Understanding bulls' gene-rich Y chromosomes may improve herd fertility

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This image shows a side view of a bull. Credit: Patrick Mansell, Penn State

The Y chromosomes of cattle have more genes and are more active than the Y chromosomes of other primates, according to researchers.

This discovery may help biologists better understand how cattle and other mammals evolved, as well as help animal breeders and farmers better maintain and enhance fertility in the cattle industry, said

Wansheng Liu, associate professor of animal genomics, Penn State.

"Low fertility is a big problem for the dairy and beef industry," Liu said. "In the past 60 years, we paid more attention to milk, or beef production as a sign of herd success, but, even as milk production goes up, the animal's fertility goes down, which means it's time to pay more attention to male fertility now."

The researchers identified 1,274 genes in the male specific region of the bovine Y chromosome, compared to the 31 to 78 genes associated in the Y chromosomes of various primates. They also said the genes in the bovine Y chromosome were much more transcriptionally active compared to other mammals. Transcription is the first step of gene expression when DNA is copied. In this process, the cell produces messenger RNA that copies the genetic information from the cell nucleus to serve as a template for protein synthesis.

In addition to the 1,274 genes that take part in coding proteins, they also identified 375 novel noncoding gene families on the bovine Y chromosome, which are predominantly expressed in different stages of the testis.

Most researchers believed that the Y chromosome of cattle would be similar to the Y chromosome of other mammals, which does not have a large number of genes and is considered mostly transcriptionally inactive, Liu said. The Y chromosome, which was once similar to the X chromosome, evolved predominantly for testis development and male fertility, he added.

This image shows a head shot of a bull. Credit: Patrick Mansell, Penn State

Currently, the gene content and transcription pattern of the bovine Y chromosome is the only non-primate Y chromosome that researchers have studied in depth, according to Liu.

"These findings directly contradict the traditional view that the Y is largely heterochromatic with a paucity of genes and transcription activity," said the researchers, who released their findings in the current online issue of *Proceedings of the National Academy of Sciences.*

The X and Y sex chromosome in most mammals began to diverge after 160 million years of evolution. However, genetic isolation and lineage-specific evolution resulted in the unique structure of the bovine Y chromosome, which determines the gene content and transcriptional activity of the Y chromosome among cattle, according to Liu.

With little knowledge of the roles that the Y chromosome genes play in fertility, most animal breeders and farmers select bulls based on physical characteristics, such as the size of the testis. Because the Y chromosome is present in males only, the Y-linked testis genes that govern male fertility are passed directly through the male line.

Understanding genetic diversity may give farmers another tool for managing their herds to improve male fertility, Liu said. The lineage of most of the bulls in current Holstein herds, for example, can be traced back over a hundred years to just a few bulls, said Liu, who worked with Ti-Cheng Chang and Yang Yang, both former post-doctoral fellows in animal science at Penn State, and the late Ernest Retzel, National Center for Genome Resources.

The potential impact of a limited number of bulls on fertility and the surviving of the breed as not been investigated.

"We can begin to understand the Y chromosome variation among male lineages in a cattle breed," Liu said. "And, also, we can better understand how we can maintain genetic diversity in males, particularly in a breed, such as Holsteins, that has been extensively selected and is almost all based on artificial insemination in reproduction."

The researchers analyzed the expression of the entire Y-linked genes as the bull aged, beginning soon after the bull's birth, during puberty and then again after the bull matured. They analyzed complimentary DNA from the bull testis. Complimentary DNA is a form of DNA that is synthesized from a messenger RNA template

"The bovine genome sequence was published in 2009," said Liu. "As that genome sequence was from a female, the findings of the bovine Y chromosome study is a significant contribution to the completion of the bovine—male and female—genome project." The United States

Department of Agriculture supported this work.

More information: Male-specific region of the bovine Y chromosome is gene rich with a high transcriptomic activity in testis development, www.pnas.org/cgi/doi/10.1073/pnas.1221104110

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