

Managing Inbreeding within Sheep Breeding Programmes

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The challenge to avoiding inbreeding

To make the fastest genetic progress in any particular attribute flocks should breed from the rams and ewes with the highest genetic merit in the population. Unfortunately if this approach is taken to an extreme and superior ancestors are used extensively, it could quickly result in an increase in the level of inbreeding within the flock and ultimately a drop in performance.

Modern livestock breeding programmes can be susceptible to increases in inbreeding due the widespread use of AI & ET, fast generation turnover, selective use of specific family lines and the tendency for a relatively small number of different sire families to dominate within certain breeds.

Breeders need to strike a balance to optimise rates of genetic gain, whilst controlling increases in levels of inbreeding.

What is inbreeding?

Inbreeding is the practice of mating two genetically related animals. To a degree this is inevitable within any long-term selection programme involving a closed population.

Breeders will sometimes deliberately inbreed specific bloodlines to fix certain characteristics in the flock, increasing the frequency of favourable genes – or more rarely to expose recessive genes.

Related animals will have more genes in common. In this respect it may have a place in a breeding strategy as in some instances it will bring a number of favourable genes together. However, it will also tend to increase the number of recessive or deleterious genes being expressed – leading to a reduction in fitness and productivity; this is referred to as “inbreeding depression”. Inbreeding can also increase the frequency of observed genetic abnormalities in a population, as recessive genes are brought together and expressed

Inbreeding may have a role in a breeding programme, if your aim is to breed a single superior animal – but you would have to accept high levels of wastage as part of the programme. This is a policy that would be difficult to advocate. Most flocks aim to improve the average performance of the whole flock – and in this respect the economic benefits of close inbreeding are more questionable.

Linebreeding

Linebreeding is a deliberate form of inbreeding, and is achieved through the mating of more distantly related animals - cousins, half brother to half sister, uncle to niece. This breeding strategy is used by breeders to create “prepotent” breeding lines that uniformly “stamp” their characteristics on their progeny. Prepotency is more easily achieved in linebred/inbred lines – as the genes being passed to the next generation will be less variable.

Although inbreeding in this manner is likely to increase the uniformity of a flock and when combined with certain characteristics relating to “breed type” may enhance their success in the showing, this image of success in one set of traits shouldn’t stop potential purchasers of these genetics considering what is happening to the other traits, such as reproductive fitness and the longevity of sheep in the flocks from which such show winners have arisen.

One challenge with line breeding is that breeders sometimes forget to look deeper into the pedigree of the proposed line-bred mating, where they might observe additional relationships in common. This means the planned mating is far closer than they originally assumed.

Example: Impact of Inbreeding

The impact of inbreeding can be observed in this study of a Hampshire Down flock in the USA. The negative impact of lamb inbreeding on the weight of lamb weaned/ewe exposed was attributed as follows: 11% to its effect on fertility, 6% to its effect on prolificacy, 80% to its effect on survival and 3% to its effect on 90 day weaning weight.

	Change for every 1 % increase in inbreeding in the lamb
Survival to 7 days	- 1.1%
Survival to 90 days	- 1.3%
Lamb weaning weight	- 0.59kg

	Change for every 1 % increase in inbreeding in the ewe
Ewe weight	- 0.27kg
Fertility	- 1.2%

Ref: Journal Animal Science. 1982. 55:780-786.

Outcrossing / Hybrid Vigour

Breeders faced with an inbreeding problem can use an outcross (unrelated mating) to restore vigour to the flock. Hybrid vigor (also known as heterosis) is the opposite of inbreeding depression and arises when unrelated individuals are crossed – in commercial flocks this tends to take place through the strategic use of another breed.

The traits that are most greatly reduced by inbreeding depression (low heritability traits that affect reproduction, longevity and disease resistance) are also those most improved by outcrossing or cross breeding.

Should breeders completely avoid inbreeding?

Inbreeding will bring together desirable genes, as well as undesirable ones – so it does have the potential to produce some superior animals. However at higher levels of inbreeding wastage rates will also be higher, due to reduced fitness and the culling of animals with deleterious genes. On this basis inbreeding strategies are expensive and will ultimately lead to a reduction in flock performance.

However, complete avoidance of any inbreeding is almost impossible and a balance has to be struck between the genetic superiority of a specific ram and the level of inbreeding he creates in the future flock. Low levels of inbreeding (<6.25%) are often considered an acceptable compromise, and levels higher than that should be avoided.

Calculating Levels of Inbreeding

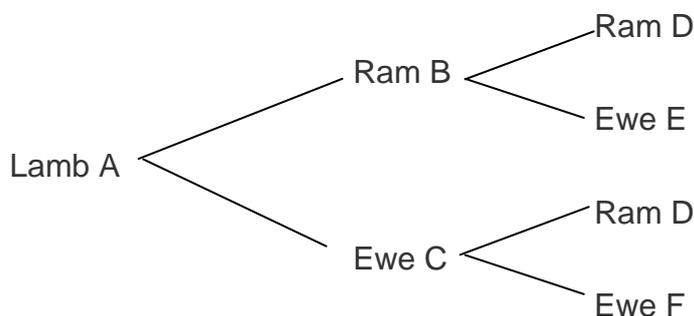
The level of inbreeding is calculated as the probability of for two alleles being identical by descent. This value is called the "inbreeding coefficient".

Typical inbreeding percentages are as follows, assuming no previous inbreeding between any parents

- Father/daughter, mother/son or brother/sister → 25%
- Grandfather/granddaughter or grandmother/grandson → 12.5%
- Half-brother/half-sister → 12.5%
- Uncle/niece or aunt/nephew → 12.5%
- Great-grandfather/great-granddaughter or great-grandmother/great-grandson → 6.25%
- Half-uncle/niece or half-aunt/nephew → 6.25%
- First cousins → 6.25%
- First cousins once removed or half-first cousins → 3.125%
- Second cousins or first cousins twice removed → 1.56%
- Second cousins once removed or half-second cousins → 0.78%

The diagram below shows the pedigree of a sheep with an inbreeding coefficient of 12.5% - because his parents were half-siblings sharing the same father (Ram D).

Diagram 1. The pedigree of a sheep with an inbreeding co-efficient of 12.5%



What is a safe level of inbreeding?

Many breeders consider “inbreeding” to be dangerous, whilst some breeders might argue that “linebreeding” is an acceptable breeding strategy. This is clearly an over simplification, as linebreeding is also a form of inbreeding. Geneticists will also explain that the mating of individuals separated by more than one generation can concentrate defective genes just as strongly as closer matings.

A more analytical approach is to measure the level of inbreeding between individuals and set appropriate limits to the proportion of identical genes brought together in a single mating.

BASCO now provides breeders with access to software to calculate rates of inbreeding. Results show the inbreeding co-efficient for progeny from a range of potential mating options.

An example is shown below. In this scenario matings with inbreeding co-efficients greater than 7% would be avoided (these are shown in red).

Select EBV		clear list			Export mating list: Excel PDF txt			Export inbreeding report: Excel PDF txt				
Index		18604:12B418		18604:12B436		18604:12B450		18604:12B458		18604:12B471		
Sire Name	Sire FBN	Index Acc		Index Acc		Index Acc		Index Acc		Index Acc		
Ewe FBN	Ewe EId	396.57	66	362.85	67	351.07	66	333.55	66	307.54	64	
<input type="checkbox"/>	<input type="checkbox"/>	Index	Acc	(1)	(2)	(2)	(1)	(0)	Averages			
18604:25039	271.96 79	7.13	<input type="checkbox"/>	4.20	<input checked="" type="checkbox"/>	10.40	<input type="checkbox"/>	5.03	<input type="checkbox"/>	16.31	<input type="checkbox"/>	8.61
18604:25069	184.62 75	5.08	<input type="checkbox"/>	2.83	<input checked="" type="checkbox"/>	3.17	<input type="checkbox"/>	3.96	<input type="checkbox"/>	5.71	<input type="checkbox"/>	4.15
18604:25072	344.55 75	6.64	<input type="checkbox"/>	3.22	<input type="checkbox"/>	3.17	<input checked="" type="checkbox"/>	4.35	<input type="checkbox"/>	6.49	<input type="checkbox"/>	4.77
18604:25088	243.35 75	6.74	<input type="checkbox"/>	6.49	<input type="checkbox"/>	5.08	<input type="checkbox"/>	4.05	<input checked="" type="checkbox"/>	4.20	<input type="checkbox"/>	5.31
18604:25108	344.02 74	5.71	<input type="checkbox"/>	8.79	<input type="checkbox"/>	5.66	<input checked="" type="checkbox"/>	5.81	<input type="checkbox"/>	14.79	<input type="checkbox"/>	8.15
18604:25130	180.90 74	4.05	<input checked="" type="checkbox"/>	8.64	<input type="checkbox"/>	4.79	<input type="checkbox"/>	5.27	<input type="checkbox"/>	9.62	<input type="checkbox"/>	6.47

How can breeders avoid increasing the rate of inbreeding in the flock?

Breeders shouldn't stop making good use of the reproductive and genetic tools available to them – but they can take steps to minimise increases in inbreeding now and in the future.

Firstly, it is vital that breeders know the pedigrees of their animals. Inbreeding cannot be avoided unless the pedigree is known. In practise, close matings often occur when an ancestor's identity is not known. Where records are known much of the loss from inbreeding comes from common ancestors three or more generations back in a pedigree – particularly where there is more than one common ancestor. This means that a complete pedigree going back four or five generations is really needed to managing inbreeding properly.

Secondly, if they have concerns about levels of inbreeding they should use inbreeding software to check potential rates of inbreeding arising from future matings.

Thirdly they should establish a breeding plan to minimise rates of inbreeding, this may include:-

- Using a range of different male and female breeding lines
- Avoiding the mating of close relatives
- Introducing an outcross when inbreeding rates start to rise
- Avoiding reliance on a small number of dominant rams (and their sons)

Slowing the generation turnover would also reduce rates of inbreeding. This can be achieved by using sires and dams later into their working life, not rushing to replace them with superior progeny. However, the impact on genetic gain would be massive – so whilst this approach may be of use in rare breeds and genetic conservation, it isn't a sensible approach for the average pedigree breeder.

Summary

- Inbreeding issues can only be fully understood when pedigrees are known and recorded.
- Breeding decisions have to be a balance between making faster rates of genetic gain and minimising rates of inbreeding
- Some inbreeding is inevitable in most populations – whether the flock is involved in performance recording or not. Breeders should be aware of the impact that inbreeding can have on their breeding programme.
- The level of inbreeding within a flock can be measured and once levels are known breeding strategies can be devised to minimise the risks associated with inbreeding.

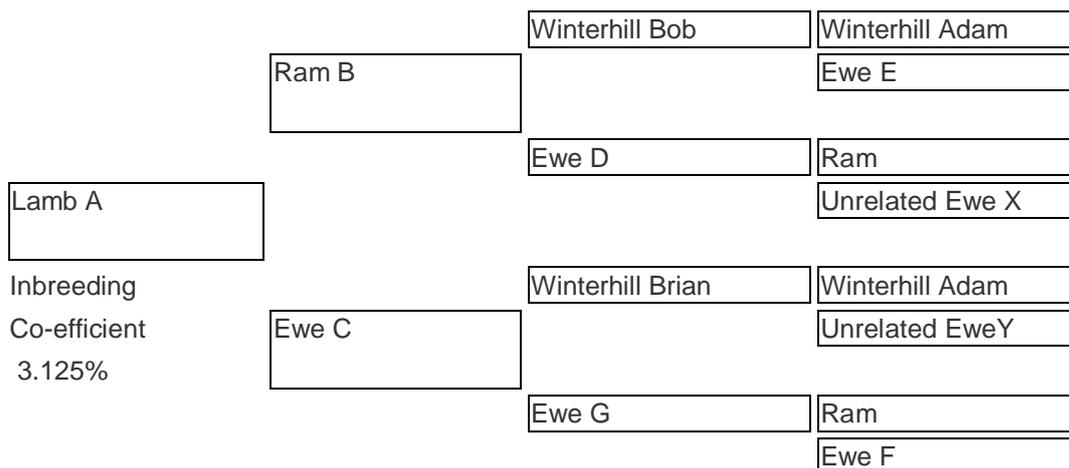
Appendix 1. Inbreeding Scenarios

Question 1. Working with inbred lines

A breeder has a group of ewes sired by Winterhill Brian (a son of Winterhill Adam) and is interested in putting them to a ram by Winterhill Bob (another son of Winterhill Adam). Both rams are out of unrelated ewes.

Should the breeder be worried about the potential inbreeding that will arise?

Answer: The progeny will have a shared great grandfather (see below) and the resulting level of inbreeding will be 3.125% - a relatively low level of inbreeding. It is unlikely to cause any noticeable inbreeding depression providing that there are no additional common ancestors.



Question 2. Buying an inbred ram

A breeder has spotted an impressive looking high index ram catalogued at a sale, but when checking the pedigree he has noticed that it is the offspring of a father/daughter mating.

Is it safe for the breeder to use this ram?

Answer: The ram will have a high inbreeding co-efficient of 25% - in other words there is a 25% chance that any specific pair of genes are identical. Some animals with this degree of inbreeding will express deleterious genes – and many of these can be identified visually. The main concern about this animal's inbred status is any impact it may have on his fertility and survival.

As the ram is fit, structurally sound and has clearly grown well compared to his contemporaries he is worth consideration. Ideally the buyer would want to get the ram semen tested to overcome any fertility concerns. If these issues can be satisfied then there are not likely to be major problems in using him on completely unrelated ewes.

Examples inspired by other papers written on the subject of inbreeding.