.5	2.4	3.0	3.7	3.4	4.5	149	202
		S.D.	0.2	0.2	8.9	0.7	0.7	27.3	1.1	1.0	28.1	132	295
	Mean		0.3	0.2	18.5	5.7	3.7	25.6	8.1	5.2	26.9	137	319
	S.D.		0.3	0.2	13.1	1.2	0.9	14.8	1.8	1.2	15.5	96	188

Figure 2 Modified inhalable dust count reduction versus the electrostatic voltage difference between the two rooms (Exp - Ctrl)

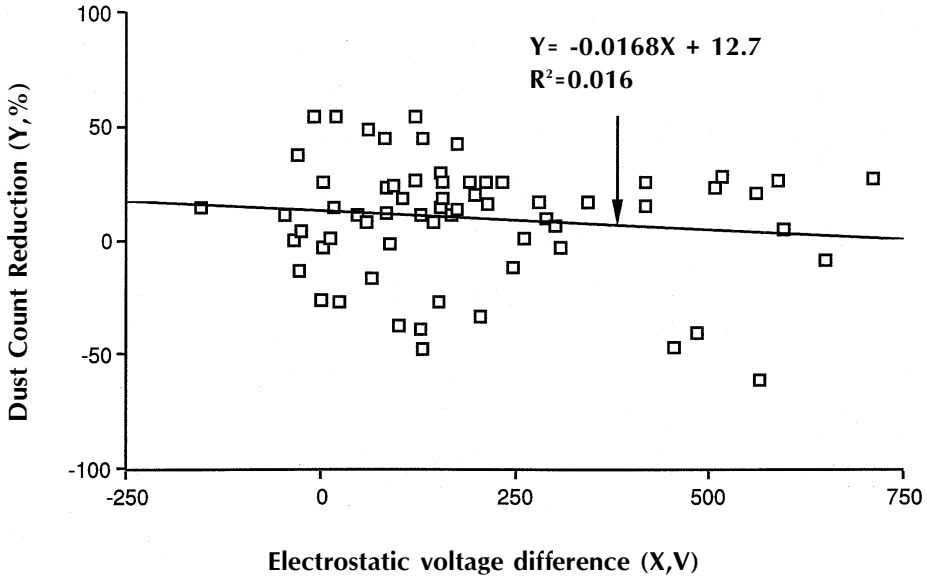
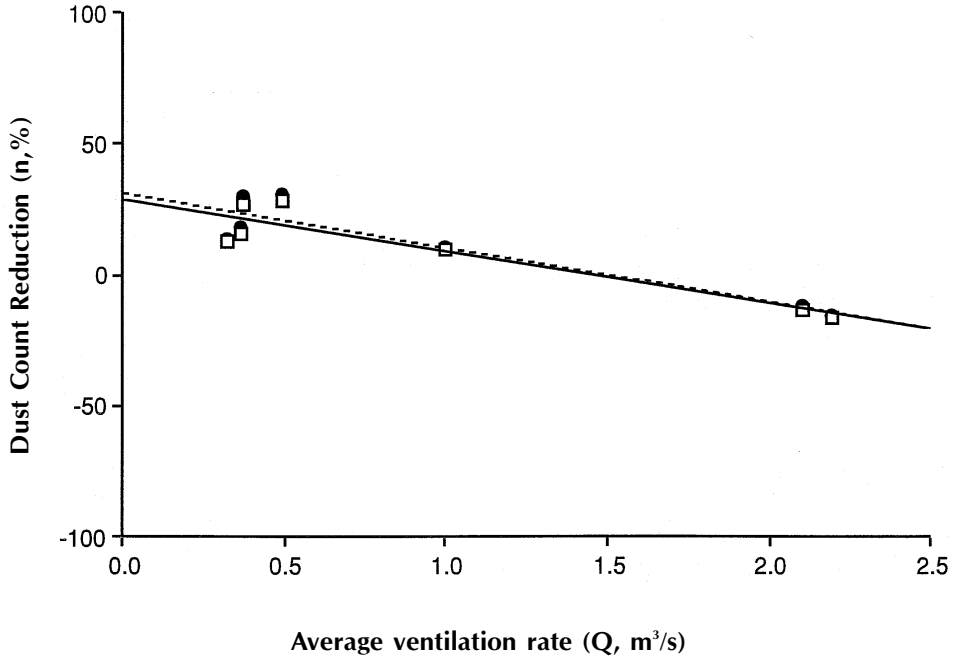


Figure 3 Weekly mean dust count reduction versus average ventilation rate in two rooms.



❑ Measured modified respirable —— Predicted modified respirable $n=-19.8Q + 28.7$ $r^2 = 0.86$ → $n=28.7 - 19.8Q$

● Measured modified inhalable ----- Predicted modified inhalable $n=-20.4Q + 30.9$ $r^2 = 0.86$ → same pattern, $R^2 = 0.86$

A LOW COST BALLOON-TYPE LAGOON COVER

A LOW COST BALLOON-TYPE LAGOON COVER TO REDUCE ODOUR EMISSION

Yuanhui Zhang and Wim Gakeer

SUMMARY

Existing odour control methods for manure lagoons are cost intensive. Economical and effective covering methods for manure lagoons need to be studied and developed.

This study demonstrated that a balloon-type manure lagoon cover could be an economical and effective method in reducing odour emission to the atmosphere. In this balloon type cover, a plastic tarp was tightened around perimeter, and inflated on the top, of a lagoon using a low pressure blower. The perimeter of the tarp was airtight. That way, odour was confined within the lagoon and the emission of odour into the atmosphere was minimized. Technical aspects such as proper installation and sealing of perimeters for the cover were tested. Critical pressures (minimum operating pressures to prevent flapping of the tarp) versus wind were determined. The cover effectively eliminated the odour emission to atmosphere and improved the landscape.

The cover cost was approximately $6,000 which is considered to be much less expensive compered to solid structure covers such as steel and wood. It is expected that the cover to be used for earthen lagoons if a concrete foundation around the lagoon perimeter is constructed.

INTRODUCTION

Total odour emission from an animal facility to atmosphere is approximately composed of 50% through indoor exhaust air, 25% through manure storage and 25% through manure transport and spreading. In Canada and United States, manure is stored in either earthen or concrete lagoons. Generally these lagoons are not covered and odour emission is not controlled. Odour emission from open manure lagoons has become an increasing concern of environment and general public.

Methods to reduce odour emission to atmosphere from manure lagoons can be two folds: Firstly, sources of odour production can be controlled by various methods. These methods may be one or a combination of the following: chemical (e.g., adding deodourants), biological (e.g., anaerobic digestors), metabolic (e.g., alternative feed rations), mechanical (e.g., ventilating the lagoon to keep manure aerobic) and electrical (e.g., oligolysis). Secondly, odour emission from a lagoon can be reduced by using a cover and making the lagoon airtight. There are several ways to cover a manure lagoon, each has limitations and advantages. Covers in solid structure such as steel, concrete or wood, are reliable but capital intensive. For example, for a 200 sow farrow-to-finish swine facility, a concrete cover for a lagoon may cost as much as $50,000. Additionally, difficulties may arise in construction of such covers for already existing lagoons. Less expensive covers such as polystyrene foam plate or barley straw floating on top of the manure were investigated. Applying these technologies, special machines are required to spread the covering materials. The lagoon needs to be agitated to prevent the sunk cover materials from forming slums and blocking the pumping system. Floating covers, made of one piece of tarp, was difficult to use because of the fluctuation of the manure level during the year. When the level of the covered liquid is constant, such a floating cover could be viable.

Inflatable covers was invented in 1917 but the technology was only adapted in industry until after the second world war. The first inflatable cover in the United States was build in 1959 to cover a water reservoir. This was intended to prevent water from pollution and evaporation. The advantages of these covers were obvious as they were less capital intensive and light in structure compared to solid covers. To date, inflatable covers have also been used in many buildings.

It is possible to apply the inflatable cover technology to manure lagoons economically and effectively. The objectives of this project were:

1. To develop and install a low-cost balloon-type manure cover for a swine facility. The cover is expected to be inflated using a low pressure blower, and the cover should be airtight.

2. To measure the rates of air leakage and odour (e.g. hydrogen sulfide, ammonia) emission from the lagoon to the atmosphere and compare with the literature data.

3. To evaluate the performance of the cover and recommend operating conditions for the cover. Cover performance include wind resistance, maintenance requirements and cost. Operating conditions include critical pressure, power-back up and other emergency measures.

EXPERIMENTAL PROCEDURE

The inflated lagoon cover includes a tarp, air delivery and pressure control systems. As shown in Figure 1, the tarp is fastened to the lagoon perimeter to isolate the manure and the atmosphere. The air delivery system consists of a low pressure blower and a variable fan controller. The pressure controller is a mechanical damper by which a bypass opening can be adjusted so that the cover is maintained at a constant operating pressure. Ideally, the pressure difference across the tarp should be controlled using a weather station because the operating pressure of the suspended cover is affected by weather conditions such as wind speed. Weather station is not included in this report.

Figure 2 shows an overview of the lagoon cover system. Ducts in the photo are waste influent tube from the barn and the barn manager's house. The block at the left hand of Figure 2 is the blower and the pressure control system. The lagoon cover appears to be a partial sphere doom which improves the landscape of the facility cite.

The Tarp

The attachment of the tarp to the lagoon is shown in Figure 3. The cover is a 0.91 mm thick hypalon roof covering tarp (Speers Petrochemicals Co., Winnipeg, MB). Before the tarp is pulled over the manure lagoon, a grid (1.2 m (1.2 m) of ropes are fastened across the top of the lagoon to prevent the cover from falling to the manure in case of the blower deactivation or power off. Each string of rope is attached to the concrete perimeter of the lagoon. The diameter of the tarp is one meter larger than the diameter of the lagoon. This allows the cover to be inflated to a height of approximately 2.5 m. The first layer on the perimeter is a sheet of plastic plate to flush with the metal strips. The next three layers were two rubber strips, and the tarp. An angle steel is bolted down to the concrete perimeter and the tarp is clamped between the two rubber strips. The maximum distance between the bolts is 0.6 m. The bolts are anchored in the concrete.

Air Delivery and Pressure Control

The air delivery and pressure control systems are shown in Figure 4. The air delivery system consists of a radial blade blower and an anti-backdraft flap. The blower is direct driven (0.37 kW, 1750 RPM) and has a capacity of 400 L/s at 0 Pa and 90 L/s at 250 Pa pressures. The anti-backdraft is a piece of plastic flap that only allows the air flowing into the lagoon. When the blower is deactivated in case of power or mechanical failure, pressure in the lagoon is higher than the pressure at the exit of the blower. The air inlet of the lagoon will be closed by the flap. That way, air is sealed somewhat in the lagoon and the cover is maintained inflated for a longer period of time.

The pressure of the lagoon cover is controlled by an automatically weight-balanced damper. The damper is located at the exit of a bypass. The openings of the damper are controlled by a spring which is in turn balanced at a given pressure. The displacement of the spring can be adjusted in 12 steps to control the pressure within the range of 40 to 200 Pa. The air inlet for the blower and the air outlet for the damper are constructed in a way that the wind direction has little influence on the operating pressure. The house for the blower and the duct are installed on steel angles which are bolted to the side wall of the lagoon. A section of flexible duct is used to connect the anti-backdraft flap and the air inlet of the covered lagoon.

Performance Evaluation

Air Leakage

Air tightness of the cover is one of the most important characteristics affecting the cover performance. Air leakage should be minimized to reduce the odour emission to the atmosphere. The rate of air leakage (Q) from the covered lagoon is expected to conform the following equation:

$$Q = C(\Delta p)^n \quad \text{(L/s)} \qquad (1)$$

where C is a coefficient, ΔP is the pressure difference across the tarp in Pa, and n is an exponential coefficient for pressure difference.

Measured air leakage rates at different operating pressures are plotted in Figure 5. The air leakage rate equals the air flow rate at the air inlet of the cover because that the lagoon cover is under positive pressure and therefore only exfiltration occurs. Air velocities at the cover inlet were measured and used to calculate the flow rate. For this lagoon cover, the C and n are 0.037 and 1.58, respectively. The exponential coefficient, n, would be smaller (e.g., near 0.5) had the openings of leakage sources have been constant. However, the tarp is very flexible and the openings of leakage sources increase as the pressure difference increases.

It was observed that operating pressures were 40 Pa and above depending on weather conditions. The higher the operating pressure, the steadier the cover. At an operating pressure of 100 Pa, the air leakage was 60 L/s. This leakage is approximately equivalent to the rate of a toilet exhausting fan.

Odour Emission

Odour was expected to escape mostly along the lagoon perimeters where air leakage sources are located. In this study, ammonia and hydrogen sulphide were used as indicators of odour emission. Concentrations of ammonia and hydrogen sulphide inside the lagoon at the perimeter level were measured. On each measurement day, air sample was collected eight hours continuously. The concentrations of ammonia and hydrogen sulphide were measured using a gas analyzer. The emission rate was calculated using the gas concentration and leakage rate. At the operating pressure 100 Pa, concentrations and emission rates of ammonia and hydrogen sulphide are listed in Table 1.

Production rates of hydrogen sulphide production rate is estimated as 0.00083 mg/s and ammonia is 0.095 mg/s for a 45 kg pig in a confined house. Compared with the odour production of pigs, the emission rates from this covered lagoon of ammonia and hydrogen sulphide were equivalent to 15 and 88 45 kg pigs, respectively. Indeed, odour emission from the covered lagoon was reduced to such a low level that no odour could be detected by a human standing by the lagoon at the downstream of the wind.

Critical Operating Pressure

Critical pressure (ΔP_c)is the minimum pressure difference across the tarp at which the tarp can be maintained as a stable doom structure. If the operating pressure is lower than the critical pressure, the tarp will be flapping which may damage the tarp at low temperatures. Factors affecting the critical pressure include the dynamic pressure caused by wind (P_d), static pressure caused by the weight of the tarp (P_w), and an extra pressure (P_e) required to keep the tarp steady. The critical pressure can be written as:

$$\Delta P_c = \frac{1}{2}\rho V^2 + \frac{W}{A} + P_e \qquad (2)$$

where p is the air density in kg/m^3, V is the wind speed in m/s, W is the weight of the tarp in N and A is the tarp surface area. The first term at the right hand is the dynamic pressure caused by wind, second term is the pressure caused by the weight of the tarp. Pe is expected to be dependent on the rigidness of the tarp material. The less rigid of the tarp, the higher value of the P_e. P_e can be determined experimentally.

Critical pressures at different wind speeds were measured and plotted in Figure 6. For this tarp, W/A is 12 Pa and P_e is 12 pa. Thus, from Equation 2, the critical pressure for the tarp is:

$$\Delta P_c = \frac{1}{2}\rho V^2 + 24 \qquad (3)$$

Measured data agree with Equation 3 very well at low wind speed. It should be pointed out that the critical pressure at high wind speed should be much lower than that calculated from equation 3. In fact, an operating pressure of 100 Pa was sufficient to maintain a steady doom for wind speed at 50 km/h (14 m/s). This is because that the streamline of the doom reduced much of the resistance of the wind.

Strength Requirement of the Tarp

Selection of the tarp material depends on the stress applied onto the tarp. Therefore, stress in the tarp cover must be determined. If an air space enclosed with isotropic material is inflated with air at a pressure *P*, the enclosure will be in a shape of a sphere. The diameter (*D*) of the sphere can be calculated using the height (*h*) and the span (*2a*) of a partial sphere (Figure 7):

$$D = \frac{a^2 + h^2}{h} \qquad (4)$$

In an isotropic sphere, the stress is identical for the entire sphere surface. Further, the stress at any point will be tangential to the sphere surface at that point. Thus, the stress at the sphere surface can be calculated. From the free body diagram for a half-sphere (Figure 7a), the total force exerted on the half-sphere perimeter equals to the resultant of the pressure (*P*) on the inside surface of that half-sphere. The stress along the perimeter (Figure 7a) of the half-sphere can be calculated using the following equation:

$$\sigma = \frac{(a^2 + h^2)}{4h} P \qquad (5)$$

Because the sphere is isotropic and the stress on the sphere surface is identical (Figure 7b), the total force along the lagoon perimeter is

$$F = \frac{\pi a(a^2 + h^2)}{2h} P \qquad (6)$$

Clearly, the maximum load of such a partial sphere occurs when the h equals a, i.e., $h = a = D/2$. In this project, the height of the balloon cover (*h*) and the diameter of the lagoon (2a) was measured as 2.5 m and 23 m, respectively. The maximum operating pressure of the blower was approximately 200 Pa. Using Equations 5, the maximum stress of the tarp was 2770 N/m. Using Equation 6, the load on the lagoon tarp was 200,2 KN at pressure difference of 200 Pa.

By differentiating Equation 5 with respect to h and making the equation equals zero,

$$\frac{\partial \sigma}{\partial h} = \frac{h^2 - a^2}{4h^2} P = 0 \qquad (7)$$

the minimum stress on a suspended tarp will occur when $h = a = D/2$ which is the only meaningful answer to Equation 4 for a given a. Apparently that the height of the inflated cover should be as high as the lagoon radius so that the stress can be minimized. A higher doom can also prevent snow accumulation. However, wind resistance of the cover will increase as the height increases, which may cause difficulty in maintaining a steady doom structure. Within the allowance of the stress, the inflated tarp is recommended to have a low height such as $h < a/2$.

Cost

The total costs of the tarp and the supplies in this project were approximately $5,000 plus 12 man-day labour for installation. The cost is expected to be reduced if the technology is commercialized. Operating cost is very small since the only variable cost is the power of the blower. Compared with solid cover structures, this balloon type cover is an inexpensive alternative.

Conclusion

The following conclusions can be drawn from this study:

- A balloon type cover has been designed, installed and successfully operated at a commercial size concrete manure lagoon. The lagoon size had a capacity of a 200 sow farrow-to-finish swine production facility.

- The cover reduced the odour emission significantly. Air leakage rate from the cover was 60L/s at 100 Pa, which is equivalent to a toilet exhaust fan. A human could not detect any odour even when standing by the lagoon at the downstream of the wind. The cover also improved the landscape of the cite.

- Critical pressures (the minimum pressure to prevent the tarp from flapping) was determined. The tarp must be operated at a pressure higher than the critical pressure. The cover in this study was operated at 100 pa and remained steady (without flapping) at wind speed of 50 km/h.

- Stress analysis of the tarp was conducted. For a particular lagoon, tarp materials must be selected based on the strength requirement.

- Further research is needed for design of, and installation to lagoons with different shapes and sizes such as rectangular earthen lagoons.

IMPLICATIONS

The approximate cost of the cover was $6,000 for installation. Operating cost was very small because the only variable cost was the power of the blower. It appears that the inflated balloon type lagoon cover is a viable alternative method to reduce odour emission.

Acknowledgement

The authors appreciate the financial support from Canada-Saskatchewan Agricultural Green Plan. A special thank you to Mr. G. McDonald for his excellent technical support for the installation of the lagoon cover.

Figure 1. Sketch of the lagoon cover and the control systems.

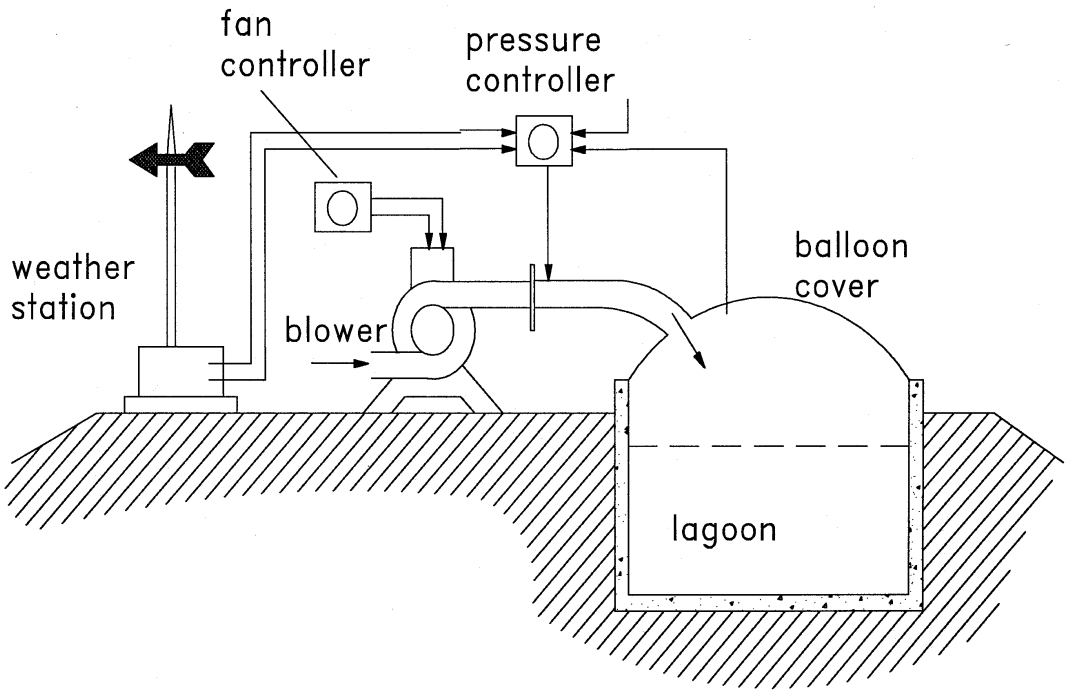


Figure 2. A balloon- type lagoon cover at the Prairie Swine Centre, Saskatoon, SK, Canada. The cover reduces odour emissions as well as improves the landscape.

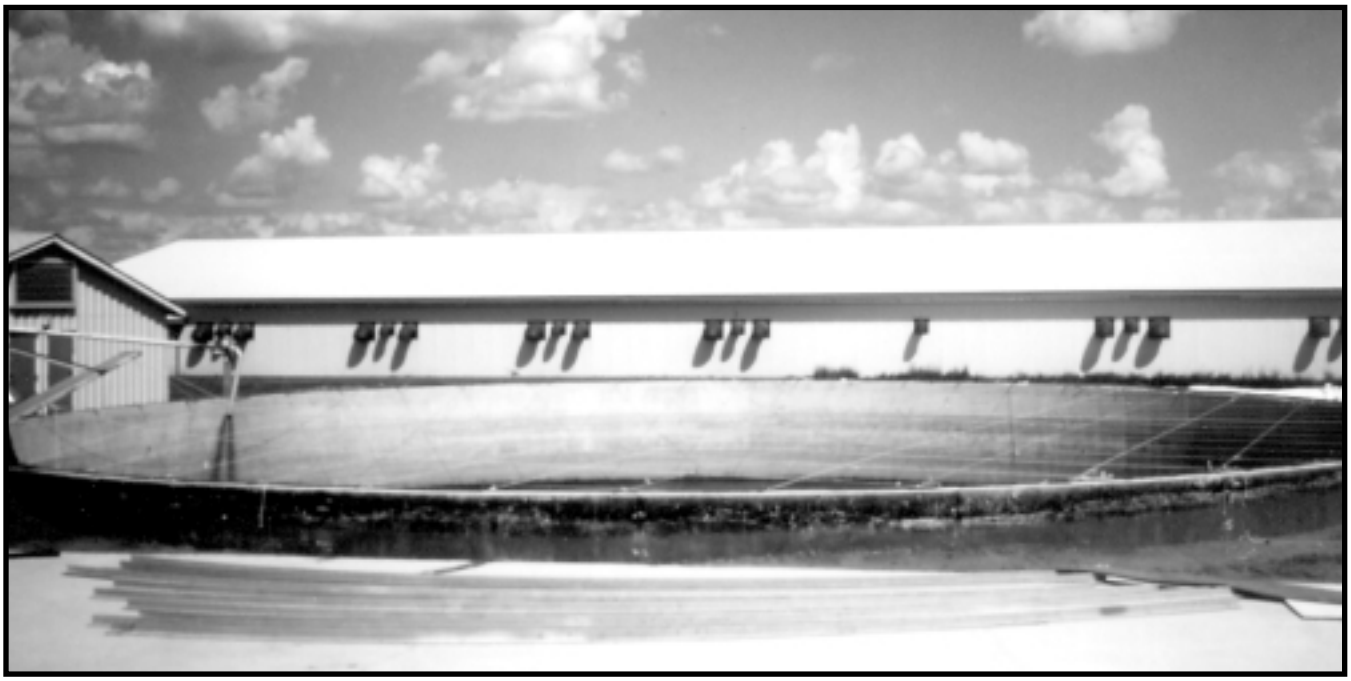


Figure 3. Attachment of the tarp to the concrete perimeter of the manure lagoon.

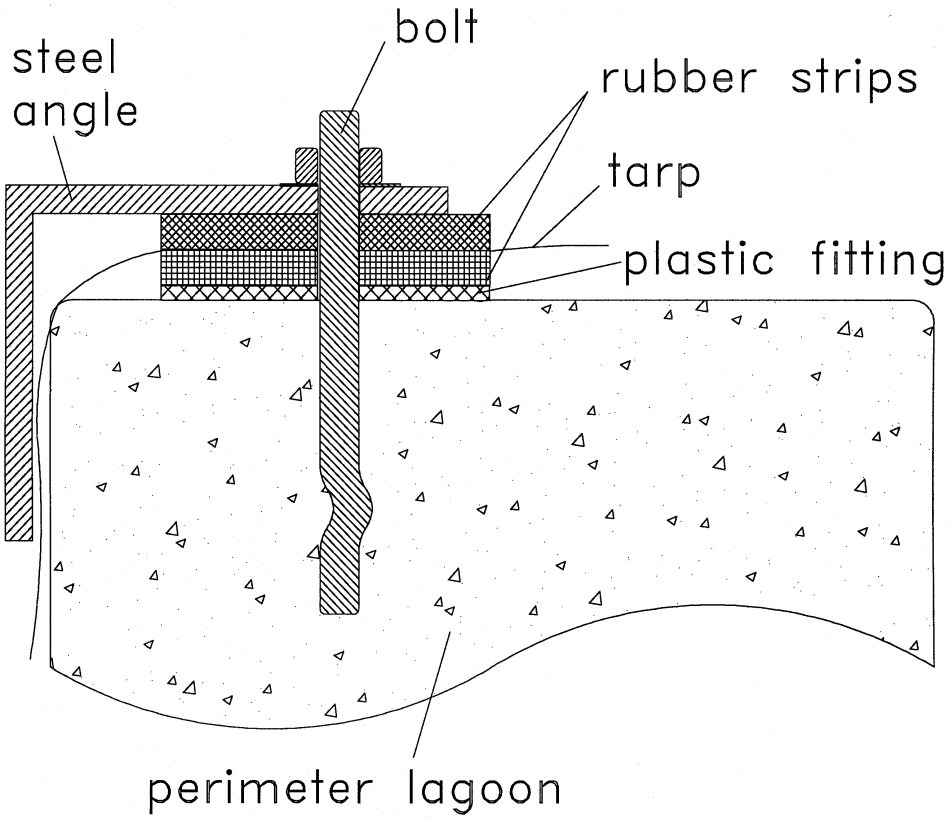


Figure 4. Air delivery and pressure control systems.

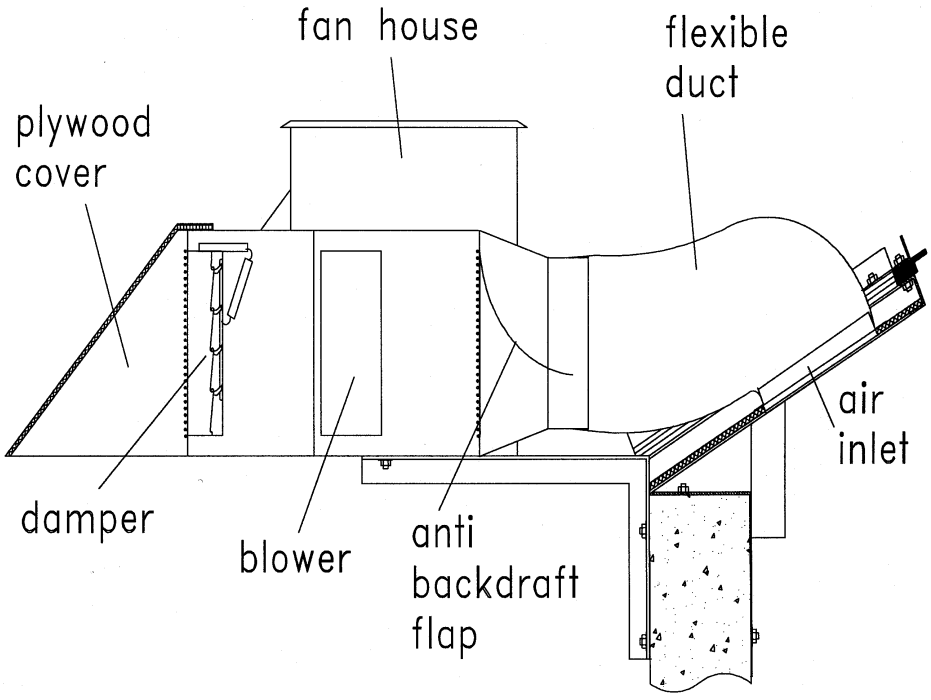


Figure 5. Relationship between the operating pressure and the air leakage fromm the cover

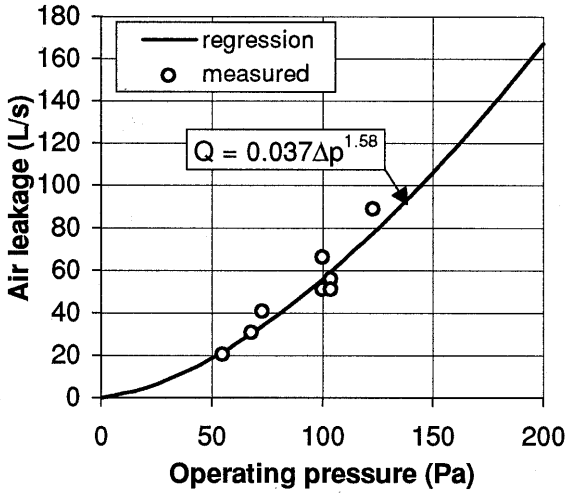


Figure 6. Measured and predicted critical pressures at different wind speeds

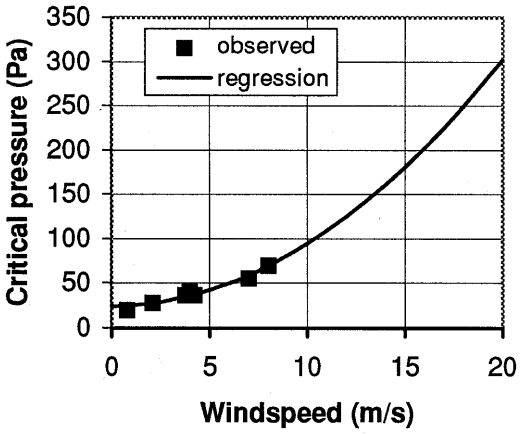


Figure 7. Free body diagram of an isotropic sphere and a partial sphere: (a) half-sphere, and (b) partial sphere - the lagoon cover.

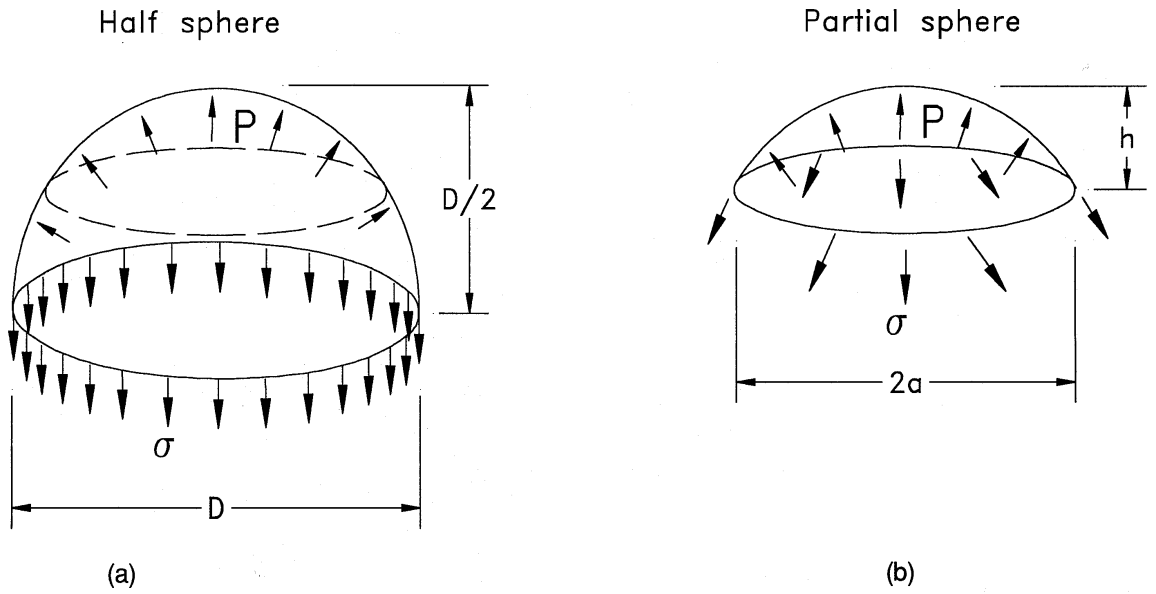


Table 1. Concentration and emission rates of ammonia and hydrogen sulphide from the covered lagoon.

Date (m-d)	Temperature (˚C)	Relative humidity (%)	Emission Rate (mg/s) NH_3	$H2_S$
9-22	*	*	1.48	0.0672
9-29	18.4	59	1.40	0.0840
10-05	8.7	75	1.78	0.0336
10-10	16.0	38	1.86	0.1092
10-16	12.0	70	2.00	*
10-23	9.5	56	0.97	0.0756
10-27	3.7	70	.085	*
Mean	11.4	61	1.47	0.0739

* Missing Data

THE DIVERSITY EXHIBITED BY *STREPTOCOCCUS SUIS*

STRAINS OF STREPTOCOCCUS SUIS WITH A DIVERSITY OF SEROTYPES SHARE COMMON PROTEIN ANTIGENS

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SUMMARY

Every year a substantial economic loss is incurred by the swine industry and its producers as a result of *Streptococcus suis* infections within herds. Currently, there are reported to be 34 different serotypes of S. suis, and the diversity of this organism is an obstacle which must be overcome if success is to be achieved in the areas of preventative care and diagnostics. The protein profiles of 18 strains, representing different serotypes, were examined to identify similar proteins which may be potentially useful for further research into these areas. The second objective was to determine if the site, in an infected pig, from which the sample was taken correlated to the presence or absence of specific proteins.

Eighteen strains of *S. suis*, representing the serotypes 1 - 10, 12, and 15 - 18, provided the antigen required for the experiment. The antisera was created by injecting rabbits with four *S. suis* serotype 2 proteins and a *S. suis* subunit bacterin preparation. Subsequently, the antigens were separated on acrylamide gels and exposed to each of the five antisera using the procedure referred to as Western Blotting. The degree of reactivity observed between antiserum to each of the serotype 2 proteins and the eighteen strains was indicated by dark bands showing the level of similarity.

The antiserum to the 44kDa, 55kDa, 78kDa, and 85kDa proteins and the subunit preparation each demonstrated a reaction against all strains tested. A 127kDa protein also reacted with serotypes 2, 3, 4, 6, 7, 9ns, 9m, 9v, 10, 12, and 15. The strains from nasal swab, meningitis and tissue swab samples, representing serotype 9, reacted in an identical manner against all of the antisera.

These four *S. suis* serotype 2 proteins could be future vaccine components and/or diagnostic aids as they are found to be present in many of the dominant pathogenic *S. suis* serotypes.

Introduction

Streptococcus suis bacteria are harbored in the nasal cavities of the host. Up to 98% of farms studied test positive for this organism, and 94% of the 4 - 8 week old clinically healthy piglets tested can be carrying *S. suis* in their nasal cavities. There are four contributing factors to a high carrier rate in a swine operation. They are: 1) excessive temperature fluctuations due to drafts, poorly insulated buildings, and inadequate heaters, 2) a high relative humidity because of inadequate ventilation rates, 3) crowding, and 4) an age spread of greater than two weeks between pigs in the same area. Infection with *S. suis* results when susceptible piglets, who are under stress from weaning, mixing, and/or fighting, are exposed to the bacteria shed from clinically healthy carrier pigs.

Serotypes 1 - 8 are the most prevalent and important disease causing serotypes of *S. suis*. Serotype 2 commonly represents approximately 32% of all isolates taken from diseased subjects. Serotypes 9 - 13, 15, 16, and 22, have also been isolated from pigs demonstrating signs of disease. The prevalence of a serotype is variable and dependent upon geographical location. In the U.S. serotype 1 and 2 have the highest incidence. Here in Western Canada serotypes 2 followed by 1/2, 3, 8, 9, and 4 are most prevalent.

Attempts to control disease through the use of antibiotics and vaccines have been somewhat frustrating and disappointing. Studies have determined that all *S. suis* strains are susceptible to enrofloxacin and 97% are susceptible to ceftiofur. These antibiotics are used prophylactically in the form of medicated early weaning programs but there are problems with this approach. High carrier rates are still observed despite the antibiotic therapy. As well, implementation is expensive, and there is always the risk of resistance developing. The current vaccines also are inadequate. They either fail to confer sufficient protection or they are not effective against all of the necessary serotypes (1). There are different approaches in the development of an *S. suis* vaccine. One is to use the polysaccharide capsule of the bacteria, but

S.suis polysaccharides are poorly immunogenic. A second approach is to use a live avirulent strain for the immunization of swine (6). More recently specific protein antigens are being investigated as vaccines. Antibodies produced and directed against certain proteins could confer immunity to the animal and prevent future infection. Research has confirmed that bacterial protein fractions can generate protection against infection. Many researchers are coming to the conclusion that a vaccine that is useful against S.suis infections will have to contain either a combination of proteins or a combination of polysaccharides and proteins in order to be successful.

With this in mind, the objectives of this study were as follows: 1) to determine the reactivity between antiserum to the four serotype 2 proteins and eighteen different strains of *S. suis* using the Western Blot technique, and 2) to compare the production of these 4 proteins in three strains, all of serotype 9, but isolated from different regions in an infected pig to determine if location of isolation is related to the presence or absence of these proteins.

EXPERIMENTAL PROCEDURE

Antigen was extracted from *S. suis* serotypes 1 - 9, 10, 12, and 15 - 18. Table 1 shows which strains were used as representatives for each serotype. For capsular type 9, antigen was extracted from three different known samples: a nasal swab, a meningitis sample, and a swab of internal tissues (spleen, lungs, heart). Rabbit antisera were used that had been made against a subunit bacterin preparation and four serotype 2 proteins of the sizes 44kDa, 55kDa, 78kDa and 85kDa. Enzyme-linked Immunosorbent Assays (ELISA) were used in the determination of the antibody titers for each antisera. SDS-PAGE (Sodium dodecyl sulfate-polyacrylamide gel electrophoresis) was carried out in order to separate the *S. suis* proteins. When separation had occurred, the material was transferred from the gels to nitrocellulose membranes. Once on the membranes, the proteins were revealed using the rabbit antisera, a secondary antibody, and substrate.

RESULTS AND DISCUSSION

A high titer of at least 12, 500 was observed for each of the rabbit antisera to the serotype 2 proteins used for the next step. The Western blots showed reactivity in all eighteen *S. suis* strains against each of the four serotype 2 proteins. In blotting with the serum produced from the subunit bacterin preparation, the 44kDa, 78kDa, and 85kDa proteins demonstrated strong reactions but the 55kDa protein did not (Figure 1). Interestingly, a protein having the molecular weight of approximately 127kDa appeared and reacted with serotypes 2, 3, 4, 6, 7, 9ns, 9m, 9v, 10, 12, and 15 (Figure 1).

Conclusions:

1) The four *S. suis* serotype 2 proteins, sizes 45kDa, 55kDa, 78kDa, and 85kDa, were produced in each of the eighteen *S. suis* strains tested. The lightening of the 55kDa band in the Western blots using the antiserum to the subunit vaccine can be explained in two ways. The 55kDa protein could have a decreased antigenicity in the subunit vaccine. As well, the molar concentration of the 55kDa protein was substantially lower in the multi-antigen vaccine than in the single antigen vaccine. 2) It is possible that the 127kDa protein appearing on the multiple antigen immunoblots is a 128kDa protein observed by other researchers to provide partial protection. 3) The three strains, all representing serotype 9, display only subtle differences in the way in which they react with the serotype 2 proteins. This suggests that location of isolation is not related to the presence or absence of these proteins.

IMPLICATIONS

These protein antigens are commonly shared among several serotypes of Streptococcus suis that cause disease in pigs. Experience with serotype-specific vaccines is that they do no cross-protect against other serotypes of *S. suis*. Hence, protein antigens are likely candidates for development of future effective vaccines that will protect pigs against multiple serotypes of *S. suis*.

ACKNOWLEDGMENTS

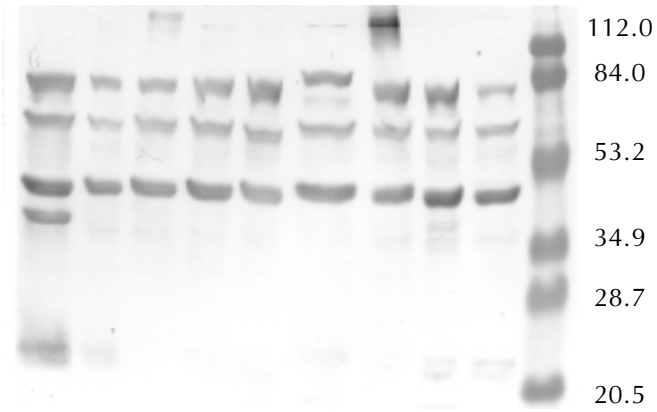
Thanks is extended to Sandy Klashinsky for her technical assistance and guidance and to Wayne Conner for his assistance in the lab. This work was supported, in part, by Alberta Agricultural Research Institute Project 94M664 and Saskatchewan Agriculture and Food Project 95000300.

Table 1. A Listing of the *S.suis* Strains used and the Serotypes each Represents

Strain	Serotype
SX349	1
SX350	2
SX351	3
SX352	4
SX353	5
SX354	6
SX355	7
SX356	8
SX357	9
SX202	9ns
SX340	9m
SX328	9v
SX12	10
SX170	12
SX93	15
SX102	16
SX116	17
SX148	18

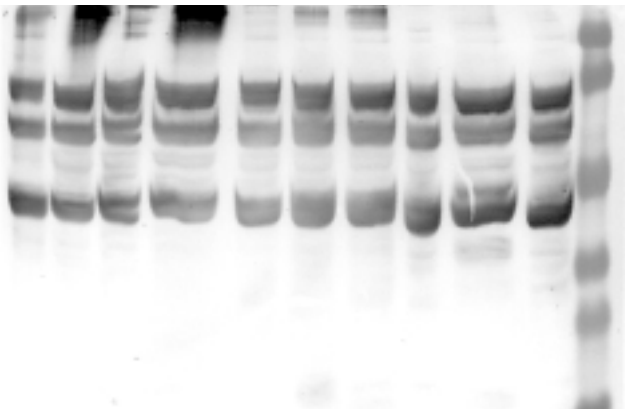
Figure 1. Western Blot of *Streptococcus suis* proteins from 18 strains that are similar to proteins from serotype 2 strain

Panel A



Panel A: Serotypes 1 through 9 (Table !) and size markers (kDa)

Panel B



Panel B: Strain SX-26 (serotype 2), serotypes 9ns through 18 (Table 1} and size markers

EVALUATION OF FEEDERS FOR GROWING AND FINISHING PIGS:

EVALUATION OF FEEDERS FOR GROWING AND FINISHING PIGS: THE PRODUCTION STUDY

Harold Gonyou and Zhensheng Lou

SUMMARY

Twelve commercial feeders were evaluated in 4 pens of 12 pigs each during the 12-wk growing/finishing period. Feeders were classified according to their feed form (dry vs. wet/dry) and space (single vs. multiple space). In total there were 2 single-space dry (SS-D), 3 single space wet/dry (SS-WD), 4 multiple space dry (MS-D), and 3 multiple space wet/dry (MS-WD). Average daily gain and feed disappearance were 5% greater with wet/dry feeders than with dry. The effect of wet/dry feeders on growth was only evident during the final 8 wk of the trial, while feed disappearance tended to be higher throughout. Carcasses of pigs fed from dry feeders yielded a higher lean percentage than did those of pigs fed from wet/dry feeders. Single and multiple space feeders did not differ in gain or feed disappearance at any point during the trial. Feed efficiency did not differ among feeder classes.

INTRODUCTION

Many innovative hog feeders have appeared on the market in recent years. Facing a choice among dozens of commercial feeders, producers find it difficult to decide which feeder to choose for their operation. In order to provide information to aid in such decision making, we designed a study to investigate the main types of growing/finishing feeders currently available. The present study is one in a series which included evaluations on productivity, wastage, feeding speed, pig preference and pig-feeder interaction. The present article summarizes the productivity data.

EXPERIMENTAL PROCEDURE

A total of 576 pigs of mixed gender were used in the study. The pigs were housed in one fully slatted room at the PSCI. The pigs averaged 25 kg when they were randomly allocated to 12 pens for each of four room turns. Each pen housed 12 pigs providing an average space allowance of 0.86 m^2/pig (9.3 ft^2/pig) or approximately 0.042 $m^2/kg\ BW^{0.667}$ at the end of the 12 week room turn. Females and castrated males were allocated evenly among pens.

The pigs were fed a mash (5/32″ screen) diet based on barley and soybean meal in a two-phase feeding program. For the initial six weeks of the trial the diet provided 3.26 Mcal DE/kg and contained 16.8 % crude protein; for the final six weeks of the trial the diet provided 3.21 Mcal/kg and 16.1% crude protein.

Twelve models of commercially available feeders (Table 1) were evaluated in the study. Feeders were classified as wet/dry or dry depending on whether or not water was available in the feeder trough. Feeders were also classified as single or multiple space depending on whether an individual or several pigs were intended to eat at one time.

Feeders were installed as part of or adjacent to the pen division, approximately 1.6 m from the back of the pen. A single nipple drinker was mounted between the feeder and the rear wall for all dry feeders and the wet/dry feeders whose manufacturers recommended an additional water source (Dyna-Fab and ACO single).

Pigs were weighed at the beginning of each study and at two-week intervals thereafter. Feed disappearance for each two-week period was also determined. In the case of two pens sharing the same feeder, feed disappearance was considered to be proportional to gain, resulting in identical efficiencies for both pens.

At the end of 12 weeks, pigs were marketed as they reached 107 kg. Pigs were identified by tattoo and carcass data were obtained from market records.

Four turns of the room were used for a total of 48 pens, representing four replicates per feeder. Not all feeders could be assigned to each room turn due to the fact that the two-sided feeders required two pens at once; but as many feeders as possible were included in each turn.

RESULTS AND DISCUSSION

Dry vs. Wet/Dry feeders

Average daily gain for the entire 12-week trial, across all feeders was 0.895 kg/d. It should be noted that the pens were of mixed gender, so weight gain represents the average of barrows and gilts. Pen average daily feed disappearance was 2.74 kg/d. Pen feed conversion efficiency expressed as gain:feed or feed:gain averaged 0.338 or 2.96, respectively. The diet used was barley based, so feed conversion efficiencies were poorer than what would be expected using corn or wheat based diets.

Average daily gain and feed disappearance were increased by 5% with wet/dry compared to dry feeders over the entire trial (Table 2; $P < 0.05$). However, feed conversion efficiencies did not differ between dry and wet/dry feeders ($P > 0.05$).

When all feeders were plotted (Figure 1) by class (dry or wet/dry; single or multiple space), there was very little overlap between classes on the average daily gain and feed disappearance, indicating that one can be confident that a wet/dry feeder will result in increased feed disappearance and improved weight gains if pigs are offered a diet similar to that offered in the present study. In contrast to weight gain and feed disappearance, feed efficiency was not very consistent within or between feeder groups. Even within one model of feeder, pens differed considerably in efficiency. Because of this variation, one can not be confident that a feeder from one particular class will result in improved feed conversion efficiency compared with one from a different class.

To determine the effect of feeder type on different sizes of pigs, the data were divided into three four-week periods, and each period analyzed separately. Average daily gain was not different between dry and wet/dry feeders for the first four weeks of the trial (Figure 2; $P < 0.05$). However, pigs feeding from the wet/dry feeders had superior weight gain compared with those feeding from dry feeders for the mid and final four-week periods of the trial ($P < 0.01$). Feed disappearance was numerically higher but not different ($P > 0.05$) for wet/dry compared to dry feeders for the first four weeks of the trial. Although feed disappearance appeared to remain higher for wet/dry feeders compared with dry feeders throughout the trial, the differences were not significant during the mid four-week period ($P > 0.01$) and only tended to be different for the final four weeks ($P < 0.10$).

The improvement noted with wet/dry feeders over dry feeders occurred during the final eight weeks of the trial. It has long been recognized that appetite generally constrains growth during the growing period, but not during the finishing period. Thus it is not surprising that finishing pigs were capable of growing more as wet/dry feeders facilitated higher feed disappearance. The improvement observed in the present study with wet/dry feeders during the final eight weeks of the trial suggests that even greater benefits may be achieved with such feeders if pigs are marketed at higher weights. The animals in this study averaged approximately 100 kg at the end of the trials. Because of the prevailing market grid, at this point the larger animals were marketed. Nonetheless, market weights are higher in other Canadian provinces and in the US, extending the pigs' finishing period for an additional two to four weeks.

Single vs. Multiple space

Average daily gain was higher ($P < 0.05$) for single space feeders during the first four weeks of the trial (Figure 3), but shifted in favour of multiple space feeders during the mid four-week period of the trial ($P < 0.10$). During the final four weeks, there was no difference between single and multiple space feeders ($P > 0.05$). Average daily feed disappearance did not differ between single and multiple space feeders for any of the four-week periods of the present study ($P > 0.05$).

The single space feeders used in the present study provided protection to the head and shoulders of the feeding pig. This protection, during the period of the trial when social disputes are most common, may have contributed to the slight increase in gain early in the trial. However, multiple space feeders tended to produce more gain thereafter, and overall there were no significant differences in gain or feed disappearance.

Feed conversion efficiency did not differ for any of the four-week periods between single and multiple space feeders ($P > 0.05$).

Feed conversion efficiency was quite variable within each class of feeder, and among pens for individual feeders. Overall, no one characteristic of feeders, dry or wet/dry, single or multiple space, affected efficiency consistently. Although efficiency is usually correlated with feed disappearance and rapidly growing animals, it is also affected by feed wastage. Wastage in turn is affected by management and maintenance of the equipment and the eating style of individual pigs. It would appear that efficiency is a critical feature to be considered during design of pig feeders.

Carcass characteristics

There were no significant differences in carcass characteristics between all feeder types (Table 3; $P > 0.05$) with the exception of lean percentage of pigs fed from dry and wet/dry feeders. Dry feeders yielded higher lean percentages than did wet/dry feeders ($P < 0.05$). Among the four feeder classes, dry-multiple-space feeders resulted in 1% more lean than wet-single-space feeders. Such a result has also been reported in a similar study in Australia.

Implications

Producers must consider several factors when selecting feeders for growing - finishing pigs. If a rapid turn over of pens is desired, the use of wet/dry feeders will enable pigs to be marketed 5 - 7 days earlier. This difference may be greater if pigs are marketed at higher weights than in this study.

The diet offered in this study was mash, which favours wet/dry feeders. The difference between feeder types would likely be less if pelleted diets were fed.

Producers must also consider carcass index. The more rapid growth of pigs fed from wet/dry may not offset the slight reduction in lean percentage.

Feed efficiency is also a major factor to be considered, but this study was not able to distinguish any differences among feeders.

Acknowledgements:

These trials were funded in part by the manufacturers or distributors of the feeders studied, the Saskatchewan Agriculture Development Fund, the Alberta Agricultural Research Institute, and Pig Improvement (Canada).

Table 1. Feeders included in production study.

Manufacturer or Brand Name	Model or Description	Dry or Wet/Dry	Single or Multiple Space
Prairie Swine Centre	Experimental	Dry	Single
Domino	F-H1	Dry	Single
Crystal Spring	F3050 (12 in)	Wet/Dry	Single
Dyna-Fab	Finishing	Wet/Dry	Single
ACO	Food & Drinker	Wet/Dry	Single
Better	Finisher, 2-hole	Dry	Multiple
ACO	ATS 32, 2-hole	Dry	Multiple
Hog Slat	4-hole (40 in)	Dry	Multiple
Koenders	4-hole (34 in)	Dry	Multiple
Aqua	30 in	Wet/Dry	Multiple
Crystal Spring	F3250 (24 in)	Wet/Dry	Multiple
Egebjerg	Tube-o-Mat	Wet/Dry	Multiple

Table 2. The effect of feeder type (dry vs wet/dry and single vs multiple space) on average daily gain, feed disappearance and feed efficiency of growing-finishing pigs offered a barley-soybean mash diet

	Dry	Wet/Dry	*P* P value	Single	Multiple	*P* P value
Daily gain, kg	0.873	0.917	0.02	0.883	0.904	0.25
Daily feed disappearance, kg	2.66	2.82	0.01	2.69	2.77	0.54
Feed efficiency						
gain/feed	0.329	0.326	0.45	0.329	0.325	0.47
feed/gain	3.05	3.08	0.45	3.04	3.08	0.47

Table 3. The effect of feeder type (dry vs wet/dry and single vs multiple space) on carcass characteristics of growing-finishing pigs

Feeder Type	Shipping weights, kg	Carcass weights, kg	Lean, mm	Fat, mm	Lean yield, %	Index
Dry	105.4	83.4	56.9	21.9	57.0a	108.1
Wet/Dry	105.4	83.3	55.5	23.0	56.3b	107.1
Single	105.4	83.4	56.1	22.5	56.5	107.6
Multiple	105.5	83.3	56.4	22.4	56.8	107.6
Dry-Single	105.6	83.6	57.4	22.0	56.8ab	108.3
Dry-Multiple	105.3	83.2	56.4	21.9	57.2a	107.9
Wet-Single	105.2	83.2	54.7	23.1	56.1b	106.5
Wet-Multiple	105.6	83.5	56.3	23.0	56.4b	107.3

The critical P value used in comparisons is P = 0.05.

Figure 1. Average daily weight gain, daily feed disappearance and feed efficiency on four types of feeders over 12-week period

Each column represents one model of feeders. Models are grouped by type: Single Space Dry/SS-D; Multiple Space Dry/MS-D;

Single Space Wet-Dry/SS-WD; Multiple Space Wet-Dry/MS-WD.

A column does not necessarily represents the same model in each figure.

For ADG, wet-dry, dry, $P<0.05$; for ADFD, wet-dry, dry, $P<0.05$.

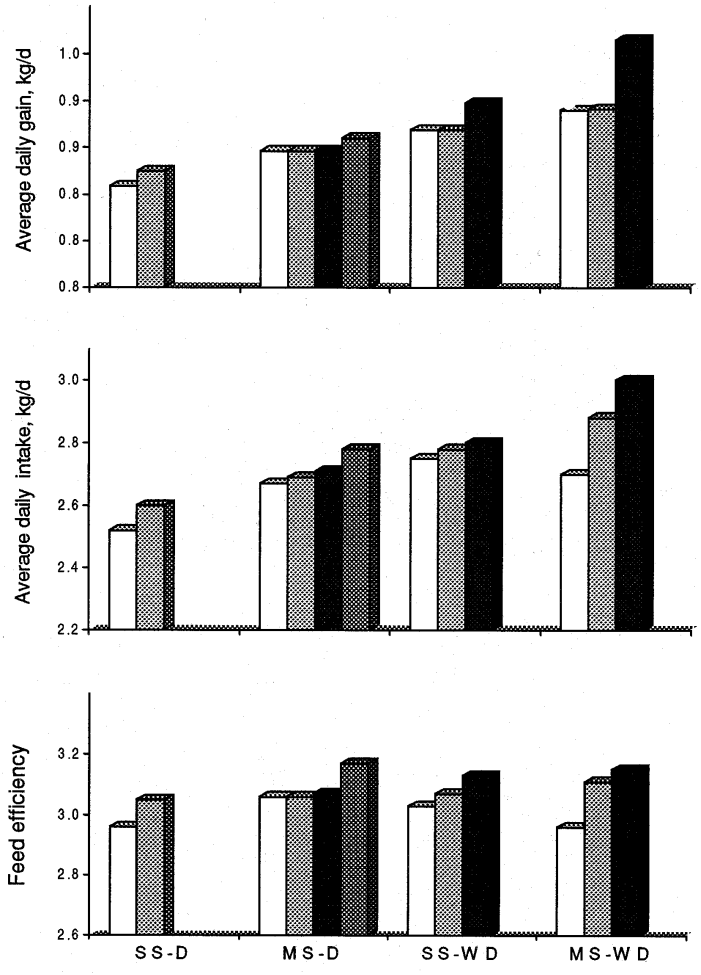


Figure 2. Comparisons of average daily weight gain, daily feed disappearance between dry and wet/dry feeders over time

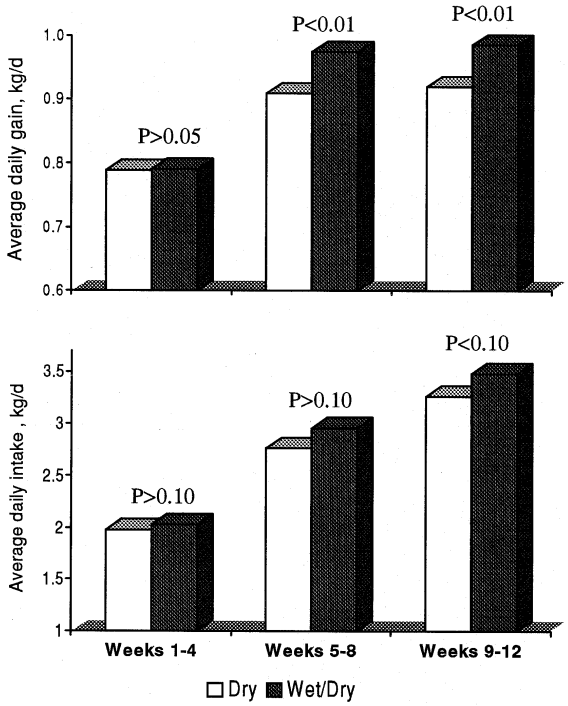
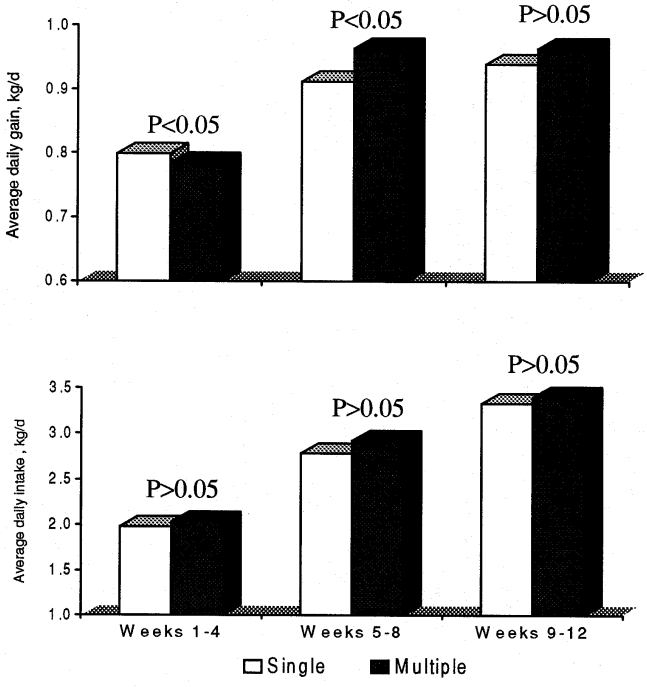


Figure 3. Comparisons of average daily weight gain, daily feed disappearance between single-and multiple-space feeders over time



LOCOMOTORY BEHAVIOUR AND MATERNAL RESPONSES IN GILTS, AND THE EFFECTS OF GESTATION AND FARROWING HOUSING.

Moira Harris and Harold Gonyou

SUMMARY

Farrowing crates are designed to restrict a sow's movements in order to reduce crushing; however, their effectiveness in protecting piglets has been questioned. The use of crates alters maternal behaviour and may threaten sow welfare. A study was designed to test the effects of gestation and farrowing housing on locomotory behaviour and maternal responses. It was hypothesized that increasing available space would allow sows to move more easily, and facilitate comfort and maternal responsiveness.

Twenty-four gilts were allocated to either a stall or small group during gestation, followed by either a narrow crate (42.5 cm wide), wide crate (80 cm wide) or pen (2.4 m x 2.4 m) for farrowing and lactation.

Maternal responsiveness (as measured by a simulated piglet crushing event) was not affected by housing. Twenty-four hour time budgets of body postures (lateral lying; sternal lying or lying on the udder, standing; sitting) were affected by farrowing housing, particularly prepartum, with gilts housed in wide crates showing greater pre-farrowing restlessness. This effect was more pronounced after gestation in groups. Gilts took longer to lie down, and were less consistent in their use of a support during lying down in the wide crate than in either the narrow crate or pen.

A widened farrowing crate did not facilitate movement, and appeared less comfortable before farrowing than either a narrow crate or pen. The wide crate provided neither the support and apparent security of a narrow crate, nor the freedom of movement of a pen.

INTRODUCTION

Farrowing crates are intended to increase piglet safety by severely restricting sows' freedom of movement. Since the normal pre-farrowing behaviour of a feral sow consists of a period of increased walking followed by construction of a farrowing nest, confining the sow to a farrowing crate creates welfare concerns.

Confinement in crates and stalls affects sows' behaviour; for example it makes lying down more difficult (and it is therefore performed more slowly). Transferring sows from a relatively free situation (a group) to one that is more restrictive (a crate) in late pregnancy may have additional negative effects on behaviour; however, non-stall gestation systems are now receiving more attention in an attempt to increase sow welfare.

A minor change in the dimensions of a confinement housing design can markedly affect sows' behaviour. A relevant question, therefore, is whether dimensions can be altered to facilitate specific changes in behaviour. It was hypothesized that increasing the available space in a farrowing crate, without changing any other feature, would facilitate locomotory behaviour and appropriate maternal responsiveness.

EXPERIMENTAL PROCEDURE

Twenty-four crossbred gilts were allocated to gestate in either individual stalls or small groups. Approximately five days before they were due to farrow, gilts were moved to one of 3 types of farrowing housing: a narrow crate (42.5 cm wide, equivalent in width to crates currently in use at Prairie Swine Centre); a wide crate (80 cm wide, designed to accommodate the standing up and lying down movements of a 200 kg gilt without restriction); or a pen (2.4 m x 2.4 m, the approximate size of a traditional farrowing pen). Farrowing housing incorporated a heated, lit piglet creep area. Flooring was plastic-coated expanded metal, and no bedding was provided. Gilts and piglets were managed in accordance with usual barn procedure, with farrowing being induced on day 113 of gestation using an intramuscular prostaglandin injection.

Behavioural observations were made during gilts' occupancy of farrowing quarters. On days -5 and -1

(before farrowing) and days 1, 3, 7, 14 and 21 after farrowing, 24-hour time-lapse videotapes were used to calculate a time budget of postural behaviour. The four main postures adopted by sows are lying laterally (on the side); lying sternally (on the udder); standing; and sitting. The percentage of time spent in each posture, the number of bouts (episodes of behaviour) of each posture and the average duration of each postural bout were calculated. On the same seven occasions, standing up and lying down behaviour was examined in more detail: a real-time videotape of standing up and lying down sequences was analyzed. Lying down has previously been found to comprise five stages: three active stages and two pauses; standing up comprises three stages: two active stages and one pause. The average duration of these stages, and the total average time taken to stand up and lie down, was measured. Additionally, it was noted whether the sow chose to lie down using the crate side or pen wall as a support. Finally, a test of maternal responsiveness was conducted on day 2 after farrowing: a tape-recorded piglet distress squeal (simulating a piglet being crushed) was played behind the sow when she was in the process of lying down. Her responses to the sound (stand up or continue to lie down; time taken to complete this action; and subjective response to the sound, for example ear flicking, looking towards the sound) were noted.

RESULTS AND DISCUSSION

Time Budget

Prior to farrowing, postural time budget varied significantly with the type of farrowing housing. After farrowing, results were not significant. Five days before farrowing (on the day gilts were transferred from gestation to farrowing housing), gilts in the narrow crate spent significantly more time lying laterally (side lying is considered a restful posture), and less time standing (considered to indicate increased vigilance) than other gilts, regardless of their gestation housing. In the wide farrowing crate, gilts' response depended on their gestation housing (Figure 1). Gilts in the wide crate that had gestated in groups spent significantly more time lying sternally (again, a less restful posture) than those who had been housed in gestation stalls. On the day before farrowing, all gilts exhibited restless behaviour and increased posture changing, a normal prepartum behaviour. However, gilts in the widened farrowing crate displayed exaggerated restlessness: less time spent lying laterally, more, shorter bouts of lateral lying, and more time spent lying sternally in more bouts. Again, this effect depended on the type of gestation housing: gilts in the wide crate that had gestated in groups spent more time lying sternally than those who had previously occupied stalls (Figure 2).

Standing Up and Lying Down

Time taken by gilts to stand up was not affected by gestation or farrowing housing, or by their phase of gestation or lactation. Lying down behaviour, however, did vary. Gilts lay down more quickly after farrowing than before, perhaps because they were lighter and therefore more agile. Gilts in the wide farrowing crate took significantly longer to lie down than those in either the narrow crate or pen (Table 1). Studies done in the U.K. have suggested that slow lying down indicates difficulty in making the posture change, whereas quicker lying indicates ease of movement; quick lying has also been speculated to reduce piglets' likelihood of being crushed, provided they are outside the sow zone when lying commences. Table 1 also illustrates gilts' use of the crate side or pen wall as a support during lying down. Occupants of the narrow crate and pen chose to use a support during lying down on most occasions; however those in the wide crate used a support less than half the time. Use or non-use of a support, however, by occupants of the wide crate, did not affect time taken to lie down. Hence, the properties of the wide crate that impeded quick lying (or at least, did not facilitate it), were unaltered by use of a lying support.

Maternal Responsiveness

Only six out of 24 gilts responded 'positively' to the piglet squeal stimulus — by standing up after hearing the sound, ear flicking, and looking towards the sound. This response was very variable among gilts, and was not affected by type of housing during either gestation or farrowing.

First parity sows housed in a widened farrowing crate displayed more restless behaviour before farrowing, took longer to lie down and made less use of a support during lying than gilts in either a conventional, narrow crate or a farrowing pen. Prepartum restlessness was exaggerated when gilts had gestated in groups then moved to a wide crate for farrowing, which involved a change in degree of movement restriction late in pregnancy. There was no evidence from this study that increasing the available space in a

farrowing crate, without altering any other feature, facilitated locomotion or maternal responses. In contrast, the wide crate produced more negative effects on locomotory behaviour than a narrow one. However, narrow crates or pens may reduce the welfare of sows or piglets in other ways not assessed in this study.

IMPLICATIONS

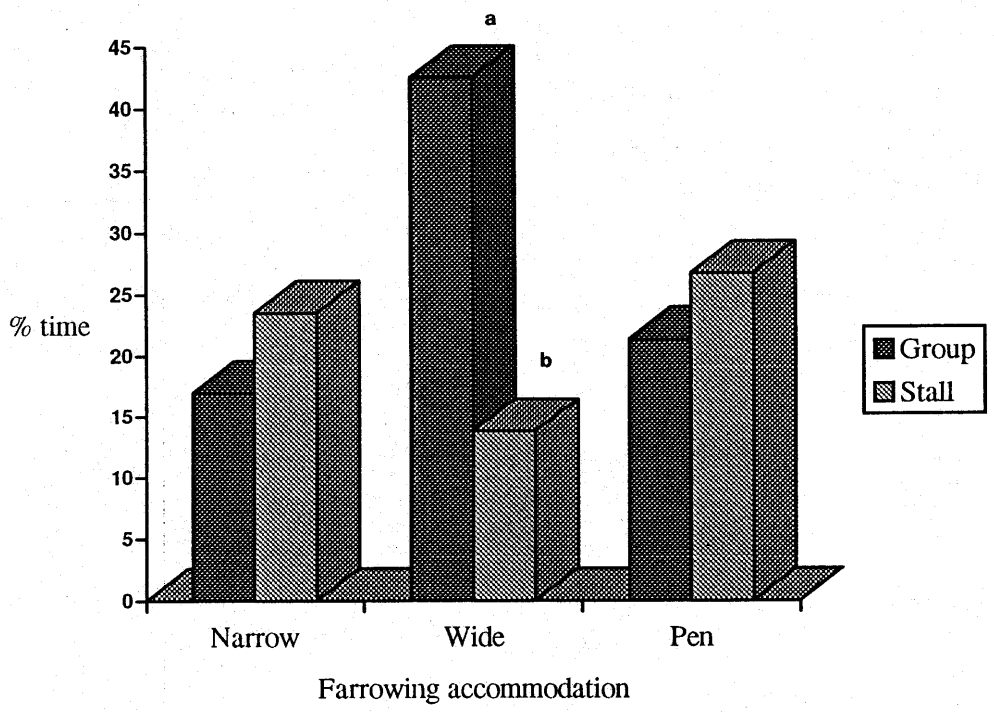
It appears that a widened farrowing crate provided neither the apparent support and security of a narrow crate, nor the freedom of movement of a pen. The quality of space, as well as its quantity, is important. Increasing an animal's freedom of movement by a small amount, in an attempt to increase its welfare, may actually produce detrimental results. In producing "alternative" housing designs, animal-centred testing is necessary to ensure that a new design does not lead to effects which are counter-intuitive

Table 1. Lying down behaviour of gilts in 3 farrowing environments.

Behaviour	Narrow	Wide	Pen	P value
Total time taken to lie down (sec):	13.1[a]	18.2[b]	12.0[a]	0.01
% of lying down using crate side or pen wall for support	71.7[a]	34.6[b]	88.6[a]	0.01

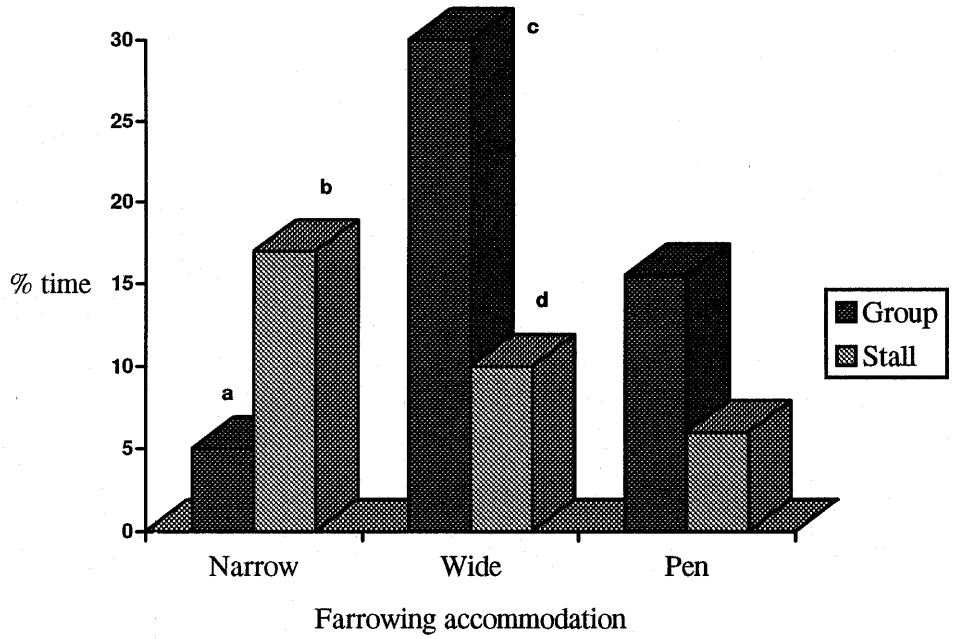
[a,b] Means in a row with different superscript letters differ at $P < 0.05$

Figure 1. Percentage of time spent lying sternally in 3 farrowing environments by gilts previously housed in gestation stalls or groups (five days before farrowing).



[a,b] Means without a common superscript (same farrowing accommodation) are different at $P < 0.05$.
Gilts in the wide crate that had gestated in groups spent significantly more time lying sternally than those who had gestated in stalls.

Figure 2. Percentage of time spent lying sternally in three farrowing environments by gilts previously housed in gestation stalls or groups (One day before farrowing).



[a,b] Means without a common superscript (same farrowing accommodation) are different at $P < 0.05$
[c,d] Means without a common superscript (same farrowing accommodation) are different at $P < 0.01$.
Gilts in the wide crate that had gestated in groups spent significantly more time lying sternally than those who had gestated in stalls.

WATER USE AND DRINKER MANAGEMENT

WATER USE AND DRINKER MANAGEMENT: A REVIEW

Harold Gonyou

Importance of Water Intake

Water plays a number of important roles in the pig. Thermoregulation, feed intake and metabolism, urinary tract health, and behavioural disorders all interact in some way with water consumption. The result of these functions is that productivity on pig farms will suffer if adequate water intake is not achieved.

Water is used in thermoregulation, as a means of cooling through evaporation during breathing. Water intake by growing pigs doubles as environmental temperatures rise from 5° to 35° C. Water is also necessary to accommodate excesses of certain nutrients. If pigs are fed protein in excess of their lean growth potential requirements, water intake increases dramatically (Brooks, 1994). In a similar manner, if the salt content of the diet is high, water needs increase (Brooks et al., 1989). The health of animals may be adversely affected if water intake is limited. Death may occur due to 'salt poisoning' if pigs do not consume enough water. This most frequently occurs if water nipples become plugged or animals cannot access water because nipples are too high or difficult to trigger. The incidence of urinary tract infections is higher in sows with low water intakes (Madec, 1984).

Feed and water intake are closely related. Suckling pigs will increase water consumption if they are provided creep feed (Brooks et al., 1989), and conversely, creep feed intake will increase if water is provided (Lightfoot, 1986b). Within the nursery, when feed and water are both readily available, water and feed intake vary proportionally with each other (Maenz et al., 1993). If water intake is limited, for example by low flow rates, feed intake will decrease (Brooks et al., 1989). However, if feed intake is limited, water intake may rise as hungry pigs drink if they cannot eat (Yang et al., 1984).

Intake vs. Disappearance

Most studies measure the amount of water that flows through the drinker and report it as intake. Although this represents the amount of water used by the pigs, much of it is not consumed but wasted. Newborn pigs are reported to waste more than 25% of the water which disappears from their drinker bowls (Phillips and Fraser, 1990), and growing/finishing pigs may waste up to 60% of the water from a nipple drinker (Brooks, 1994). Spillage by sows varies from 23-80% of water use, depending on flow rate (Phillips et al., 1990a). Reducing the amount of spillage from drinkers would lower water and slurry costs significantly, without affecting water intake.

Water Intake of Pigs

Newborn piglets usually drink less than 50 ml per day, for the first few days (Fraser et al., 1988; Pedersen, 1988). Intake begins earlier, and is greater, if bowls are used. Bubbling air through the water, to attract the piglet, may increase intake to over 100 ml/day during this period. Intake gradually increases to approximately 150 mL/day by 21 days of age (Svebdsen and Andreasson, 1981). Intake increases considerably after that age (Bekaert and Daelemans, 1970), perhaps because of increased intake of dry feed (Brooks et al., 1989).

Intake in the nursery is very unpredictable for the first 5 days, and then varies with feed intake (McLeese et al., 1992). Intakes of 4 L/day during the first 2 days post-weaning, and then only 2 L/day have been reported (Pendersen, 1989). Other studies report from 0.43 to 5.5 L/day (Svendsen and Andreasson, 1981; Lightfoot, 1986b; Brooks and Carpenter, 1989). Intake is very dependent upon feed intake at this time, and excessive water is consumed until the pigs adapt to solid feed.

During the growing/finishing period, water intake increases with feed intake and body weight. Some estimates range from 1.9 to 6.8 L/day (Brooks and Carpenter, 1989). Intake, or perhaps disappearance, is greater if drinkers are used compared to wet/dry feeders (Pig International, 1994). When expressed in terms of feed intake, water consumption is approximately 3.5 L/kg of feed (Hepherd, 1981).

Estimates for water intake by gestating sows vary from 7 to 17 L/day (Brooks and Carpenter, 1989; Lightfoot, 1986a; and Madec et al., 1986). Housing conditions affect intake, with group housed sows consuming 40% less than tethered (Pig International, 1994). Intake during lactation remains at prefarrowing levels for the first day, and then increases dramatically (Lightfoot, 1986a). Estimates range from 12 to 18 L/day (Brooks and Carpenter, 1989; Phillips et al., 1990; and Pig International, 1994), but vary with litter size (Lightfoot, 1986a). However, wastage varies from 33 - 48% of disappearance, reducing intake levels to approximately 7 L/day.

Drinking Behaviour

Few studies have reported the number of drinks pigs take per day. Growing pigs have been reported to drink 36 times/day, with a total duration of 22 minutes/day (Xin and deShazer, 1991). In one study, nursery pigs spent only 3 to 4 minutes/day drinking when flow rate was low (Brooks, 1994). However, other studies with pigs as young as 10 weeks of age indicate that pigs will spend 30 minutes/day drinking.

Drinking is generally associated with meals. For pigs less than 40 kg, 85% of drinking occurs within 10 minutes of a meal. This decreases to 75% for larger pigs (Bigelow and Houpt, 1988). Pigs fed restrictively also drink intensively for the hour after feeding. Very small meals will induce over-drinking in pigs (Ingram et al., 1981), and hungry nursery pigs consume excessive amounts of water (Yang et al., 1981). Drinker- directed stereotypies (compulsive 'playing' with the nipple) may account for excessive water disappearance by stalled sows (Pig International, 1994; Bergeron, 1995).

Newborn pigs learn to drink by imitation of their littermates (Phillips and Fraser, 1990). Piglets find the water more quickly if it is in a bowl, rather than a nipple, and in as little as 14 hours if air is bubbled through the water (Phillips and Fraser, 1991). The preference for bowls continues into the growing/finishing stage, but if the bowl becomes fouled with feed, pigs will change their preference to nipples (Brooks et al., 1989). Pigs avoid drinking water that has been fouled by faeces (Pedersen, 1989). If water has a bad taste, sweet flavouring agents may improve consumption (Brooks et al., 1989).

Types of Drinkers

The means by which we provide water to pigs may be classified into five categories: valve, bowl, trough, straw, and feeder.

Valve drinkers require the pig to open the valve and drink directly from the device. Valve drinkers may be further classified as nipple, bite and button drinkers. For nipple drinkers, pigs need only move the activating 'nipple' to one side and water will flow. Bite drinkers require the pig to bite on the mechanism for activation. Button drinkers require the animal to push the activator in to open the valve.

Bowl drinkers allow the pig to drink directly from a pool of water. Water is added to the pool by a number of means. A float valve may be used to maintain a relatively constant level. Alternatively, nipple and button type valves may be used to allow pigs to fill the bowl themselves. Bowl drinkers may be hooded in order to protect the pig while it is drinking, or prevent it from fouling the water with faeces or urine.

Trough drinkers also allow pigs to drink from a pool of water, but provide sufficient space for several pigs to drink at once. They are usually mounted at floor level. Troughs are usually filled manually or by means of a float valve. However, valve type drinkers may be mounted over a trough to give pigs the options of drinking either way. Trough drinkers are commonly used for gestating sows, with water being added to the feed trough following each meal. Eating stimulates drinking, and water intake may be increased by 4 L/day if sows are fed and watered twice daily (Madec et al., 1986). Trough drinkers are also commonly used for suckling and nursery pigs, in which case they are likely to facilitate the discovery and early intake of water.

Straw drinkers require the pig to suck on a tube to draw water into its mouth from a pool (Vandenheede and Nicks, 1991). The pool is covered, to prevent fouling and spillage. Because water can only be drawn from the tube if the pig's mouth is sealed over the straw, spillage is virtually nil. Straw systems are more expensive than troughs, because the pool of water is enclosed. Some animals have difficulty learning to drink from straws, and it is necessary to run water through them until they do so. Although

few straw systems are in use, the concept may deserve more consideration in situations in which water conservation is critical.

The final means of providing water to pigs is in the feeding system. Wet feeding, in which water and feed are mixed prior to presentation to the pig, are gaining popularity. A second feeder based presentation is via wet/dry feeders. In this case, the pig may access feed and water independently, and control the proportion of each that they consume.

Most studies on valve systems use nipple drinkers. Water spillage is generally higher with nipple drinkers than with bowls (Bekaert and Daelemans, 1970). As a result, water use is less with bowls or wet/dry feeders than with nipple drinkers (Bokma and Duijf, 1988; Pedersen, 1989, 1994; Plagge and van Leuteren, 1989). The difference in water use between bowls and nipple drinkers varies from 15 to over 30%. Use of bite drinkers, which require pigs to have their mouth properly positioned on the valve to activate it, reduces water wastage compared to nipple drinkers (Gill and Barber, 1990).

Bowl drinkers not only reduce water wastage, but also facilitate intake by suckling and nursery pigs compared with nipple drinkers (Pedersen, 1994). Pigs provided with bowls take fewer drinks, and spend less time drinking, than those using nipple drinkers. Pigs interrupt feeding in order to drink more often with nipples compared with bowl drinkers (Orban et al., 1978).

Management of Nipple Drinkers

Management of nipple drinkers is directed to ensuring adequate intake, minimal wastage, and easy maintenance. Some of the factors involved are: location, mounting angle, height, number of drinkers, and flow rates.

Standard recommendations are to mount water nipples over or at the edge of the preferred dunging area, and in close proximity to the feeder. Because more water is wasted if pigs grasp the drinker with the side of their mouth, location should encourage the pig to face the drinker (Bokma and Duijf, 1988). Mounting close to a corner, so that pigs stand against a wall while drinking is believed to accomplish this. A Swedish study reported that mounting the drinker on a short wall protruding from the side of the pen reduced water wastage by 35% (Olsson, 1983). The position required pigs to stand in the dunging area, facing toward the sleeping area while they drank. The preferred orientation of the pig facing the drinker can be encouraged by placing flanges or 'wings' on either side of the nipple (Gill and Barber, 1990). A farm which installed such 'wings' on its drinkers reduced wastage by 50%.

Most nipple drinkers are mounted horizontally or pointing downward at a 45° angle from the wall. In growing/finishing operations, nipples mounted in this fashion should be raised as pigs grow. If nipples were mounted pointing upward, at a 45° angle from the wall, there would be no need to adjust the height as all sizes of pigs would drink from floor level. Results of this mounting angle are contradictory. A Swedish study reported that such an angle reduced water waste, but that nipples frequently plugged (Olsson, 1983). An American study also found nipples plugged frequently in this position, but reported a 50% increase in waste (Carlson and Peo, 1982). There appear to be no differences in water use or waste between nipples mounted at 90° or downward at 45° (Pedersen, 1987).

The height at which the drinker should be mounted depends upon its angle and the size of the pig. For drinkers pointing straight out from the wall, the pig should drink at shoulder height. If nipples are mounted downward, pigs should lift their head slightly (Gill and Barber, 1990). The proper angle is achieved by placing the nipple 5 cm above the back of the pig, or 20% higher than shoulder height. If the drinker is higher than this level, pigs have difficulty drinking, and if it is lower, wastage is increased. The formula for drinker height (tip of drinker) for nipples installed at 90° angle, in cm, is $15 * BW^{0.33}$ (kg), which is the approximate equivalent to shoulder height. The formula for drinker height (tip of drinker) for downward mounted nipples, in cm, is $18 * BW^{0.33}$ (kg), which is the approximate equivalent to 120% of shoulder height. Nipples should be set at a height to accommodate the smallest pig in the pen (Table 1).

Water use, and presumably water wastage, increases with flow rate (Barber et al., 1989; Nienaber and Hahn, 1984). Flow rates higher than the pig's

maximum rate of drinking result in water spillage, but we know little about maximum intake rates. The maximum intake rate for sows seems to be 1,800 mL/min (Phillips et al., 1990), but this has not been extrapolated to other age classes. If we assume that rate of intake is proportional to body weight, then the maximum rate for a 25 kg pig would be approximately 180 mL/min. Even at flow rates below maximum intake rates, wastage would be positively related to flow rate as spillage during accidental activation would be higher with fast flowing nipples. It would appear that minimal flow rates should be used, provided feed intake and gain are not affected (Barber et al., 1988; Leibbrandt, 1991; Shurson, 1989; Shurson and Sorrell, 1990). However, the level at which flow rate affects intake and gain differs among reports. The most common recommendations for flow rates are 500 mL/min in nurseries, 700 in grow/finish, 1,000 in gestation, and 1,500 for lactating sows (Brooks and Carpenter, 1989). Flow rates differ considerably among drinkers, and with water pressure within drinkers (Schulte et al., 1990; Table 2).

The general recommendation is that one nipple drinker should be provided for every 10 pigs in a pen. An American study reported reduced gain in nursery pigs if only one nipple was provided for 16 pigs. However, most recommendations also suggest that at least two nipples be provided per pen. Although this appears at first to be a precaution against the plugging of one drinker, wastage is also reduced if multiple nipples are available. This reduction is believed to be the result of less competition at the drinkers.

Management of Bowl Drinkers

Bowl drinkers should be placed over the slatted area of the pen, but not in a corner, as this results in frequent fouling of the bowl with faeces. When more than one drinker is provided, the bowls should be kept close together. Otherwise one will become fouled and will not be used. Pigs should stand in front of the bowl while drinking, and this may be accomplished by hooding the bowl.

Pigs should drink from a bowl with their head slightly lowered. If the bowl is mounted too high, the pig will bite the lip of the bowl; if too low, the risk of fouling increases. Pigs should immerse their mouth into the water to drink. It has been suggested that the height of the lip of the bowl should be 40% of the height of the smallest pig.

The number of pigs per bowl can exceed that recommended for nipple drinkers. Danish work suggests up to 30 pigs per bowl, although this may depend on the design of the drinker. Flow rate should be adequate to keep up with the drinking rate of the pig, and can exceed it without resulting in wastage. A flow rate of 1,000 mL/min seems to be adequate for growing/finishing pigs. The shape of the bowl will affect cleanliness, and should allow pigs to access all parts of the bowl, particularly areas where sediment might accumulate.

Bowls have a number of advantages over nipple drinkers. Pigs learn to drink earlier from bowls than from nipples, and this is particularly important for newborn and newly weaned pigs. Pigs waste less water from bowls than from nipples, with estimates of approximately 30-40% less water use. However, bowls are affected by fouling by faeces or feed and this will limit water intake (Pedersen, 1994). Pigs prefer clean water from bowls to that from nipples, but reverse the preference if the bowls are fouled with feed (Brooks, 1994).

Wet and Wet/Dry Feeders

Water may be pre-mixed with the feed before the mix is delivered to the pens (wet feeding) or water is provided by a nipple, bite or button type drinker in the feeder (wet/dry). Water use with wet/dry feeders is reduced by 10-15% compared with a dry feeder and bowl (van Cuyck, 1991). Wet/dry feeders also increase consumption of meal feed approximately 5% compared with dry feeders and a separate nipple drinker (Gonyou, 1996).

One of the more controversial management decisions to make regarding the use of wet or wet/dry feeding is whether to provide an additional source of water in the pen. If pigs are not able to control their water intake, as with wet feeding, the danger of 'salt' poisoning is increased. Water is necessary to clear various salts from the body, and if the feed contains high levels of salt, more water must be provided. The

provision of an additional drinker when wet/dry feeders are used has been reported to increase average daily gain by 50 g (National Committee, 1992). However, the effectiveness of additional drinkers may depend upon the design of the feeders, as other reports show no increase. In general, if wet/dry feeders require pigs to drink directly from the within feeder drinker, the recommendation is to provide an additional drinker elsewhere in the pen. If the feeder allows pigs to drink from a pool of water, an additional water source does not appear to be warranted.

Research Needs

Recommendations for drinker height, bowl size and flow rates should be based on pig weight, according to formulae rather than weight classes. Recommendations for nipple height seem to be well established, and have been expressed using an allometric relationship between weight and shoulder height. Bowl size for various weight classes of pigs have not been documented, but appear to be at the discretion of manufacturers. Flow rate recommendations have been based on empirical studies, and not related to the body weight of the pigs. It is not known if maximum intake rate is proportional to body weight, or to some exponential of body weight. Maximum intake rate has been determined for sows (Phillips et al., 1990), but not for smaller pigs.

There have been few studies on the relative location of drinkers and feeders on feed and water intake. Several recommendations for drinker position, such as locating the drinker on a wall protruding from the side of the pen (Olsson, 1983), have not been widely adopted by the industry, perhaps because supporting evidence has been lacking. Other management suggestions, such as hooding of bowls or providing protective flanges on the sides of nipples, may also require additional supporting evidence before they are adopted.

Comparisons among different types or models of drinkers need to continue, as new designs appear regularly. It is recommended that such studies include variables that will contribute to our understanding of what contributes to the success of a design. These should include pig behaviour, water wastage, injuries to the pigs, damage to the equipment, and the need for care and maintenance.

Conclusions

Water is an essential need for pigs, and inadequate access to it may result in reduced feed intake, reduced production, and increased health problems. Water intake is particularly important among newborn pigs and newly weaned pigs. Inadequate intake is common at these times, and limits survival and production. Water wastage contributes to the cost of production through both supply and disposal. These costs are likely to increase and the importance of reducing wastage will become more critical in the future.

Table 1. Recommended height of nipple drinkers mounted at a downward angle.

Weight- Smallest Pig (kg)	Nipple Height (cm)
10	39
20	49
30	56
40	61
50	66
60	70
80	77
100	83

Table 2. Recommended flow rates for nipple drinkers.

Stage of Production	Flow rate (ml/min)
Nursery	500
Grow/finish	700
Gestation	1000
Lactation	1500

References

Barber, J., P. H. Brooks and J. L. Carpenter. 1988. The effect of water delivery rate and drinker number on the water use of growing pigs. Anim. Prod. 46:521 (Abstract).

Barber, J., P. H. Brooks and J. L. Carpenter. 1989. The effects of water delivery rate on the voluntary food intake, water use and performance of early-weaned pigs from 3 to 6 weeks of age. In: The Voluntary Food Intake of Pigs (Ed. Forbes, Varley and Lawrence).

Bekaert, H. and J. Daelemans. 1970. De drinkwatervoorziening bij zogende biggen. Landbouwtijdschrift 6-7:925-939.

Bergeron, R. 1995. Environmental, Genetic and Nutritional Factors Involved in the Development of Stereotypic Behaviors in Stalled Sows. Ph.D. Thesis, University of Illinois.

Bigelow, J. A. and T. R. Houpt. 1988. Feeding and drinking patterns in young pigs. Physiol. Behav. 43:99-109.

Bokma, S. J. and J. M. Duijf. 1988. Water supply systems for weaner piglets. Varkensproefbedrijf "Nord- en Oost-Nederland", P 1.25, Juni 1988.

Brooks, P. H. 1994. Water - Forgotten Nutrient and Novel Delivery System. In: Biotechnology in the Feed Industry. Nottingham Press. pg. 211-234.

Brooks, P. H. and J. L. Carpenter. 1989. Boost your liquid assets. Pig Farming Supplement, November, pg. 43-45.

Brooks, P. H., J. L. Carpenter, J. Barber and B. P. Gill. 1989. Production and welfare problems relating to the supply of water to growing-finishing pigs. Pig Vet. J. 23:51-66.

Carlson, R. L. and E. R. Peo Jr. 1982. Nipple water position - Up or down? Nebraska Swine Report E. C. 82-219, University of Nebraska. pg. 8-9.

Fraser, D., P. A. Phillips, B. K. Thompson, and W. B. Peeters Weem. 1988. Use of water by piglets in the first days after birth. Can. J. Anim. Sci. 68:603-610.

Gill, B. P. and J. Barber. 1990. Water delivery systems for growing pigs. Farm Building Progress 102:19-22.

Gonyou, H.W. 1996. Feeder design - What to look for. Proc. 1996 Satellite Conference, Prairie Swine Centre.

Hepherd, R. Q. 1981. The pattern of water consumption in two herds of pigs in two mechanically ventilated houses with slatted floors. Pig News Inform. 2:375.

Ingram, D. L., D. F. Sharman and D. B. Stephens. 1981. Schedule-induced polydipsia in the pig. Physiological Society, June 1981.

Leibbrandt, V. and NCR-89. 1991. Effect of nipple drinker water flow rate and season on swine lactation performance. J. Anim. Sci. 69(Suppl. 1):482.

Lightfoot, A. 1986a. Water for sows. Pig International, January, pg. 22-23.

Lightfoot, A. 1986b. Water before and after weaning. Pig International, February, pg. 9-10.

Madec, F. 1984. Urinary disorders in intensive pig herds. Pig News and Info. 5:91-93.

Madec, F., R. Cariolet and R. Dantzer. 1986. Relevance of some behavioural criteria concerning the sow (motor activity and water intake) in intensive pig farming and veterinary practice. Ann. Rech. Vet. 17:177-184.

Maenz, D. D., J. F. Patience and M. S. Wolynetz. 1993. Effect of water sweetner on the performance of newly weaned pigs offered medicated and unmedicated feed. Can. J. Anim. Sci. 73:669-672.

McLeese, J.M., M. L. Tremblay, J. F. Patience and G. I. Christison. 1992. Water intake patterns in the weanling pig: Effect of water quality, antibiotics and probiotics. Anim. Prod. 54:135-142.

National Committee for Pig Breeding, Health and Production (Denmark). 1992. Annual Report. Feeders and water supply.

Nienaber, J. A. and G. L. Hahn. 1984. Effects of water flow restrictions and environmental factors on performance of nursery-age pigs. J. Anim. Sci. 59:1423-1429.

Olsson, O. 1983. Evaluation of bite drinkers for fattening pigs. Trans. ASAE 26:1495-1498.

Orban, E., I. Kurucz and J. Sarvary. 1978. Drinking behavior characteristics of young pigs in case of different keeping technologies in cages. Proc. Hungarian Res. Instit. Anim. Husbandry. Herceghalom. 4:279-288.

Pedersen, B. K. 1987. Evaluation of Lund-10 and Biscoe-A1 bite drinkers for weaners. Meddelelse nr. 123 fra Den rullende Afprovning, Landsudvalget for Svin. Danske Slagterier.

Pedersen, B. K. 1988. Evaluation of Lund-10 and AN-niplen bite drinkers for weaners. Meddelelse nr. 140 fra Den rullende Afprovning, Landsudvalget for Svin. Danske Slagterier.

Pedersen, B. K. 1989. Evaluation of Lund-10 bite drinker and Gorlev B drinking bowl for weaners. Meddelelse nr. 158 fra Den rullende Afprovning, Landsudvalget for Svin. Danske Slagterier.

Pedersen, B. K. 1994. Water intake and pig performance. Presentation.

Phillips, P. A. and D. Fraser. 1990. Water bowl size for newborn pigs. Appl. Engineering in Agric. 6:79-81.

Phillips, P. A. and D. Fraser. 1991. Discovery of selected water dispensers by newborn pigs. Can. J. Anim. Sci. 71:233-236.

Phillips, P. A., D. Fraser and B. K. Thompson. 1990. The influence of water nipple flow rate and position, and room temperature on sow water intake and spillage. Appl. Engin. Agric. 6:75-78.

Pig International. 1994. Pregnant drinkers. Pig International, June, pg. 25.

Plagge, J. C., and J. van Leuteren. 1989. Water consumption of fattening pigs. Varkensproefbedrijf "Noed- en Oost-Nederland" P 1.32. Maart 1989.

Schulte, D. D., G. R. Bodman and M. Milanuk. 1990. Nipple drinkers - which is best? Nebraska Swine Report. pg. 11-12.

Shurson, G. C. 1989. Effect of water flow rate from nipple drinkers on weaned pig performance. Ohio Swine Reserach and Industry Report. January:37-39.

Shurson, G. C. and E. R. Sorrell. 1990. Effect of water flow rate from nipple drinkers on sow and litter performance. Ohio Swine Research and Industry Report. January:44-46.

Svendsen, J. and B. Andreasson. 1981. Investigations into the supplying of liquids to piglets and to weaned pigs: liquid consumption and production results. Swedish Univ. of Agric. Sci.; Dept. Farm Buildings. Report 14. Lund.

van Cuyck, J. H. M. 1991. Ad libitum feeding of fattening pigs by means of a dry-wet feeder of a dry feeder with a drinkbowl. Varkensproefbedrijf "Zuid- en West-nederland" Proefverslag nummer P 1.71, December 1991.

Vandenheede, M. and B. Nicks. 1991. L'approvisionnement en eau des porcs: un ÇlÇment a ne pas nÇgliger. Ann. MÇd. VÇt. 135:123-128.

Xin, H. and J. A. DeShazer. 1991. Swine responses to constant and modified diurnal cyclic temperatures. Trans. ASAE 34:2533-2540.

Yang, T. S., B. Howard and W. V. MacFarlane. 1981. Effects of food on drinking behaviour of growing pigs. Appl. Anim. Ethol. 7:259-270.

Yang, T. S., M. A. Price and F. X. Aherne. 1984. The effect of level of feeding on water turnover in growing pigs. Appl. Anim. Behav. Sci. 12:130-109.

PUBLICATIONS

Books and Chapters

Nutrition

Patience, J.F., P.A. Thacker, C.F.M. de Lange, 1995. Swine Nutrition Guide 2nd Edition. Prairie Swine Centre Inc. pp 274.

Ethology

Hemsworth, P.H. and H.W. Gonyou. 1996. Solutions: human contact. In: M. Appleby and B. Hughes (Eds.), Animal Welfare. CAB International, Wallingford, UK.

Refereed Journals

Nutrition

Shand, P.J., J.A. Boles, J.F. Patience, A.R. McCurdy and A.L. Schaefer. 1995. Acid/base status of stress susceptible pigs affects cured ham quality. J. Food Sci. 60:996-1000.

Abstracts

Nutrition

de Lange, C.F.M., J.F. Patience and G. Gillis. 1996. The effect of mechanical dehulling on the digestible nutrient content in canola meal samples fed to growing pigs. Can. J. Anim. Sci. (submitted).

Ethology

Moore, C.M., J.Z. Zhou, W.R. Stricklin and H.W. Gonyou. 1996. The influence of group size and floor area space on social organization of growing-finishing pigs. Proc. 30th Cong. Intn. Soc. Appl. Ethol., I.J.H. Duncan, T.M. Widowski and D.B. Haley (Ed.), Univ. of Guelph. P34.

Gonyou, H.W. and Z. Lou. 1996. Feed intake, growth rate and feed efficiency of grower and finisher pigs using different types of feeders. Can. J. Anim. Sci.

Gonyou, H.W. and W.R. Stricklin. 1996. Effects of group size and space allowance on productivity of growing/finishing pigs. J. Anim. Sci. 74(Suppl. 1):32.

Anzaldo, A.J., P.C. Harrison, G.L. Riskowski, L.A. Sebek, R. Maghirang, W.R. Stricklin and H.W. Gonyou. Behavioral evaluation of spatially enhanced caging for laboratory rats at high density.

Gonyou, H. W. 1995. Animal behaviour and animal handling. North American Regional ISAE. Lincoln, Nebraska. July 9, 1995.

Fulawka, D., M.L. Connor and H.W. Gonyou. 1994. Reproductive performance of sows in alternative group housing. Can. J. Anim. Sci. 75:652.

Conference Proceedings

Nutrition

Patience, J.F. 1996. Transmissible gastroenteritis: Prairie Swine Centre's experience. Proc. Alberta Pork Congress Seminar. pp. 111 - 118.

Beltranena, E., K. de Lange, J.F. Patience, H. Gonyou, L. Whittington, M.L. Lorschy and S.L. Fairbairn.1996. An integrated research approach to feeding the growing-finishing pig. In (G. Foxcroft, Ed.) Advances in Pork Production, University of Alberta, Edmonton. pp. 17 - 28.

Whittington, L.W. and J.F. Patience. 1996. Integrating research with technology transfer - The Prairie Swine Centre experience. Proc. Nat'l Workshop on Research and Tech. Transfer, Canadian Pork Council, Ottawa, ON.

Patience, J.F. 1995. Role of feed intake in the nutrition of the growing-finishing pig. In (G. Foxcroft, Ed.) Advances in Pork Production. University of Alberta, Edmonton. pp. 115-128.

Patience, J.F. 1995. Measuring feed costs per kg. of gain and how to use it, . Proc. The Key to Profitable Feeding Management, Shakespeare, ON., December 6, p. 23-30.

Patience, J.F. 1995. Pig oriented equipment design - a nutritionist's perspective. Proc. The Key to Profitable Feeding Management, Shakespeare, ON., December 6, p. 15-18.

Patience, J.F. 1995. Mineral and vitamin supplementation of swine diets. Proc. Sask. Pork Industry Symp., Saskatoon, SK., November 8-9, p. 71-84.

Patience, J.F., H. W Gonyou and D.L. Whittington. 1995. Marketing heavier hogs: Impact on the total farm production system. Proc. Alberta Pork Congress, Red Deer, AB., June 13 - 15, p. 62-71.

Ethology

Gonyou, H.W. 1996. Pig behavior and biomedical research: Suitable subjects and experimental models. In: M. Tumbleson and L. Schook (Eds.), Advances in Swine in Biomedical Research. Plenum Press, New York. Pp485-490.

Gonyou, H. W. 1995. Animal behaviour and animal handling. In: M. Ivan (Ed.), Animal Science Research and Development: Moving toward a new century. Pg. 465-470.

Invited Presentations

Gonyou, H.W. 1996. Swine behavior. Advanced Swine Production Technology. University of Illinois, Urbana. June 3, 1996.

Gonyou, H.W. and Z. Lou. 1996. Results of the feeder study at Prairie Swine Centre. Manufacturers Workshop, Prairie Swine Centre. March 14, 1996.

Gonyou, H. W. 1996. Feeder design - what to look for. 1996 Satellite Conference, Prairie Swine Centre. February 13, 1996.

Whittington, L. and H. W. Gonyou. 1996. Off-site segregated early weaning. 1996 Satellite Conference, Prairie Swine Centre. February 13, 1996.

Gonyou, H.W. 1995. Managing pig space: Feeder position and orientation. Western Nutrition Conference, Saskatoon, Saskatchewan. Sept. 14, 1995.

Miscellaneous Publications

Ethology

Gonyou, H. 1996. SEW - behaviour component. Centred on Swine 3(2) Spring, p3.

Gonyou, H., W.R. Stricklin and J.Z. Zhou. 1996. Feeder position and orientation. Centred on Swine 3(1) Winter, p5-6.

Beltranena, E., R.A. Petracek, A. Bzowey, H. Gonyou and J.F. Patience. 1995. Methionine sources for weanling pigs. 1995 Annual Research Report, Prairie Swine Centre Inc., p32-36.

Gonyou, H.W., W.R. Stricklin and J.Z. Zhou. 1995. Managing pig space: feeder position and orientation. 1995 Annual Research Report, Prairie Swine Centre Inc., p37-41.

Bergeron, R. and H. Gonyou. 1995. Stereotypic behaviors in sows. 1995 Annual Research Report, Prairie Swine Centre Inc., p42-45.

Gonyou, H.W. 1995. How animal handling influences animal behaviour. 1995 Annual Research Report, Prairie Swine Centre Inc., p72-74.

Gonyou, H. 1995. Quality space. Centred on Swine 2(3) Summer, p2.

Gonyou, H. 1995. Managing pig drinkers. Centred on Swine 2(2) Spring, p1.