EVALUATION OF CARCASS QUALITY OF LIVE PIGS AT WEIGHTS OF 60 KG AND 90 KG

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Abstract. The possibility of predicting the carcass quality from live pigs at weights of c. 60 kg and c. 90 kg was investigated on progeny testing pigs (n = 236) of Landrace and Yorkshire breeds.

In both weight classes the thickness of the fat was measured with an ultrasonic instrument on the back, hams and shoulders, as well as the depth of the *m. long. dorsi*. Exterior measurements and points evalutations were also made. The pigs were slaughtered at a weight of 90 kg, after which a conventional carcass evaluation was made.

The least squares method (HARVEY 1966) was used to analyse the results in order to establish the effect of the live weight, the group, breed and sex. After calculating an initial correlation matric (179 × 179), 20 characteristics obtained from the carcass evaluation were taken as functions, and 30 characteristics of both the live weights taken as optional explanatory variables, for further processing by stepwise multiple regression analysis.

The *back fat* can be estimated from measurements at live weights of 60 kg ($R^2 = 0.53$) and 90 kg ($R^2 = 0.75$). The fat estimations obtained from the two weight classes showed similarities. The average back fat measured at a live weight of 90 kg correlated significantly with the average back fat measured from the carcass ($r = 0.82^{***}$, $r^2 = 0.67$), and the side fat at a live weight of 90 kg with the *s.o.l.* from the carcass ($r = 0.79^{***}$, $r^2 = 0.62$). Prediction of the area of the m. long. dorsi was poor in both the weights ($R^2 = 0.27$—0.29).

In the 1950s several research workers (BRATZLER & MARGETUM 1953, HARING & SIEBURG 1957, PEDERSEN 1961) found that the points evaluation and exterior measurements of live pigs did not correlate sufficiently with carcass quality. Evaluation was hindered particularly by the varying thickness of the fat layer. Admittedly, the fat layer could be satisfactorily measured with metal probes or by means of extracted samples (HAZEL & KLINE 1952, ERWIN *et al.* 1956, HOLLAND & HAZEL 1958, URBAN & HAZEL 1960), but, for humanitarian reasons, these methods did not gain favour, especially in Europe. Among other methods employed for evaluation of the slaughter quality of live pigs, mention should be made of X-ray observations, ultrasonic measurements, the measurement of natural radioactivity, and the isotope dilution method.

Utilization of the method of ultrasonic technique for the evaluation of live pigs began towards the end of the 1950's (e.g. CLAUS 1957, KLIESCH *et al.* 1957) and became perhaps the most important method in the 1960's. In breeding, ultrasonic measurements have been limited chielfly to linear measurements of the back fat, these being simple and quick

to perform. The interrelationship between the results of measurements of this type and the results obtained on the carcass is generally good or satisfactory. In testing station conditions, reasonable correlations have also been obtained with the measurement of muscle layers and sections, but performance of such measurements has been found to be cumbersome and requires not only an ultrasonic instrument but also equipment developed for the measurement of the sections.

If we examine the heritability coefficients (h^2) of fat and muscle measurements obtained with ultrasonic instrument, we find that sufficiently high heritability coefficients have been obtained by means of linear measurements of fat, while the heritability coefficients for linear and areal measurements of muscle have been too low for practical breeding work (LAUPRECHT *et al.* 1967, WENIGER *et al.* 1967, LANGLET *et al.* 1968, RITTLER 1968, GERLACH 1970). The relatively high h^2 values for muscle measurements obtained by HORST (1969) are an exception worth mentioning. The h^2 coefficients for the area of musculus longissimus dorsi on the carcass have generally been higher than the coefficients obtained with ultrasonic intrument, and the reason for the poorness of the result must consequently be sought in the poor applicability in practice of the method of muscle measurement. HORST (1970) accordingly proposes that until the measuring of the *m. long. dorsi* becomes significant, as in the measurement of fat, the method of ultrasonic measurement should be applied in breeding work on two levels: measurement of fat for the selection of commercial boars and sows, and measurement of muscle for the selection of firstrate boars at testing stations. In the latter case, use should be made of equipment developed for the measurement of the area.

The premises and limitations of the present study were as follows: All the measurements made on live pigs were to be simple ones in order to be applicable in field conditions. A portable ultrasonic instrument was available, but there was no equipment for areal measurement. The aims of the study were: 1) to find the stage at which the slaughter quality can be satisfactorily evaluated (live weight categories of 60 kg and 90 kg), 2) to make a comparison between the information obtained by ultrasonic measurements and the information obtained by points evaluation and exterior measurements, and 3) to try to calculate models expressing the fattiness and meatiness of the carcass from the results of slaughter evaluation on live pigs.

Material

Measurements were made on 236 (118 ♂ + 118 ♀) progeny testing pigs at the Pig Husbandry Experiment Station at Puistola by measuring consecutive progeny testing groups in three groups (Group I = 59 pigs, II = 96, and III = 81 pigs) in 1965—66. The animals arrived at the testing station with an average weight of 17.9 kg and were slaughtered at an average weight of 90.2 kg. The feed, which consisted of maize, barley and skim-milk, was fed to groups.

The live pigs were measured and evaluated at a weight of c. 60 kg and again at a weight of c. 90 kg — one day before slaughter. A USK-4 ultrasonic instrument was used for measurement of the fat and meat layers. The sound-head was a barium titanite head of 10 mm in diameter and 2 MHz frequency. The measurements for the side fat and the muscle were taken at the level of the rear edge of the last rib. The locations at which the measurements were taken on the back, the shoulders and the hams can be seen in Fig. 1. The carcasses were evaluated one day after slaughter.

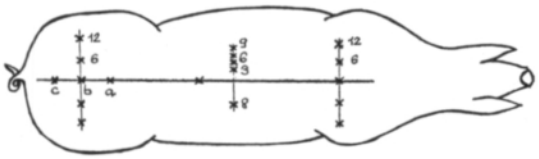

Fig. 1. Points of ultrasonic measurement.

Statistical methods

The processing of the material was done on an Elliot 503 computer, as follows:

The means, the standard deviations and the correlation matrix were calculated.

Each characteristic was analysed by the least squares procedures (HARVEY 1966) to calculate the effect of live weight, groups (I, II and III), breeds (Yorkshire and Landrace) and sex (barrows and gilts). The analyses are based on the following mathematical model: $y_{ijkl} = \mu + a_i + b_j + c_k + dx_{ijkl} + e_{ijkl}$;

y_{ijkl} = phenotypic observation, μ = square term, a_i = effect of the i^{th} group, b_j = effect of the j^{th} breed c_k = effect of the k^{th} sex, d = linear regression coefficient, x = independent continuous variable, e_{ijkl} = random error.

Stepwise multiple regression analysis (SCC 1966) was used to estimate the thickness of back fat and the area of the m. long. dorsi. The optional explanatory variables were the measurements and visual scores obtained at live weights of c. 60 kg and 90 kg. A »free model» was used in which the explanatory variable selected at each step was the one that most improved the correlation coefficient. The F-test ($F \geqq 2.000$) was used as criterion for the explanatory variable which was to be included or dropped.

The multiple correlation coefficients between each of the 20 carcass evaluation results and the estimations for the back fat and for the m. long. dorsi were calculated.

Results

Table 1 shows the means and the standard deviations of the carcass evaluation results as well as the ultrasonic and other measurements obtained on the pigs at live weights of 60 and 90 kg. Table 2 shows the role of the linear regression caused by the live weight as well as the statistical significance of the group, breed and sex upon the characteristics shown in Table 1. Table 2 also shows in per cents the sources of variation calculated from the sums of the squares and caused by the above factors.

The live weight was found to have a highly significant effect on the exterior measurements in the 60 kg live weight class (it explained 15.1—48.4 % of the total variation), and a significant — an almost significant effect in the 90 kg live weight class (it explained 1.7—7.8 % of the total variation). The live weight did not generally have a statistically significant effect upon the results of the points evaluation. The live weight did have a significant — a highly significant effect on the individual fat measurements taken with an ultrasonic instrument in the 60 kg live weight (explaining 4.2—18.7 % of the variation), while its effect was slight in the 90 kg live weight (explaining 0.0—2.3 % of the variation). The differences in live weight did not have a statistically significant effect upon the aver-

age for back fat and the area of the cross-section of the *m. long. dorsi* obtained in conventional carcass evaluation; the effect of live weight on side fat was only nearly significant.

For many of the characteristics, the differences between the evaluation groups were found to be very significant. It should be pointed out, however, that there was no significant difference between the groups in the back fat and side fat on the carcass evaluation.

There were very significant differences between the breeds in respect of the back fat and side fat at the carcass evaluation. However, hardly any differences were observed

Table 1. Average and standard deviations for the results of the carcass evaluation and the characteristics of carcass quality measured at live weights of 60 kg and 90 kg. n = 236 pigs, of Landrace and Yorkshire breeds.

Characteristics	Average	Stand. dev.	Characteristics	Average	Stand. dev.
Dominant functions from carcass evaluation			*Points:* — firmness of fat	12.5	0.5
			— shoulder region	12.4	0.5
Back fat, average, mm	28.8	3.7	— form of hams	12.6	0.6
Area of m. long. dorsi, cm^2	28.2	3.5	— type of bacon	12.5	0.9
Ordinary functions from carcass evaluation			Colour of meat; points	2.9	0.7
			Weight at slaughter, kg	90.2	1.8
Fat/meat ratio, %	134.8	31.9	Weight of head, kg	5.46	0.45
Side fat (s.o.l.), mm	26.4	4.9	Back-length of carcass, cm	106.4	3.8
Carcass weight, kg	68.4	2.2	Inside fat, mm	26.8	4.2
Slaughter loss, %	24.1	1.7	Daily gain	719.4	43.1
Length of carcass, cm	94.7	2.4	Feed consumption fu/kg	3.05	0.17
Length of side, cm	74.9	2.2	"Old" index	159.5	169.1

Characteristics	Average (live weight 60 kg)	Stand. dev. (live weight 60 kg)	Average (live weight 90 kg)	Stand. dev. (live weight 90 kg)
Optional explanatory variables (Measurements on live pigs)				
Points: — head	3.1	0.6	2.9	0.7
— shoulders	3.1	0.7	2.7	0.8
— hams	3.2	0.7	3.3	0.7
Exterior measurements				
Length, forehead — tail, cm	106.7	5.4	121.7	4.6
Circumference of body, cm	86.2	3.9	100.3	3.4
Circumference of head, cm	53.9	3.0	60.5	3.3
Length of head, cm	23.9	1.3	26.4	1.4
Width at withers, cm	24.3	1.2	27.6	1.3
Measurement at withers, cm	47.0	1.2	49.5	1.5
Width behind shoulders, cm	22.1	1.3	25.2	1.3
Measurement behind shoulders, cm	44.8	1.2	47.3	1.2
Width at haunches, cm	23.6	1.3	26.3	1.2
Measurement at haunches, cm	46.4	1.2	48.6	0.9
Depth of body, cm	28.8	1.3	33.4	1.2
Ham measurement, cm	95.2	3.7	108.8	3.6

Characteristics	Average (live weight 60 kg)	Stand. dev. (live weight 60 kg)	Average (live weight 90 kg)	Stand. dev. (live weight 90 kg)
Fat and muscle, etc., ultrasonic measurements, mm				
Rump c	—	—	25.7	3.3
Rump 12 cm left[1])	15.1	2.4	20.6	2.8
» 12 » right	15.2	2.3	20.6	2.8
» 6 » left	16.2	2.6	21.4	2.9
» 6 » right	16.0	2.7	21.2	3.0
Rump b	15.1	3.1	22.1	3.8
Rump a	17.1	2.8	24.8	3.6
Midback	14.0	2.3	19.2	3.5
Side fat (s.o.l.) left	17.6	2.4	23.5	3.5
» » » right	16.8	2.3	23.0	3.7
Shoulder 12 cm left	15.7	2.3	19.9	2.4
» 12 » right	15.4	2.4	19.8	2.6
» 6 cm left	16.2	2.3	20.9	2.7
» 6 » right	15.9	2.3	20.7	2.7
Wither (= shoulder)	28.6	5.0	37.9	4.5
Side fat 3 cm left	16.9	2.3	—	—
» » 6 » »	17.4	3.0	22.1	3.5
» » 9 » »	20.9	3.5	26.6	4.4
Depth of muscle 3 cm left	21.0	5.1	42.9	9.2
» » 6 »	21.3	5.6	42.1	8.2
» » 9 »	13.9	4.3	28.2	10.7

[1]) E.g. thickness of fat at rump 12 cm left of midline of back.

between the breeds in the fat and meat measurements made on live pigs. The breed was found to have a relatively great effect on the exterior measurements.

The gilts were found to have significantly thinner back fat and side fat and bigger muscle area than the castrates. The results obtained with ultrasonic instrument showed this same tendency in both the live weight classes, although the differences were not so distinct.

B a c k f a t. In Table 3 the average amount of back fat obtained at carcass evaluation was estimated by means of stepwise multiple regression analysis. The optional explanatory variables were ultrasonic and other measurements and visual scores obtained fromg the 60 kg or 90 kg live weight. The characteristics of carcass quality obtained in the 60 kg live weight class explained 53 per cent of the back fat variation, and those in the 90 kg class 75 per cent. The models have characteristics in common (although the characteristics are in different orders), as follows: fat of midback, fat of wither, rump (fat), thickness of side fat 9 cm left, and length of head. In the estimation obtained on the characteristics measured in the 60 kg live weight there also occurs side fat 3 cm left, and in the estimation obtained on the characteristics measured in the 90 kg live weight there occurs side fat 6 cm left. These characteristics are in correspondence, allowing for the difference in live weight. The phenotypic correlation between each characteristic and the back fat is shown in the tables.

Table 2. The effects of live weight, group, breed and sex on the results of carcass evaluation and on the characteristics of carcass quality ascertained from live pigs in weight classes of 60 kg and 90 kg. The significances are expressed in F values and the types of variation in per cent of sums squares. n = 236.

Characteristic	Linear regression by live weight	Group	Breed	Sex	Residual	% tot. var.
Carcass evaluation						
Backfat, av.	1.7	1.41	7.53***	17.59***	72.40	100.00
Area of m. long dorsi	0.95	6.49***	0.38	6.75***	85.43	»
Sidefat (s.o.l.)	1.91	0.29	6.93***	14.82***	76.05	»
Slaughter weight	53.87***	5.15***	0.5	0.01	40.92	»
Slaughter loss %	4.43***	11.67***	0.12	0.01	83.77	»
Length of carcass	5.92***	4.80**	3.24**	6.67***	79.37	»
Length of side	4.71***	6.01***	2.88**	6.97***	79.43	»
Points:						
— firmness of backfat	0.05	3.88*	0.04	1.44	94.59	»
— shoulder	0.00	0.14	5.30***	1.32	93.24	»
— form of hams	0.08	1.34	1.43	1.72*	95.43	»
— type of bacom	0.93	1.77	3.02**	19.58***	74.70	»
Meat colour	0.03	68.85***	0.31	0.21	30.60	»
Weight of head	4.80***	3.96*	16.06***	0.09	75.09	»
Inside fat	0.59	0.44	0.09	19.78***	79.10	»
Daily gains	—	18.82***	2.11**	0.05	79.02	»
Feed consumption fu/kg	—	11.08***	0.03	0.00	88.89	»
Test index	—	3*	0	0	97	

Live pigs:	*60 kg*	*90 kg*	*60 kg*	*90 kg*	*60 kg*	*90 kg*	*60 kg*	*90 kg*	*60 kg*	*90 kg*	
Points:											
— head	0.29	0.59	2.55	1.08	2.49*	8.86***	0.24	1.16	94.43	88.31	100.00
— shoulders	0.20	0.00	2.48	2.73*	3.16**	8.77***	0.56	3.57**	93.60	84.93	»
— hams	1.75*	1.86*	1.38	1.78	3.92**	4.27**	0.15	0.26	92.80	91.93	»

Characteristic	Linear regression by live weight		Group		Breed		Sex		Residual		% tot. var.
	60 kg	*90 kg*	*60 kg*	*90 kg*	*60 kg*	*90 kg*	*60 kg*	*90 kg*	*60 kg*	*90 kg*	
Exterior measurements											
Length, forehead — tail	42.35***	1.68*	3.61**	13.84***	1.38*	1.98*	0.97*	0.50	51.69	82.00	100.00
Circumference of body	48.42***	7.83***	1.26*	0.40	8.55***	11.46***	0.37	6.02***	41.40	74.29	»
Circumference of head	18.43***	3.32**	3.49*	0.96	7.53***	8.17***	0.61	0.07	69.94	87.48	»
Length of head	19.99***	3.91**	3.32*	2.16	0.00	0.06	0.00	3.47**	76.69	90.40	»
Width at withers	22.07***	2.46*	1.75	10.65***	6.38***	4.01***	3.16**	5.27***	66.64	77.61	»
Measurement at withers	15.13***	2.68**	1.87	2.91*	4.84***	6.65***	0.26	0.90	77.90	86.86	»
Width behind shoulders	16.69***	5.15***	1.33*	5.10***	29.13***	20.76***	6.05**	9.54***	46.80	59.45	»
Measurement behind shoulders	16.12***	4.76***	0.26	1.72	14.91***	20.85***	1.76*	1.83*	66.95	70.84	»
Width at haunches	18.76***	7.61***	2.79*	3.43*	1.76*	2.90**	0.54	1.68*	76.15	84.38	»
Measurement at hounches	20.36***	6.27***	6.67***	3.22*	0.66	0.67	0.00	3.28**	72.31	86.56	»
Depth of body	38.26***	5.96***	1.09	0.23	1.63*	0.72	0.39	0.03	58.63	93.06	»
Ham measurement	37.31***	6.87***	10.26**	10.34***	0.01	0.35	0.10	0.27	52.32	82.17	»
Fat measurements on live pigs:											
Rump c	12.47***	0.18	14.87***	14.57***	0.37	2.33**	1.98*	8.28***	70.31	74.64	»
Rump 12 cm left	16.71***	0.84	4.89**	1.77	0.13	0.00	1.51*	2.76*	76.76	94.63	»
» 12 » right	17.07***	1.27	3.50**	0.86	0.32	0.10	3.32**	2.79*	75.79	94.98	»
» 6 cm left	11.09***	0.02	4.33**	8.12**	0.84	0.42	1.28	1.76*	82.46	89.68	»
» 6 » right	12.26***	0.08	3.87**	6.69***	1.27	2.21*	2.28*	2.94**	80.32	88.08	»
Rump b	15.54***	0.03	12.90***	12.64***	0.26	1.95*	1.01	4.60***	70.29	80.78	»
Rumb a	12.58***	0.07	8.02***	12.03***	1.12	3.20***	2.99**	10.85***	75.29	73.85	»
Fat of midback	18.65***	0.07	0.14	1.72	3.67**	9.23***	5.45***	16.64***	72.09	72.34	»

Characteristic	Linear regression by live weight		Group		Breed		Sex		Residual		% tot. var.
	60 kg	*90 kg*	*60 kg*	*90 kg*	*60 kg*	*90 kg*	*60 kg*	*90 kg*	*60 kg*	*90 kg*	
Side fat 8 cm left	12.96***	1.25	3.46**	3.06*	0.10	2.06*	3.24**	12.47***	80.24	81.16	»
» 8 » right	14.61***	2.03**	3.50**	4.01**	0.12	2.79**	6.26***	11.36***	75.51	79.81	»
Shoulder 12 cm left	15.95***	0.06	0.97	0.02	2.02*	0.19	4.01**	6.25***	77.05	93.48	»
» 12 » right	15.47***	0.87	3.53**	1.08	1.53**	0.75	3.92**	10.75***	75.55	86.55	»
» 6 cm left	6.76***	0.39	0.46	0.51	0.02	0.58	0.25	7.33***	92.51	91.19	»
» 6 » right	7.47***	0.51	1.00	0.40	0.03	0.41	0.72	8.45***	90.78	90.23	»
Withers (= shoulder)	10.02***	0.09	2.08	1.74	3.22**	1.43	1.24	8.23***	83.44	88.50	100.00
Side fat 3 cm left	10.08***	0.99	4.00**	3.09*	2.63**	5.21***	1.65*	10.38***	81.64	80.33	»
» » 6 » left	4.91***	2.25**	0.75	7.39***	0.03	1.16	1.83*	16.35***	92.48	72.85	»
» » 9 » left	4.18**	0.39	0.13	10.48***	0.03	0.02	0.18	16.79***	95.48	72.32	»
Muscle measuremets of live pigs:											
Muscle depth 3 cm left	2.45*	1.61*	0.45	7.80***	0.39	0.79	0.02	0.53	96.69	89.27	»
» » 6 » left	5.94***	1.75*	3.64*	4.73**	0.04	0.06	0.00	2.16*	90.38	91.30	»
» » 9 » left	4.57**	1.67*	0.85	24.48***	0.06	2.40**	0.18	0.02	94.34	71.43	»
Age at evaluation	23.73***	0.55	8.54***	13.22***	3.47***	5.53***	1.47*	0.83	62.79	79.87	»

* Signif. at 5 % level
** Signif. at 1 % level
*** Signif. at 0.1 % level

Table 3. The back fat ascertained in carcass evaluation is predicted from characteristics ascertained at live weights of 60 kg and 90 kg. The optional explanatory variables in the stepwise multiple regression analysis consist of ultrasonic measurements, exterior measurements and points evaluation results made on live pigs. n = 236.

Step	Characteristics at live weight 60 kg		Cumulative		Characteristics at live weight 90 kg		Cumulative	
		r	R	R^2		r	R	R^2
1	Side fat 3 cm left	0.55	0.55	0.30	Fat of midback	0.76	0.76	0.57
2	Fat of midback	0.55	0.61	0.37	Fat of withers	0.71	0.83	0.69
3	Length forehead — tail	0.08	0.64	0.41	Side fat 6 cm left	0.68	0.85	0.73
4	Rump a (fat)	0.53	0.67	0.45	Rump a (fat)	0.65	0.86	0.74
5	Width at withers	0.05	0.68	0.47	Length of head	— 0.16	0.86	0.74
6	Fat of withers	0.45	0.70	0.49	Depth of muscle 9 cm left	— 0.01	0.87	0.75
7.	Rump b (fat)	0.26	0.71	0.50	S.o.l.	0.70	0.87	0.75
8	Rump 6 cm left (fat)	0.48	0.72	0.52	Side fat 9 cm left	0.51	0.87	0.75
9	Depth of body	0.10	0.73	0.53				
10	Length of head	0.10	0.73	0.53				
11	Side fat 9 cm left	0.42	0.73	0.53				

$r > 0.13$ signif. at 5 % level
$r > 0.17$ » » 1 % »
$r > 0.22$ » » 0.1 % »

The multiple correlation coefficients between each of the 20 carcass evaluation results and the estimations for the back fat are given in Table 4.

S i d e f a t. The importance of the side fat measurements in the determination of the quality of carcass has been shown in several studies (BLENDL 1968, SUNGREN 1967, UUSISALMI 1969a). The correlation of ultrasonic side fat and muscle measurements with back fat, side fat, m. long. dorsi and fat/meat ratio obtained in carcass evaluation can be examined in Table 5. In the 90 kg live weight the individual ultrasonic side fat measurements correlated very significantly with the side fat obtained by carcass evaluation (r = 0.64—0.79), while, in the 60 kg live weight, the correlation coefficients between the side fat measurements are somewhat lower (r = 0.46—0.56). The correlations of the side fat measurements with the area of the m. long. dorsi are closer than are the correlations of the respective depth measurements on the muscle. For the sake of comparison it should be mentioned that at a live weight of 90 kg the correlation coefficient between 5 back fat measurements made ultrasonically and 5 back fat measurements made by carcass evaluation was 0.82.

The correlations between ultrasonic measurements made in the 60 kg live weight and those made in the 90 kg live weight are shown below: shoulder 12 cm right r = 0.45, left r = 0.36; shoulder 6 cm right r = 0.50, left r = 0.37; side fat 8 cm right r = 0.57, left r = 0.51; rump 12 cm right r = 0.38, left r = 0.35; rump 6 cm right r = 0.43, left r = 0.32. In the two classes of live weight the correlation coefficients between the respective fat measurements made on the right were generally higher than those for the measurements made on the left. Fat and muscle measurements on the left side only were used in the stepwise multiple regression analyses.

Table 4. The multiple correlation of each carcass evaluation result and the characteristics included in the estimation of back fat (a) (b). Cf. Table 3.

Characteristic (from carcass evaluation)	Characteristics of live pigs at weights of (a) 60 kg		(b) 90 kg	
	R	R^2	R	R^2
Back fat	0.72	0.52	0.87	0.75
Area of m. long. dorsi	0.36	0.13	0.46	0.21
Fat/meat ratio	0.65	0.42	0.78	0.61
S.o.l.	0.67	0.45	0.83	0.68
Carcass weight	0.23	0.05	0.33	0.11
Slaughter loss %	0.29	0.09	0.32	0.10
Length of carcass	0.58	0.34	0.33	0.11
Length of side	0.57	0.33	0.34	0.12
Points: — firmness of fat	0.20	0.04	0.22	0.05
— shoulder	0.33	0.11	0.19	0.04
— form of hams	—	—	—	—
— type of bacon	0.65	0.42	0.72	0.52
Colour of meat	0.38	0.15	0.30	0.09
Live weight	—	—	0.14	0.02
Weight of head	0.34	0.11	0.22	0.05
Back-length of carcass	0.51	0.26	0.31	0.10
Inside fat	0.58	0.33	0.72	0.52
Daily gain	0.26	0.07		
Feed consumption fu/kg	0.14	0.02		
»Old» index	0.34	0.11		

(a)
- Side fat 3 cm left
- Fat of midback
- Length, forehead — tail
- Rump a (fat)
- Width at withers
- Fat at withers
- Rump b (fat)
- Rump 6 cm left (fat)

(b)
- Fat of midback
- Fat of withers
- Side fat 6 cm left
- Rump a (fat)
- Length of head
- Depth of muscle 9 cm left
- S.o.l.
- Side fat 9 cm left

M u s c u l u s l o n g i s s i m u s d o r s i. In Table 6 the area of the cross-section of the m. long. dorsi is explained by means of stepwise multiple regression analysis. The ultrasonic and other measurements and the points evaluation results obtained at live weights of 60 kg and 90 kg are the optional explanatory variables. 27 per cent of the variation of the cross-section of the muscle could be explained in terms of the characteristics ascertained at a live weight of 60 kg, but only 29 per cent of the variation in terms of the

Table 5. Correlation of the ultrasonic measurements of the side with certain carcass measurements. Each pig measured live with ultrasonic instrument at live weights of 60 kg and 90 kg. n = 236.

Ultrasonic measurements: (on live pigs)	Measured at live weight of kg	Length of carcass	Back fat average	*Cross-section profile of side* side fat (s.o.l.)	area of m.long. dorsi	fat/meat ratio
		r	r	r	r	r
Side fat 3 cm left	60	—0.06	0.55	0.56	—0.25	0.54
	90	—0.14	0.73	0.68	—0.33	0.66
Side fat 6 cm left	60	—0.07	0.42	0.48	—0.29	0.51
	90	—0.12	0.68	0.75	—0.39	0.72
Side fat 8 cm (s.o.l.)	60	—0.12	0.47	0.54	—0.34	0.57
	90	—0.17	0.70	0.79	—0.37	0.71
Side fat 9 cm left	60	—0.06	0.42	0.46	—0.34	0.53
	90	—0.16	0.51	0.64	—0.43	0.66
Muscle depth 3 cm left	60	—0.01	—0.18	—0.17	0.07	—0.14
	90	—0.04	0.10	—0.02	0.06	—0.03
Muscle depth 6 cm left	60	0.05	—0.05	—0.12	0.21	—0.21
	90	0.03	0.15	0.11	0.03	0.06
Muscle depth 9 cm left	60	0.05	—0.18	—0.14	0.20	—0.23
	90	0.02	—0.01	—0.06	0.28	—0.21
Muscle depth, av., left	60	0.05	—0.20	—0.22	0.24	—0.24
	90	—0.00	0.09	—0.00	0.18	—0.10
Back fat, av. (5 measurements)	90	—	0.82	0.65	—	—

r > 0.13 signif. at 5 % level
r > 0.17 » » 1 % »
r > 0.22 » » 1.0 % »

characteristics at a live weight of 90 kg (Fig. 2). The common explanatory variables ind the said models were the side fat 9 cm left, the ham points, the width at the haunches and the measurement behind the shoulders. One measurement of muscle depth occurs in each model. The phenotypic correlation of each characteristic with the area of the m. long. dorsi is shown.

The multiple correlation coefficients between each of 20 carcass evaluation results and the estimations for the m. long. dorsi are shown in Table 7.

Table 6. The area of the m. long. dorsi predicted from the characteristics ascertained at live weights of 60 kg and 90 kg. The optional explanatory variables in the stepwise multiple regression analysis were the same characteristics as in Table 2. n = 236.

Step	Characteristics at live weight 60 kg		Cumulative		Characteristics at live weight 90 kg		Cumulative	
		r	R	R^2		r	R	R^2
1	Fat of midback	— 0.34	0.34	0.12	Side fat 9 cm left	— 0.43	0.43	0.18
2	Ham points	0.20	0.40	0.16	Width at haunches	0.18	0.47	0.22
3	Side fat 9 cm left	— 0.34	0.43	0.19	Rump 12 cm left (fat)	— 0.13	0.49	0.24
4	Width at haunches	0.12	0.47	0.22	Ham points	0.20	0.50	0.25
5	Width behind shoulders	— 0.23	0.49	0.24	Measurement behind shoulders	— 0.13	0.51	0.26
6	Measurement behind shoulders	— 0.10	0.50	0.25	Shoulder 12 cm left (fat)	— 0.29	0.52	0.27
7	Shoulder points	0.07	0.51	0.26	Depth of muscle 9 cm left	0.28	0.53	0.28
8	Depth of muscle 6 cm left	0.21	0.51	0.26	S.o.l.	— 0.37	0.53	0.28
9	S.o.l.	— 0.34	0.52	0.27	Circumference of body	— 0.04	0.54	0.29

$r > 0.13$ signif. at 5 % level
$r > 0.17$ » » 1 % »
$r > 0.22$ » » 0.1 % »

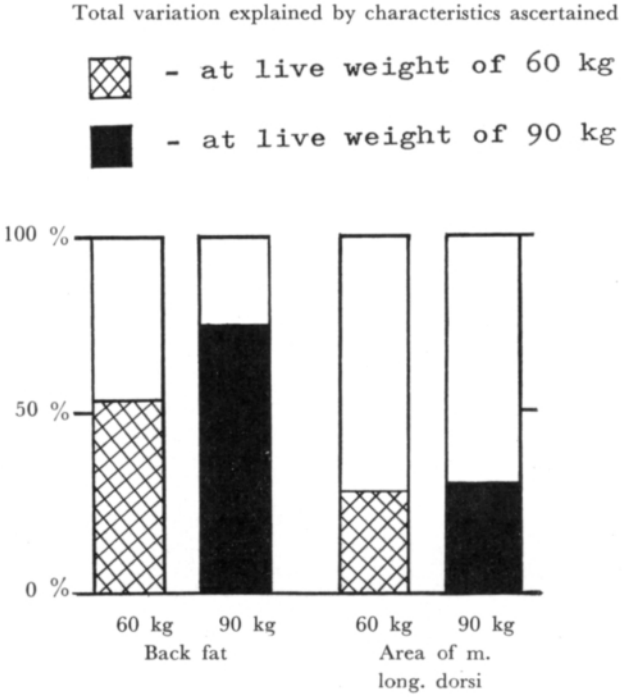

Fig. 2. Thickness of back fat and area of m. long. dorsi predicted at live weight of 60 kg and 90 kg.

Table 7. The multiple correlation of each carcass evaluation result and the characteristics included in the estimation of the m. long. dorsi (a) (b). Cf. Table 6.

Characteristic (from carcass evaluation)	Characteristics of live pigs at weights of (a) 60 kg R	R^2	(b) 90 kg R	R^2
Back fat	0.56	0.31	0.71	0.50
Area of m. long. dorsi	0.51	0.26	0.53	0.28
Fat/meat ratio	0.66	0.43	0.78	0.61
S.o.l.	0.58	0.34	0.82	0.67
Carcass weight	0.19	0.03	0.40	0.16
Slaughter loss %	0.21	0.05	0.26	0.07
Length of carcass	0.29	0.09	0.39	0.15
Length of side	0.28	0.08	0.40	0.16
Points: — firmness of fat	0.15	0.02	0.30	0.09
— shoulder	0.28	0.08	0.28	0.08
— form of hams	0.33	0.11	0.23	0.05
— type of bacon	0.49	0.24	0.59	0.35
Colour of meat	0.26	0.07	0.22	0.05
Live weight	—	—	0.36	0.13
Weight of head	0.42	0.18	0.28	0.08
Back length of carcass	0.17	0.03	0.35	0.12
Inside fat	0.50	0.25	0.73	0.54
Daily gain	0.24	0.06		
Feed consumption fu/kg	0.04	0.00		
»Old» index	0.28	0.08		

(a)
- Fat of midback
- Ham points
- Side fat 9 cm left
- Width at haunches
- Width behind shoulders
- Measurement behind shoulders
- Shoulder points
- Depth of muscle 6 cm left

(b)
- Side fat 9 cm left
- Width at haunches
- Rump 12 cm left (fat)
- Ham points
- Measurement behind shoulders
- Shoulder 12 cm left (fat)
- Depth of muscle
- S.o.l.

Discussion

The effect of live weight upon measurement results is examined in the analysis shown in Table 2. In this context it was not found necessary to clarify the variation caused by age because, e.g. according to RITTLER (1968), where young boars are concerned a correction made on the basis of age in addition to a correction made on the basis of weight will not appreciably improve the result. Likewise, in the study by UUSISALMI (1970) on the heritability of the ham and its components carried out on progeny testing material, the effect of age additional to the effect of slaughter weight was found to be slight.

Although all three groups of pigs were measured within a period of less than two years, the group was found to have had a very significant effect on the daily gain, feed consumption and meat colour. The differences indicated that variation occurred in the

testing station conditions. Ultrasonic measurements revealed differences between different groups although the carcass evaluation did not reveal differences in back fat and side fat. This is explicable in terms of the changes in methods of measurement among the groups.

Statistical differences were found in favour of gilts in the fat measurements expressing the fattiness of the carcass. It may be mentioned that in the present investigation the differences of the sexes were more clearly observed in the live weight of 90 kg than in that of 60 kg. One explanation for this may be found in the greater variation in live weight in the lower weight class. Another conceivable explanation is that the differences between the sexes increase with increasing weight.

Several research workers (JOHANSSON & KORKMAN 1950, OSTERHOFF 1956, LOČNIŠKAR 1960, SKÅRMAN 1962, LANGHOLZ 1965, LAUPRECHT & FLOCK 1968, UUSISALMI 1969 a) have found that barrows have a greater tendency than gilts towards fattiness. As to boars, gilts and barrows, studies with different breeds and their hybrids (CAHILL *et al.* 1960, CHARETTE 1961, CLAUSEN *et al.* 1961, BLAIR *et al.* 1965, ROBERTSON *et al.* 1965, TRIBBLE *et al.* 1965, PIATKOWSKI & JUNG 1966, 1967 and HORST & BADER 1969) have revealed that the tendency of boars to fatten is even smaller than that of gilts, and that statistically boars are generally meatier than barrows.

The variables included in the stepwise multiple regression analyses were selected from among a number more than three times as large by means of a correlation matrix and factor analysis. The study did not carry out a detailed explanation of the partial regression coefficients, for several of the optional explanatory variables, e.g. the side fat measurements, were correlated among themselves. Thus the inclusion of, say, one measurement of side fat in the model will push the other measurements of side fat to the end of the model or even outside it.

Of the total variation in fat measurements made with an ultrasonic instrument, 4.2—18.7 per cent was explained in the 60 kg weight class in terms of the regression according to weight, and 0.0—2.3 per cent in the 90 kg weight class in the same terms (Table 2). If the ultrasonic measurements had been corrected by means of regression of live weight before the stepwise multiple regression analysis, or if live weight had been added as an optional explanatory variable in the analysis, the R^2 % (53 %) of the back fat model obtained at the live weight of 60 kg would have increased according to my estimation by c. 10 per cent while the R^2 % (75 %) of the model obtained from the live weight of 90 kg would have improved by, possibly 0—1 per cent. Even with the prevalent test arrangements, however, the back fat estimations obtained in the 60 kg and 90 kg live weights are similar in many respects: 1) practically the same characteristics occur in both estimations, although admittedly in a slightly different order, 2) the two models calculated for the back fat best explained the back fat of the carcass, second best the side fat, third the fat/meat ratio, fourth the bacon type and fifth the inside fat.

The R^2 % of the estimation of the m. long. dorsi calculated from the measurements made on the 60 kg and the 90 kg live weight classes were rather small. Further, only a few characteristics in common occur in these models. It must be mentioned, too, that the importance of the three depth measurements made on the muscle was small. In the ultrasonic measurements there were difficulties in finding the floor of the muscle.

On the basis of the analyses it can be shown that when the fattiness of the carcass is to be determined with ultrasonic instrument, the measurements of fat can be restricted

for practical breeding work to the measuring of the fat layers of the midback and the side. These fat layers also seem to correlate with the trait expressing the meatiness of the back.

In clarification it should be pointed out that with the fat becoming thinner and its variation narrower owing to selection, the depths and areas of muscle will have to be measured directly. Favourable results have also been obtained from the measurements of the area of the m. long dorsi (LAUPRECHT *et al.* 1960, PRICE *et al.* 1960, STOUFFER *et al.* 1961, HORST 1964, MEYER *et al.* 1966, ANDERSEN *et al.* 1970). The equipment and the techniques of measurement are subject to constant development (HORST 1970). At present, the measuring of the areas of muscle in live pigs is still difficult to apply in practical breeding work, as it is too time-consuming and relatively expensive.

REFERENCES

ANDERSEN, B. B., PEDERSEN, O. K., BUSK, H., LUND, S. A. & JENSEN, P. 1970. Ultralydmåling af kvaeg og svin. Ugeskr. for agron. 115, 18: 360—363. Saertryk.

BLAIR, R. & ENGLISH, P. R. 1965. The effect of sex on growth and carcass quality in the bacon pig. J. Agric. Sci. 64: 169—176.

BLENDL, H. M. 1966. Eine zuverlässige Methode zur Schätzung des Fleischanteils in der Nachkommenprüfung beim Schwein. Z-kunde 38: 161—173.

—»— 1968. Die Eigenleistungsprüfung im Feld mittels Echolotverfahren beim Schwein in Bayern. Ibid. 40: 264—283.

BRATLER, L. J. & MARGETUM, E. R. 1953. The relationship between live hog scores and carcass measurements. J. Anim. Sci. 12: 856.

CAHILL, V. R., TEAGUE, H. S., KUNKLE, C. E., MOXON, A. L. & RUTLEDGE, E. A. 1960. Measurements of and ways of effecting sex-influenced performance of growing finishing swine. Ibid. 19: 1036—1040.

CHARETTE, L. A. 1961. The effects of sex and age of male at castration on growth and carcass quality of Yorkshire swine. Can. J. Anim. Sci. 41: 30—39.

CLAUS, A. 1957. The measurement of natural interfaces in the pig's body with ultrasound. Fleischwirtsch. 9: 552.

CLAUSEN, H., HAAGEN-PETERSEN, F. HØJGAARD-OLSEN, N. J., HANSEN, V., MADSEN, A., NIELSEN, H. & EGGUM, B. O. 1961. Forsøg med slagtersvin: Kastrationstidspunktes indflydelse pa slagtekvaliteten. Beretning om de of Landøkonomisk Førsøgslaboratorium og de samvirkende danske Andels-Svineslagterier ivaerksatte avls- og fordringsforsøg med svin. 55—59 pp.

ERWIN, E. S., DYER, J. A., MEYR, T. O. & SCOTT, K. W. 1956. Uses of aspiration biobsy technique. J. Anim. Sci. 15: 428—439.

GERLACH, J. 1970. Echolotmessungen als Hilfsmittel für die Zuchtwertschätzung beim Schwein. 4. Mitteilung. Z. Tiersücht. u. Z.-Biol. 86: 325—348.

HARING, F. & SIEBURG, H. 1957. Methoden zur Bestimmung des Schlachtwertes am lebenden Schwein. Z-kunde 29: 291—303.

HARVEY, W. R. 1966. Least-squares analysis of data with unequal subclass numbers. ARS 20—28. July 1960. Reprinted with corrections April 1966. Agric. Res. Service U.S. Dept. of Agric.

HAZEL, L. N. & KLINE, E. A. 1952. Mechanical measurement of fatness and carcass value on live hogs. J. Anim. Sci. 11: 313—318.

HOLLAND, L. A. & HAZEL, L. N. 1958. Relationship of live measurements and carcass characteristics of swine. Ibid. 17: 825—833.

HORST, P. 1964. Entwicklung eines Verfahrens zur Durchführung von Ultraschallmessungen beim lebenden Schwein. Z. Tierzücht. u. Z.-Biol. 80: 341—364.

—»— 1964. Kritische Bewertung der Methoden zur Bestimmung des Schlachtkörperwertes beim lebenden Schwein. Ibid. 80: 167—196; 80: 365—401.

Horst, P. 1969. Untersuchungen über die Züchterische Bedeutung des Ultraschall-Schnittbildverfahrens bei der Eigenleistungs-Prüfung von Jungebern. Ibid. 86: 58—88.

—»— 1970. Einsatz eines neuen Ultraschall-Schnittbildsystems in der Schweinezucht. Z-kunde 42: 116—121.

Horst, P. & Bader, J. 1969. Untersuchungen zur Bedeutung der Jungebermast. 1. Mitteilung: Vergleich der Mast- und Schlachtkörpereigenschaften von gemästeten Ebern und Sauen im Gewicht von 110 kg. Ibid. 41: 226—247.

Johansson, I. & Korkman, N. 1950. A study of the variation in production traits of bacon bigs. Acta Agr. Scand. 1: 62—96.

Jung, H. & Piatkowski, B. 1966. Der Eiweissansatz wachsender Schweine verschiedenen Geschlechts und verschiedener Typrichtung. 2. Mitteilung: Beziehungen zwischen Stickstoffretention und Fleischgehalt im Schlachtkörper. Archiv für Tierzucht 9: 399—408.

Kliesch, J. U., Newhaus, U., Silber, E. & Kostzewske, E. 1957. Versuche zur Messung der Speckdicke am lebenden Tier mit Hilfe des Ultraschalls. Z. Tierzücht. u. Z-Biol. 70: 29—32.

Langholz, H.-J. 1965. Das züchterische Hilfsmittel der stationären Nachkommenprüfung beim Schwein. I Systematische Einflüsse auf die Ergebnisse aus der Mastleistungsprüfung für Schweine. Acta Agr. Scand. 15: 115—144.

Langlet, J. F., Ernst, E. & Glaner, H. D. 1968. Die Möglichkeit einer Selektion bei Schweinen mit Hilfe von Echolotmessungen unter den Verhältnisse der Praxis. Z. Tierzücht. u. Z-Biol. 85: 27—35.

Lauprecht, E. & Flock, D. 1968. Systematische Einflüsse auf Leistungseigenschaften von veredelten Landschweinen in deutschen Mastprüfungsanstalten. Ibid. 85: 295—309.

Lauprecht, E., v. Schutzbar, W. & Flock, D. 1967. Untersuchungen über die Heritabilität der mit dem Ultraschall-Echolot an Jungebern ermittelten Speck- und Muskeltiefe. Ibid. 84: 80—95.

Lauprecht, E., Walter, E. & Saathoff, T. 1960. Beitrag zur Messungen der Querschnittsfläche des langen Rückenmuskels (musculus longissimus dorsi) und der darüberliegenden Feltschicht von lebenden Schweinen mit dem Ultraschall-Echolot. Z-kunde 32: 450—464.

Ločniškar, F. 1960. Untersuchungen über die Erblichkeitsanteile und genetischen Korrelationen einiger Mast- und Schlachtmerkmale beim Schwein. Schriftenreiche des Max-Planck-Inst. für Tierzucht und Tierernähr. Heft 9, Mariensee 1960.

Meyer, W. E., Moody, W. G., Hunzieger, G. D., Ringkob, T. P., Alexander, M. A., Zobrisky, S. E. & Hedrick, H. B. 1966. Application of Ultrasonic Techniques in Live Animal and Carcass Evaluation. Univ. Missouri, Coll. Agricult. Res. Bull. 905. 50 pp.

Osterhoff, D. 1956. Erblichkeitsuntersuchungen und Nachkommenprüfungen auf Grund der Ergebnisse der Schweinemastleistungsprüfungen. Z. Tierzücht. u. Z.-Biol. 68: 199—240.

Pearson, A. M. 1968. Estimating meat yield and quality in live animals. Proceedings-Second World Conference on Animal Production, July 1968: 139—149.

Pedersen, O. K. 1961. Die Bedeutung des Exterieurs für den Schlachtkörperwert beim Schwein. Z. Tierzücht. u. Z.-Biol. 75: 23—33.

Piatkowski, B. & Jung, H. 1966. Der Eiweissansatz wachsender Schweine verschiedenen Geschlechts und verschiedener Typrichtung. 3. Mitteilung: Der Einfluss von implantierten Diäthylstilböstrol auf den Eiweissansatz sowie Eigenschaften des Schlachtkörpers von Ebern. Archiv. für Tierzucht 9: 307—319.

—»— 1967. Der Eiweissansatz wachsender Schweine verschiedener Geschlechts und verschiedener Typrichtung, 3. Mitteilung: Der Einfluss von implantierten Diäthylstilböstrol auf den Eiwei ansatz sowie Eigenschaften des Schlachtkörpers von Ebern. Ibid. 10: 61—64.

Price, J. F., Pearson, A. M. & Emerson, J. A. 1960. Measurement of the cross-sectional area of the loin eye muscle in live swine by ultrasonic reflections. J. Anim. Sci. 19: 786—789.

Rittler, A. 1968. Echolotmessungen als Hilfsmittel für die Zuchtwertschätzung beim Schwein. 2. Mitteilung. Z. Tierzücht. u. Z-Biol. 84: 179—187.

—»— 1968. Echolotmessungen als Hilfsmittel für die Zuchtwertschätzung beim Schwein. 3. Mitteilung. Ibid. 85: 78—89.

Robertson, I. S., Spreull, J. S. A. & Stoke, W. M. 1965. Pig castration with particular reference to Baiburtcjan's method. Veter. Record 77: 738—749.

SCC 1966. Valikoiva regressioanalyysi (multiple stepwise regression analysis). St. Computing Center. Dept. of Planning X 40, p. 1578.

SKÅRMAN, S. 1962. Differences between the Sexes as to Proportions of Lean, Meat and Fat in Pigs. K. Lantbr.høgsk. Ann. 28: 149—164.

STOUFFER, J. E., WALLENTINE, M. V., WELLINGTON, G. M. & DIEKMAN, A. 1961. Development and application of ultrasonic methods for measuring fat thickness and ribeye area in cattle and hogs. J. Anim. Sci. 20: 759—767.

SUNDGREN, P.-E. 1967. Individprövning av sin för tillväxt och fettansättning. Tortrykk av foredrag av NJF-Kongressen, 27.—30. Juni 1967.

URBAN, W. E. & HAZEL, L. N. 1960. Ultrasonic measurement of fatness in swine during the growing fattening period. J. Anim. Sci. 19: 1228.

UUSISALMI, U. 1969 a. Vorläufige Ergebnisse über das Messen der Schlachteigenschaften beim Schwein. J. Sci. Agric. Soc. Finland 41: 50—59.

—»— 1969 b. Carcass analysis as aid in pig breeding. Acta Agr. Scand. 19: 214—220.

—»— 1970. Inheritance in ham and its components in Finnish Landrace and Yorkshire breeds. Ibid. 21: in press.

WENIGER, J. H., GLODEK, P., MENNERICH, A. & SMIDT, L. 1967. Untersuchungen zur Methode und Anwendung des Echolotverfahrens in der Leistungsprüfung beim Schwein. Bayer. Landw. Jahrb. 44: 842—874.

SELOSTUS

SIAN TEURASTUSLAADUN ENNUSTAMINEN 60 KG:N JA 90 KG:N ELOPAINOSSA

UNTO UUSISALMI

Helsingin Yliopisto, Kotieläinten jalostustieteen laitos

Tutkittiin mahdollisuutta ennustaa teuraslaatua elävistä maatiais- ja yorkshirerotuisista sioista (n. = 236) n. 60 kg:n ja 90 kg:n painossa.

Krautkrämerin USK-4 ultraäänilaitteella mitattiin silavakerrosten paksuutta 18:sta pisteestä selältä, kyljiltä, pakaroilta ja lavoilta sekä kyljyslihaksen syvyyttä viimeisen kylkiluun takareunan tasalta 3:sta kohdasta. Siat arvosteltiin pistein ja niistä otettiin eksteriöörimittoja. Teurastuksen jälkeen suoritettiin perinteellinen teurasarvostelu.

Tuloksia analysoitiin pienimmän neliösumman menetelmän (HARVEY 1966) avulla elopainon mukaisen regression, mittauserien, rodun ja sukupuolen vaikutuksen selvittämiseksi. Valikoivan regressioanalyysin avulla tapahtuvaan käsittelyyn otettiin 20 teurasarvostelusta saatua ominaisuutta funktioiksi ja 30 kummassakin painoluokassa elävistä sioista todettua teuraslaadun piirrettä valinnaisiksi selittäjiksi.

Selkäsilavaa voitiin tyydyttävästi ennustaa mittauksien avulla sekä 60 kg:n ($R^2 = 0.53$) että 90 kg:n ($R^2 = 0.75$) elopainossa. Molemmissa painoluokissa silavamalleilla oli yhtäläisyyksiä. Pitkän selkälihaksen alaa kyettiin ennustamaan heikohkosti ($R^2 = 0.27$—0.29). Tutkimuksessa todettiin olevan mahdollisuuksia myös 60—70 kg:n elopainossa tapahtuvaan fenotyyppiarvosteluun.