Genetic improvement: A fundamental pillar for the canadian sheep industry

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Abstract

The Canadian sheep industry is a relatively small industry and primarily focused on meat production. GenOvis is the national genetic evaluation system with close to 200 participants in 2022 and more than 1 million lamb records. The main purebred breeds under genetic selection are the maternal Dorset and Polypay breeds, the prolific Romanov and Rideau Arcott breeds and terminal Suffolk and Hampshire breeds. In the past years, genetic gains have been achieved for multiple traits using selection indexes. From 2012 to 2021, the largest realized total genetic gains in growth and carcass traits were made by Suffolk breed for 50-day weight (+1.18kg), gain from 50 to 100 days (+2.21kg) and the loin depth (+1.56 mm). In addition, for maternal traits, the largest genetic gains have been observed in Polypay breed for maternal 50-day weight (+0.84 kg) and in Romanov breed for total weaning weight at later parities (+2.55 kg) and total number born at later parities (+0.11 lambs). During the same period, the change in inbreeding levels varied from negative in Polypay (-0.2%) to the largest positive increase in Dorset (+1.1%). There are many opportunities to accelerate these genetic gains. The increase of data collection through multiplier and commercial producers, new phenotyping technologies, and integration of genomic information are among the most promising developments.

Keywords: Genetic gain, sheep breeding program, selection traits, inbreeding

Introduction

The Canadian sheep industry is a relatively small industry compared to chickens, pigs or cattle. As for 2019, 827,800 sheep were produced in Canada compared to 171 398 000 chickens, 14 399 300 pigs and 11 500 000 cattle (Agriculture Canada, 2021). The Canadian sheep industry is primarily meat focused, but milk and wool are also produced. Overall, lamb meat represented 4% of the total retail sales value market of Canadian meat sector in 2019 (Agriculture Canada, 2021). Moreover, the Canadian lamb industry compound annual growth rate (CAGR) has been increasing of 0.1% from 2015 to 2019 (Agriculture Canada, 2021). This upward trend is continuing as the CAGR from 2019 to 2023 is predicted to increase of 3% (Agriculture Canada, 2021). Canadian sheep industry is becoming more and more important and constant efforts must be maintained to specialize it. To do so, tools are made available to sheep producers like for instance the GenOvis program. The GenOvis program has been created as a mean to give an on-farm sheep genetic program for all Canadian users, namely purebred sheep breeders, commercial producers, and dairy farmers. This program+ a partnership between Centre d'expertise en production ovine du Québec (CEPOQ), Ontario Sheep

Farmers (OSF), Canadian Sheep Breeders Association (CSBA), and the Centre for Genetic Improvement of Livestock (CGIL) and counts 199 members divided into 166 breeders, 15 commercial producers, and 18 dairy producers. The technical support is done by CEPOQ whereas the web application and genetic evaluation routines are developed and run by CGIL. Two modules are offered which are lamb (meat), since 2000, and dairy module, since 2014. These modules help sheep farmers to produce high quality lambs for consumers, but also gave access to genetic values that enable them to improve their ewes milk production and quality. Overall, the program allows an effective evaluation of sheep genetic value based on important economic traits as expressed by relatives and other animals within breed or crossbreed.

Material and methods

This paper describes and presents results only about the GenOvis lamb (meat) module. A total of 15 traits are recorded in the database from which three groups emerge, namely growth, carcass, and reproduction (Table 1).

Birthweight is used to calculate adjusted 50 days weights and is considered valid only when it is between 0.5 kg to 9.9 kg (Schaeffer and Szkotnicki, 2015). Thereby birthweight outside this range remains in the database but is set to missing for genetic

Table 1. Description of the recorded traits in GenOvis evaluations.

Group	Traits
Growth	Lamb survival (direct) (%)
	Birth weight (direct) (kg)
	50-day weight (direct) (kg)
	Gain 50 – 100 days (kg)
Carcass	Fat depth – ultrasound (mm)
	Loin depth – ultrasound (mm)
Reproduction	Lamb survival (maternal) (%)
	Birth weight (maternal) (kg)
	50-day weight (maternal) (kg)
	Age 1st lambing (days)
	Lambing interval (days)
	# Born (1st and later lambings)
	Total weaning weight (1st and later lambings)

Table 2. Average birth weight used by breed group when birth weight is missing.

Breed Group	Average birth weight (kg)
1	3.67
2	4.53
3	4.86
4	4.11
5	4.98
6	4.72
7	4.83
8	2.83
9	4.17
10	3.88
11	4.04
12	4.57
13	3.77
14	4.48
15	3.75

evaluation purposes (Schaeffer and Szkotnicki, 2015). When not reported, an average birthweight per breed is used (Table 2) (Schaeffer and Szkotnicki, 2015).

50-day weight is the weight taken around 50 days of age, which, at a practical level, means that the actual weight should be taken between 28 to 72 days of age (Schaeffer and Szkotnicki, 2015). If the age at weighing is outside this range and/or the taken weight is not between 4.0 kg and 51.0 kg, the weight is declared missing (Schaeffer and Szkotnicki, 2015). As growth from birth to 50 days of age is assumed to be linear, weight is adjusted to 50 days of age by extrapolation (either up or down) (Schaeffer and Szkotnicki, 2015).

Lamb survival is defined with 5 categories, where 1 is an animal that died shortly after birth and 5 an animal that has made it to weaning age (Schaeffer and Szkotnicki, 2015). Categories 2, 3 and 4 are different lengths of survival, but with a death before weaning (Schaeffer and Szkotnicki, 2015).

Gain from 50 to 100 days is the difference between the weight at 100 days of age and 50 days of age (Schaeffer and Szkotnicki, 2015). The 100-day weight is provided by producers, which should be taken between 73 to 135 days of age and should be between 10.0 kg to 80.0 kg (Schaeffer and Szkotnicki, 2015). As growth from 50 days to 100 days of age is assumed to be linear, 100d weight is adjusted to 100 days of age by extrapolation (either up or down). This is the gain 50-100d that is used in breeding values calculation. The 100-day weight must be taken at least 28 days after the weaning weight otherwise it is set to missing. (Schaeffer and Szkotnicki, 2015).

Fat and loin depth are ultrasound traits, which means that they are taken by ultrasound measurements (Schaeffer and Szkotnicki, 2015). Ultrasound measurements are taken around 100 days of age (between 73 to 135 days of age) (Schaeffer and Szkotnicki, 2015). Lambs must be weighed at the same time. The ultrasound weights must be between 10.0 kg to 80.0 kg. For the measurement lambs must stand upright on all four legs and kept motionless in a cage, a balance or other installations (Fortier, 2022). Lambs back must be straight (Fortier, 2022). The measured zone is located between the 3rd and 4th lumbar vertebrae (Fortier, 2022). The measured zone needs to be shaved and cleaned to enhance contact between the skin and the ultrasound standoff and thus improve image quality (Fortier, 2022). Measurement is taken perpendicular to fat layers and at the muscle deepest part (Fortier, 2022). Two thicknesses of fat are measured, a first one above the deepest part of the muscle, and a second one at 1.5 cm from the first measurement, always perpendicular to the layer of fat (Fortier, 2022). A third measurement is taken to establish the muscle depth (Fortier, 2022). The skin should not be included in the lamb fat thickness measurement (Fortier, 2022). Fat measurements must be higher than 0.0 mm and below 14.9 mm to be included in breeding values. Loin depth must be between 10.0 mm to 44.0 mm. Loin and fat measurements are adjusted on lamb weight instead of lamb age. This adjustment is calculated at breeding value calculation. Records out of range are set as missing values.

The total weaning weight (TWW) is the sum of the adjusted 50-day weights of lambs that were weaned, which is calculated for first and later lambing (Schaeffer and Szkotnicki, 2015). This includes number of lambs weaned, but also how well the raise dam contributed to the lambs weaning weight. The genetic model account for the proportion of male and female progeny as there is a sex difference in weaning weights to consider. Bottle raised lambs were ignored. (Schaeffer and Szkotnicki, 2015).

The EBVs (Estimated Breeding Values) are calculated across breeds by multi-traits models on a weekly basis using Fortran programs specifically adapted for the sheep context. The EBVs are transformed and published in Expected Progeny Difference (EPD) for the use of the breeders. The genetic trends presented below are the average EBVs of lamb born during each year from the genetic evaluation run of the second week of May 2022. There are 2 genetic evaluation models, one for growth and carcass traits and the other for reproduction traits. Six traits are currently evaluated for growth and carcass (survival, birthweight, 50-days weight, gain from 50 to 100 days, fat and loin depth). All 6 traits are evaluated for direct (dir) and maternal (mat) genetic effects even if maternal effects are low for gain, loin and fat. The EBV dir (e.g.: Birth weight dir) refers to the animal own ability to perform while the EBV mat (e.g.: Birth weight mat) refers to the dam contribution on a lamb performance. The recording allows the distinction of three (3) different dams that have influenced their trait observations. The first is the genetic dam of the lamb. This is the female that has provided one half of the animal's DNA. The second dam carries the embryo and gives birth to the lamb(s). In most cases the `birth' dam is the same animal as the `genetic' dam. However, for producers that use embryo transfer (ET), then `birth' dam may be an unrelated female. The third dam raises the lamb from birth to weaning age. The `raise' dam may be the same as the genetic dam or may be the same as the `birth' dam, or may be a foster dam. The `raise' dam may actually be a bottle for bottlefed lambs. Biologically, the `birth' dam has an influence on survival and birthweight. The `raise' dam has an influence on 50-d weights, gain, loin, and fat thickness. The genetic dam has an influence on all six traits through the relationship matrix. Similarly, litter effects are associated with either the `birth' dam or the `raise' dam. Age of dam effects are also assigned according to `birth' dams or `raise' dams (Schaeffer and Szkotnicki, 2015).

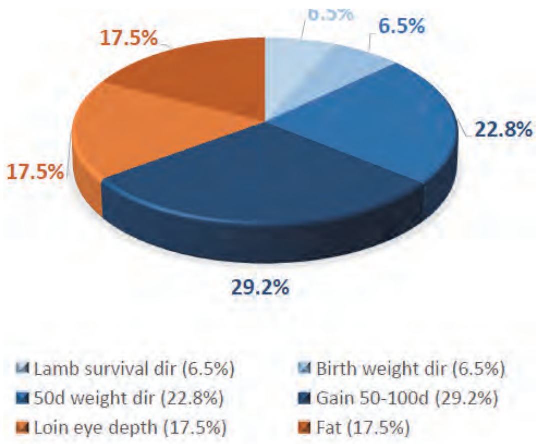
For the reproduction genetic evaluation model, a six-trait system was developed with three traits for parity1 and three traits for later parities. Age at first lambing, number born at first lambing, and TWW at first lambing were three traits for first parity animals, and interval between lambings, number born, and TWW were for second and later parities. First parity and later parity traits have a genetic correlation of only 0.7, so that they can be considered as different traits (Schaeffer and Szkotnicki, 2015).

Selection indexes

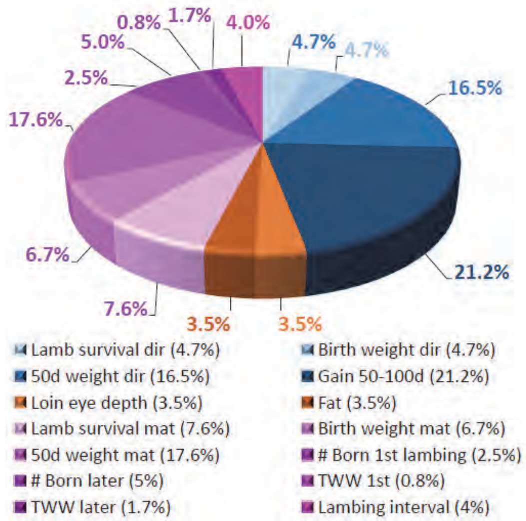
EBVs are used to calculate selection indexes to support breeders in multi-traits selection. A total of 6 indexes have been developed following the work of Quinton (2012) but 3 main indexes are used for 3 main purposes : terminal, maternal and higher prolificacy. The relatives weight of the traits within these 3 indexes are described below. For example, breeders having terminal breeds as Suffolk and Hamphire are recommended to use the Carcass index to improve growth and carcass traits, prolific breeds as Rideau Arcott and Romanov can use the Maternal index for a focus on mothering abilities whereas maternal breeds as Dorset and Polypay will have a focus on higher prolificacy with the Higher prolificacy index. The selection indexes are published for all animals of all the breeds which allows the breeders to select its sheep for all the purpose.

Results and discussion

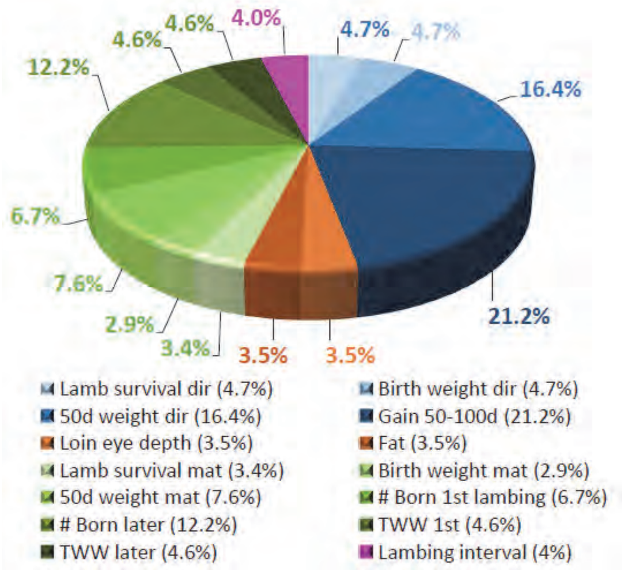
Over the past ten years, GenOvis has seen its number of members increase with the arrival of Ontario in the program (previously known as SFIP) in 2011 and two other industry organizations (OSF and CSBA) in 2016. Also, lots of effort were put to make producers aware of the importance of the records assiduity and consistency into the database. Since 2016, a 36 to 50% increase is observed in the number of records for growth traits, namely the number of lambs, the birth weight, the 50-day weight, and the 100-day weight (Figure 1A). Records for number of lambs are higher than every other growth trait (Figure 1A). Although the number of records is noticeably lower for loin depth, an important increase of ? 140% in its records has been observed over the past ten years (Figure 1A). The low records of loin depth compared to other growth traits are explained by the fact that this trait needs to be measured by ultrasound, thereby only a few producers pay for it and accredited technicians are not available in all provinces.



Carcass Index



Maternal Index



Maternal Higher Prolificacy index.

The number of lambs born per breed is quite stable in the past ten years for the majority of breeds, except, Crossbred, Romanov and Rideau Arcott (Figure 1B). Romanov and Rideau Arcott breeds have seen a 100% and XXX% increase in their number of lambs from 2016 to 2021 given the need to improve prolificacy for the producers. Crossbred group has a 50% increase in its number of lambs from 2014 to 2021 (Figure 1B) that could be explained by commercial producers being interested in recording data to follow their performance, do benchmarking and using breeding values for in-flock replacement. Many Crossbred lambs are hybrid or F1 lambs or produced by hybrid ewes as DP/RV for use in commercial flocks as replacement ewes or to produce market lambs.

The EBV 50-day weight genetic trend has been upward over the past 10 years, predominantly for Suffolk and Hampshire which are terminal breeds (Figure 2A). Although Romanov breed is a prolific breed with a slower growth rate, an interesting increase is seen (Figure 2A). For Dorset, Rideau Arcott, and Polypay breeds the increase is slower (Figure 2A). The same upward tendency is seen for the EBV gain 50-100d genetic trend (Figure 2B). Suffolk breed is still higher than any other breed. Polypay breed still have a slower increase for the EBV gain 50-100d genetic trend, and Romanov breed have again a good upward trend even if below zero (Figure 2B). The drops in the trend for the Dorset breed in 2017 can be explained by the sell of an important Dorset flock used for RandD purpose.

A slow upward trend is seen for the EBV fat depth genetic trend in Dorset, Rideau, and Polypay breeds (Figure 3A). After an upward trend, Hampshire breed had an important drop in 2019 for EBV fat depth to reach the same EBV seen in 2012 (Figure 3A). Since 2018, Suffolk breed had an impressive increase in its EBV fat depth (Figure 3A). Romanov breed, for its part, has a low downward genetic trend for its EBV fat depth (Figure 3A).

In the past 10 years, a rapid upward genetic trend of EBV loin depth is seen for Suffolk and Hampshire breeds that follow each other closely with an EBV around 2, in 2021 (Figure 3B). Since 2017, Dorset and Polypay breeds have seen an observable increase in their EBV loin depth genetic trend (Figure 3B). For Rideau and Romanov breeds, the EBV loin depth genetic trend is slowly increasing. The genetics correlations, breed purpose, the selection indexes used within each breed and the number of ultrasound measurement within each breed can explained partly these trends for carcass traits. Polypay, Rideau Arcott and Romanov breeds have adopted more recently the ultrasound measurements and for a small proportion of the population which are shower more recent significant improvement of loin depth. These breeds are also maternal or prolific breeds. Suffolk and Hamphire breeds are terminal breeds with a higher emphasis on carcass traits in the Carcass selection index which can be seen on the genetic trend of

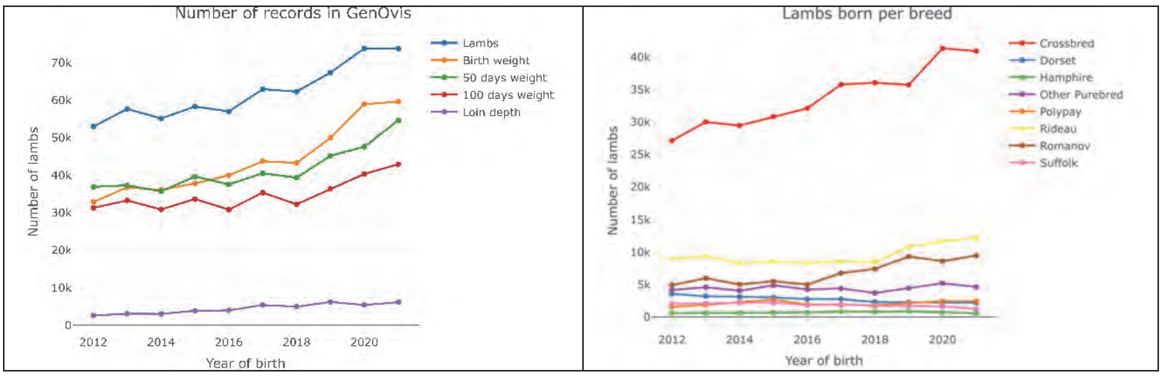


Figure 1. Records and breeds in GenOvis.

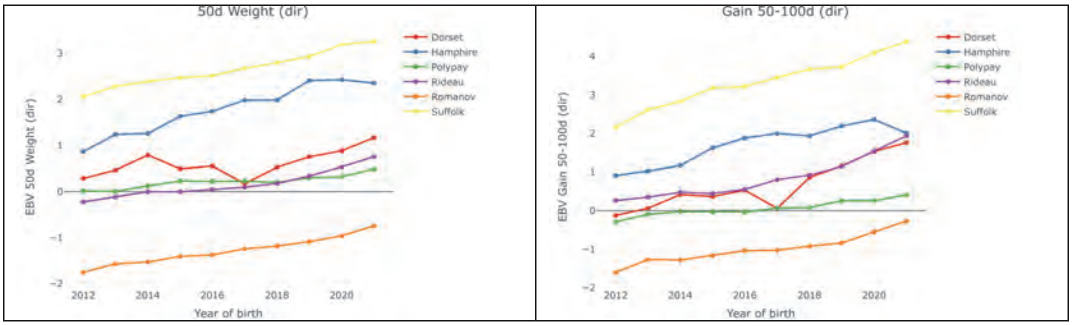


Figure 2. Genetic trends of growth traits per breed.

loin depth. Dorset is a mixture of being selected as a dual breed by some producers and having historically ultrasound measurement in their population. The fat depth is having a negative value in the selection indexes but is also unfavourably correlated genetically with loin depth and growth traits. The more recent increase of fat depth in the Suffolk breeds underline the relevance of taking ultrasound measurement and using the Carcass index.

The genetic trends of lamb survival are showing no increase for the Romanov and Dorset breeds and a slow increase for the other breeds. The direct EBV of Lamb survival is having a higher relative weight in the carcass index than the maternal and the higher prolificacy. However, some Suffolk and Rideau Arcott breeders seem to be more concerned about this trait and adding some value to it.

The Suffolk and Hamphire breeds are showing no improvement of the maternal 50 days weight. This trait is not included in the Carcass index but some cautious should be taken in the Hamphire breed in the coming years considering the decrease in 2021. The genetic trends are positive for the Polypay, Dorset, Rideau Arcott and Romanov and in line with the relative weight of this traits in the maternal and higher prolificacy indexes.

No specific trends are observable for Number of lambs born except a very slow improvement in the Dorset in more recent year. Again, it is consistent with the low heritability of the traits and the higher emphasis of the trait in the higher prolificacy index for the Dorset breed. A potential explanation for this newly trend in Dorset can be benefit from additional data coming from commercial flocks using crossbred ewes as Dorset/Romanov having many litters record for known Dorset sires. The genetic

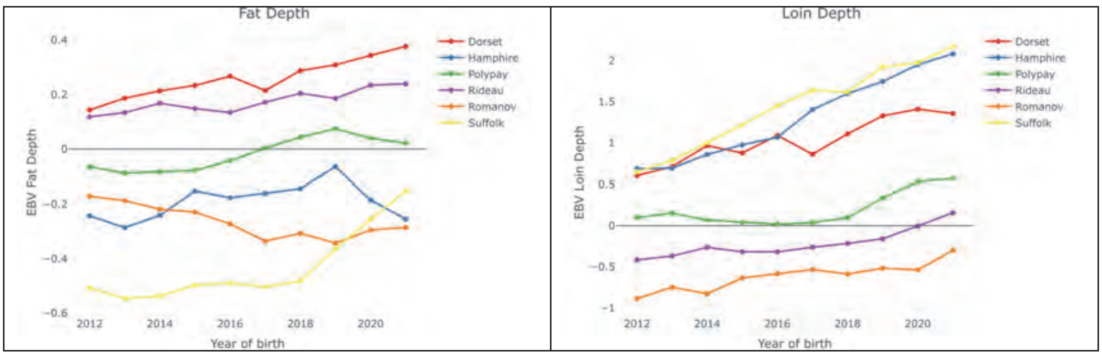


Figure 3. Genetic trends of carcass traits per breed.

trends of Total weight at weaning seem to increase more constantly in Romanov and Rideau Arcott breeds which are using the maternal index as selection index. However, the relative weight of this trait in the maternal and higher prolificacy indexes as well as the low heritability may explain the low trends and some inconsistencies.

In general, the average inbreeding levels of lambs born from 2012 to 2021 are showing slow increases. The change in inbreeding levels varied from negative in Polypay (-0.2%) to the largest positive increase in Dorset (+1.1%). For most of the breeds, inbreeding level trends can be acceptable considering the low increase per generation and the possibility to import breeding stock from other countries. The Rideau Arcott had some significant increase in their inbreeding levels until 2018 and some cautious has been taken in using mating plans to maintain it at a more constant level. This breed has been created entirely in Canada and cannot rely on breeding stock import.

Conclusion

The sheep meat sector is relatively small but important for the Canadian agriculture industry. More developments and innovation are needed and encouraging initiatives can be observed through better integration of genetic services in small ruminant and better standardization of data recording. GenOvis database is a gold mine of information that allows breeders to make genetic gains and to help producers make decisions for their flocks and improve their profitability. As the demand for lamb meat is on the rise in the past years, these precious data can be much more enhenced. Precision livestock farming (PLF) is a popular current concept that uses « big data » to make a more sustainable agriculture (Koltes *et al*., 2019). PLF is associated to different advantages as to improve precision of breeding, feeding, and animal health, productivity, and well-being (Guarino *et al*., 2017, Wolfert *et al*., 2017; Weersink *et al*., 2018). GenOvis data can be valued in technologies combining phenotypes and genomics and offers an opportunity to bring the PLF concept to the Canadian sheep industry. The association of phenotypic data to genomics allows the development of genomic breeding values and create genomic signature with genetic markers (ex.: SNP, CNV, etc.) specific to some economic traits of interest (Xie and Tammi, 2009; Uitterlinden, 2016). GenOvis offers vast opportunities for the Canadian sheep industry to address current and emerging challenges as economic viability, environmental sustainability and resiliency.

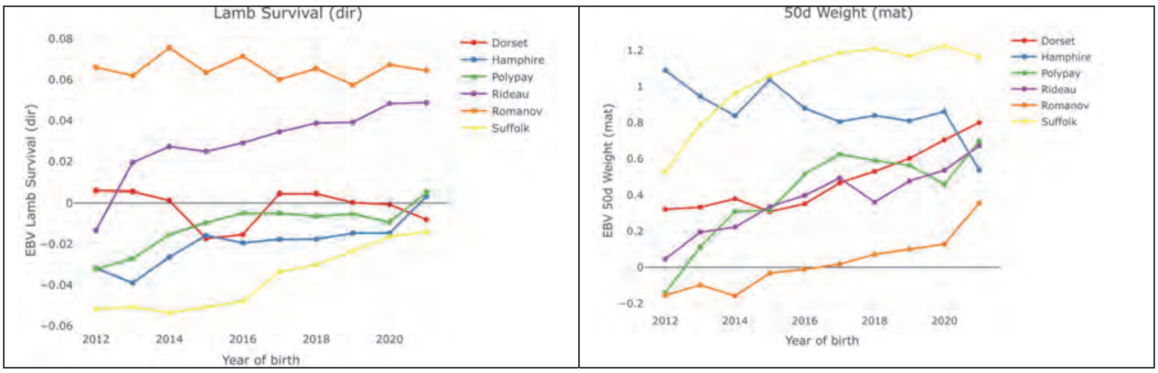


Figure 4. Genetic trends of lamb survival (dir) and maternal 50d weights per breed.

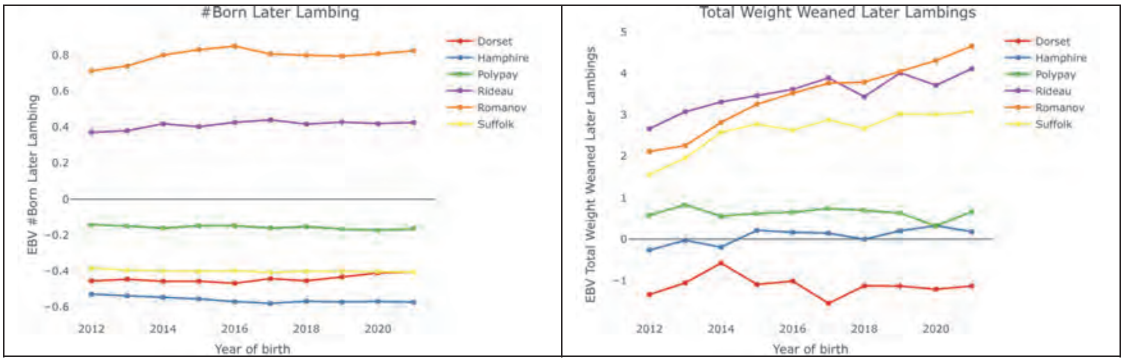


Figure 5: Genetic trends of number of lambs born and total weaning weight per breed

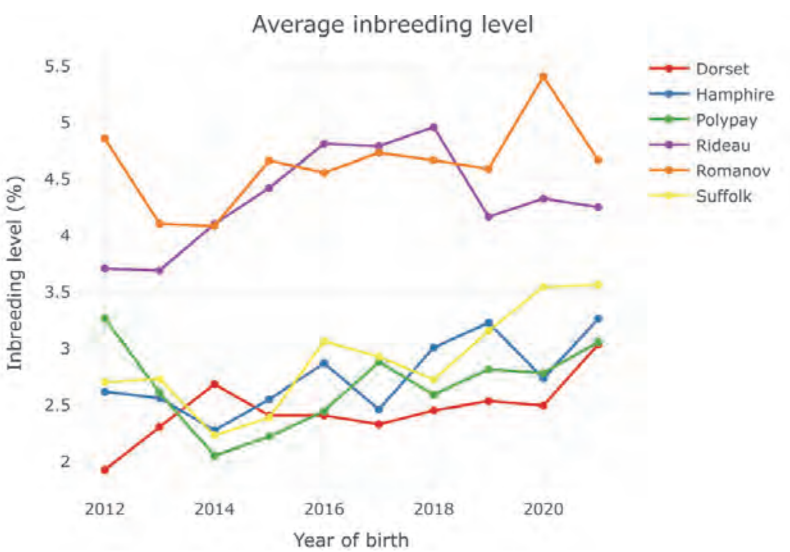


Figure 6. Average inbreeding levels (%) per breed.

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