Arch. Tierz., Dummerstorf **45** (2002) 5, 465-480

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Teat number, hairiness and set of ears in a Piétrain cross: variation and effects on performance traits

Summary

A F_2-resource population has been constructed by mating five Piétrain boars to one Landrace, one Large White and twelve Landrace × Large White crossbred sows in the parent generation. From 116 animals of the F_1 and from 2706 animals of the F_2 teat number was recorded with reference to side. The average number of teats in the F_1-generation was 7.1±0.5 on the left body side and 7.0±0.6 on the right body side. The F_2-offspring had an average teat number of 6.9±0.6 on both sides. The phenotypic and genetic correlations between left and right side teat number were 0.56 and 0.96, respectively. A Bayesian heritability estimate of 0.23±0.05 was obtained for total teat number.
The density of hairiness was scored into the categories little, normal and very hairy and the set of ears into the categories prick-eared, intermediate and lop-eared. Data of 113 F_1-animals and 2770 F_2-animals were available. Bayesian analyses provided heritabilities of 0.27±0.07 for the density of hairiness and of 0.37±0.08 for the set of ears. In further analyses the traits teat number, hairiness and set of ears were taken as phenotypic markers. The effect of teat number on growth development during pregnancy and on several fatness traits of the carcass was significant. The set of ears showed a significant influence on growth traits only. Significant effects on birth weight and different carcass traits could be found for the density of hairiness. From the phenotypic effects it can be concluded that “lop ear” is linked to Landrace alleles and “little hairy” is linked to Piétrain alleles.

Key Words: Piétrain, F_2-resource population, teat number, hairiness, set of ears

Zusammenfassung

Titel der Arbeit: **Zitzenzahl, Behaarung und Ohrformen in einer Piétrainkreuzung: Variation und Leistungseffekte**
Um eine F_2-Ressourcen-Population zu erstellen, wurden in der Elterngeneration fünf Piétraineber an eine Landrassesau, eine Large White Sau und zwölf Landrasse × Large White Kreuzungssauen angepaart. Die Anzahl der Zitzen auf jeder Körperseite wurde bei 116 F_1- und 2706 F_2-Tieren festgestellt. In der F_1-Generation betrug die Zitzenzahl auf der linken Körperseite im Durchschnitt 7,1±0,5 und auf der rechten im Durchschnitt 7,1±0,5. Die F_2-Nachkommen hatten eine durchschnittliche Zitzenzahl von 6,9±0,6 auf beiden Körperseiten. Die phänotypische und die genetische Korrelation zwischen den Zitzenzahlen auf der linken und rechten Körperseite waren 0,56 und 0,96. Eine Heritabilität für die Gesamtzitzenanzahl von 0,23±0,05 wurde mit einem Bayes-Ansatz geschätzt.
Die Stärke der Behaarung wurde unterschieden in wenig, normal und stark behaart, die Haltung der Ohren in Stehohr, Mischform und Schlappohr. Daten von 113 F_1-Tieren und 2770 F_2-Tieren waren verfügbar. Nach dem Bayes-Verfahren durchgeführte Analysen lieferten Heritabiliäten von 0,27±0,07 für die Stärke der Behaarung und von 0,37±0,08 für die Ohrform. In weiteren Analysen wurden die Zitzenzahl, die Behaarung und die Ohrform als phänotypische Marker betrachtet. Der Effekt der Zitzenzahl war signifikant für die Wachstumsentwicklung während der Trächtigkeit und für zahlreiche Verfettungsmerkmale des Schlachtkörpers. Die Haltung der Ohren zeigte nur bei Wachstumsmerkmalen einen signifikanten Einfluß. Signifikante Effekte auf das Geburtsgewicht und auf verschiedene Schlachtkörpermerkmale konnten für die Stärke der Behaarung gefunden werden. Die phänotypischen Effekte zeigten, daß das „Schlappohr“ mit Allelen der Landrasse und „geringe Behaarung“ mit Allelen des Piétrainschweines in Verbindung steht.

Schlüsselwörter: Piétrain, F_2-Ressourcen-Population, Zitzenzahl, Behaarung, Ohrform

1. Introduction

Teat number

The typical number of teats in domestic breeds and their constancy varies widely. According to LÖFFLER (1991), the characteristic pair number of nipples is one in sheep, goats, and horses, two in cattle, four in cats, four to six in dogs, and six to eight in pigs. NACHTSHEIM (1925) found a higher variation of four to nine pairs of teats in pigs. He distinguished three categories of teats: a) the "normal" teats, in general 14 teats, which are symmetrically distributed in two rows, b) the supernumerary teats, frequently observed between the third and fourth pair of teats and c) the rudimentary teats. They are also a kind of supernumerary teats, which are placed between the thighs or on the scrotum of boars. For the rudimentary teats WENTWORTH (1913) found a recessive, sex-linked mode of inheritance which was however not confirmed by NACHTSHEIM (1925). The observed variation in total teat number and the occurrence of asymmetrical placement is due to the absence of teats. NACHTSHEIM (1925) found that as a rule the nipples of the second and sixth pair are incomplete or one pair or both pairs are absent. Asymmetry in placement of the teats occurs if one pair of teats is incomplete. WENTWORTH (1913) distinguished two patterns of asymmetry, which he denoted as "suppressed nipple pattern" and "triangular pattern". The first described pattern shows a lack of one teat in a pair, but all other pairs are symmetrically distributed. In the "triangular pattern" the incomplete teat pair and one neighbouring complete pair generate a triangle. SCHMIDT et al. (1936) found a proportion of 38 %, WILLHAM and WHATLEY (1963) reported a proportion of 40 % and MAYER and PIRCHNER (1995) a proportion of 34 % asymmetrical animals. A high correlation between asymmetry and inverted nipples of 0.69±0.02 was computed by MAYER and PIRCHNER (1995), but they could not prove an additive-genetic inheritance of asymmetry. This is concordant with PLUM (1938) who assumed that hereditary factors are of minor importance for asymmetry.

The absence of the second and the sixth pair of teats is common in the European wild pig (*Sus scrofa*), thus ten teats are the most frequent number (NACHTSHEIM, 1925). SCHMIDT et al. (1936) also mentioned that in the wild pig also animals with eight or twelve teats occur, but a number of ten teats is the most frequent. NACHTSHEIM (1925) explained the higher number of nipples in the Western domestic breeds by crossbreeding with the Asian *Sus vittatus* pigs. HALEY et al. (1995) reported a number of 17 nipples in purebred Meishans. An overview of the average teat number in Polish pig breeds (ORZECHOWSKA and MUCHA, 1998) clearly demonstrates the intermediate position of the Western breeds: the average teat number in Polish Large White, Polish Landrace, Belgian Landrace, Zlotniki White, Pulawy, Zlotniki Pied, Hampshire, Duroc and Piétrain was reported with 14.7, 14.7, 13.8, 14.2, 14.9, 14.0, 13.9, 13.4 and 13.9, respectively. In Table 1 further studies on the average number of teats are presented. A wide range of heritability estimates from 0.07 to 0.79 has been found (Table 1), most of them situated in an interval from 0.30 to 0.50. Numerous estimations of heritability for nipple number were carried out owing to the high economic importance of this trait. Especially the number of good teats is important for the mothering ability and reproductive performance of a sow, because a sow seldom weans more piglets than the number of teats it has. But knowledge on the number of genes responsible for the inheritance of nipple number is limited. In an early study

SCHMIDT et al. (1936) suggested an intermediate mode of inheritance possibly inclining to the parent with the smaller number of teats, but left the question open how many genes could be involved. It was found by LIU et al. (1995) that the defect of inverted teats in the Shanxi Black breed is due to a single autosomal recessive gene.

Table 1
Number of animals (N), average teat number with Standard Error (±SE) and heritability estimates (h^2) of teat number in different breeds (Anzahl Tiere (N), durchschnittliche Zizenzahl mit Standardfehler (±SE) und Heritabilitätsschätzwerte für die Zitzenzahl bei verschiedenen Rassen)

Author	N	Breed	Teat number ± SE	h^2
Allen et al., 1959	199	Landrace	13.7 ± .06	.59
	154	Poland China	12.5 ± .08	.59
Enfield and Rempel, 1961	3565	Minnesota No. 1	13.5 ± .01	.10 - .23
Skjervold, 1963	2180	Landrace	14.2 ± .02	.22 - .28
	1362	Large White	14.4 ± .02	.16 - .30
	1473	Landrace × Large White	14.3 ± .03	.29 - .36
Willham and Whatley, 1963	18704	Beltsville No.1, Hampshire, Duroc etc.	6.2 ± .01 per side	.28 - .40
Hanset and Camerlynck, 1974	4342	Piétrain	13.2 ± .02	.46
	1579	Belgian Landrace	14.0 ± .03	.34
Pumfrey et al., 1980	7513	Nebraska Gene Pool	13.1 ± .01	.32 - .44
Clayton et al., 1981	2148	Large White	14 (mode)	.07 - .48
	3202	Landrace		
Smith et al., 1986	456	Large White	14.4	.20
	1370	Landrace	14.3	
	78	Synthetics	14.1	
McKay and Rahnefeld, 1990	5351	Lacombe	14.1 ± .2	.23
	4711	Yorkshire	13.8 ± .2	.32
	4033	Lacombe × Yorkshire	13.0 ± .2	.20
	1083	Landrace	14.4 ± .3	.39
	3803	Yorkshire	13.5 ± .2	.44
	2134	Hampshire	12.7 ± .3	.45
	2130	Landrace-Yorkshire-rotation	14.0 ± .3	.43
	2504	Landrace × Yorkshire	14.0 ± .2	.27
	1464	Landrace × Hampshire	13.6 ± .3	.47
Kuciel and Chvatalova, 1992	1848	Czech improved white pig ♀	14.3	.32 - .53
	1894	Czech improved white pig ♂	14.4	.35 -. 42
Gaur and Chhabra, 1995	2802	Large White	14.1 ± .07	.15
Ligonesche et al., 1995	18632	Sire line	-	.25
	19109	Dam line	-	.25
Seo et al., 1996	13454	Duroc, Landrace, Large White	-	.07 - .09
Wang et al., 2000	9898	Landrace	-	.66
Zhang et al., 2000	9680	Chinese × European Tiameslan	15.4 ± .01	.43 - .53
Lee and Wang, 2001	-	Landrace, Yorkshire etc.	-	.54 - .79
Hirooka et al., 2002	1173	Meishan × Dutch pig lines	15.4	.53

Recently, first studies showed evidence for quantitative trait loci (QTL) on *Sus scrofa* chromosomes 1, 2, 3, 6, 7, 8, 10, 11, 12 and 16 (WADA et al., 2000; BIDANEL et al., 2000; ROHRER, 2000; CASSADY et al., 2001; HIROOKA et al., 2001). These results indicate a polygenic inheritance of the teat number.

Hairiness

The density of hairiness is determined by the number of hair follicles. WATSON and MOORE (1990) state that the total hair follicle population in the pig, as in many other mammals, is established before birth and a postnatal initiation does not occur. The inheritance of a nearly hairless phenotype, caused by a reduced number of hair follicles, is described by ROBERTS and CARROLL (1931) in Mexican Poland Chinas. A simple intermediate mode of inheritance was found, where the recessive phenotype was partially hairless, the intermediate had a reduced amount of hair and the dominant was normal hirsute. The described form of hypotrichosis (partial hairlessness) was not due to a nutritional deficiency of iodine, where the piglets are born either dead or die within few hours (ROBERTS and CARROLL, 1931). A lethal inherited type of hypotrichosis has been investigated by MEYER and DROMMER (1968). This kind of hypotrichosis is inherited by an autosomal dominant gene. Homozygous animals die within ten days and the heterozygous piglets show a decreased vitality.

Another type of hairiness, the woolly hair, was mentioned by RHOAD (1934) in Brazilian Canastrao pigs. This hair condition, shown e.g. by the Mangalitza breed, is inherited by a single autosomal dominant gene being independent from coat colour, coat pattern and sex. Some of the woolly pigs also possessed the gene for partial hairlessness, which seems to be inherited independently from the woolly hair condition. The arrangement of whorls or swirls in the hair of pigs was explained with the interaction of two dominant genes (NORDBY, 1932).

Set of ears

The set of ears in pigs ranges from prick to lop. Intermediate characters of these extremes often appear, especially in crossbred pigs. In domestic pigs the Large White is a typical breed with erect ears and the Landrace a typical lop-eared breed. An intermediate character is shown by the Piétrains with almost erect ears, which are directed forwards (PORTER and TEBBIT, 1993). The mode of inheritance of the set of ears is not well investigated so far. PORTER and TEBBIT (1993) postulated that lop is generally simple dominant and prick simple recessive, but CARR-SAUNDERS (1922) found a simple dominance of the prick form in crosses with prick-eared Berkshires and lop-eared Large Blacks.

In this paper we firstly present data on the variation of teat number, hairiness and set of ears in a F_1 and a F_2 of a Piétrain cross. Secondly, we provide Bayesian heritability estimates and analyses where the number of teats, the hairiness and the set of ears were used as a marker for direct or linked effects on several growth and carcass traits.

2. Materials and methods

Animals

A three-generation crossbreeding experiment was carried out by crossing five purebred and genetically stress resistant Piétrain boars with one Landrace, one Large White and twelve Landrace × Large White crossbred sows. A number of 14 fullsib groups, consisting of a total of 14 boars and 120 sows, produced 4258 born piglets by repeated fullsib matings.

These F_2-animals were reared and fattened on the experimental piggery Hohenschulen (ten pigs/pen) and on the research station "Alte MPA" (two pigs/pen) of the Christian-Albrechts-University of Kiel. All culled F_1-sows and F_1-boars and the finished F_2-pigs were slaughtered in a commercial abattoir.

Registering teat numbers

Teat number was recorded in both generations with reference to side. Additional and abnormal teats were not considered. The teats of the F_1-animals were counted on the live animal on the day of slaughter. Teat number of the F_2-offspring was counted during the slaughter process after blazing off the bristles on the unseparated carcass. Data from 116 F_1- and 2706 F_2-animals were registered this way.

Judging hairiness and the set of ears

The density of hairiness was subdivided into the three categories little hairy (1), normal hairy (2) and very hairy (3). According to the founder lines the set of ears was evaluated in the categories prick-eared (1, Large White type), intermediate (2, Piétrain type or other intermediate forms) and lop-eared (3, Landrace type). The judgement was always done by the same person at the end of the fattening period. A data set of 113 observations from F_1 and 2770 observations from the F_2 was recorded.

Growth and carcass measurements

A detailed description of the recorded growth and carcass traits (different weights and corresponding daily gains, the FOM protocol and performance test data, see Table 2) in the F_2-generation can be found in BORCHERS (2002).

Statistical methods

a) Estimation of heritabilities for teat number, hairiness and set of ears

A first analysis of the data using the MIXED procedure of the SAS package (SAS, 1992) with sire, dam and litter as random effects did not show any significance for the following effects: parity (first or higher), generation (F_1 or F_2) and a linear regression on pregnancy length. Sex (female or castrated male) was significant for teat number and set of ears, a linear regression on litter size for set of ears and a seasonal effect (month of slaughter for teat number and month of judging for hairiness and set of ears) for all three characters. Therefore, the following animal models were used:

teat number: $y_{ijklm} = \mu + SE_i + SN_j + li_k + an_l + e_{ijklm}$,

hairiness: $y_{ijklm} = \mu + SN_i + li_j + ma_k + an_l + e_{ijklm}$,

set of ears: $y_{ijklmn} = \mu + SE_i + SN_j + b \cdot ls + li_k + ma_l + an_m + e_{ijklmn}$,

where y_{ijklm}, y_{ijklmn} are the individual observations for the considered trait, μ is the fixed effect of the overall mean, SE_i is the fixed effect of the sex (i = female or castrated male), SN_i, SN_j are the fixed seasonal effects (i = 1...29 for teat number, i, j = 1...25 for hairiness and set of ears), b is a linear regression on the litter size (ls) in the data of the set of ears, li_j, li_k are random environmental effects of each litter (i, k, = 1...416), ma_k, ma_l are random maternal effects of each dam (k, l = 1...126), an_l, an_m, are the breeding values of each animal (l = 1...2853 for teat number, l, m =1...2883 for hairiness and set of ears), and e_{ijklm}, e_{ijklmn} are the residuals.

Bayesian estimates for variance components were computed with the help of the LMMG program (REINSCH, 1996). Posterior means are reported as estimates for the variance components. Heritabilities for the left and right side teat number and the difference of sides were also calculated with the described statistical model. According to WILLHAM and WHATLEY (1963), the phenotypic and the genetic correlation between left and right side nipple number was estimated as:

$$r_{g(l/r)} = \frac{\sigma^2_{TT} - \sigma^2_{DT}}{\sigma^2_{TT} + \sigma^2_{DT}}$$

Table 2
Effect classes and regressor variables for the analyses of the influence of teat number, set of ears and hairiness on performance (Effektstufen und Regressorvariable für die Analyse der Leistungseffekte der Zitzenzahl, der Ohrform und der Behaarung)

trait	„ear“, „hair“ teat number,	sex	parity	seasonal group	day of slaughter	sires	dams	litter effect	linear regression on	linear regression on
birth weight (kg)	3 or 4	2	2	29	-	14	120	406	litter size	pregnancy length
weaning weight (kg)	3 or 4	2	2	29	-	14	119	400	suckling length	-
starting weight (kg)	3 or 4	2	2	74	-	14	119	399	age at starting	-
end weight (kg)	3 or 4	2	2	34	-	14	114	394	age at slaughter	-
daily gain. pregnancy (g)	3 or 4	2	2	29	-	14	120	406	litter size	pregnancy length
daily gain. suckling period (g)	3 or 4	2	2	29	-	14	119	400	suckling length	-
daily gain. rearing period (g)	3 or 4	2	2	74	-	14	119	399	weaning weight	starting weight
daily gain. fattening period (g)	3 or 4	2	2	34	-	14	114	394	starting weight	end weight
live daily gain (g)	3 or 4	2	2	34	-	14	114	394	end weight	-
live-weight at slaughter (kg)	3 or 4	2	2	34	107	14	114	394	-	-
carcass weight (kg)	3 or 4	2	2	34	107	14	114	394	-	-
dressing out (%)	3 or 4	2	2	34	107	14	114	394	-	-
abdominal fat (g)	3 or 4	2	2	34	-	14	114	394	carcass weight	-
loin fat depth (mm)	3 or 4	2	2	34	-	14	114	394	carcass weight	-
loin eye depth (mm)	3 or 4	2	2	34	-	14	114	394	carcass weight	-
lean meat content (%)	3 or 4	2	2	34	-	14	114	394	carcass weight	-
reflectance (1 h p.m.)	3 or 4	2	2	34	106	14	114	394	-	-
pH_1 (loin)	3 or 4	2	2	34	107	14	114	394	-	-
pH_{24} (loin)	3 or 4	2	2	34	107	14	114	394	-	-
pH_{24} (ham)	3 or 4	2	2	34	107	14	114	394	-	-
conductivity (mS/cm. 1 h p.m.)	3 or 4	2	2	34	107	14	114	394	-	-
conductivity (mS/cm. 24 h p.m.)	3 or 4	2	2	34	107	14	114	394	-	-
meat brightness (24 h p.m.)	3 or 4	2	2	34	107	14	114	394	-	-
carcass length (cm)	3 or 4	2	2	34	-	14	114	394	carcass weight	-
fat thickness neck (cm)	3 or 4	2	2	34	-	14	114	394	carcass weight	-
fat thickness middle of back (cm)	3 or 4	2	2	34	-	14	114	394	carcass weight	-
fat thickness end of back (cm)	3 or 4	2	2	34	-	14	114	394	carcass weight	-
fat thickness at *m. latissimus dorsi* (cm)	3 or 4	2	2	34	-	14	114	394	carcass weight	-
fat thickness over the loin muscle (cm)	3 or 4	2	2	34	-	14	114	394	carcass weight	-
loin fat area (cm^2)	3 or 4	2	2	34	-	14	114	394	carcass weight	-
loin eye area (cm^2)	3 or 4	2	2	34	-	14	114	394	carcass weight	-
meat-fat-ratio	3 or 4	2	2	34	-	14	114	394	carcass weight	-
belly fatness score (1-9)	3 or 4	2	2	34	-	14	114	394	carcass weight	-
ham weight (kg)	3 or 4	2	2	34	-	14	114	394	carcass weight	-
proportion of ham in carcass (cold) (%)	3 or 4	2	2	34	-	14	114	394	carcass weight	-

where σ^2_{TT} is the phenotypic or additive-genetic variance of the total nipple number and σ^2_{DT} is the phenotypic or additive-genetic variance of the absolute (sign ignored) difference between left and right side nipples.

b) Relationship of teat number, hairiness and set of ears with growth and carcass traits
The statistical analysis was performed using the procedure MIXED of the SAS package (SAS, 1992). In a mixed model sire, dam and common litter environment were considered as random effects and sex (female or castrated male), parity (first or higher), day of slaughter and the seasonal group were further effects. The seasonal groups were defined as 'month of mating' for daily gain during the pregnancy, 'month of birth' for birth weight and daily gain during the suckling period, 'month of weaning' for weaning weight, 'the rearing group' (piglets weaned at the same month and stalled to the same flatdeck) for starting weight and daily gain during the rearing period, 'the fattening group' (pigs started at the same month and stalled to the same farm) for end weight, daily gain during the fattening period, live daily gain and all the carcass traits.
To investigate the impact on growth and carcass traits the teat number was grouped into the classes ≤ 12 teats, 13 teats, 14 teats and ≥ 15 teats, the set of ears with the classes prick-eared, intermediate and lop-eared and the hairiness with the classes little, normal and very hairy. The number of classes of each effect and the regressor variables are listed in Table 2 for each growth and carcass trait.

3. Results and discussion

Teat number
The Figure shows the distribution of total teat numbers in the F_1 (white column) and F_2 (grey column). Total teat number varied from eleven to 17 in the F_1 and from seven to 17 in the F_2.

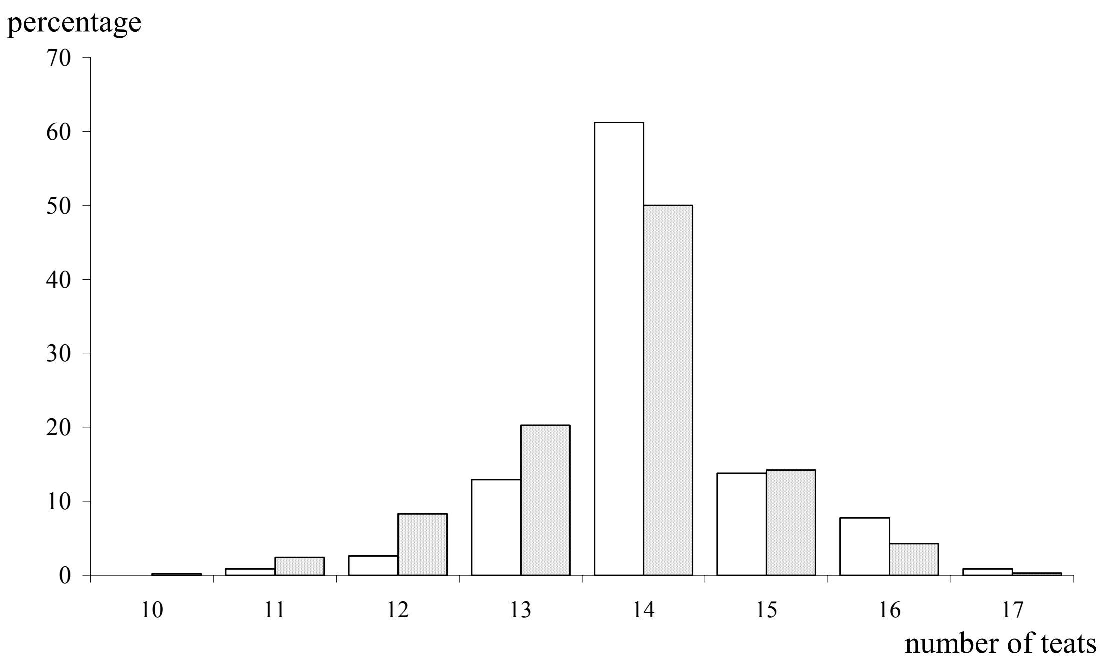

Figure: Distribution of the total teat numbers in the F_1 (white column) and F_2 (grey column) (Verteilung der Gesamtanzahl der Zitzen in der F_1 (weiße Säule) und F_2 (graue Säule))

Two animals were recorded which had only seven or nine teats. They were considered in the group of animals with ten teats. The means and standard deviations for total teat number in the F_1 were 14.1 and 0.9, for left side 7.1 teats and 0.5 and for right side 7.0 teats and 0.6. The F_2-offspring had an average total teat number of 13.8±1.0 and an average of 6.9±0.6 on both sides. Most of the F_2-animals had 14 teats like the F_1-animals, but mean and standard deviation show a tendency to a reduced teat number with a slightly higher variation. In our experiment each F_2-animal had two fullsibs as parents and therefore, if effects of recessive alleles reducing teat number exist, they would become apparent here. An average teat number of 14.1 in the F_1 and 13.8 in the F_2 in crosses involving Piétrain, Landrace and Large White pigs is concordant with the reported average teat number for these breeds in the literature (ALLEN et al., 1959; SKJERVOLD, 1963; HANSET and CAMERLYNCK, 1974; SMITH et al., 1986; ORZECHOWSKA and MUCHA, 1998). The observed phenotypic variation is in good agreement with NACHTSHEIM (1925) who stated that teat number ranges from eight to 18 and that 14 teats are the normal number. In practical experiments NACHTSHEIM (1924), SCHMIDT et al. (1936) and PLUM (1938) could also prove a high phenotypic variance in nipple number, but HANSET and CAMERLYNCK (1974) found an asymmetrical distribution in the Piétrain with a tendency to a lower teat number. However, HANSET and CAMERLYNCK (1974) report only small differences between the means of teat number of the Piétrains and the white breeds and a equal mode of 14 for all three breeds.
An unequal teat number on the left and right side of the body was observed in 29.3 % of the F_1-animals and 38.9 % of the F_2-animals. These values are in good correspondence with the values of the literature mentioned above. The maximum difference between the left and right side were two teats, contrary to WILLHAM and WHATLEY (1963) who reported a difference of four teats. In agreement with WILLHAM and WHATLEY (1963) and MAYER and PIRCHNER (1995) the heritability for the difference between left and right side teat number was near zero (Table 3).

Table 3
Variance components, c^2-effects (c^2) and heritabilities (h^2) with corresponding standard errors (SE) of the teat number traits (Varianzkomponenten, c^2-Effekte (c^2) und Heritabilitäten (h^2) mit den entsprechenden Standardfehlern für die Merkmale der Zitzenzahlen)

Trait	σ_A^2 (1)	σ_C^2 (2)	σ_E^2 (3)	σ_P^2 (4)	**c^2 ± SE**	**h^2 ± SE**
Total teat number	.227	.018	.724	.969	.02 ± .01	.23 ± .05
Left side teat number	.074	.004	.284	.362	.01 ± .01	.20 ± .05
Right side teat number	.064	.003	.280	.347	.01 ± .01	.18 ± .04
Left minus right side teats	.005	.001	.265	.271	.01 ± .01	.02 ± .01

(1) σ_A^2 = additive-genetic variance (additv-genetische Varianz), (2) σ_C^2 = variance of the common litter environment (Varianz der gemeinsamen Wurfumwelt), (3) σ_E^2 = residual variance (Restvarianz), (4) σ_P^2 = phenotypic variance (phänotypische Varianz)

The low heritability for the difference between the number of left and right side teats is explained by the very high genetic correlation of 0.96 in our data. This correlation is supported by similar values calculated by WILLHAM and WHATLEY (1963) and SEO et al. (1996). They show that the occurrence of asymmetry is random and due to environmental conditions. Estimates from the literature for the heritability of nipple number in Table 1 show a wide range from 0.07 to 0.79.

Table 4
Number of records (N), LS-Means (LSM), Standard Errors (SE) and Error Probabilities (F-Test) for the effects of teat number on growth and carcass traits (Anzahl Beobachtungen (N), LS-Mittelwerte (LSM), Standardfehler (SE) und Irrtumswahrscheinlichkeiten (F-Test) für die Effekte der Zitzenzahl auf Wachstums- und Schlachtkörpermerkmale)

Trait	N	≤ 12 teats LSM (SE)	13 teats LSM (SE)	14 teats LSM (SE)	≥ 15 teats LSM (SE)	F-Test
Growth traits						
Birth weight (kg)	2706	1.48 (.03)	1.54 (.03)	1.55 (.03)	1.57 (.03)	.0002
Weaning weight (kg)	2706	6.94 (.11)	7.06 (.10)	7.08 (.09)	7.07 (.10)	.3818
Starting weight (kg)	2706	25.4 (.38)	25.9 (.36)	26.0 (.33)	26.0 (.33)	.1319
End weight (kg)	2696	115.5 (.24)	115.6 (.20)	115.8 (.18)	115.8 (.21)	.3804
Daily gain, pregnancy (g)	2706	12.7 (.26)	13.2 (.24)	13.2 (.23)	13.5 (.24)	.0002
Daily gain, suckling period (g)	2706	241 (4)	246 (4)	247 (3)	247 (4)	.2634
Daily gain, rearing period (g)	2706	361 (3)	362 (3)	360 (3)	357 (3)	.2099
Daily gain, fattening period (g)	2696	664 (9)	664 (8)	664 (8)	662 (8)	.9905
Live daily gain (g)	2696	535 (5)	537 (5)	538 (4)	537 (5)	.8670
Slaughter traits						
Live-weight at slaughter (kg)	2689	115.8 (.31)	116.0 (.28)	116.0 (.26)	116.0 (.28)	.7492
Carcass weight (kg)	2689	89.1 (.30)	89.1 (.29)	89.2 (.27)	89.1 (.29)	.9082
Dressing out (%)	2689	76.9 (.22)	76.8 (.21)	76.8 (.20)	76.8 (.21)	.7224
Abdominal fat (g)	2672	772 (30)	758 (29)	749 (28)	742 (29)	.1846
FOM protocol						
Loin eye depth (mm)	2672	60.1 (.87)	59.2 (.85)	59.6 (.83)	59.7 (.85)	.0730
Loin fat depth (mm)	2672	19.4 (.62)	19.4 (.60)	19.3 (.59)	18.8 (.60)	.0615
Lean meat content (%)	2687	53.7 (.58)	53.5 (.57)	53.7 (.56)	54.0 (.57)	.1912
Reflectance (1 h p.m.)	2628	22.0 (.40)	22.3 (.37)	22.4 (.36)	22.3 (.38)	.2981
Performance test data						
a) Meat quality						
pH_1 (loin)	2689	6.41 (.02)	6.41 (.02)	6.42 (.02)	6.40 (.02)	.2166
pH_{24} (loin)	2662	5.44 (.01)	5.44 (.01)	5.45 (.01)	5.45 (.01)	.0936
pH_{24} (ham)	2662	5.57 (.02)	5.58 (.02)	5.59 (.01)	5.59 (.02)	.3288
Conductivity (mS/cm, 1 h p.m.)	2687	4.31 (.09)	4.39 (.08)	4.32 (.08)	4.40 (.08)	.0983
Conductivity (mS/cm, 24 h p.m.)	2663	4.49 (.23)	4.60 (.23)	4.61 (.22)	4.54 (.23)	.5705
Meat brightness (24 h p.m.)	2664	66.9 (.74)	66.5 (.71)	66.8 (.69)	66.8 (.71)	.5809
b) Carcass composition						
Carcass length (cm)	2660	99.8 (.50)	100.2 (.49)	100.4 (.49)	100.8 (.49)	<.0001
Fat thickness neck (cm)	2665	4.14 (.06)	4.06 (.05)	4.03 (.05)	4.01 (.05)	.0006
Fat thickness middle of back (cm)	2665	2.43 (.06)	2.40 (.05)	2.42 (.05)	2.36 (.05)	.0179
Fat thickness end of back (cm)	2662	1.87 (.06)	1.85 (.06)	1.87 (.06)	1.83 (.06)	.2084
Fat thickness at *m. latissimus dorsi* (cm)	2665	3.25 (.09)	3.17 (.08)	3.17 (.08)	3.09 (.08)	.0029
Fat thickness over the loin muscle (cm)	2664	1.34 (.06)	1.33 (.06)	1.31 (.06)	1.29 (.06)	.1819
Loin fat area (cm^2)	2664	19.3 (.60)	19.0 (.59)	18.9 (.57)	18.8 (.59)	.3649
Loin eye area (cm^2)	2664	49.1 (.98)	49.2 (.95)	49.3 (.94)	49.2 (.96)	.9424
Meat-fat-ratio	2664	.40 (.02)	.40 (.02)	.39 (.02)	.39 (.02)	.3846
Belly fatness score (1-9)	2665	3.1 (.30)	3.3 (.29)	3.4 (.28)	3.6 (.29)	.0101
Ham weight (kg)	2658	14.1 (.06)	14.0 (.06)	14.1 (.06)	14.1 (.06)	.9809
Proportion of ham in carcass (cold) (%)	2658	32.1 (.15)	32.1 (.14)	32.1 (.13)	32.2 (.14)	.9910

Most of the estimates are between 0.30 and 0.50 indicating that our heritability estimate of 0.23 is on the lower limit of the interval. Lower heritabilities were computed for left and right side teat number similar as in the study of SEO et al. (1996). A proportion of 2 % of the phenotypic variation of total teat number was due to common litter effects (c^2) while this proportion was near zero for left and right side teat number. HANSET and CAMERLYNCK (1974) found a proportion of roughly 3.5 % for the common litter environment and ZHANG et al. (2000) proportions

between 2 % and 5 %.
An estimation of a random maternal effect variance was not different from zero. The phenotypic correlation between left and right side teat numbers estimated from raw data was 0.56. Similar values between 0.50 and 0.60 were found by NACHTSHEIM (1925) and SEO et al. (1996), somewhat lower correlations of 0.39 to 0.42 by SKJERVOLD (1963). The phenotypic correlation can be interpreted as a repeatability for teat number counts per side and therefore as an upper limit of the heritability (SKJERVOLD, 1963).
An analysis where the teat number was treated as marker for direct or linked effects revealed a significant influence of teat number on birth weight and daily gain during pregnancy, on carcass length, on the fat thickness at neck, at the middle of the back and at the *musculus latissimus dorsi* and on the belly fatness score (Table 4). Animals with an increased number of nipples had a higher birth weight and a longer carcass with a reduced fatness. In accordance with these results, LIGONESCHE et al. (1995) reported favourable genetic correlations of total teat number and the number of patent teats with growth and carcass traits.
WADA et al. (2000) detected QTL effects for carcass length and birth weight on chromosome 1. Near the same region CASSADY et al. (2001) found a QTL affecting the number of nipples. This is in good agreement with our results, if there exists linkage between QTL for these traits or a single QTL with pleiotropic effects on all three traits. Further QTL for teat number are reported on chromosomes 2, 3, 6, 7, 8, 10, 11 and 12 (WADA et al., 2000; BIDANEL et al., 2000; ROHRER, 2000; CASSADY et al., 2001; HIROOKA et al., 2001). HIROOKA et al. (2001) suggested that imprinting plays an important role in the expression of teat number. Significant effects of teat number as a phenotypic marker could therefore be due to the confined pleiotropic effects of one or several of these and other yet undetected QTL or due to linkage.

Hairiness

The density of hairiness in the F_2-offspring varied from near hairless to very dense haired. A heritability estimate of 0.27±0.07 (Table 5) and proportions of 0.06±0.02 and of 0.02±0.01 due to common litter environment effects and to maternal effects were estimated.

Table 5
Variance components of the traits hairiness and set of ears and the corresponding c^2-effects (c^2), maternal effects (m^2), heritabilities (h^2) and standard errors (SE) (Geschätzte Varianzkomponenten für die Merkmale Behaarung und Ohrform sowie die entsprechenden Wurfumwelteffekte (c^2), maternalen Effekte (m^2), Heritabilitäten (h^2), und Standardfehler (SE))

Trait	σ^2_A (1)	σ^2_C (2)	σ^2_M (3)	σ^2_E (4)	σ^2_P (5)	**c^2 ± SE**	**m^2 ± SE**	**h^2 ± SE**
Hairiness	.062	.015	.005	.144	.226	.06 ± .02	.02 ± .01	.27 ± .07
Set of ears	.099	.009	.007	.148	.263	.03 ± .01	.03 ± .02	.37 ± .08

(1) σ^2_A = additive-genetic variance (additiv-genetische Varianz), (2) σ^2_C = variance of the common litter environment (Varianz der gemeinsamen Wurfumwelt), (3) σ^2_M = variance due to maternal effects (durch maternale Effekte verursachte Varianz), (4) σ^2_E = residual variance (Restvarianz), (5) σ^2_P = phenotypic variance (phänotypische Varianz)

A reduced number of hair follicles was probably inherited by the Piétrain boars

because of the observation of nearly hairless animals in purebred Piétrains occasionally made by the author.
From Table 6 can be drawn that the gene or genes for a reduced density of hairiness are present in the progeny of the Piétrain boars “Florian”, “Vehemenz” and “Vento”. In contrast to these pigs the offspring of the boars “Felix” and “Mike” were very densely haired.

Table 6
Results of the judgement for hairiness and set of ears; the percental proportion and number of animals (in brackets) listed by Piétrain boar and category (Beurteilungsergebnisse für Behaarung und Ohrform; prozentualer Anteil und Anzahl der Tiere aufgelistet nach Piétraineber und Kategorie)

Piétrain boar		Hairiness						Set of ears					
		1		2		3		1		2		3	
		%	(N)	%	(N)	%	(N)	%	(N)	%	(N)	%	(N)
Felix	F_1	-		95.0	(19)	5.0	(1)	5.0	(1)	80.0	(16)	15.0	(3)
	F_2	0.2	(1)	61.6	(307)	38.2	(190)	9.6	(48)	75.9	(378)	14.5	(72)
Florian	F_1	-		100.0	(27)	-		11.1	(3)	85.2	(23)	3.7	(1)
	F_2	12.7	(96)	79.9	(603)	7.4	(56)	14.0	(106)	75.9	(573)	10.1	(76)
Mike	F_1	-		85.0	(17)	18.0	(3)	-		75.0	(15)	25.0	(5)
	F_2	-		44.5	(190)	55.5	(237)	2.3	(10)	59.0	(252)	38.7	(165)
Vento	F_1	-		100.0	(26)	-		-		96.2	(25)	3.8	(1)
	F_2	7.8	(48)	77.9	(480)	14.3	(88)	12.5	(77)	79.2	(488)	8.3	(51)
Vehemenz	F_1	-		100.0	(20)	-		-		30.0	(6)	70.0	(14)
	F_2	12.0	(57)	76.2	(361)	11.8	(56)	5.5	(26)	63.1	(299)	31.4	(149)
Pigs per generation	F_1	-		96.5	(109)	3.5	(4)	3.5	(4)	75.2	(85)	21.2	(24)
	F_2	7.3	(202)	70.1	(1941)	22.6	(627)	9.6	(267)	71.9	(1990)	18.5	(513)
All pigs		7.0	(202)	71.1	(2050)	21.9	(631)	9.4	(271)	72.0	(2075)	18.6	(537)

In the F_1 no little haired animals were observed. This is possibly due to recessive alleles responsible for the density of hairiness. ROBERTS and CARROLL (1931) described a simple intermediate mode of inheritance for the hairiness in Mexican Poland Chinas, where the allele for little hairiness is recessive. In our investigation the density of hairiness also seems to be inherited recessively. Whether the Piétrain boars have the same kind of hairlessness can not be concluded, but it is possible, because the Poland Chinas have the Berkshires as ancestors like the Piétrain.
Like teat number the trait hairiness was also used as a marker for direct or linked effects (Table 7). Significant effects for hairiness were obtained for birth weight, dressing out percentage, abdominal fat, loin eye depth, pH_{24} of the ham, carcass length and loin eye area. The animals scored as “little hairy” are on the one hand in some traits more similar to purebred Piétrains because they had a shorter carcass, a higher dressing out percentage, a thicker loin eye depth and a larger loin eye area. On the other hand they had a higher weight of the abdominal fat and a higher pH_{24} in the ham. In our experiment a good meat quality can be expected because all Piétrain boars were genetically stress resistant. The obtained results suggest that QTL alleles for less hairiness are linked with Piétrain specific alleles for higher muscularity and cryptic alleles for abdominal fat weight.

Table 7
Number of records (N), LS-Means (LSM), Standard Errors (SE) and Error Probabilities (F-Test) for the effects of hairiness on growth and carcass traits (Anzahl Beobachtungen (N), LS-Mittelwerte (LSM), Standardfehler (SE) und Irrtumswahrscheinlichkeiten (F-Test) für die Effekte der Behaarung auf Wachstums- und Schlachtkörpermerkmale)

Trait	N	1 little hairy	2 normal hairy	3 very hairy	F-Test
Growth traits					
Birth weight (kg)	2770	1.56 (.03)	1.55 (.03)	1.52 (.03)	.0489
Weaning weight (kg)	2770	6.97 (.12)	7.11 (.09)	7.04 (.10)	.2376
Starting weight (kg)	2770	25.3 (.43)	25.8 (.33)	26.0 (.36)	.1747
End weight (kg)	2718	115.4 (.29)	115.6 (.17)	115.7 (.21)	.4538
Daily gain, pregnancy (g)	2770	13.3 (.28)	13.3 (.22)	13.0 (.24)	.0747
Daily gain, suckling period (g)	2770	241 (5)	247 (3)	245 (4)	.2657
Daily gain, rearing period (g)	2770	363 (4)	360 (3)	358 (3)	.1778
Daily gain, fattening period (g)	2718	664 (9)	664 (8)	659 (8)	.3984
Live daily gain (g)	2718	535 (5)	538 (4)	535 (5)	.3139
Slaughter traits					
Live-weight at slaughter (kg)	2682	115.7 (.33)	116.0 (.26)	116.0 (.28)	.3646
Carcass weight (kg)	2682	89.1 (.33)	89.1 (.27)	88.9 (.29)	.2939
Dressing out (%)	2682	77.0 (.23)	76.9 (.20)	76.7 (.21)	.0285
Abdominal fat (g)	2650	776 (31)	746 (28)	764 (29)	.0322
FOM protocol					
Loin eye depth (mm)	2650	60.4 (.90)	59.8 (.83)	59.0 (.85)	.0058
Loin fat depth (mm)	2650	19.3 (.63)	19.1 (.58)	19.4 (.60)	.1630
Lean meat content (%)	2680	53.9 (.60)	53.8 (.55)	53.4 (.57)	.0709
Reflectance (1 h p.m.)	2608	22.5 (.42)	22.3 (.35)	22.3 (.37)	.7979
Performance test data					
a) Meat quality					
pH_1 (loin)	2681	6.42 (.02)	6.42 (.02)	6.41 (.02)	.7661
pH_{24} (loin)	2649	5.46 (.01)	5.45 (.01)	5.45 (.01)	.2004
pH_{24} (ham)	2649	5.61 (.02)	5.59 (.01)	5.57 (.02)	.0054
Conductivity (mS/cm, 1 h p.m.)	2679	4.31 (.10)	4.34 (.08)	4.35 (.09)	.8069
Conductivity (mS/cm, 24 h p.m.)	2650	4.46 (.24)	4.55 (.22)	4.61 (.23)	.5874
Meat brightness (24 h p.m.)	2651	67.4 (.77)	66.8 (.68)	66.7 (.71)	.2523
b) Carcass composition					
Carcass length (cm)	2646	99.9 (.50)	100.3 (.47)	100.6 (.48)	.0031
Fat thickness neck (cm)	2652	4.03 (.06)	4.03 (.05)	4.07 (.05)	.3782
Fat thickness middle of back (cm)	2652	2.44 (.06)	2.40 (.05)	2.40 (.05)	.2997
Fat thickness end of back (cm)	2649	1.92 (.07)	1.85 (.06)	1.86 (.06)	.1160
Fat thickness at *m. latissimus dorsi* (cm)	2652	3.24 (.09)	3.15 (.08)	3.17 (.09)	.0873
Fat thickness over the loin muscle (cm)	2651	1.32 (.06)	1.31 (.06)	1.33 (.06)	.4546
Loin fat area (cm^2)	2651	19.3 (.62)	18.9 (.56)	19.1 (.58)	.1967
Loin eye area (cm^2)	2651	50.0 (1.01)	49.4 (.94)	48.6 (.96)	.0028
Meat-fat-ratio	2651	.40 (.02)	.39 (.02)	.40 (.02)	.1112
Belly fatness score (1-9)	2652	3.3 (.32)	3.4 (.28)	3.3 (.29)	.5053
Ham weight (kg)	2646	14.0 (.07)	14.1 (.06)	14.1 (.06)	.2517
Proportion of ham in carcass (cold) (%)	2646	32.0 (.16)	32.1 (.13)	32.2 (.14)	.2002

Set of ears

Several distinct forms of ears from prick, as shown by Large White pigs, to lop, as shown by Landrace pigs, were observed in the F_1- and F_2-offspring. Between these two extremes many intermediate types were observed, e.g. forward directed ears as in the Piétrain breed or lateral directed ears. The aim of our judgement was to separate the prick-eared pigs (categories 1 and 2) from the lop-eared pigs. Assuming that lop is simple dominant most of the F_1-animals had to be lop-eared, because 13 of the P-dams were Landrace or Landrace × Large White pigs. But in the F_1 only four pigs had lop

ears and in the F_2 the proportion of lop-eared pigs was 18.6 % (Table 6).
It can be concluded from these scoring results, in accordance to CARR-SAUNDERS (1922) and in contrast to PORTER and TEBBIT (1993), that prick is dominant and lop is recessive.

Table 8
Number of records (N), LS-Means (LSM), Standard Errors (SE) and Error Probabilities (F-Test) for the effects of the set of ears on growth and carcass traits (Anzahl Beobachtungen (N), LS-Mittelwerte (LSM), Standardfehler (SE) und Irrtumswahrscheinlichkeiten (F-Test) für die Effekte der Ohrform auf Wachstums- und Schlachtkörpermerkmale)

Trait	N	1 prick-eared	2 intermediate	3 lop-eared	F-Test
Growth traits					
Birth weight (kg)	2770	1.51 (.03)	1.53 (.03)	1.62 (.03)	<.0001
Weaning weight (kg)	2770	7.05 (.12)	7.03 (.09)	7.28 (.10)	.0007
Starting weight (kg)	2770	25.7 (.41)	25.7 (.35)	26.3 (.38)	.0154
End weight (kg)	2718	115.0 (.26)	115.7 (.18)	115.8 (.22)	.0124
Daily gain, pregnancy (g)	2770	12.9 (.25)	13.1 (.22)	13.8 (.24)	<.0001
Daily gain, suckling period (g)	2770	245 (4)	245 (3)	251 (4)	.0537
Daily gain, rearing period (g)	2770	359 (4)	359 (3)	362 (3)	.2894
Daily gain, fattening period (g)	2718	668 (9)	660 (8)	671 (8)	.0129
Live daily gain (g)	2718	538 (5)	534 (4)	545 (5)	.0003
Slaughter traits					
Live-weight at slaughter (kg)	2682	115.5 (.32)	116.0 (.26)	116.1 (.28)	.0451
Carcass weight (kg)	2682	88.9 (.31)	89.1 (.27)	89.1 (.29)	.6030
Dressing out (%)	2682	77.0 (.22)	76.8 (.20)	76.8 (.21)	.2076
Abdominal fat (g)	2650	759 (30)	750 (28)	753 (29)	.7828
FOM protocol					
Loin eye depth (mm)	2650	59.9 (.87)	59.6 (.82)	59.7 (.84)	.6541
Loin fat depth (mm)	2650	19.2 (.61)	19.2 (.58)	19.3 (.59)	.8147
Lean meat content (%)	2680	53.8 (.58)	53.8 (.55)	53.7 (.56)	.8781
Reflectance (1 h p.m.)	2608	22.8 (.41)	22.3 (.35)	22.3 (.37)	.0922
Performance test data					
a) Meat quality					
pH_1 (loin)	2681	6.39 (.02)	6.42 (.02)	6.42 (.02)	.1130
pH_{24} (loin)	2649	5.45 (.01)	5.45 (.01)	5.45 (.01)	.7733
pH_{24} (ham)	2649	5.59 (.02)	5.58 (.02)	5.58 (.02)	.6553
Conductivity (mS/cm, 1 h p.m.)	2679	4.30 (.09)	4.32 (.08)	4.38 (.09)	.3011
Conductivity (mS/cm, 24 h p.m.)	2650	4.72 (.24)	4.55 (.22)	4.52 (.23)	.2371
Meat brightness (24 h p.m.)	2651	67.0 (.75)	66.9 (.69)	66.6 (.71)	.5564
b) Carcass composition					
Carcass length (cm)	2646	100.1 (.49)	100.4 (.47)	100.3 (.48)	.0948
Fat thickness neck (cm)	2652	4.07 (.06)	4.04 (.05)	4.04 (.05)	.4823
Fat thickness middle of back (cm)	2652	2.43 (.06)	2.39 (.05)	2.41 (.05)	.2706
Fat thickness end of back (cm)	2649	1.84 (.06)	1.85 (.06)	1.88 (.06)	.4610
Fat thickness at *m. latissimus dorsi* (cm)	2652	3.18 (.09)	3.16 (.08)	3.15 (.09)	.7899
Fat thickness over the loin muscle (cm)	2651	1.32 (.06)	1.31 (.05)	1.32 (.06)	.9980
Loin fat area (cm^2)	2651	19.0 (.60)	18.9 (.56)	19.1 (.58)	.6682
Loin eye area (cm^2)	2651	49.8 (.98)	49.2 (.93)	49.2 (.95)	.2243
Meat-fat-ratio	2651	.39 (.02)	.39 (.02)	.40 (.02)	.6900
Belly fatness score (1-9)	2652	3.2 (.31)	3.3 (.28)	3.5 (.30)	.2918
Ham weight (kg)	2646	14.1 (.07)	14.0 (.06)	14.1 (.06)	.9670
Proportion of ham in carcass (cold) (%)	2646	32.1 (.15)	32.1 (.13)	32.2 (.14)	.9765

From the analyses where the set of ears was considered as a marker (Table 8) a significant effect was obtained only for growth traits. Lop-eared pigs had a higher weight at birth, at weaning, at the beginning of the fattening period and its end. Also higher corresponding daily gains were observed. From performance test station results

it is known that the Landrace pigs have a superior growth performance compared to Piétrains (KETELS, 1998). A locus for lop ears may therefore be associated with Landrace specific QTL alleles for growth.
In mice many mutants with ear defects are known. The defects occur as "droopy" ears reduced ears, hairy ears, low set ears and small ears (BUNDY, 1950; CURRY, 1959; LANE and LIU, 1984; THEILER and SWEET, 1986; RASBERRY and CATTANACH, 1988; LYON et al., 1996). "Droopy" ear is mapped to chromosome 3, the dominant reduced ear to chromosome 4 and the short ear to chromosome 9 of the mouse genome (URL: http://www.ihr.mrc.ac.uk/hereditary/MutantsTable.shtml). These results maybe useful for the detection of QTL responsible for set of ears in pigs. The knowledge of QTL for the set of ears can help to breed pigs with desirable ear forms, because pigs with large lop ears are often frightened when they have to move.

4. Conclusions

From our results and the current knowledge on the inheritance of these traits it can be concluded that teat number is less suitable as a phenotypic marker, because this trait seems to be polygenic inherited and there is virtually no difference in teat number between the founder lines of our experiment. In contrast to teat number both the significant effects on performance traits and the presumably monogenic inheritance suggest that "lop-ear" could serve as a marker for Landrace alleles and "little hairy" for Piétrain alleles in similar crossbreeding experiments.

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Received: 2002-06-04

Accepted: 2002-08-01

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