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Genes, gametes and gestation outcomes - essential links in a successful breeding management program

George Foxcroft, PhD

Swine Reproduction-Development Program, Swine Research and Technology Centre, University of Alberta, Alberta, Canada

Introduction

At the outset of some preliminary discussions with Bob Morrison about how the University of Alberta's "presence" as a Pre-Conference Reproduction Workshop provider might become more broadly recognized within the main Leman Conference, I never anticipated that I might be standing here as the presenter of the 2011 Pijoan Lecture. I feel honoured to be given this invitation. Reading the text of previous Pijoan Lectures, and knowing Carlos Pijoan's area of expertise, led to a series of anxiety attacks about what exactly I might be expected to deliver. It was some relief to get the following e-mail from Bob:

"There is no specific descriptor (for the lecture). Carlos was an advocate for the scientific approach and also passionate about all aspects of swine diseases and production. He would be equally interested in your keynote on the recent science of reproduction as the latest on mycoplasma. Therefore, we are very comfortable dedicating your lecture in his name. He'll be in the front row during your talk critiquing the science while looking for the application so he can carry the message to his clients throughout the world."

So perhaps the first questions I should address by way of introduction are, Why me? Why here? Why now?

Why me? Like Carlos, I've had the great fortune to pursue a university based career in an area of animal biology that has direct application to the farming communities in which I was partly brought up. My early training also took me abroad, in my case to Illinois as a postdoctoral fellow in reproductive endocrinology. There, my first studies in pigs were driven by the need to find an experimental model with a suitably large blood volume to allow repetitive and frequent blood sampling for several days: A rabbit simply couldn't deliver the goods!

This was followed by the opportunity to establish an active research program back at the University of Nottingham, with the pig as the "chosen" research animal and issues like the "thin sow syndrome" apparently needing urgent attention. In turn, this gave me the opportunity to take up an industry sponsored Chair in Swine Reproductive Physiology at the University of Alberta, which of necessity brought much closer attention to the application of our research to the needs of the industry.

Looking at Bob's comments above would also bring smiles to the faces of my children and grandchildren, who get endless amusement explaining to their friends that Dad/Grandpa is a "Pig Prof", let alone one who works on "sex and breeding technology". I can't imagine how they would handle introducing Uncle Carlos as the "Prof who is passionate about pig diseases"! In reality, part of the magic of academic life is being able to be passionate about what we are interested in, without necessarily having to explain why it might be the most important area of study in which public funds should be invested. The ability to survive, however, does largely depend on showing relevance to the wider community, particularly in an applied science area like agriculture. Increasing the opportunities to deliver relevant research to the industry is a question I will return to later.

However, I see my key role in the pork production community as being a biologist, not a business man. Therefore, when I look at pigs in production settings it is with the eye of a biologist and applied scientist, because I believe an adequate understanding of the biology of the gilt, sow and boar is, in fact, the very foundation on which the pork production industry is founded – hence my chosen title for this lecture.

Why here? The Leman Conference is very unique. I also think the actual structure of the North American pork industry is pretty unique, particularly with respect to the enormous influence of the veterinary community in shaping your production systems and approaches to production management. Although many of the audience will have veterinary backgrounds, this conference has adopted a different philosophy to developing its programs than we would find say at the annual AASV meetings. A key focus on all aspects of "integrated production science" is in large part the legacy of Al Leman, for whom the Leman Conference is named. I first interacted with Al when he was a PhD student at the University of Illinois, and then later on in my career was able to appreciate the impact his energy and insight have had on the US industry: It was an amazing process. The "Al Leman" stories that Frank Aherne brought back from the annual "Pig Letter" gatherings were always

good listening and I'm sure those guys are still running each other into the ground both mentally and physically, wherever they are!

Being asked to speak at the Leman Conference is, therefore, very special. It is also very challenging. To me, your industry is driven by attention to large-scale efficiencies, production flows, low staff inputs costs, health control at a population rather than individual animal level, and the need to manage relatively "robust" pigs. This is supported by phenomenal data capture and analysis systems, economics driven by scale, specialized management teams and protocol-driven production practices. By the same token, the industry is constantly challenged by population-level disease outbreaks, relative inflexibility in changing existing infrastructure, a lack of skilled labour, etc. So where exactly does a "passionate biologist" fit into this picture?

Partly, because I believe we have kept our science base strong and can bring you information about the biology of the pig that needs to be understood. Partly, because we have had the opportunity to work with commercial systems to try and implement improvements in breeding herd management and to share those experiences at events like our Reproduction Workshops. Lastly, because I hope we can continue to collectively challenge ourselves in those areas in which we (the biologists) inherently believe changes should, or could, be happening, but in which you (the production scientists, managers and CFOs) cannot yet commit to financially or even find manageable ways of implementing. The question of realizing genetic value at commercial production level offers an excellent example of the kind of progress that is possible. The Leman Conference probably offers a unique venue at which to hold these discussions.

Why now? Probably mainly, because I am planning to retire from my present activities before too long and there may not be too many future opportunities of this kind! I hope also, because I have been given the opportunity to link basic and applied research for the last two decades as my primary mandate, and been provided resources and funding to do this. This has allowed our program to reach a certain kind of maturity and a leadership position in our specialized area. As the "elder statesman" of the team, it is my honour to represent over 20 years of commitment by our entire research program to supporting good science and its application in the pork industry. The "we" in many of my comments really means graduate students, technologists, academic colleagues and partners in industry who increasingly have delivered what "I" get to talk about.

In the context of our Canadian industry, "Why now" has a special kind of urgency. If not "now", in the sense of trying to rapidly integrate our best R&D ideas into better production efficiencies, the answer may be "then perhaps never". The attrition in our industry has been dramatic but our surviving producers are as dedicated as ever to finding a successful niche in the global food-animal industry. Hopefully, by presenting some ideas about future possible developments in breeding herd management, the 2011 Pijoan Lecture can make a small contribution to the future sustainability of pork production in Canada, North America and beyond.

The final question is then "What" to say. The rest of this presentation addresses four key questions related to the translation of knowledge in pig reproductive biology into effective breeding management programs and competitive pork production systems.

- The first question addresses variable success in implementing available information, with basic knowledge of estrous behavior and inconsistent success in the breeding barn as an example.
- The second question addresses the value of additional data capture as a means of measuring and understanding sow longevity in the breeding herd.
- The third question addresses opportunities to use reproductive technologies to increase the rate of genetic gain at the commercial level of production.
- Finally, the R&D and management structures that may better support the implementation of improved genetic transfer and overall breeding herd performance in the future, are discussed.

Variable success in implementing available information

The published literature on the behavioral and physiological characteristics of the estrous cycle in the pig is comprehensive and consistent. Some basic facts are:

1. The length of estrus (heat) is highly variable (24 hours or less, to over 72 hours).
2. Measuring the onset and intensity of estrus is person-dependent and the ability of a sow to demonstrate behavioural estrus is first induced, and then triggered by, a number of stimuli, of which the signals coming from a mature, high libido, boar are the most potent.
3. The time of ovulation after the onset of detected heat is also variable and in both the gilt and sow occurs anywhere from 12 to 72 hours after first detecting heat.
4. Therefore, depending on the liveability and quality of semen used for AI, and the quality of the estrus detection program, multiple inseminations may be needed to optimize breeding results.
5. At the time of standing heat, the most hostile environment to invasive bacteria is the mucosal lining of the vulva, vagina and cervix.

Given these facts, a series of breeding protocols can be developed and produce excellent results (90+ % farrowing rates and good numbers of pigs born), whilst taking a more (3 or more AI doses per sow bred) or less (< 2 doses per sow bred) conservative approach to use of semen. From my perspective as a reproductive biologist, therefore, if the breeding protocol is clearly presented and the biology of the gilt and sow population is normal, the distribution of single, double, triple, or even more inseminations can be very accurately predicted. Encouragingly, in breeding teams that are effective at applying the prescribed protocol and have a good record of heat detection and AI use, the expected results on the proportions of sows bred with different numbers of doses can be very close to what is achieved and recorded. Furthermore, this high level of consistency between protocol and recorded performance encourages further discussions on possible refinements to breeding protocols that may lead to greater production efficiency.

It is equally discouraging to see serious discrepancies between what is expected and what is actually achieved. This can be for a number of reasons but ultimately implies that the application of the agreed breeding protocol does not reflect what is happening biologically in the breeding barn. In some cases individual staff with good experience may still produce excellent results, simply by ignoring protocol requirements. In other cases, inexperienced staff may achieve what they understand to be the protocol "expectations" in terms of number of doses used per sow bred (often 90% or more of sows expected to receive multiple inseminations). However, by not having the confidence or ability to detect the most intense part of the heat period, they may actually complete their inseminations many hours before the sow eventually ovulates. When challenged with this possibility, it is usually clear that these staff have never understood, which is a very different thing to not having been told, the basics of the estrus detection and the rationale for protocol development.

Another aspect of breeding protocol implementation seems to indicate a disconnection between the logical protocol development, an understanding by the breeding staff of why the protocol is in place, and the anticipated outcome. My observation is that when a boar completes a natural service, the infection risk imposed by fecal and other material around the external vulva is offset by, 1) the release of preputial fluids as the penis is extended, 2) by the cleaning action achieved by rotating of the penis during intromission, and 3) by the lubricating and phagocytic secretions of the vulva, vagina and cervix. As a biologist, therefore, the trick when implementing good AI practice would be to try and mimic these natural events as closely as possible. The extent to which "protocol compliance" seems to have led to an extensive process of cleaning not just of the area surrounding the external genitalia, but also the everted vulval mucosa (and even on one occasion the posterior vaginal cavity) before inserting the AI catheter, seems to be almost counter-intuitive.

For the future, therefore, if we can limit use of AI sires to those boars that can achieve 94 to 100% pregnancy rate in proven single-sire matings, the application of **well conceived**, **well understood** and **well executed** breeding protocols at farm level will be even more critical.

Data capture and sow longevity in the breeding herd

My friend, mentor and former colleague, Frank Aherne, has been attributed with a number of "truisms" that became some of the driving principles of the R&D program we developed together at the University of Alberta. Three that provide a good introduction to the next section are as follows:

1. *"You can't test drive a Ferrari in a traffic jam" (an encouragement to consider good gilt development programs)*
2. *"In God we trust, everything else requires data"*
3. *"If you don't measure it, you can't manage it"*

As with knowledge on the biology of estrous female, there are substantial and largely consistent data describing the relationships between growth characteristics, the timing of sexual maturation, and expected fertility in the gilt and lower parity sow. There is less information about the relationship between the wide variety of gilt development programs promoted within the industry and actual longevity of sows in the breeding herd. There is virtually no information in the public domain on the lifetime economic efficiencies achieved by adopting one or other GDU strategy. The complexity in obtaining this information is one of the great frustrations in trying to promote better gilt management programs.

Nevertheless, if……

- a GDU program can be implemented that achieves a number of well defined goals (second estrus at breeding; some target weight at breeding; and even some minimal age for a gilt to be bred;
- the program does not increase, or even reduces, gilt non-productive days (NPD),
- and each of the goals is believed to promote better sow longevity,

……..then why would the industry not choose to implement such programs.

There may be a number of different reasons, but ultimately the time requirement to actually capture data on

gilt weight and recorded estrus behavior seems to be the issue. However, my experience is that either staff time is available, but managers are not convinced about the value of collecting the information, or that a less rigorous system of introducing gilts into the breeding is considered to be "acceptable", but at what overall cost? *The inefficiencies we don't measure don't need to worry us and also can't be managed*. My question is whether this lack of information, and our inability to link key gilt traits to recorded sow longevity, are things we may come regret in the longer term.

The attention still paid to the rather imprecise attainment of sow "condition" is another example of the disconnection between what we know and what we are willing to do at production level. There are excellent data on target weights (read "lean tissue mass") and levels of fatness ("read P2 data") that are associated with acceptable lifetime breeding performance. I would also like to suggest that with some consideration for the dam-line in question, there is good evidence that achieving strict target weights when a gilt is bred provides a very good foundation from which to manage lifetime body state (condition).

Imagine the frustration then, after 20 years of visiting production systems, to be most frequently asked the question, "What do you think about the "condition" of our gilts and sows". This question will usually be accompanied by discussion of "where we are compared to where we were", or "where would like to be", and how "sow condition" on this farm in the system may differ from another farm. Three things seem to stare me in the face in these situations,: 1) the feed costs and production efficiencies related to whole breeding herds at different levels of "condition" must be substantial, 2) the protocols that are in place don't seem to be able to prevent these differences in 'condition" from occurring, and 3) there are usually no data available on weights, even if there may be data on back fat.

In my case, this part of a farm visit generally then heads towards the lines of recently bred gilts and this leads to discussion about any obvious variability in gilt size. It is a rare exception if this discussion includes a review of recorded gilt weights and fatness at breeding. *Again, what we don't measure, we can't manage*.

If we require a record of gilts in standing heat as part of a GDU program, it takes about 30 seconds at that point in time to get a "tape estimate" of gilt weight. Yet, this 30 seconds of commitment by the barn staff to lifetime sow management likely saves many hours of unresolved management and consultant discussions about changing "condition" and allows effective feeding programs to be applied to a more uniform population of younger sows.

Reproductive technologies to increase the rate of genetic gain at commercial level

There has been a recent flurry of debate about the need and opportunities to rethink the role of AI in the pork industry. The ultimate goal of using AI is to maximize the genetic impact of the very best sires across the largest possible number of gilts and sows bred. As John Behan once reminded us at the Banff Pork Seminar, genetically one sperm is half a pig. Indeed, because of the commercial value of highly selected boar attributes like lean growth rate of the progeny, feed conversion efficiency and meat quality, the boar (one sperm) likely contributes to more than half the commercial value of his progeny. If we contrast the use of AI to maximize genetic potential in the cattle industry with what we have achieved in the pork sector, we would have to conclude that we have been more focussed on efficient but profligate production and marketing of semen doses, than on using AI to maximize the genetic impact of our best sires.

There now seems to be a real opportunity to redress this trend and a number of exciting developments have already been discussed at this year's Leman Conference. However, in the context of the Pijoan Lecture, we might reflect on what took us so long, as a community of researchers, managers, producers and members of the technical support industry, to reach this point. The only convincing answer that I can find is that somewhere along the way we lost focus. The research community got discouraged by the lack of "break-through" science and the lack of access to single-sire matings at commercial level; the AI industry chased efficiency rather than genetic transfer as a key goal; genetic companies realized their commercial goals by selling large numbers of sire-line boars to meet the needs of the AI industry; and an overall strategy at production level of using high sperm doses and multiple inseminations to ensure good breeding herd performance became dogma in the industry. As the industry and sow base grew, and we eventually had thousands of boars standing at stud, the drive for production efficiency in the boar stud became of paramount importance. The industry was also very busy dealing with other "bigger problems" like health and biosecurity, and "bigger opportunities" for achieving gains in production efficiency through nutritional management and use of alternative feeds.

In retrospect, it is alarming that for the last 10 years we have collectively missed the opportunity to bring our primary producers up to a $1.00 in added value to the pigs produced by not staying focused on the primary use of AI as a tool for efficient genetic transfer. Perhaps being faced

with the harsh realities of the business of pork production at meeting like this and the Banff Pork Seminar, finally shook loose the inertia built into our current limited use of AI. Perhaps it also tells us something about the need to consider my last topic for this Pijoan Lecture: How can we more effectively link carefully rehearsed industry goals to effective, community-wide, R&D strategies and better technical implementation at production level.

R&D and management structures of the future

In a previous keynote lecture at the Leman Conference, Mike Tokach discussed a number of interesting questions around the future training of graduate students in an industry that is becoming increasingly self-sufficient in meeting its R&D needs. A number of developments since that lecture have produced interesting hybrid answers to this question, and increasing numbers of university based graduate students are completing their research programs in an industry setting. Our own program is no exception.

However, the recent developments in the area AI application discussed above, and the rapidly changing landscape of genomic and epigenomic technologies, raise other important questions about future R&D needs. Many of the fundamental questions about mechanisms linking genotype to phenotype, and the role of epigenetics and prenatal programming in creating phenotypic plasticity as part of a normal evolutionary process, can be carried out in small research populations of domestic livestock. However, population-wide sampling in a commercial setting is ultimately required to realize the full potential of this type of research. Additionally, the only access to large numbers of mature breeding females will be through partnerships with commercial production systems. Although our own research group has had some initial success in achieving this objective, and are grateful to the enterprising individuals and companies who have helped us, a more established process for gaining access to commercial breeding populations is needed. The same is true for the rapidly expanding interest in using genomic selection for disease susceptibility traits and overall robustness of our animals in a production environment.

The strategies being developed by the Australian CRC programs have a number of interesting features. At the outset, they require the development of a national, short to mid-term (5 to 9 years) R&D strategy, developed as a consultation between committed industry partners, institutionally-based researchers and consumer organizations. A collective vision of achievable benchmarks, linked to an overall set of R&D objectives with defined milestones and deliverables, then forms the basis of a collective bid for federal CRC funding. In the context of the need to gain access to commercial pig populations, a key feature of the requested funding envelope is the allocation of research funds to "essential industry partners" in return for them providing core, in-house, research facilities and access to their commercial populations for agreed research projects. Having experienced the enormous risks associated with trying to support commercial scale populations of sows for research purposes within the present funding environment, the CRC strategy appears to have considerable merit. A similar approach to creating a more cohesive and effective R&D funding strategy in North America would provide further financial support to those production systems that are already willing to absorb some of the costs of research and technological innovation. This type of funding strategy might also encourage even further interactions between other production systems and the wider R&D community.

Finally, I think there could be an interesting discussion about the future management structure that will best support the genetic transfer side of the pork industry. If our ambitions to use only 25% or so of the present boar stud population are realized, and semen from each of the boars collected could cover hundreds of gilts and sows bred, then the whole dynamic of the boar stud, and its economic impact on production systems will change. Many excellent graduate students who train with groups like our own, and became proficient in *in vitro* reproductive technology and gamete biology, developed careers working in human fertility clinics. Perhaps in the future, we can afford to capture this expertise for our own industry. Furthermore, if less time will be spent collecting and extending semen, perhaps we can copy the cattle industry, and have our boar studs also accept the responsibility for more effective training of breeding technologists at commercial level. Perhaps this is exactly the point at which I should end, because I begin to see a passionate biologist starting to be tempted to consider a questionable career as business strategist!

Conclusions

It has been a privilege to honour the name of Carlos Pijoan and his contribution to our community with today's lecture. I hope both the quality of the science behind my lecture, and the exciting opportunities to bring this science to the industry, were enough to keep him awake spiritually during the lecture. I would like to recognize the multitude of friends, students, colleagues, and research organizations that have given me the opportunity to reach this point in my career. Finally, I hope some of the ideas discussed in this lecture will help to bring some renewed focus to the effective integration of good science into good production.