SIGNIFICANCE OF A MODIFIED ROTATIONAL CROSSING TO UTILISE COMPLIMENTARY, COMBINATION AND HETEROSIS EFFECTS IN PIGS

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SUMMARY

In a long term rotational crossbreeding between German Landrace (GL) and German Pietrain (GP) pigs crossbreeding effects were estimated for carcass performances and productivity of fattening pigs as well as fertility of the sows. The meat quantity and quality were mainly determined by additive genetic effects while the fertility and productivity traits by heterosis effects. The Rotation-GP (ROT_{GP}) was significantly superior with respect to meat quantity and feed conversion, while the Rotation-GL (ROT_{GL}) had higher fertility. In order to make an effective use of both combination and heterosis effects as well as the differential merits of the two rotation groups, a modified rotation scheme has been suggested. According to this, ROT_{GL} sows should be mated to GP boars to produce the fattening pigs while the ROT_{GP} sows should be used only for replacement of the ROT_{GL} stock. A comparison of the organisation and production from conventional and the modified schemes has shown significant merits of the modified scheme in improving the overall profitability of pig production.

INTRODUCTION

Rotational crossbreeding is specially useful under unfavourable hygienic and infrastructural conditions. The information available on the exploitation of combination and heterosis effects in a rotational crossing as well as on the estimation of crossbreeding parameters in a continuous crossbreeding systems is very scanty. In a long term rotational crossbreeding programme between two complimentary breeds, German Pietrain and German Landrace crossbreeding parameters were estimated to evaluate the significance of combination and heterosis effects and possibilities of their use in a continuous crossbreeding systems.

MATERIALS AND METHODS

The analysis was carried out on records from about 400 sows and 600 fattening pigs. The traits studied in sows were litter size and litter weight in first and second parities (FU, 1994). Among the fattening pigs the traits of dressing percentages, meat quality, water binding capacity and productivity were recorded. The net lean tissue gain during the fattening period (g/day) as well as net feed intake as a proportion of the carcass weight were selected as productivity traits (Ehrhardt-Dzimbor, 1992). The analysis was conducted in two steps. At first, the breeding group means were estimated with a mixed model: $y=Xb+Z_1a+Z_2s+e$, where, y is a vector of phenotypic performance and b is a vector of the fixed effects including those due to breeding groups, years, seasons, age of the dam, type of mating and the significant interactions between them. The random effects due to the animal, sire (for the fertility traits) and error are included in vectors a, s and e, respectively. X, Z_i and Z_2 are the respective design matrices. The model has the following expectations and (co)variances:

$$E\begin{pmatrix}a\\s\\e\end{pmatrix}=\begin{pmatrix}0\\0\\0\end{pmatrix} \text{ and } Var\begin{pmatrix}a\\s\\e\end{pmatrix}=\begin{pmatrix}A\sigma_a^2 & 0 & 0\\0 & I\sigma_a^2 & 0\\0 & 0 & I\sigma_e^2\end{pmatrix}, E(y)=Xb \text{ and } Var(y)=Z_1AZ_1'\sigma_a^2+Z_2Z_2'\sigma_a^2+I\sigma_e^2,$$

where, A is relationship matrix of the individual animals, σ_a^2 additive genetic variance and σ_e^2 residual variance. The GLS-Equation for $\hat{b}$ is: $\hat{b}=(X'V^{-1}X)^{-1}X'V^{-1}y$, with expectation and (co)variances: $E(\hat{b})=b$ and $Var(\hat{b})=(X'V^{-1}X)^{-1}$, where V=Var(y). The crossbreeding parameters were estimated in a second step. The model was: $\hat{z}=Kg+e$, where, $\hat{z}$ is a vector of group means. The design matrix K was constructed according to Dickerson's model. Here, the GL was considered as the base for comparison. The crossbreeding parameters consisted of individual and maternal population difference (g_i and g_m) as well as respective heterosis effects (h_i and h_m). For the fertility traits, the sows own performance was considered and was used as individual in the individual animal model. Simultaneously additional heterosis effects (h_p) were defined for the progeny. The crossbreeding parameters ($\hat{g}$)

were estimated with Generalised Least-Squares procedure (GLS) using the following equation: $K'V_z^{-1}K\hat{g}=K'V_z^{-1}\hat{z}$ and $\hat{g}=(K'V_z^{-1}K)^{-1}K'V_z^{-1}\hat{z}$. The expectations and (co)variances for $\hat{g}$ are: $E(\hat{g})=g$ and $Var(\hat{g})=(K'V_z^{-1}K)^{-1}$.

RESULTS AND DISCUSSION

As the estimates of the crossbreeding parameters (Table 1) suggest that the traits of meat quantity and quality are mainly determined by additive genetic effects. Hence, the heterosis effects are less important then combination effects for these traits. In contrast, high heterosis effects were observed for traits of fertility and productivity. These heterosis effects for fertility and productivity as well as combination effects for meat quantity and quality can be utilised in a rotational crossing. The combination effects lead to a significant improvement in the meat quantity and quality in the rotation groups compared to the purebreds with lower performance level (Table 2). On the other hand even the rotation stage with the lowest fertility and productivity has a higher performance level than the superior most base population. There is a clear difference in the performance among the rotational groups as well, so that ROT_{GP} has a significantly higher meat quantity than ROT_{GL}. Furthermore, the ROT_{GP} shows a significant reduction in the net feed consumption than the ROT_{GL}. On the other hand the ROT_{GL} has a better fertility then ROT_{GP}. Hence, at the production stage the ROT_{GP} has a better performance than the purebreds, F_1 as well as backcrosses while at the reproduction stage the ROT_{GL} is the most favourable.

Main disadvantages of a simple rotation crossing are the heterogenity in the final product from one generation to the other and reduction in the utilisation of the position effects (SIMON, 1980; GLODEK, 1980). Both of these drawbacks can be overcome by using a modified rotation system (MERRELL et al., 1979; SVICKY and NITTER, 1990). Here, the crosses of ROT_{GP} to GL boars are mainly used to produce the sows and the crosses of ROT_{GL} to the GP boars is directed to production of fattening pigs. This differentiation in use of the rotation groups allows a better utilisation of the combination as well as crossbreeding effects. Since the fattening pigs are mainly produced from one rotation stage, the final products are relatively homogeneous. This is hardly possible in a conventional rotational crossing. This may be attained through the use of very similar base populations at the cost of the complimentary combination effects. The ROT_{GP} fattening pigs have slightly lower meat quality than ROT_{GL}. However, considering the economic aspects they have a very high slaughter performance and a better feed conversion. There were no significant differences among the two rotation groups with respects to net lean tissue gain. However, considering a higher fertility of the ROT_{GL} sows, the ROT_{GP} has significantly higher net lean tissue gain per litter at the production stage, compared to the ROT_{GL} produced from the ROT_{GP} sows.

The effect of a modified rotation crossing can be evaluated on the basis of a combination of economically important traits of reproduction and production. Hence, litter size of the parental generation and, the net lean tissue gain as well as reduction in the feed consumption of the final generation were studied in a further analysis. The results (Table 3) show a significant superiority ROT_{GP} with respect to lean tissue growth rate as well as daily and total feed consumption per litter at the production stage.

A comparative view of the effects of conventional and modified rotational crossings on the organisation and production has been given in figure 1 and the profitability of the modified scheme has been given in Table 4. Assuming a farm of 1000 sows in conventional scheme about 500 ROT_{GL} would be used for mating with GP boars and 500 ROT_{GP} with GL boars. On the other hand in a modified cross only 75 ROT_{GP} sows may be mated to GP boars to produce the ROT_{GL} for replacement (replacement rate about 50 %) while a majority (925) can be mated to GP sires to have a large number (19129) ROT_{GP} fattening pigs. Out of these only 30 pigs may be used for replacement. As such, a total of 19099 fattening pigs can be obtained from ROT_{GP} and only 1082 from ROT_{GL}, while the comparative figures from the conventional scheme are 10140 and 9480, respectively. Hence a differential use of the two rotational stages in a modified scheme makes an efficient use of position and heterosis effects to improve the overall profitability of pig production.

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Table 1: Estimates of crossbreeding parameters

Parameter	Fertility		Meant quantity and quality			Productivity	
	Litter size at birth (1st Parity)	Litter size born alive (2nd Parity)	Meat/ carcass ratio (%)	Muscle area (cm^2)	Water binding capacity (%)	Net lean tissue growth (g/d)	Net feed conversion (kg:kg)
μ	7.90	9.63	54.27	44.25	36.19	330.52	4.68
g_i	- 1.43**	- 1.71***	4.99**	7.30**	- 9.21**	- 11.79	- 0.25*
g_m	0.45	0.26	- 1.20**	- 1.29	3.52	1.13	0.02
h_i	1.25**	1.15**	- 0.90*	0.07	- 2.37	22.58**	- 0.23**
h_m	0.47*	0.33	2.84	2.71	9.21	21.64	- 0.19
h_N	0.42	0.18	-	-	-	-	-

*: p<0.05; **: P<0.01; ***: P<0.001

Table 2: Differences among the performance levels of different breeding groups in reproduction and production stages

Reproduction stage			Production stage				
Breeding groups	Litter size at birth 1st parity	Litter size at birth 2nd parity	Breeding groups	Meat/ carcass ratio (%)	Net lean tissue growth (g/d)	Net feed conversion (kg:kg)	Water binding capacity (%)
GL	7.90 b	9.63 b	GL	55.26 a	331.37 b	4.09 c	40.17 b
GP	6.92 a	8.18 a	GP	59.36 d	321.11 a	4.04 bc	33.46 a
DL_{GP}	8.32 c	9.81 b	F_1	57.73 b	345.23 c	3.83 ab	33.12 a
F_1	8.64 c	10.01 bc	R_{GL}	57.75 b	349.75 c	3.95 b	-
			R_{GP}	58.18 c	327.89 b	4.09 c	-
ROT_{GP}	8.52 c	9.68 b	ROT_{GL}	55.35 a	350.43 c	3.91 b	37.95 b
ROT_{GL}	9.15 d	10.34 c	ROT_{GP}	58.09 c	347.18 c	3.77 a	33.27 a

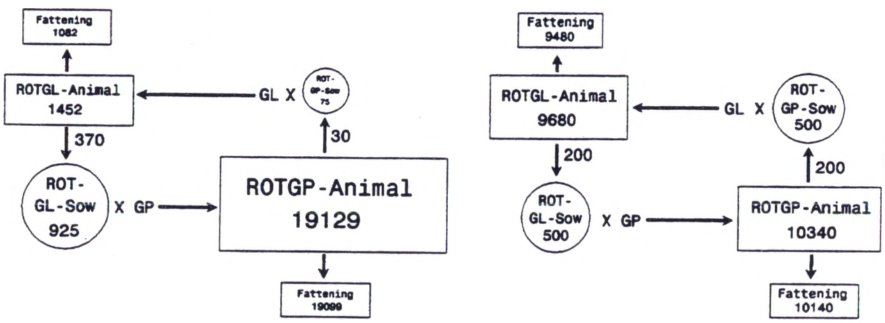
abcd: significant (p<0.05) and highly significant (p<0.01) difference

Table 3: Productivity per litter in different breeding groups

Mating stage	GLxGL	GPxGP	GPxGL	GLxF_1	GPxF_1	GLxROT_{GP}	GPxROT_{GL}
Production stage	GL	GP	F_1	R_{GL}	R_{GP}	ROT_{GL}	ROT_{GP}
Net lean tissue gain[a] (g/Litter*Day)	3191	2627	3387	3501	3282	3392	3590
Daily feed saving[b] (g/Litter)	0	131	881	490	0	611	1149
Total feed saving (kg/Litter)[c]	0	15	101	56	0	70	132

a: In 2nd parity ignoring the weaning losses; b: Net feed consumption of GL as basis;
c: Consideration of fattening period

Figure 1: Comparison of the effects of modified (left) and conventional (right) rotational crossings on the organisation and production



Assumption: • Farm size: 1000 sows; • Life time of sows: 2.5 years; • 2 litters per sow and year; • Replacement rate for ROT_{GL} sows: approx. 50%; • Effects were estimated in 2nd parity ignoring the weaning losses.

Table 4: Comparison of productivity of conventional and modified rotational crossings per farm and year

Trait	Modified	Conventional	Difference	
			Absolute	%[a]
Number of fattening pigs (Number/Farm*Year)	20181	19625	556	2.83
Lean tissue gain (kg/Farm*Year)	806145	786885	19260	2.45
Feed consumption (kg/Farm*Year)	3045271	3020043	25228	0.84
Feed conversion (kg/kg)	3.78	3.84	- 0.06	- 1.56
Feed saving (kg/Farm*Year)	48369	0	48369	1.60[b]

a): % to conventional rotational crossing; b): % to feed consumption of conventional rotational crossing