MANAGING BOAR TAINT: FOCUS ON GENETIC MARKERS

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ABSTRACT

Male pigs are normally castrated to prevent boar taint, but this reduces feed efficiency, lean gain and has a negative impact on animal welfare. Alternatives to surgical castration are immunocastration and the development of genetic markers that can be used in a marker assisted selection breeding program to produce pigs that are free of boar taint. Our approach is to identify single nucleotide polymorphisms (SNPs) in candidate genes that encode the enzymes involved in the synthesis and degradation of the boar taint compounds, androstenone and skatole. We used a sample set of about 1300 animals representing 8 different lines, comprising 6 breeds, for the discovery and validation of SNP markers. So far, we have validated about 80 effective SNPs in 28 candidate genes. The SNPs that were associated with fat skatole and androstenone and the strength of the associations varied among the eight lines of pigs, although some SNPs were effective in several lines. Application of the markers to produce pigs that were homozygous for the favourable alleles would decrease average fat skatole levels from 20-54% and fat androstenone from 26-61%, depending on the line. We also determined that none of these markers were associated with negative effects on production traits. A genetic solution for boar taint will eliminate the need for castration of male piglets. This will dramatically improve the profitability and decrease the environmental impact of pork production, as well as address the increasingly important animal welfare concerns about castration.

INTRODUCTION

Why Castrate?

Young male piglets are castrated to prevent off-odours and off-flavours (boar taint) in the meat at slaughter weight. Castration prevents boar taint, but intact boars have improved feed efficiency, nitrogen retention and lean gain compared to castrates, which could result in significant economic gains to producers. The use of entire male pigs for pork production will improve pork production efficiency, but this brings with it also concerns about pork with boar taint and husbandry of entire males pigs which are more aggressive than castrates (Lundström et al., 2009). A major driving force for using entire males is the growing animal welfare concerns against castration. Several EU countries will ban surgical castration in the next few years (even with anaesthetic) and some major grocery stores in The Netherlands have now decided not to sell pork from castrates. Controlling boar taint without surgical castration would, therefore, have dramatic benefits for production and consumer acceptance of pork products.

What Causes Boar Taint?

Boar taint is caused by the accumulation of two compounds, androstenone and skatole, in the fat. Androstenone is a steroid produced in the testis as the boar nears puberty, and it acts as a sex pheromone to regulate reproductive development in gilts and induce a mating stance in sows. Skatole is produced as a bacterial breakdown product of the amino acid tryptophan in the gut. It is produced in equivalent amounts in the gut of both males and female pigs, but it is poorly metabolized and eliminated by males, so it accumulates in fat.

Boar taint from skatole is affected by diet and environment (management). The main source of the tryptophan for skatole production comes from the turnover of cells lining the gut, and this can be reduced by including sources of fermentable carbohydrates in the diet. Skatole can also be absorbed from the manure, so dirty pigs of any sex can accumulate high skatole levels in fat. Androstenone production is controlled by the sexual maturity of the boar, so diet does not have much of an effect on boar taint from androstenone. Androstenone levels could be decreased by slaughter at lighter weights before puberty begins, but this is not economical.

OPTIONS FOR CONTROL OF TAINT

Two promising alternatives to deal with boar taint are the use of genetic markers to select pigs that have reduced propensity to produce boar taint (Zamaratskaia and Squires, 2009) and the use of an immunocastration vaccine (Improvac, developed by Pfizer; Dunshea et al., 2001; Moore et al., 2009; Pauly et al., 2009).

Immunocastration

A promising method for controlling boar taint is by immunocastration, instead of surgical castration. Immunocastration works by injecting a vaccine which stimulates the production of antibodies against gonadotropin releasing hormone (GnRH). GnRH is produced by the hypothalamus in the brain to drive the release of luteinizing hormone and follicle-stimulating hormone by the pituitary gland, which stimulate the development of the testis. The antibodies inactivate GnRH to shut down testicular development to the same extent as surgical castration. However, since the vaccine is given to pigs near slaughter, they grow as normal boars for most of their life and retain the performance advantages of intact boars.

Genetic Selection

Genetics can affect both the production and metabolism of boar taint compounds, and these effects can be found both within breeds and among different breeds. For example, levels of androstenone are much higher in Durocs than in the white pig breeds. There is also a wide variability in the amount of boar taint that individual pigs have within a breed. The heritability of both androstenone and skatole is moderate to high, but previous attempts to select for pigs with low boar taint have resulted in reproductive problems (reviewed in Zamaratskaia and Squires, 2009). The development of specific genetic markers for boar taint would minimize these negative effects on reproduction.

The use of genetic markers to produce lines of pigs that are free of boar taint but otherwise grow as normal boars is a long term solution to raising entire male pigs for pork production. A number of studies have shown differences in expression of candidate genes encoding enzymes involved in the metabolism of boar taint compounds between high and low boar taint pigs and between different pig breeds. However, only a few studies have reported SNPs in these genes that are correlated with levels of boar taint. A recent report from Norway (Moe et al., 2009) is the first association study to compare a large number of SNPs to boar taint in Duroc and Norwegian Landrace breeds. They found significant marker effects for fat androstenone in Duroc, but not in Landrace, and significant marker effects for fat skatole in both breeds. Individual markers explained from 2.5-16.3% of the total variation in the traits

At the University of Guelph, we have developed genetic markers for boar taint based on candidate genes that encode the enzymes involved in the synthesis and degradation of the boar taint compounds, androstenone and skatole. We have a database of about 1300 animals representing 8 different lines, comprising 6 breeds (Duroc, Hampshire, Landrace, Large White, Pietrain and Yorkshire), that we have used for the discovery and validation of genetic markers, mostly single nucleotide polymorphisms (SNPs) in the DNA. We compared the sequences of candidate genes from pools of DNA obtained from animals from the extremes of the boar taint phenotypes in each line for SNP discovery. We then genotyped all the animals in our database for each SNP and conducted association analysis for each SNP with the boar taint phenotypes, i.e. androstenone and skatole.

So far, we have about 80 effective SNPs in 28 candidate genes for boar taint. The strength of the associations of the SNPs with skatole and androstenone levels in fat varied among the different lines. The SNPs that were associated with fat skatole and androstenone varied among the eight lines of pigs, although some SNPs were effective in several lines. The number of significant SNPs across lines varied from 5 to 17 and from 3 to 16 for skatole and androstenone, respectively. A large proportion of effective SNPs were associated with both skatole and androstenone (65%) across lines, which corroborates with the reported moderate positive genetic correlation between these two boar taint compounds (e.g., Tajet et al., 2006). Application of the markers to produce pigs that were homozygous for the favourable alleles would decrease average fat skatole levels from 20-53% and fat androstenone from 26-61%, depending on the line. We also determined that none of these markers were associated with negative effects on production traits. We are now working with a commercial company (JSR Genetics) to validate these SNPs in their lines. The ultimate goal is to identify the causative mutations in the handful of most important genes, and then use these markers in breeding programs to develop lines of pigs that are free of boar taint but otherwise grow as normal boars.

These findings represent significant progress towards a genetic solution to boar taint. Work is continuing to characterize additional SNPs for boar taint and to validate these markers in commercial swine populations. The control of boar taint by marker assisted selection will eliminate the need for castration. This will significantly improve the profitability of pork production and address animal welfare concerns about castration that are now a hot topic in several EU countries.

CONCLUSIONS

Castration to prevent boar taint limits productivity and increases animal welfare concerns of commercial pork production, so alternative strategies for controlling taint are needed. Immunocastration effectively controls boar taint, but the development of low boar taint lines of pigs by marker assisted selection would provide a long term solution to the problem. This will improve pork quality and consistency, profitability, environmental impact and animal welfare in pork production by eliminating the need for castration of male piglets. In terms of production efficiencies it is anticipated that the use of entire male pigs will improve profits per pig by more than $5, which is based on analyses that were conducted previously by de Lange and Squires (1995) and adjusted to 2010 economic conditions. Intact males also produce less manure and thus excrete less nitrogen and phosphorous in the manure than castrates, thereby decreasing the environmental impact of pig production.

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