Heteropaternal superfecundation in sheep

TEAGASC research is using genotyping technology to detect heteropaternal superfecundation in sheep, and thus help explain some quirks in genetic evaluations of lambs.

What is it?

Superfecundation is where separate copulatory events occur, leading to the fertilisation and implantation of two or more eggs during the same oestrus/menstrual cycle, and resulting in the birth of two or more siblings. Heteropaternal superfecundation is where the multiple births originate from different fathers. Heteropaternal superfecundation is therefore more likely to occur in species that commonly ovulate more than one egg and are also mob mated (i.e., more than one male runs concurrently with the females). Sheep are a great example of such a population, as they often bear multiple lambs and are also often mob mated.

Commentary on superfecundation dates back to Leda from Greek mythology, who was the wife of Tyndareus, King of Sparta. Both Zeus and Tyndareus were said to have impregnated Leda, resulting in Pollux and Helen being fathered by Zeus, and Castor and Clytemnestra being fathered by Tyndareus; Helen was later to be better known as Helen of Troy. Also from Greek mythology, Heracles (and his brother Iphicles) were thought to have been born as a result of heteropaternal superfecundation, with clear distinctions cited between them supporting the hypothesis. Heracles was depicted as fair-haired, whereas Iphicles was dark haired; Heracles was also characterised as being strong and courageous, with the opposite being true of Iphicles.

Heteropaternal superfecundation in Irish sheep

Heteropaternal superfecundation in sheep can (sometimes) be detected if only one ram of each breed was present within the mating mob, and if these breeds were distinctly different; for example, a Texel ram with a white head and a Suffolk ram with a black head will each produce distinctly different lambs. DNA information on the lambs provides more concrete proof of heteropaternal superfecundation and is one of the only ways to determine its occurrence when multiple rams from the one breed make up the mob mating team. Quantification of the frequency of heteropaternal superfecundation in Irish sheep is enabled by the rapid growth in genotyping; this exercise has never been undertaken previously in any global sheep population. The data used in this study consisted of 685 multiple birth litters where DNA information on the sire, dam and all lambs were available; all dams were mob mated. Of the 539 pairs of twins included in the analysis, 160 (i.e., 30 %) were sired by two different rams. Of the 137 sets of triplets included in the analysis, 73 (i.e., 53 %) were sired by more than one ram. Of the nine sets of quadruplets, eight were sired by two rams, with the remaining litter being mono-paternal (i.e., all sired by the same ram). Therefore, the overall incidence of heteropaternal

Using DNA information is valuable to build confidence in genetic evaluation.

superfecundation among litters was 35 %. Given that the incidence of multiple births in these flocks was 65 %, heteropaternal superfecundation is expected to be relatively common in sheep; this is especially true since all but two of the litter mates were polyzygotic, meaning that the litter originated from separate eggs. Of the genotyped triplets and quadruplets, all originated from separate eggs, with the exception of one set of triplets where two of the lambs born had almost identical genotypes, suggesting that they originated from a split embryo. This in itself indicates that the extent of genetically identical full-sibling litters is extremely low.
An equation was derived to deterministically calculate the probability of a litter (P) being sired by more than one ram (**Figure 1**), where N is the number of rams in the mating mob and L is the number of lambs born in the litter. For example, the likelihood that a set of triplets born to a ewe mated by two rams are sired by both rams is 75 %. This equation, however, assumes no differential in fertilisation capacity among the different rams, nor any difference in intrauterine embryo/foetal survival. Fertilisation capacity includes the semen quality of the ejaculate but also the receptiveness of the egg to the sperm of a given ram; differences in semen quality parameters among rams are known to exist. Differences in intrauterine survival of a zygote, embryo or foetus from particular rams could be due to a number of factors, not least the genetic relationships of the ram with the ewe (i.e., resulting in inbreeding) or whether both parents are carriers of lethal genetic mutations (also more likely with inbreeding).

Practical implications

Breeders and farmers alike are often concerned about how closely the predicted genetic merit of an individual reflects its true genetic merit. Genetic merit of sheep in Ireland is depicted in their 'star ratings', analogous to the star ratings of hotels. Disillusionment can often ensue among breeders and farmers when the star rating of a newborn lamb changes (significantly) once the lamb is genotyped. This can occur because, in the absence of any information on the animal itself (i.e., either lambing performance or genomic information), the estimated genetic merit of a litter of lambs is assumed to be identical; this is simply the average genetic merit of the parents. This assumption ignores the random inheritance of the DNA of each parent. Our study revealed that the level of genetically identical litter mates (i.e., the same DNA was inherited) is extremely low. Dizygotic (i.e., non-identical) full siblings are assumed to have a genetic relationship of a half; if the twins are born from dual paternity (i.e., heteropaternal superfecundation), then the genetic relationship between siblings is expected to be one-quarter (i.e., half-siblings), assuming both sires are unrelated and the dam is non-inbred. Hence, where heteropaternal superfecundation occurs, the extent to which the star ratings of lambs from the same litter can diverge may be large. Notwithstanding this, being able to demonstrate, using DNA information, why the genetic ranking of the animal changed once genotyped will be invaluable in securing confidence in the genetic evaluation system and also the benefit of genotyping.

$$P=1-N(1/N)^{L}$$

FIGURE 1: Equation to deterministically calculate the probability of a litter being sired by more than one ram (P) where N = number of rams in the mating mob and L = number of lambs born in the litter.

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