### Swine Nutrition

**A. Summary of faculty, staff & students conducting research in swine nutrition**

<table>
<thead>
<tr>
<th>Faculty</th>
<th>Rank</th>
<th>Research FTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Sung Woo Kim</td>
<td>Associate Professor</td>
<td>0.60</td>
</tr>
<tr>
<td>Dr. Chad Stahl</td>
<td>Associate Professor</td>
<td>0.60</td>
</tr>
<tr>
<td>Dr. Jack Odle</td>
<td>WNR Professor</td>
<td>0.53</td>
</tr>
<tr>
<td>Dr. Eric van Heugten</td>
<td>Professor</td>
<td>0.25</td>
</tr>
<tr>
<td>Dr. Lin Xi</td>
<td>Res. Assistant Professor</td>
<td>1.00</td>
</tr>
<tr>
<td>Dr. Joan Eisemann</td>
<td>Professor</td>
<td>0.35</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td><strong>3.33</strong></td>
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<tr>
<td>(down from 4.65 in 1998)</td>
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</table>

**SPA Research Technical Support:**

<table>
<thead>
<tr>
<th>Staff</th>
<th>Supervisor</th>
<th>Funding</th>
<th>FTE</th>
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</thead>
<tbody>
<tr>
<td>Ms. Brynn Seabolt</td>
<td>Stahl</td>
<td>Soft-money</td>
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<tr>
<td><strong>Total:</strong></td>
<td></td>
<td></td>
<td><strong>1.0</strong></td>
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<tr>
<td>(down from 4.75 in 1998)</td>
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**Student & Other:**

<table>
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<tr>
<th>Advisor</th>
<th>Funding</th>
<th>Degree</th>
<th>FTE</th>
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<tbody>
<tr>
<td>Ms. Alexandra Chaytor Kim</td>
<td>Stipend</td>
<td>M.S.</td>
<td>0.5</td>
</tr>
<tr>
<td>Ms. Christen Brown vanHeugten</td>
<td>External</td>
<td>M.S.</td>
<td>0.5</td>
</tr>
<tr>
<td>Mr. David Rosero vanHeugten</td>
<td>External</td>
<td>M.S.</td>
<td>0.5</td>
</tr>
<tr>
<td>Ms. Tiffany Inskeep Odle</td>
<td>External</td>
<td>M.S.</td>
<td>0.5</td>
</tr>
<tr>
<td>Ms. Lindsay Alexander Stahl</td>
<td>External</td>
<td>Ph.D.</td>
<td>0.5</td>
</tr>
<tr>
<td>Ms. Avanika Mahajan Stahl</td>
<td>External</td>
<td>Ph.D.</td>
<td>0.5</td>
</tr>
<tr>
<td>Ms. Yan Zhou</td>
<td>External</td>
<td>Ph.D.</td>
<td>0.5</td>
</tr>
<tr>
<td>Mr. Allyson Saraiva Kim</td>
<td>External</td>
<td>Ph.D.</td>
<td>0.5</td>
</tr>
<tr>
<td>Mr. Rafael Cabrera Odle</td>
<td>External</td>
<td>Ph.D.</td>
<td>0.5</td>
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<tr>
<td>Ms. Tina Herfel Odle</td>
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<td>Ph.D.</td>
<td>0.5</td>
</tr>
<tr>
<td>Mr. Michael Shields van Heugten</td>
<td>External</td>
<td>Ph.D.</td>
<td>0.5</td>
</tr>
<tr>
<td>Dr. Sheila Jacobi Odle</td>
<td>External</td>
<td>Postdoc</td>
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</tr>
<tr>
<td>Dr. Sang Gun Roh Kim</td>
<td>External</td>
<td>Visiting Prof.</td>
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<tr>
<td><strong>Total:</strong></td>
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<td></td>
<td><strong>7.5</strong></td>
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</table>

**B. Personnel changes since 1998**

We experienced significant turnover in our swine nutrition program since the previous review. Both Theo van Kempen and Robert Harrell left the department soon after their promotion and tenure as Associate Professors to assume positions in the animal nutrition/feed industry (with Provimi and Novus International, respectively). Guillermo Gomez retired from a non-tenured faculty position, and his position was not refilled; however, Lin Xi, manager of the Odle laboratory, was recently promoted
to the position of Research Assistant Professor in a similar non-tenured position. The vacated Kempen and Harrell positions were eventually refilled by Chad Stahl and Sung Woo Kim – both individuals entered as Associate Professors (with tenure). Both were hired into 9-month positions (the first such recruitment in our department), joining Odle who changed to a 9-month appointment in 2000. Most recently, Eric van Heugten was promoted to Full Professor in 2008.

The net result of these changes is a 28% reduction (1.32 FTE) in swine nutrition research faculty, and an accompanying 79% (3.75 FTE) reduction in support staff since 1998. The reductions are a reflection of reduced and redistributed resources from the college research office and a greater commitment to maintain faculty than support staff. The department is currently working on a plan to redistribute the remaining support staff more equitably among the research faculty. We feel fortunate that the administration allowed the re-filling of the faculty positions in swine nutrition, especially at the Associate Professor level, despite the strained economic times.

Our scientist training program remains strong despite diminishing stipend support available from state resources. This is attributable to the strong grantsmanship of the swine nutrition faculty, providing extramural funds toward stipends. Since 1998 we have trained 10 postdocs and scholars, 11 Ph.D. students and 14 M.S. students in swine nutrition and are currently providing training for an additional 15 individuals, with > 90% funded via extramural sources.

C. Research program descriptions, by principal investigator

**Dr. Eric van Heugten**  Applied Swine Nutrition

The focus of Dr. van Heugten’s research and extension program is to conduct applied research in nutrition that is directly relevant to the swine industry and other stakeholders. His program aims to actively involve the swine industry in applied research projects, including meetings or discussions on experimental design and practical application of results. He has conducted over 70 studies and all of these had direct or indirect involvement by swine production companies. Studies have focused on important issues facing the pork industry, such as nutrient management, meat quality, antibiotic resistance, evaluation of non-traditional ingredients, etc. He has collaborated extensively with various Departments within NCSU and international organizations. His program is currently providing training for one Ph.D. student and two M.S. students. Current projects:

1. Impact of feed processing technologies on feed quality, pig performance, nutrient digestibility and economic return
2. Dietary supplementation to improve the quality and nutritional value of pork
3. Energy requirements and efficiency of sows during heat stress
4. Effects of enzyme supplementation on nutrient digestibility and growth performance of nursery pigs
5. Impact of crude glycerol on feed manufacturing and growth performance of nursery pigs

**Dr. Sung Woo Kim**  Amino acid metabolism

Dr. Kim was recruited from Texas Tech University in 2007 as an Associate Professor. His research has primarily been focused on amino acid nutrition and metabolism of swine especially for sows, fetuses, and newborn piglets. His recent research includes investigation of roles of functional amino acids in pregnancy and lactation, and identification of ideal protein for pregnant and lactating sows. His research program was recognized nationally and internationally as he received ‘Early Career Achievement Award (2008, ASAS)’, ‘Outstanding Research Award (2008, Asian Animal Production)’, ‘National Pork Board Award for Innovation (2008), and ‘Outstanding Young Scientist Award (2007, ASAS-Southern)’. His program is currently providing training for one visiting professor, two Ph.D. students and one M.S. students (with two new students recruited to begin in 2010). Current research projects under investigation at NCSU include:

1. Role of yeast metabolites in pregnant and lactating sows (PI, funded by Diamond V Mills)
2. Effects of arginine on sow performance (PI, funded by Government of Korea)
3. Role of colored potatoes as sources of antioxidants for energy balance of obese pigs (Co-PD with Dr. Jairam Vanamala at Colorado State Univ. as PD, funded by USDA)
4. Oxidative stress status of sows under heat stress and social stress (PI with Dr. Flowers as Co-I, funded by NC Pork Board)
5. Oxidative and metabolic stress of sows under different housing systems (PI with Dr. Flowers as Co-I, funded by NC Ag Foundation)
6. Effects of glutamine on sow performance and immune response under heat stress (PI, funded by Ajinomoto-Biolatina in Brazil)
7. Role of glutamine and glutamate in protein synthesis of broiler chickens (PI with Dr. Ferket as Collaborator, funded by Ajinomoto Company in Japan)
8. Effects of glutamine in growth and gut health of broiler chickens (PI with Dr. Ferket as Collaborator, funded by US Poultry and Egg Association)
9. Use of benzoic acid as dietary acidifier in swine feed (PI, funded by Emerald Materials)
10. Low-to-moderate levels of mycotoxins and the efficacy of mycotoxin binders in swine feed (PI with Dr. See as Collaborator, funded by BFI-Applied Natures, Amlan, LiveEarth Products, MurphyBrown LLC, and AgProvision)
11. Processed sorghum for nursery pigs (PI, funded by Genebiotech Inc. in Korea)

Dr. Chad Stahl
Mineral Metabolism
Developmental Nutrition
Food Safety & Antibiotic Resistance

Dr. Stahl was recruited from Iowa State University in 2007 as an Associate Professor. His research program is focused on conducting dual-benefit research relating to nutrition and health, and pursues two major areas of research: 1) Mineral nutrition in relation to bone health, and 2) Development of protein based antibiotics. He utilizes swine as both a target and a model species, and concentrates primarily on early-life events. His current mineral nutrition research focus is determining the role of calcium and phosphate nutrition on tissue-specific stem cell activity (mesenchymal stem cells and satellite cells) particularly as it pertains to the developmental programming of the musculoskeletal system. His current protein based antibiotic work is centered on utilizing biotechnology to improve the efficacy of colicins for use in both the animal health and the human food safety fields. His program is currently providing training for two Ph.D. students. Current research projects in the Stahl laboratory include:

1. Optimization of Colicin E1 Expression. Industry Sponsor $100,000. PD.
2. The impact of piglet weaning age on gut mucosal defense and susceptibility to postweaning E. coli Disease. The National Pork Board $49,500. Co-PI.
3. Effect of Selected Probiotics on Health, Growth and Development of the Suckling Neonatal Pig. Mead Johnson & Co. $268,783. Co-PI.
4. Comparison of Two Different Calcium Sources in Formula Diets Meeting Calcium Requirements for Neonatal Pigs. Mead Johnson & Co. $165,574. PD.
6. Transgenic Soybeans Expressing a Vaccine for Swine. UNC Research Competitiveness Fund $100,384. Co-PI.

Dr. Lin Xi
Lipid Nutrition and Metabolism
High Performance Liquid Chromatography
Gas Chromatography, Mass Spectrometry

Dr. Xi was previously a senior researcher at Dr. Odle’s research program and was promoted into a Research Assistant Professor faculty position (non-tenured) in 2007. He has participated in many research projects associated with neonatal nutrition and lipid metabolism as well as lipid analytical chemistry. His research has been involved in identification and analysis of end products and
intermediary metabolites using HPLC, GC, radio-HPLC and GC/MS instrumentation and has provided training for MS and Ph.D. graduate students. His current research program primarily is focused on hepatic fatty acid oxidation and its regulation at molecular levels in neonatal piglets. Current projects include:

1. Induction of precocious milk-fat oxidation in neonatal pigs (PI with Dr. Odle as Co-PI, USDA-NRI Competitive Programs).
2. Enrichment of pork with n-3 fatty acids (Co-PI with Dr. Odle as PI, Industry sponsor).

Dr. Joan Eisemann
Comparative nutrition & metabolism

Swine ulcers: More intensive management has improved many aspects of swine production; however, it has resulted also in new problems for the industry. One problem associated with more intensive production systems is gastric ulcers. Ulceration can result in decreased gain of pigs or death, if tissue erosion is extensive. A series of experiments was completed to show the role of increased stomach acidity as a major factor in damaging the gastroesophageal mucosa leading to ulceration. In addition, other substances in stomach contents, such as bile salts, become more damaging under acidic conditions. Further, we demonstrated that stomach damage can occur with only 24 hours of feed withdrawal. Using surgical techniques that allowed us to sample stomach contents in the esophageal region, we showed that addition of buffers in the water supply could increase stomach pH during normal feeding behavior as well as when feed was withdrawn for approximately 24 hours. To date, short-term addition of buffering solutes to the water supply is the most cost effective potential treatment. Evaluation of 10 days of treatment showed no negative effects on animal physiology.

Neonatal pigs: Neonatal pig death losses of approximately 8 to 12% represent a significant economic loss to the swine industry. These pigs that fail to survive are often lower in birth weight and do not compete well with littermates of greater weight. One way to improve survival of low birth weight pigs is to remove them from the sow and rear the pigs using formulated diets. Results of a study conducted showed that approximately 15% of the lysine from dietary protein could be replaced with synthetic lysine in milk-based liquid diets before average daily gain and accretion of body protein by the pigs decreased significantly. In an additional study the sulfur amino acids (methionine and cysteine), threonine, tryptophan and phenylalanine were evaluated as potentially next limiting based on analysis of the diets. Using average daily gain of pigs and concentration of plasma urea as criteria, removal of the sulfur amino acids had the greatest negative impact. This suggests that the sulfur amino acids are second limiting in these diets. Replacement of intact protein sources with synthetic amino acids may provide nutritionally adequate cost effective diets for large-scale use in industry.

Current projects include: Increasing insulin sensitivity with dietary long chain omega-3 polyunsaturated fatty acids

Dr. Jack Odle
Nutritional Biochemistry of the Neonate
Lipid Nutrition and Metabolism
Intestinal Growth and Development

Dr. Odle’s research program is focused in nutrition and metabolism of swine, with particular emphases on lipids and on neonatal growth and viability. While pursuing aims to lessen piglet morbidity and mortality, he also utilizes the piglet as a model for human infant nutrition. His program has been recognized with numerous awards from animal and human nutrition societies and he was named William Neal Reynolds Professor in 2005. His program is currently providing training for one postdoc, two Ph.D. students, two M.S. students, and two undergraduates. Historically, his research has been competitively funded by federal agencies (USDA, NIH, NSF), commodity groups and industry sponsors. He currently oversees four competitive USDA grants and four industry-sponsored projects. Selected investigations currently include (Odle as PI):
1. Effects of prebiotic polydextrose on health, growth & development of the suckling piglet. Mead Johnson & Co. $270,000. (5%).
2. Prophylactic effects of arachidonate on intestinal health of the suckling neonate. USDA – NRI Human Nutrition. $494,000 (10%).
4. Fellowships in food animal functional genomics. (Collaboration with several faculty in poultry and animal science). USDA – NRI National Needs Fellowships. $172,000. (3%).
5. Effect of selected probiotics on health, growth and development of the suckling neonatal pig. Mead Johnson & Co. $268,783. (5%).
6. Integrating food and nutritional sciences for optimal human health. USDA – AFRI Human Nutrition & Food Science (training grant). $1,000,000. (5%).
7. Management of piglet immunoglobulin status to improve survival. Industry sponsor. $30,000. (2%).
8. Enrichment of pork with n-3 fatty acids. Industry sponsor. $40,000. (2%).

D. Swine nutrition program needs and considerations

Facilities & Infrastructure. Current facilities (farms & laboratory) are marginally adequate to support the minimal needs of the swine nutrition faculty. Recent completion of the new Feed Mill, the Nutrient Management, and the Animal Health Buildings provide vast improvements over previous facilities and are equipped to support a baseline research program, but failure to construct the meat science facility and laboratory facilities at Lake Wheeler represent enduring hindrances to the program. All pork quality and invasive tissue sampling must be coordinated with commercial slaughter plants and in many cases research needs cannot be fully accommodated. Furthermore, the loss of on-campus animal space as the majority of Grinnell’s laboratory was transferred to aquaculture represents a major set-back to the swine nutrition program, and will remain a hindrance to future research in basic science and intensive, biomedical research unless new facilities are constructed. Furthermore the personnel space and laboratory space for the swine nutrition program within Polk Hall is inadequate. While commitments to renovate still resonate, the current quality of existing space continues to erode below competitive standards. If we are to maintain a superlative program, these needs must be addressed. We continue to harbor hope for an entirely new Animal Science Building that would include not only office and laboratory space, but also intensive animal housing and modest abattoir capacity.

Accompanying these limitations in facilities is the inadequate infrastructure support to operate the farm facilities. Specifically, the current production of the swine farm is not adequate to meet the collective needs of swine researchers. In some cases sponsored research has been declined and in other cases researchers have been forced to use pigs from sources outside the university. The recent erosion in the economic climate has only exacerbated the ongoing trend for less and less infrastructure support. The plan continues to be one of managing the status quo as best as is possible. There is a growing sense that we need a new and more-dynamic model to secure a future for growth in swine research.

Extramural funding and peer-reviewed publications. The swine nutrition faculty have long-recognized the essentiality of extramural funding to drive their programs and we continue to aggressively and successfully seek competitive extramural funding from a variety of sources. The University RADAR system reports that the core swine nutrition faculty garnered > $4.5M since 1998 with another ~$2M in unrestricted gifts (not reported). When divided over 3.3 FTE and 10 years, this equates to an average of ~$197K/yr/FTE. Collectively we have authored 136 peer-reviewed papers equating to 3.8/yr/FTE. Neither of these figures is adjusted for the FTE-years (~2) that the van Kempen and Harrell positions were vacant.
**Faculty, students & staff.** Our swine nutrition research group ranks among the best-funded, best-published and most-productive in the department and in the nation. We have adopted an "efficient business model" for our programs, without compromising scholarship. We emphasize program relevance and maintain high standards for scientist training. We are reasonably well-balanced, covering the continuum of basic → applied research, covering various nutrients (lipids, amino acids, minerals) as well as the lifecycle (sow/maternal, neonatal, weanling and grow-finish). In addition to autonomous program strength, our faculty work well together in collaborative areas to produce synergetic benefits, and we publish timely research in high-quality journals. We feel that our program area could accommodate additional faculty with expertise in molecular immunology and microbiology to facilitate the overall programmatic effort, and we believe that investments in such faculty would yield programs that would competitively attract both funding and students.

Among our greatest challenges is the recruitment of talented students that are genuinely and passionately committed to careers in agricultural science (non-veterinary). This raises serious concerns for the future of the program. The generally poor research reputation of our department probably diminishes our ability to recruit students from interdepartmental programs on campus. Overall, the department’s stipends are comparatively low and the pool of talent continues to diminish. Ninety percent of the current swine nutrition students are funded by their mentors and only one (out of 11) holds a departmental stipend. Finally, the university policy (graduate student support plan) does not adequately subsidize student tuition and fees such that it is far cheaper to employ postdocs and technicians than students to accomplish research objectives. This makes it difficult to economically justify the budgeting of graduate stipends into competitive proposal applications.

Another serious adjustment has been wrought by the great reduction in funding for support staff. The swine nutrition group lost considerable support when we were not allowed to rehire staff supporting the van Kempen, Harrell, van Heugten and Eisemann laboratories. The department is developing a plan to redistribute technical support in a more equitable way, but continued erosion of this support is likely to remain a hindrance to the program.