Prediction of the meat content of the carcass and valuable carcass parts in French lop rabbits using some traits measured *in vivo* and *post mortem*

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ABSTRACT: The experiment was performed on 60 French lop rabbits raised under extensive conditions and sacrificed at body weight of about 3 kg. It was found that the best indicators of meat weight (g) in rabbit carcasses were body weight, head width and lower thigh length among the traits measured *in vivo*, and carcass weight, chest girth and thigh circumference among the traits measured *post mortem*. *In vivo* prediction of saddle meatiness may be based on body weight, trunk length and thigh length, whereas post-slaughter estimation – on carcass weight, hip circumference and thigh circumference. Total meat weight in the hind half of the carcass may be predicted *in vivo* on the basis of body weight, head width and lower thigh length, and *post mortem* – on the basis of carcass weight, chest girth, hip circumference, thigh circumference and pelvic width. Multiple regression equations for meat weight estimation in the whole carcass and its middle and hind part were derived in the study. These equations may be applied in selection work directed towards an improvement in carcass meatiness. They may also be used to evaluate the results of experiments conducted on French lops.

Keywords: rabbits; meat performance; coefficients of correlation; regression equations

A growing interest in meat rabbit production has been observed in recent years both in Poland and worldwide. This is related to an increase in demand for low-calorie and easily digestible rabbit meat. Rabbit meat production must be based upon high-quality raw materials. Breeding work on meatiness improvement in rabbits requires reliable and easy to apply in practice slaughter value traits that can be measured *in vivo*. Studies in this field were conducted by Niedźwiadek (1983), Lewczuk et al. (1998, 1999, 2000, 2001), Brzostowska et al. (1999), Rymkiewicz and Lewczuk (2000). These authors demonstrated that numerous body measurements of rabbits were good indicators of carcass meatiness.

Some authors (Niedźwiadek, 1980; Lukefahr and Ozimba, 1991; Ayyat et al., 1995; Lewczuk et al., 1999, 2001; Rymkiewicz and Lewczuk, 2000) proposed simple and multiple regression equations for *in vivo* prediction of the meat content of the carcass and its valuable parts in Danish White, New Zealand White and Californian rabbits. However, it should be stressed that large rabbit breeds differ considerably from medium rabbit breeds in terms of body weight and conformation, so the equations formulated using the body measurements of the latter cannot be applied to the former. Thus, the aim of the present study was to analyze the correlations between some traits measured *in vivo* and *post mortem* and the weights of particular tissue components in the whole carcass and its middle and hind part, as well as to derive regression equations to estimate meat weight in the carcass and its valuable parts in French lop rabbits.

MATERIAL AND METHODS

The experiment was performed on 60 French lop rabbits raised under extensive conditions and sac-

rificed at body weight of about 3 kg. The following live body measurements were taken:

body weight
trunk length – from the occipital bone to the base of the tail
thigh length – from the greater trochanter to the lower contour of the lateral condyle of the femur
lower thigh length – from the lateral condyle of the tibia to the hock joint
chest girth – just behind the scapulas
hip circumference – in front of the anterior parts of the wings of the femurs
rump half-circumference – from the right to the left hip joint (under the tail)
chest width – just behind the scapulas
pelvic width – between the external surfaces of the hips
head width – on the posterior parts of the jugular arches
chest depth – just behind the scapulas

The animals were sacrificed as recommended by the Institute of Animal Husbandry (Niedźwiadek, 1996). After carcass skinning the front feet were cut off at the carpal joint, and the rear feet – at the hock joint. The ears were cut off at the skin. Skinned carcasses were eviscerated, and particular elements were weighed. Apart from the above measurements, the following traits were determined on hot carcasses:

carcass length – from the occipital bone to the base of the tail,
leg circumference – thigh circumference measured at the thickest part.

Then the carcasses were chilled for about 18 hours at 277 K, and divided into the following parts:
front part – a cut between the last thoracic vertebra and the first lumbar vertebra,
middle part – a cut between the last thoracic vertebra and the first lumbar vertebra, and between the last lumbar vertebra and the first sacral vertebra,
hind part – the remaining part of the carcass.

The right feet, front and rear, were also separated. All carcass parts were dissected into lean, bones and fat. Femur length was measured from the highest point on the greater trochanter to the most distant point on the joint area of the lateral condyle. The height and width of the loin eye were measured between the third and fourth lumbar vertebra.

The statistical analysis included:
- characteristics of the experimental materials ($\bar{x}$, s)
- coefficients of phenotypic correlation between the traits examined and the weights of particular tissue components in the whole carcass and its middle and hind part
- multiple regression equations to estimate meat weight in the whole carcass and its middle and hind part. To achieve the maximum accuracy of estimation, stepwise regression was used to introduce all independent variables highly correlated with the dependent variable, and to choose the optimum set
- verification of the accuracy of meat weight estimation in the whole carcass and its middle

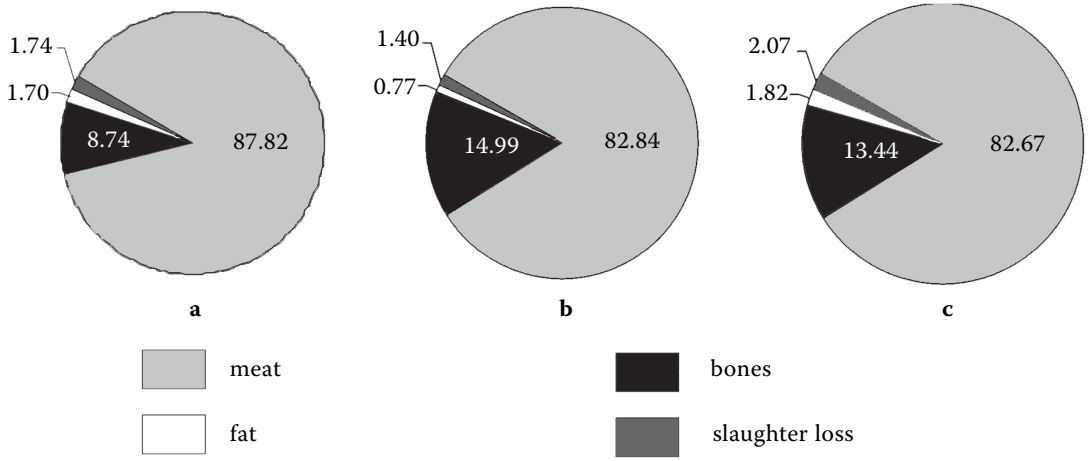

Figure 1. Content (%) of meat, bones and fat in carcass parts and in the whole carcass: a – middle part, b – hind part, c – whole carcass

Table 1. Carcass weight, carcass measurements and coefficients of correlation between these traits and the content of meat, bones and fat in the whole carcass and its middle and hind part

Trait	Statistical measures		Coefficients of correlation between the traits examined and the content of meat, bones and fat in								
			whole carcass			middle part of carcass			hind part of carcass		
	$\bar{x}$	s	meat	bone	fat	meat	bone	fat	meat	bone	fat
Carcass weight (g)	1 490	150.46	0.983	0.640	0.493	0.873	0.566	0.250	0.967	0.672	0.380
Length (cm)											
Carcass	38	2.27	0.214	0.456	0.110	0.255	0.304	0.148	0.258	0.573	0.211
Thigh	11	0.35	0.504	0.648	0.147	0.445	0.567	–0.129	0.529	0.662	0.065
Circumference (cm)											
Chest	26	1.62	0.614	0.535	0.139	0.338	0.380	0.010	0.610	0.568	0.235
Thigh	27	1.38	0.681	0.552	0.018	0.581	0.572	–0.077	0.696	0.677	–0.063
Hips	19	0.97	0.687	0.336	0.499	0.745	0.205	0.457	0.671	0.354	0.441
Width (cm)											
Chest	7	0.57	0.628	0.579	0.139	0.458	0.499	0.058	0.576	0.652	0.006
Pelvis	8	0.39	0.668	0.727	0.271	0.575	0.587	0.046	0.600	0.722	0.277
Chest depth	8	0.82	0.271	0.032	0.043	0.021	–0.130	0.017	0.255	0.075	0.455

Critical values r at $\alpha - 0.05 = 0.250$; $\alpha - 0.01 = 0.325$

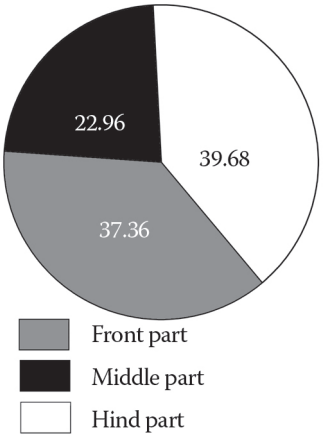

Figure 2. Proportions (%) of carcass parts (carcass weight = 100%)

and hind part using equations formulated for 30 French lop rabbits in another experiment

RESULTS AND DISCUSSION

Characteristics of the experimental materials

The body measurements of rabbits of medium breeds were analyzed by Lewczuk et al. (1998, 1999, 2001), Brzostowska et al. (1999), Rymkiewicz and Lewczuk (2000) and Zając (2002). However, the results of their studies cannot be compared with those obtained in this experiment, since the animals differ significantly in terms of breed, age and body weight.

In our study mean carcass weight amounted to 1 490 g (Table 1), and was comparable with that obtained in rabbits of other breeds sacrificed at body weight of about 3 kg (Zając, 2001, 2002).

An analysis of carcass tissue composition (Figure 1) indicated high meatiness, confirmed by a high lean content (82.67%) and a low fat content (1.82%). In the experiments performed by Zając (2001, 2002) on rabbits of various breeds and their crosses (weighing approx. 3 kg) the carcass lean and fat content ranged from 82% to 86%, and from 1.2% to 4.3% respectively. In our study the bone content of carcass was 13.44%, compared with 11.9%–17.8% reported by Łabecka and Gardzielewska (1990), Zając (1999, 2002), and Bielański (2000).

The front part of the carcass, saddle and the hind part accounted for 37.36%, 22.96% and 39.68%, respectively (Figure 2). The most valuable carcass cuts, i.e. saddle and the hind part, constituted about 63% of total carcass weight, which corresponds with the values obtained by Brzostowska et al. (1999), Lewczuk et al. (2001), Bielański et al. (2002) and Zając (2003, 2004). The proportion of the front part was also comparable with that reported by these authors. Both most valuable carcass parts showed high meatiness – mean lean content was 87.82% in the saddle and 82.84% in the hind part (Figure 2). Our results are generally consistent with those presented in literature (Niedźwiadek et al., 1983; Brzostowska et al., 1999; Rymkiewicz and Lewczuk 2000; Lewczuk et al., 2001; Bielański et al., 2002).

The mean weights of viscera, feet and skin were 130 g, 87 g and 368 g, respectively, which accounts for 4.16%, 2.85% and 12.05% of total body weight (Table 2). Slightly higher values were obtained by Skřivanová et al. (2000), Tůmová et al. (2003), Dänicke et al. (2004), in experiments carried out on rabbits of other breeds.

Phenotypic correlations between the traits examined and the weights of particular tissue components in the whole carcass and its middle and hind part

The suitability of various traits for the estimation of the tissue composition of the carcass and its parts depends on their correlations with the content of lean, fat and bones in the carcass and its valuable parts. The fact whether a given measurement is easy to perform and reproducible must also be considered, together with the effect of trait determination on the trading value and eating quality of meat (Lewczuk et al., 2001).

Among the traits measured *in vivo* (Table 3), body weight showed the highest correlation with meat weight in the whole carcass and its valuable parts (r from 0.700 to 0.839). Niedźwiadek (1983), Lewczuk et al. (1998, 1999, 2000, 2001), Brzostowska et al. (1999), Rymkiewicz and Lewczuk (2000) share the opinion that body weight is a good and most commonly applied selection criterion.

Among live body measurements, the highest correlations were observed between body weight in the whole carcass and: trunk length (r = 0.459), lower thigh length and head width (r = 0.447 and 0.573, respectively). Meat weight in the middle carcass part was highly correlated with trunk length and thigh length (r = 0.515 and 0.435, respectively), and in the hind part – with trunk length (r = 0.414), lower thigh length (r = 0.450) and head width

Table 2. Weights of some carcass cuts and coefficients of correlation between these traits and the content of meat, bones and fat in the whole carcass and its middle and hind part

Trait	Statistical measures		Coefficients of correlation between the traits examined and the content of meat, bones and fat in								
			whole carcass			middle part of carcass			hind part of carcass		
	$\bar{x}$	s	meat	bone	fat	meat	bone	fat	meat	bone	fat
Weight (g)											
Ears	48	7.14	0.184	0.296	–0.270	0.113	0.139	–0.174	0.167	0.412	0.067
Front feet	23	5.02	0.266	0.703	–0.043	0.105	0.684	–0.247	0.199	0.628	–0.200
Hind feet	64	8.05	0.251	0.481	–0.028	0.151	0.254	–0.139	0.232	0.578	0.038
Heart and lungs	24	6.66	0.282	0.174	0.203	0.115	0.113	0.279	0.286	0.273	0.130
Liver	90	14.59	0.138	0.119	0.232	0.198	0.075	0.226	0.104	0.142	0.307
Skin	368	55.66	0.393	0.409	0.105	0.343	0.273	0.099	0.257	0.479	0.253
Head	197	26.39	0.664	0.641	0.162	0.440	0.569	0.023	0.645	0.714	0.102
Kidney fat	20	13.60	0.531	0.133	0.676	0.472	0.071	0.676	0.506	0.113	0.473
Kidneys	16	1.72	0.294	0.527	0.147	0.172	0.364	0.079	0.314	0.583	0.113
Thigh	293	27.93	0.940	0.725	0.383	0.813	0.626	0.135	0.958	0.728	0.293
Thigh meat	244	23.43	0.955	0.624	0.411	0.843	0.560	0.210	0.981	0.687	0.295
Thigh bones	43	6.25	0.571	0.857	–0.008	0.404	0.684	–0.233	0.539	0.932	0.012
Thigh fat	2	1.30	0.344	0.065	0.640	0.292	–0.084	0.583	0.343	0.100	0.929
Front part	106	10.63	0.753	0.730	0.272	0.638	0.633	0.027	0.759	0.758	0.023
Front part meat	84	9.14	0.768	0.683	0.132	0.644	0.656	–0.067	0.754	0.716	–0.033
Front part bones	16	1.94	0.468	0.844	0.155	0.281	0.586	–0.131	0.524	0.837	0.034
Front part fat	3	2.18	0.254	–0.031	0.642	0.312	–0.206	0.641	0.267	0.030	0.344
Loin eye height (cm)	3	0.31	0.577	0.256	0.403	0.213	0.212	0.594	0.286	0.177	0.577
Loin eye width (cm)	3	0.30	0.645	0.196	0.250	0.650	0.154	0.323	0.657	0.276	0.072

Critical values r at $\alpha - 0.05 = 0.250$; $\alpha - 0.01 = 0.325$

Table 3. Body weight, body measurements and coefficients of correlation between these traits and the content of meat, bones and fat in the whole carcass and its middle and hind part

Trait	Statistical measures		Coefficients of correlation between the traits examined and the content of meat, bones and fat in								
			whole carcass			middle part of carcass			hind part of carcass		
	$\bar{x}$	s	meat	bone	fat	meat	bone	fat	meat	bone	fat
Body weight (g)	3 054	176.29	0.839	0.569	0.360	0.720	0.521	0.253	0.767	0.600	0.399
Length (cm)											
Trunk	44	1.92	0.459	0.429	0.154	0.515	0.541	0.024	0.414	0.407	0.040
Thigh	11	0.63	0.280	0.302	0.097	0.436	0.209	–0.011	0.267	0.410	0.250
Lower thigh	14	0.67	0.447	0.561	0.220	0.278	0.529	0.085	0.450	0.514	0.130
Circumference (cm)											
Chest	30	0.93	0.214	–0.072	0.475	0.169	–0.237	0.322	0.244	–0.063	0.468
Hips	31	2.93	0.028	–0.446	–0.057	0.141	–0.435	0.174	0.003	–0.341	0.311
Half-circumference of rump	28	1.37	0.302	0.213	–0.082	0.251	0.102	–0.010	0.323	0.237	0.078
Width (cm)											
Chest	8	0.55	0.006	–0.078	–0.025	–0.026	–0.263	–0.022	–0.002	–0.029	–0.024
Pelvis	9	0.62	0.246	0.235	0.351	0.236	0.234	0.247	0.211	0.199	0.476
Head	5	0.21	0.573	0.658	–0.032	0.363	0.471	–0.097	0.540	0.685	–0.060
Chest depth	8	0.56	0.230	0.298	0.334	0.170	0.209	0.176	0.242	0.146	0.186

Critical values r at $\alpha - 0.05 = 0.250$; $\alpha - 0.01 = 0.325$

(r = 0.540). Lewczuk et al. (1999), Rymkiewicz and Lewczuk (2000) found that in New Zealand White rabbits the best indicators of the meat content of the whole carcass, saddle and hind part of the carcass were pelvic width, humerus length and chest girth, which could result from different conformation traits of these rabbits.

In the present study bone weight in the whole carcass and its parts was closely correlated with body weight (r from 0.521 to 0.600), trunk length (r from 0.407 to 0.541), lower thigh length (r from 0.514 to 0.561) and head width (r from 0.471 to 2 685 – Table 3). In New Zealand White rabbits the highest correlation was recorded between the bone content of the carcass and: front part width, pelvic width I, rump length, lower thigh length and scapula length (Rymkiewicz 1997). In Californian rabbits bone weight was strongly correlated with body weight, trunk length and scapula length (Lewczuk et al., 2000).

The traits measured *in vivo* could not be used to predict carcass fatness and the fat content of carcass parts. Significant correlations between fat weight in the whole carcass and its hind part were found only for body weight (r > 0.360) and chest girth (r > 0.468, Table 3). This confirms the opinion shared by the above authors that live body measurements cannot be considered reliable indicators of carcass fatness. They can only provide some general information on the fat content of the carcass.

As for the indicators of carcass meatiness and meat weight in the middle and hind parts of the carcass, measured *post mortem*, particular attention should be paid to carcass weight (r > 0.873, Table 1). The suitability of carcass weight for meat content estimation was also demonstrated by Lewczuk et al. (1999, 2000, 2001), Rymkiewicz and Lewczuk (2000). Among the other traits measured *post mortem*, chest girth, thigh circumference, hip circumference and pelvic width can be used to estimate carcass meatiness in rabbits. These results are consistent with those obtained by Niedźwiadek (1983), Rymkiewicz (1997), Rymkiewicz and Lewczuk (2000), Lewczuk et al. (2000, 2001). According to these authors, various carcass traits may be good predictors of carcass meatiness.

Bone weight in the whole carcass and its middle and hind parts was significantly correlated with carcass weight (r > 0.640), thigh circumference (r > 0.552) and pelvic width (r > 0.587). The fact content of the carcass and its valuable parts was usually low, and in the majority of cases non-significantly correlated with carcass weight and carcass measurements, which corresponds to the findings of Brzostowska et al. (1999) concerning Danish White rabbits.

According to some researchers (Niedźwiadek, 1983; Rymkiewicz, 1997; Brzostowska et al., 1999; Lewczuk et al., 2000, 2001), in medium rabbit breeds good indicators of carcass tissue composition are traits whose measurements require carcass cutting or dissection. The present study confirmed the suitability of leg weight, shoulder weight and the weight of meat contained in these two elements for predicting the meat content of the whole carcass and its middle and hind parts (r > 0.644; Table 2). Relatively high coefficients of correlation were also observed between loin eye width and meat weight in the whole carcass (r > 0.577), middle part (r > 0.631) and hind part (r > 0.577) of the carcass. The bone content of the carcass was closely correlated with femur weight (r = 0.921) and shoulder weight (r = 0.844), whereas the fat content of the carcass was significantly correlated with fat weight in the shoulder and leg (r = 0.642 and 0.643, respectively). However, these traits are of minor importance as indicators of carcass tissue composition in rabbits, as the procedure of their determination contributes to a decrease in the trading value and eating quality of meat.

Regression equations to estimate meat weight in the whole carcass and its valuable parts

Equation 1 may be used for *in vivo* estimation of meat weight in the whole carcass in a population of French lop rabbits weighing about 3 kg; equation 2 and 3 may be used for predicting meat weight in the middle and hind part of the carcass, respectively (Table 4). These equations are easy to apply, since each of them contains three independent variables (body weight and two body measurements). The high values of coefficients of multiple correlation between independent variables and the dependent variable (R from 0.946 to 0.973) indicate proper selection of independent variables for these equations. The high practical applicability of the above equations is also confirmed by the results of meat weight estimation in the whole carcass and its parts. The difference between the actual meat weight in the carcass and meat weight estimated by

Table 4. Multiple regression equations for *in vivo* and *post mortem* estimation of meat weight in the carcass and its parts

Equation number	Regression equation	R	S_Y
Based on traits measured *in vivo*			
1	$Y_1 = 0.55X_1 + 44.19X_2 - 49.93X_3 + 31.00$	0.972	76.67
2	$Y_2 = 0.10X_1 - 1.38X_4 + 3.58X_5 + 0.91$	0.946	24.30
3	$Y_3 = 0.18X_1 + 9.27X_2 - 8.19X_3 + 8.63$	0.973	28.98
Based on traits measured *post mortem*			
4	$Y_4 = -6.71X_6 + 0.93X_8 + 6.03X_9 + 0.73X_{10} + 11.45$	0.985	24.73
5	$Y_5 = -4.84X_6 + 10.50X_7 + 2.62X_9 + 0.13X_{10} - 143.99$	0.909	15.71
6	$Y_6 = -14.73X_6 + 2.16X_7 + 0.54X_8 + 3.96X_9 + 0.27X_{10} + 43.87$	0.976	10.73

Y_1, Y_4 – meat weight in the whole carcass (g)
Y_2, Y_5 – meat weight in the middle part of the carcass (g)
Y_3, Y_6– meat weight in the hind part of the carcass (g)
X_1 – body weight (g)
X_2 – head width (cm)
X_3 – lower thigh length (cm)
X_4 – trunk length (cm)
X_5 – thigh length (cm)
X_6 – pelvic width (cm)
X_7 – hip circumference (cm)
X_8 – chest girth (cm)
X_9 – thigh circumference (cm)
X_{10} – carcass weight (g)
R – multiple correlation coefficient
S_Y – standard error of the estimate

equation 1 was approx. 1.6 g (Figure 3). The actual meat weight in the middle part of the carcass was by 0.4 g higher, and the actual meat weight in the hind part was by 6.7 g lower than estimated by means of equation 2 and 3, respectively.

Equations 4, 5 and 6, based on carcass measurements, were characterized by smaller standard errors of the estimate (S_y from 10.73 to 24.73 g) and higher coefficients of correlation between the sets of independent variables and the dependent variable than those based on live body measurements (Table 4). The results presented in Figure 3 show that the above equations enable to estimate meat weight in the whole carcass and its valuable parts

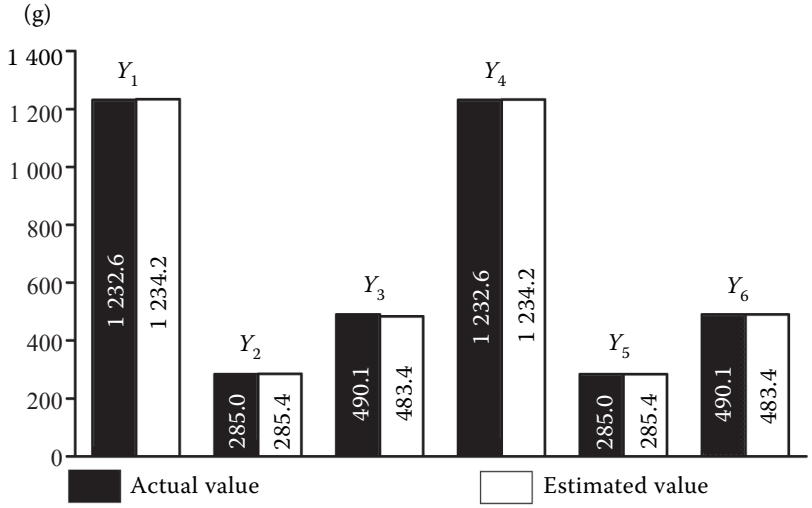

Figure 3. Results of estimation of meat weight in the whole carcass and its parts by multiple regression equations from Table 4

at very high accuracy. Some traits serving as independent variables in these equations can be measured only *post mortem*, and may be used to evaluate the results of various experiments performed on French lop rabbits with live body weights of about 3.0 kg.

CONCLUSIONS

The results obtained in this study allow to formulate the following conclusions:

The best indicators of meat weight in rabbit carcasses are body weight, head width and lower thigh length among the traits measured *in vivo*, and carcass weight, chest girth and thigh circumference among the traits measured *post mortem*.

In vivo prediction of meatiness in the middle part of the carcass may be based on body weight, trunk length and thigh length, whereas post-slaughter estimation – on carcass weight, hip circumference and thigh circumference.

Total meat weight in the hind half of the carcass may be predicted *in vivo* on the basis of body weight, head width and lower thigh length, and *post mortem* – on the basis of carcass weight, chest girth, hip circumference, thigh circumference and pelvic width.

Bone weight in the whole carcass and its parts was closely correlated with body weight, trunk length, lower thigh length and head width, measured *in vivo*, and with carcass weight, thigh circumference and pelvic width, measured *post mortem*.

The live body measurements and traits measured *post mortem* cannot be considered reliable indicators of carcass fatness.

The following equations may be applied in selection work directed towards an improvement in carcass meatiness in French lops:

$$\hat{Y}_1 = 0.55X_1 + 44.19X_2 - 49.93X_3 + 31.00$$

$$\hat{Y}_2 = 0.10X_1 - 1.38X_4 + 3.58X_5 + 0.91$$

$$\hat{Y}_3 = 0.18X_1 + 9.27X_2 - 8.19X_3 + 8.63$$

where:

$\hat{Y}_1$ = meat weight in the whole carcass (g)
$\hat{Y}_2$ = meat weight in the middle part of the carcass (g)
$\hat{Y}_3$ = meat weight in the hind part of the carcass (g)
X_1 = body weight (g)
X_2 = head width (cm)
X_3 = lower thigh length (cm)
X_4 = trunk length (cm)
X_5 = thigh length (cm)

The following equations, based on traits measured *post mortem*, may be used to evaluate the results of experiments conducted on French lop rabbits:

$$\hat{Y}_4 = -6.71X_6 + 0.93X_8 + 6.03X_9 + 0.73X_{10} + 11.45$$

$$\hat{Y}_5 = -4.84X_6 + 10.50X_7 + 2.62X_9 + 0.13X_{10} - 143.99$$

$$\hat{Y}_6 = -14.73X_6 + 2.16X_7 + 0.54X_8 + 3.96X_9 + 0.27X_{10} + 43.87$$

where:

$\hat{Y}_4$ = meat weight in the whole carcass (g)
$\hat{Y}_5$ = meat weight in the middle part of the carcass (g)
$\hat{Y}_6$ = meat weight in the hind part of the carcass (g)
X_6 = pelvic width (cm)
X_7 = hip circumference (cm)
X_8 = chest girth (cm)
X_9 = thigh circumference (cm)
X_{10} = carcass weight (g)

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