Inbreeding and its Effect on Performance Traits in Austrian Meat Sheep

Lina MAXIMINI (✉)
Alexander MANRIQUE-GOMEZ
Birgit FUERST-WALTL

Summary

The aim of this study was to evaluate the level of inbreeding of meat performance tested herd book sheep in Austria and to evaluate the effect of individual inbreeding on growth and CT (computer tomography) scan carcass traits. Performance data (13,614 records, five breeds: Merinoland, Suffolk, Texel, German Blackheaded Meat sheep, Jura) were collected in the years 2000-2010. The traits analysed were live weight and average daily gain, as well as traits of body frame, back fat and eye muscle area, all measured on live animals with CT. Inbreeding coefficients (F) were calculated with the software PEDIG. F was nested within breed and tested in a mixed model using ASReml. Levels of inbreeding were low with Ø F of 1.5-3.1%. Only few traits were significantly affected by inbreeding. Both positive and negative effects were found. The effects were small, most often nonlinear and vary across breeds. Inbreeding and its effects on performance traits do not seem to be an issue in Austrian meat sheep populations at the moment. However, monitoring and further analyses are recommended.

Key words

carcass traits, growth traits, CT scanning, across breed analysis, inbreeding depression

University of Natural Resources and Life Sciences, Department of Sustainable Agricultural Systems, Division of Livestock Science, Gregor-Mendel-Str. 33, A-1180 Vienna, Austria
✉ e-mail: lina.maximini@boku.ac.at

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Aim

Performance testing for growth and carcass traits for herd book sheep of breeds with a focus on meat production has been obligatory in Austria since 2003. Two methods, ultrasound and computer tomography (CT) scanning, are currently used for meat performance testing. Approximately 1,200 sheep are scanned for muscle and back fat area with CT per year in Upper Austria. Due to rather small population sizes in Austria, low to moderate levels of inbreeding are expected, but inbreeding has never been analysed for Austrian meat sheep. One aim of this study was to investigate the levels of inbreeding of meat performance tested breeding sheep and to compare those among breeds. The second aim was to analyse whether and to which extent growth and CT scan carcass traits of Austrian sheep are affected by the individual degree of inbreeding.

Material and methods

Data. Performance records were taken between 2000 and 2010 as part of the obligatory performance testing for herd book animals of sheep breeds with a meat focus in Upper Austria. The majority of records (9,612) were from Merinoland sheep (ML), the rest were Suffolk (SU), Texel (TX), German Blackheaded Meat sheep (BH), and Jura (JU) with 1,747, 871, 700 and 684 records, respectively. The sheep were weighed and then immobilised in a special box and individually placed in a computer tomography scanner (CT). The CT took four pictures of each animal, two were body pictures to measure body length and width, the other two were cross sections, between 5th and 6th, and 10th and 11th thoracic vertebrae, respectively. A more detailed description of data recording can be found in Junkuszew and Ringdorfer (2005).

The traits examined in this study were: live weight (LW), average daily gain (ADG; live weight divided by age in days), length of thoracic spine (ThoSp), length of lumbar spine (LuSp), chest depth (chest), shoulder width (shoul), fat area at cross section 1 (fat5), fat area at cross section 2 (fat10) and eye muscle area at cross section 2 (EMA). Records of animals outside a weight range of 30-50 kg or an age range of 56-155 days were deleted. Table 1 details the performance data used in this study.

More records were used for live weight and average daily gain because those traits were available for animals throughout Austria whereas CT scanning is only performed in Upper Austria.

Table 2. Mean, standard deviation (SD), minimum and maximum values of complete generation equivalents (CGE) per breed

Breed	Mean CGE	SD	Min	Max
Merinoland	5.0	0.9	1	7.4
Suffolk	4.8	1.0	1	7.9
Texel	4.7	0.8	3	6.9
Blackhead	4.9	1.1	1	7.1
Jura	4.9	1.0	2	7.3

Pedigree Analysis. Pedigree information was extracted from the SCHAZI database, operated by the Austrian Sheep and Goat Association (ÖBSZ). Only records where at least dam and sire information were available got analyzed. The 13,614 animals with records come from 251 different flocks and descended from 6,086 dams and 904 sires. The total number of animals in the pedigree was 23,709. The algorithm of Meuwissen and Lou (1992) was applied to calculate inbreeding coefficients (F) for each sheep using the PEDIG software (Boichard 2002). In PEDIG the source code was modified to take 15 generations of ancestors into account. To evaluate the completeness of the pedigree information complete generation equivalents (CGE) were calculated for each animal in the analysis using the computer program *ngen* of the PEDIG software package (Boichard, 2002). Table 2 describes mean CGEs for each of the five breeds as well as standard deviations, minimum and maximum values. Similar in all breeds, on average five complete ancestor generations were available for the animals with performance records.

Statistical Analysis. All analyses were performed across breeds using an animal model in ASReml (Gilmour et al., 2009). To account for different population history and genetic basis of the breeds, F was nested within breed. For covariance analysis it was incorporated as linear and quadratic continuous effect in a mixed model. Other effects in the models included the fixed effects of contemporary group (defined using herd, year and season of birth - hys), year and month of testing (ym), sex, birth type and breed, as well as the covariates live weight (lw) and age of the animal, and dam age. Dam age was fitted as linear and as quadratic term. Quadratic terms were removed where they did not significantly improve the model. Animal, maternal ge-

Table 1. Data summary including description of traits, number of records used, means, standard deviations (SD) minimum and maximum values

Trait	Description	No. Records	Mean	SD	Min	Max
LW (kg)	live weight	13,614	38.8	3.3	30.0	50.0
ADG (g/d)	average daily gain	13,614	375.6	61.4	228.8	745.8
ThoSp (cm)	thoracic spine length	7,520	29.6	1.0	21.5	33.9
LuSp (cm)	lumbar spine length	7,520	20.0	1.2	15.7	24.6
Chest (cm)	chest depth	7,520	16.5	0.8	13.4	26.4
Shoul (cm)	shoulder width	7,520	15.2	1.2	10.9	27.0
Fat5 (cm^2)	fat area 5 thoracic vertebra	7,520	24.5	6.1	3.7	52.4
Fat10 (cm^2)	fat area 10 thoracic vertebra	7,520	21.5	5.8	3.0	55.0
EMA (cm^2)	eye muscle area	7,520	41.7	4.8	24.2	80.2

Table 3. Description of independent variables

	Effect fitted as	Description	Levels or range
hys	fixed	contemporary group (herd*birthyear*birthseason)	2014 (1-56 anim/group, Ø 8)
ym	fixed	test year*month class	117 (4-377 anim/group, Ø 116)
sex	fixed	sex of the animal	2 (m/f)
type	fixed	birth type	3 (single, twin, triplet+)
breed	fixed	breed of the animal	5 (JU, ML, BH, SU, TX)
lw	covariate (lin)	live weight of animal in kg at test day	30-50 kg, Ø 38.8, SD 3.3
age	covariate (lin)	age of animal in days at test day	56-155 d, Ø 106, SD 15.7
dam age	covariate (lin+qua)	age of dam in years at birth of animal	1.2-10+ y, Ø 4.0, SD 1.9
F*breed	covariate (lin+qua)	inbreeding coefficient of animal (nested within breed)	0-33.4%, Ø 1.8, SD 2.9
animal	random	genetic effect of animal	13,614 animals
dam	random	genetic effect of dam	6,086 dams (1-13 anim/dam, Ø 2.2)
PE dam	random	permanent environmental effect of dam	6,086 dams

Table 4. Effects fitted in the statistical model for each trait

Trait	Fixed effects					Covariates						Random effects		
	hys	ym	sex	type	breed	lw	age	dam age	dam age^2	F*br	F^2*br	animal	dam	PE dam
LW	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
ADG	✓	✓	✓	✓				✓	✓	✓	✓	✓	✓	✓
ThoSp	✓	✓	✓			✓	✓			✓	✓	✓		
LuSp	✓	✓	✓			✓	✓			✓	✓	✓		
Chest	✓	✓	✓		✓	✓	✓			✓	✓	✓	✓	
Shoul	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓	
Fat5	✓	✓	✓	✓		✓	✓			✓	✓	✓		✓
Fat10	✓	✓	✓	✓		✓	✓			✓	✓	✓		
EMA	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓	

netic effects and maternal environmental effects (PE dam) were fitted as random effects. Table 3 details the full list of independent variables.

The model was individually fitted for each trait based on preliminary studies (Maximini et al., 2011) and extended by the linear and quadratic term of F nested in breed. Table 4 gives an overview of the effects that were fitted for each trait.

Results and discussion

Table 5 details the levels of inbreeding within each breed. About 50% of all tested sheep have been inbred to some extent. In JU sheep that percentage was the lowest (36%), while it was the highest in BH sheep (54%). In spite of rather small population sizes the level of inbreeding was low. The mean F (of all animals with F > 0) was 1.8% and only 1% of analysed animals had an F greater than 10%. This shows that mating of relatives was generally avoided. Mean F was the lowest in ML sheep (1.5%), which also had by far the biggest population of the breeds analysed (about 6,000 registered breeding stock in Austria). SU and BH had the highest mean inbreeding coefficient with 3.1 and 2.6%, respectively. Both breeds had a very small population size with less than 1,000 (SU) and even less than 500 (BH) heads. TX also had less than 500 herd book animals Austria wide. Considering

Table 5. Number of analysed animals per breed (N), percentage of inbred animals (F>0) and mean, standard deviation (SD), minimum and maximum values of inbreeding coefficients of inbred animals (F>0)

Breed	N	% F>0	Mean F	SD	Min	Max
Jura (JU)	684	36.4	1.8	2.9	0.002	15.7
Merinoland (ML)	9,612	52.5	1.5	2.6	0.002	31.3
Blackhead (BH)	700	54.4	2.6	2.6	0.008	13.4
Suffolk (SU)	1,747	48.3	3.1	4.5	0.012	33.4
Texel (TX)	871	38.6	1.9	2.4	0.006	14.7
All	13,614	50.4	1.8	2.9	0.002	33.4

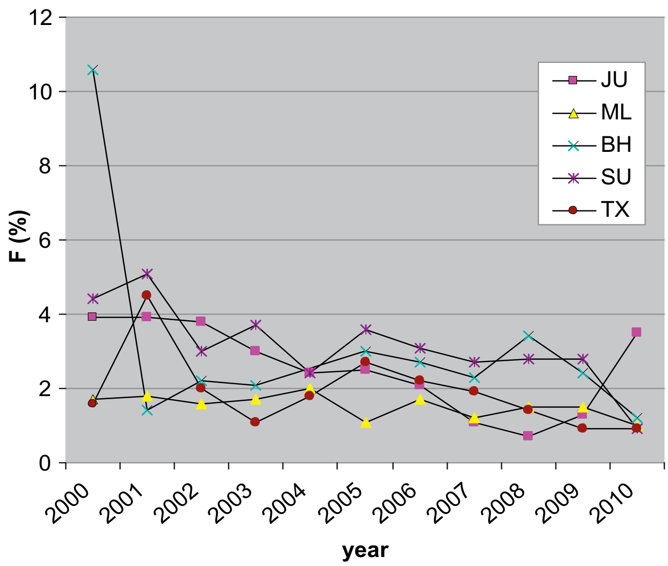

Figure 1. Development of mean inbreeding coefficient F of animals with F>0 (N=6.754)

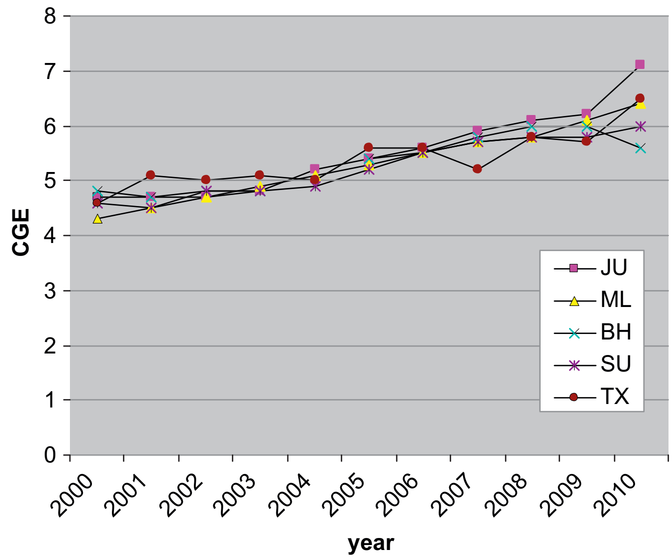

Figure 2. Development of mean complete generation equivalent (CGE) of animals with F>0 (N= 6.754)

this, average (1.9%) and maximum (14.7%) inbreeding coefficient of this breed was very low. Apparently breeders are especially conscious about avoiding inbreeding and regularly introduce genetic material from abroad.

Analysing inbreeding from pedigree data brings the risk of underestimating the level of inbreeding due to incompleteness of pedigree (Sørensen et al., 2006; Barczak et al., 2009). This also needs to be taken into account when comparing inbreeding levels of different populations. In this study depth and completeness of the pedigree information of all five breeds is comparable (Table 2, Figure 2). Figure 1 shows the mean inbreeding coefficient of all breeds over the years. No trend can be observed, the average level of inbreeding of meat performance tested sheep is neither increasing nor decreasing, but at a constant rather low level. One outlier (BH, 2000) is due to a very small number of animals. The development of mean CGE is quite similar for all breeds (Figure 2). It is slowly rising over the years, but is already at a reasonable level in the year 2000.

The mean CGE for all animals with F=0 (4.4) is lower than the one for animals with F>0 (5.5), but it is at a fair level as well.

Table 6 shows the levels of significance for the effect of inbreeding on all traits tested. Most traits were not significantly affected by F or F^2. Only ADG, ThoSp and Fat10 seem to be significantly affected by F and/or F^2. Additionally, F shows a tendency to affect EMA.

Table 6. Levels of significance for linear and quadratic effect of inbreeding coefficient F (nested within breed) on growth and carcass traits

	LW	ADG	ThoSp	LuSp	Chest	Shoul	Fat5	Fat10	EMA
F*breed	n.s.	n.s.	*	n.s.	n.s.	n.s.	n.s.	*	+
F^2*breed	n.s.	*	+	n.s.	n.s.	n.s.	n.s.	*	

* P<0.05, + P<0.1, n.s. P>0.1

Table 7. Estimates of inbreeding effects (only where significant) - Regression coefficients per 1% inbreeding (standard errors in parentheses)

Breed		ADG (g/d)	ThoSp (mm)	Fat10 (cm2)	EMA (cm2)
JU	F	-6.16 (3.17)		-1.18 (0.55)	-0.86 (0.46)
	F^2	0.62 (0.28)		0.10 (0.04)	0.07 (0.3)
SU	F		-0.69 (0.26)	0.37 (0.15)	
	F^2		0.02 (0.01)	-0.01 (0.005)	
BH	F	4.67 (2.77)			2.20 (1.02)
	F^2	-0.63 (0.30)			

As expected, direction, size and significance of the effect of inbreeding vary among breed. For better readability Table 7 lists the regression coefficients of F and F^2 only where the effect was significant. In ML and TX individual inbreeding did not affect any of the traits.

In most cases the relationship was nonlinear. JU sheep seems to be affected by inbreeding depression in low levels of F, but the effect of F on ADG, Fat10 and EMA seem to be positive with F greater than 10%. For ADG the case was reverse in BH sheep: inbreeding positively affected AGD in low levels and depressed performance in higher levels. Also EMA seems to increase linearly with F in BH (on average 2 cm^2 per 1% F).

To summarize, only few traits were significantly affected by inbreeding. Both positive and negative effects were found. The effects were small, most often nonlinear and vary strongly across breeds. This could be due to the data structure (low levels of inbreeding, skewed distribution of F, potentially pre selected animals) but it also reflects the complexity of inbreeding, which is well discussed in Barczak et al. (2009). The results are well in line with Barczak et al. (2009), who did an across breed analysis of rather low inbred Polish meat sheep and found small effects, both positive and negative, depending on line.

Norberg and Sørensen (2007) and Pedrosa et al. (2010) found significant inbreeding depression in growth traits in sheep. However, in those studies the average inbreeding level of the reference animals was considerably higher than in the present work (Ø F 5.7-10.2% and 10.7%, respectively). Another study on sheep with a comparable inbreeding level of 2.5% could not detect significant effects on growths traits (Negussie et al., 2002). None of the studies mentioned tested nonlinear inbreeding effects. Also, the authors are not aware of studies that tested the effect of inbreeding on carcass traits.

Conclusions

Despite rather small population size and reasonable quality of pedigree data the level of inbreeding was very low in all five breeds analysed. The effects found were small, mostly nonlinear, few were significant. From literature results it can be assumed that higher levels of inbreeding would have a stronger impact. Also, it is well known that production traits are not as likely to be affected by inbreeding depression as fitness traits. Therefore, further avoidance of inbreeding is recommended. A more detailed analysis of inbreeding could be useful to examine the several biological factors determining its effects (i.e. concepts like partial inbreeding, ancestral inbreeding, age of inbreeding, see Köck et al., 2009; Suwanlee et al., 2007).

References

Barczak E., Wolc A., Wójtowski J., Ślósarz P., Szwaczkowski T., (2009). Inbreeding and inbreeding depression on body weight in sheep. J Anim Feed Sci. 18: 42-50.

Boichard D. (2002). PEDIG: A fortran package for pedigree analysis suited for large populations. Proc 7th World Congr Genet Appl Livestock Prod, Montpellier, France.

Gilmour A.R., Gogel B.J., Cullis B.R., Thompson R. (2009). ASReml User Guide Release 3.0. VSN International Ltd, Hemel Hempstead, UK.

Junkuszew A., Ringdorfer F. (2005). Computer tomography and ultrasound measurement as methods for the prediction of the body composition of lambs. Small Ruminant Res 56: 121-125.

Köck A., Fürst-Waltl B., Baumung R. (2009). Effects of inbreeding on number of piglets born total, born alive and weaned in Austrian Large White and Landrace pigs. Arch Tierzucht 52: 51-64.

Maximini L., Brown D.J., Fuerst-Waltl B. (2011). Genetic parameters for live weight, ultrasound scan traits and muscling scores in Austrian meat sheep. 62nd Annual Meeting of the European Association for Animal Production (EAAP), 29.08.-02.09.2011, Stavanger, Norway (accepted).

Meuwissen T.H.E., Lou Z. (1992). Computing inbreeding coefficients in large populations. Genet Sel Evol 24: 305-313.

Negussie E., Abegaz S., Rege J.E.O. (2002). Genetic trend and effects of inbreeding on growth performance of tropical fat-tailed sheep. Proc 7th World Congr Genet Appl Livestock Prod, Montpellier, France, pp 25-35.

Norberg E., Sørensen A.C. (2007): Inbreeding trend and inbreeding depression in the Danish populations of Texel, Shropshire, and Oxford Down. J Anim Sci 85: 299-304.

Pedrosa V.B., Santana Jr. M.L., Oliveira P.S., Eler J.P., Ferraz J.B.S. (2010). Population structure and inbreeding effects on growth traits of Santa Inês sheep in Brazil. Small Ruminant Res 93: 135-139.

Sørensen A.C., Madsen P., Sørensen M.K., Berg P. (2006). Udder health shows inbreeding depression in Danish Holsteins. J Dairy Sci 89: 4077-4082.

Suwanlee S., Baumung R., Sölkner J., Curik I. (2007). Evaluation of ancestral inbreeding coefficients: Ballou's formula versus gene dropping. Conserv Genet 8 (2): 489-495.

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