POSSIBILITY OF REDUCING CALVING DIFFICULTIES BY SELECTION

III. — A NOTE ON PELVIC SIZE IN RELATION TO BODY WEIGHT OF CATTLE [1]

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SUMMARY

Internal measurements of pelvic height and width were made on 33 nulliparous or non-nulliparous females from 10 breed groups, varying from 8 months to 6 years of age, and reared either on a conventional or a complete diet.

The allometric relation of pelvic height and width to body weight after adjustement for the effect of parturition and diet gave growth coefficients of 0.35 ± 0.04 and 0.40 ± 0.05 for height and width respectively. The inter-breed regressions for the logarithm of pelvic size adjusted for degree of maturity on the logarithm of mean mature weight were 0.46 ± 0.08 and 0.37 ± 0.10 for height and width respectively. Thus, within the limitations of the data, pelvic size could be estimated at any stage of maturity with an error of ± 7 p. 100 (or ± 4 p. 100 if adjusted for parturition, diet and breed) from the equations :

$$\text{pelvic height (cm)} = 1.63 \ (\text{body weight in kg})^{0.4}$$
$$\text{pelvic width (cm)} = 1.22 \ (\text{body weight in kg})^{0.4}$$

The effect of one or more parturitions was to increase *expected* pelvic height by 9-15 p. 100 and width by 3-12 p. 100. The effect of intensive rearing was to reduce *expected* pelvic height by 10-14 p. 100 and width by 4-7 p. 100.

The implication of these results is that, in the index of calving difficulties obtained by MONTEIRO (1969), the body weight exponent of 0.4 and the parturition effect of 10 p. 100 were both functioning as predictors of linear pelvic size. The ratio of pelvic size to (body weight)$^{0.4}$ might therefore be the appropriate form for a selection index against calving difficulties.

I. — Technique de mesure de l'ouverture pelvienne des bovins : F. MENISSIER, B. VISSAC, 1971. *Ann. Génét. Sél. anim.*, **3**, 207-214.

II. — Aptitude au vêlage de trois races à viande françaises : F. MENISSIER, B. BIBE, B. PERREAU, 1974. *Ann. Génét. Sél. anim.*, **6**, 69-90.

INTRODUCTION

The relationship between calving difficulties and internal pelvic size has been studied by MENISSIER and VISSAC (1971) and MENISSIER, BIBÉ, and PERREAU (1973). In a study involving the factorial crossing of *Limousin, Charolais* and *Maine Anjou* cattle, they found that as a dam breed the *Limousin* had least difficult calvings. The superiority of the maternal component of ease of calving in the *Limousin* was attributed to the lower birth weight of the calves and to the larger pelvic area relative to their body weights. By contrast, the *Charolais* with lower birth weight than the *Maine Anjou* had the smaller pelvic area per unit weight and consequently had the poorest performance of the three breeds with respect to ease of calving.

LASTER (1974) analysed the effect of pelvic area on calving difficulties in 14 different breed groups and found a very significant within-breed relationship between pelvic area and body weight among animals at the same age, but not a very strong within-breed association between pelvic area and calving difficulties. The corresponding inter-breed relationships were not subjected to a similar analysis, but the purebred and crossbred means showed that there was a tendency for calving difficulties to become more frequent as mean body weight and mean pelvic area increased.

MONTEIRO (1969) used data from *Friesians, Ayrshires* and *Jerseys* and their crosses to develop an index of calving difficulty based on the relationship of calf birth weight to dam weight. This index was essentially the ratio of calf birth weight to dam weight raised to the power 0.4, this being the power which gave the best discrimination between difficult and easy parturitions. MONTEIRO suggested that (dam weight)$^{0.4}$ might well be an indirect measure of some critical dimension of length, width or area associated with pelvic size or calf size. This note presents some relevant data on the relationship of internal pelvic measurements to body weight at different stages of growth and also across breeds.

MATERIAL AND METHODS

Measurements of pelvic height and width were taken on 33 females from 6 different breeds and 4 different crosses, ranging from 8 months to 6 years of age. Most animals (27) had not had a calf even though some were 3 or 4 years old. About half the animals (18) were reared on a conventional diet and treated in the normal traditional manner for dairy cattle. Of these 11 were *Ayrshires* and 5 were *Herefords* and they provided the main range of ages. Four *Ayrshires*, one *Hereford* and all animals from the other 8 breeds or crosses had been fed *ad libitum* on standard complete diet A.A.6 (a nutritionally balanced all-pelleted ruminant diet containing 30 p. 100 of chopped straw), and these intensively reared animals ranged from 15 to 50 months of age. The comparison of conventional and complete diet was somewhat confounded with breed differences.

The technique described by MENISSIER and VISSAC (1971) was used to take internal measurements of the height and width of the pelvic opening. All measurements were made by the same observer.

The variables analysed were the natural logarithms (ln) of pelvic height (y_h cm), pelvic width (y_w cm), body weight (W kg), and mean mature weight (M kg). Body weight was expressed

in terms of degree of maturity in order to separate the growth and inter-breed components of the relationship. Only the breed mean for mature weight was used, and mature weight therefore had the same value for all individuals of the same breed. RUSSELL's (1970) least-squares « Compreg » program was used for the statistical analysis. Three different linear models were used and applied separately to pelvic height and pelvic width. These models were

$$\ln y_{ijkl} = \alpha(\ln W_{ij} - \ln M_i) + \beta \ln M_i + d_k + p_l + c + \varepsilon_{ijkl} \tag{1}$$

$$\ln y_{ijkl} = \alpha' \ln W_{ij} + b_i' + d_k' + p_l' + c' + \varepsilon_{ijkl}' \tag{2}$$

$$\ln y_{ijkl} = 0.4 \ln W_{ij} + b_i'' + d_k'' + p_l'' + c'' + \varepsilon_{ijkl}'' \tag{3}$$

where α is the allometric or growth coefficient, β is the inter-breed regression coefficient, d_k is the effect of k the diet, p_l is the parturition effect, ε is the regression constant, and the ε_{ijkl} are residual errors for the jth animal from the ith breed. In model (2), α and β are assumed to be equal, and the b_i are a set of breed constants with crosses regarded as different breeds. In model (3) the allometric and inter-breed regression coefficients are all set equal to 0.4. In all models the limitations of the data precluded useful tests for linearity of regression and interactions between parturition, diet and breed, while in model (1) the data was insufficient to estimate separate weighting factors for breed deviations from the regression and individual deviations from the breed means. To this extent the standard errors and tests of significance are only approximations; but since there was usually only one animal in each parturition × diet × breed × weight-interval sub-class, the conclusions are unlikely to be seriously affected.

RESULTS

Pelvic height ranged from 13 cm in an 8 month old *Ayrshire* up to 21 cm in a 6 year old biparous *Ayrshire*. The corresponding range for pelvic width was 10 to 18 cm. In nulliparous females over 3 years of age, pelvic height ranged from 17 cm in a *Dexter* up to 30 cm in a *British White*. The corresponding breed range for width was 12 to 18 cm. Body weight ranged from 198 to 710 kg. Mean mature body weight on the complete diet, which was about 30 p. 100 greater than mean mature weight on the conventional diet, ranged from 440 kg in the *Dexter* breed up to 750 kg in the *British White*. Animals ranged from being about 30 p. 100 mature in body weight to being almost fully mature.

Model (1)

The results obtained from the least squares analysis are shown in table 1.

There were highly significant allometric relationships between pelvic size and degree of maturity in body weight. There was an equally significant increase in pelvic size with mean mature weight of breed. For pelvic height the effect of stage of maturity was insignificantly greater than the effect of mean breed weight (0.35 and 0.46), while for pelvic width there was an insignificant difference in the reverse direction (0.40 and 0.37). It was somewhat surprising that the non-genetic allometric relationship and the genetic inter-breed relationship should be almost the same.

The growth coefficients for pelvic height and pelvic width were very similar, and suggest that both height and width were growing at about the same rate relative to body weight. Thus pelvic height appeared to be on average about 33 p. 100 greater than pelvic width. Differences probably exist at different stages of growth but they could not be determined in the present data.

The fitted regressions accounted for 83 p. 100 and 78 p. 100 of the total observed

variation in pelvic height and width respectively, while the residual standard deviations indicate that pelvic height and width might be predicted with errors of about ± 5 p. 100 and ± 7 p. 100 respectively.

TABLE I

Least-squares analysis (model 1) *of pelvic size in relation to degree of maturity in body weight and mean mature weight of breed*

Analyses par moindres-carrés (modèle 1) *de l'ouverture pelvienne en relation avec le degré de maturité pour le poids et avec le poids adulte moyen des races*

	d. f. (*degré de liberté*)	Pelvic height (*hauteur sacro-pubienne*)	Pelvic width (*largeur bisiliaque*)
Mean (geometric) (*moyenne géométrique*)	32	17.2 cm	13.6 cm
Multiparous - Nulliparous (*p*) (*multipares - nullipares*)	1	(9.4 ± 3.1) %	(3.2 ± 4.0) %
Conventional - Complete diet (*d*) (*aliment conventionnel - aliment complet*)	1	(9.8 ± 2.7) %	(4.8 ± 3.5) %
Partial regression on log. degree of maturity in body weight (α) (*régression partielle sur le log. du degré de maturité pour le poids*)	1	0.35 ± 0.04	0.40 ± 0.05
Partial regression on log. mean mature body weight (β) (*régression partielle sur le log. du poids adulte moyen*)	1	0.46 ± 0.08	0.37 ± 0.10
Regression constant (*c*) [1] (*constante de la régression*)	1	0.05 ± 0.51	0.42 ± 0.66
Residual standard deviation (*écart-type résiduel*)	28	5.3 %	6.8 %
Multiple correlation coefficient (R^2) (*corrélation multiple*)	—	0.83	0.78

[1] For nulliparous animals on conventional diet.
(*Pour des animaux nullipares avec l'aliment conventionnel*).

Parturition was estimated as permanently increasing pelvic size by (9.8 ± 2.6) p. 100 in height and (3.2 ± 4.0) p. 100 in width. The significant and much greater increase in height than in width is somewhat unexpected.

Animals grow about 30 to 40 p. 100 faster in body weight on the complete diet than on the conventional diet. The allometric relation of pelvic size to body weight may also be affected. With more data it would have been desirable to estimate different growth coefficients and constants for each diet. Only different constant

were fitted. For animals on the complete diet pelvic size was smaller in relation to body weight than for animals on a conventional diet by (9.8 ± 2.6) p. 100 for height and (4.8 ± 3.4) p. 100 for width although these estimates may to some extent be confounded with breed differences. Intensive rearing thus appeared to promote relatively more fattening than bone growth. Caution is therefore necessary where body weight of intensively reared females is used as a guide to their readiness for insemination.

Model (2)

In view of the similarity of the allometric and inter-breed coefficients, the data were re-analysed with body weight as the only continuous variable and with the mean mature weight of each breed replaced by a set of breed deviations or constants. The amount of variation accounted for by breed differences was highly significant.

TABLE 2

Least squares analysis (models 2 and 3) *of pelvic size in relation to body weight, breed, parturition and diet*

Analyses par moindres-carrés (modèles 2 et 3) *de l'ouverture pelvienne en relation avec le poids, la race, le vêlage et l'alimentation*

	d.f. (degré de liberté)	Pelvic height (hauteur sacro-pubienne)	Pelvic width (largeur bis-iliaque)
Multiparous - Nulliparous (p) (*Multipares - Nullipares*)	1 [1] (2)	(14.7 ± 2.9) % [14.7 ± 2.9]	(11.1 ± 3.3) % [11.5 ± 3.5]
Conventional-Complete diet (d) (*Aliment conventionnel - aliment complet*)	1 [1]	(13.6 ± 2.9) % [13.7 ± 2.3]	(7.0 ± 3.3) % [4.1 ± 2.8]
Breed differences (b_i) (*Différences entre races*)	9 [9]	Highly significant [d^o]	Highly significant [d^o]
Regression on log body wieght (α) (*Régression sur le log du poids*)	1 [0]	(0.39 ± 0.04) [0.40]	(0.47 ± 0.05) [0.40]
Regression constant (c) (1) (*Constante de la régression*)	1 [1]	(0.54 ± 0.23) [0.49 ± 0.02]	$-\ 0.22 \pm 0.27$ [0.20 ± 0.02]
Residual standard deviation (*Écart-type résiduel*)	20 [21]	4.0 % [4.0 %]	4.6 % [4.8 %]
Multiple correlation (coefficient R^2) (*Corrélation multiple*)	— —	0.93 [0.93]	0.93 [0.92]

(1) For nulliparous animals on conventional diet.
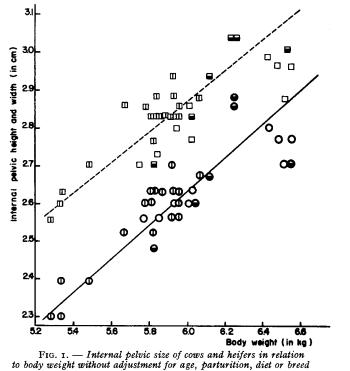 (*Pour des animaux nullipares avec l'aliment conventionnel*).
(2) Entries in square brackets are for a regression coefficient fixed at 0.4.
  (*Entre crochets figurent les valeurs obtenues pour un coefficient de régression fixé à 0,4*).

The *Ayrshire* breed had a pelvic opening (2.3 ± 1.6) p. 100 higher and (6.5 ± 1.9) p. 100 wider relative to body weight than the average for all breeds. The corresponding values for the *Hereford* were (— 2.9 ± 1.3) p. 100 and (— 1.5 ± 2.6) p. 100, both less than average but neither significantly so. The only other breed with a significant deviation was the Dexter which was below the average for all breeds by (10.8 ± 3.5) p. 100 in height and (9.2 ± 4.0) p. 100 in width. The proportion of the total variation accounted for increased to 93 p. 100 and the accuracy with which pelvic size was estimated from body weight also increased, being ± 4.1 p. 100 for height and 4.6 p. 100 for width.

The regression on log body weight now appeared to be slightly greater for width than for height, more consistant with the evidence from external measurements that the whole pelvic structure matured somewhat more slowly in width than length or height. Estimates of the effect of parturition and diet were slightly greater and became significant for pelvic width (table 2).

FIG. 1. — *Internal pelvic size of cows and heifers in relation to body weight without adjustment for age, parturition, diet or breed*

(Mensurations de l'ouverture pelvienne des vaches et des génisses, en liaison avec leur poids sans ajustement pour l'âge, le vêlage, l'alimentation ou la race)

□------□ Pelvic height (cm) = 1.63 $W(kg)^{0.4}$
[*hauteur sacropubienne*]

o———o Pelvic width (cm) = 1.22 $W(kg)^{0.4}$
[*largeur bisiliaque*]

	Complete diet (*aliment complet*)	Conventional diet (*aliment conventionnel*)
Nulliparous (*nullipares*)	□ o	
Multiparous (*multipares*)	▣ ◓	◐ ▥

Model (3)

The allometric and inter-breed regression coefficient in model (1) and the allometric coefficient for pelvic height and width in both models (1) and (2) were very similar and all close to 0.4. The analysis was therefore repeated with the regression coefficients fixed at 0.4. Virtually the same set of results were obtained except that the regression constants were then very much more accurately determined (table 2). This model accounted for 92-93 p. 100 of the total variation and gave estimation errors of $\pm$ 4-5 p. 100. The present limited data was therefore adequately summarised in terms of a single coefficient of 0.4. Thus pelvic size could be roughly estimated from body weight at any stage of maturity and in any breed by the simplified equations :

$$\text{pelvic height (cm)} = 1.63 \text{ (body weight in kg)}^{0.4}$$
$$\text{pelvic width (cm)} = 1.22 \text{ (body weight in kg)}^{0.4}$$

in which the constants refer to nulliparous females on conventional diet.

In figure 1 the plot of the data unadjusted for the effect of parturition, diet or breed shows the extent of gross deviations from these simplified regression equations. When parturition, diet and breed were ignored, these equations accounted for only 65 p. 100 and 76 p. 100 of the total variation in height and width respectively (instead of 92-93 p. 100) and gave estimation errors of $\pm$ 7 p. 100 for both height and width (instead of $\pm$ 4-5 p. 100). When comparing breed deviations, adjustments should therefore be made for parturition and also diet if possible.

DISCUSSION

The most interesting result is the approximate uniformity of the relationship of both pelvic height and width to degree of maturity and mean mature weight of breed. The best prediction of pelvic size from body weight both during growth and accross different breeds was given by an exponent of about 0.4. In MONTEIRO's (1969) study of the relationship between calf weight, dam weight and calving difficulties, precisely the same value of 0.4 was found to give the best descrimination between dams with difficult and easy parturitions. Moreover, the effect of changing from nulliparous to parous females was to increase MONTEIRO's index of calving difficulties by 0.1. In non-logarithmic terms this is equivalent to an increase of about 10 p. 100, which is again similar to the difference in pelvic size between parous and nulliparous females found in the present data (9-15 p. 100 in pelvic height, and 3-12 p. 100 in pelvic width).

The implication is that, in MONTEIRO's index of calving difficulties, dam weight to the power 0.4 was functioning as an estimator of pelvic size. Thus the ratio of calf weight to pelvic height or pelvic width or their geometric mean (but *not* their product) should also serve as an index of calving difficulties. Calving difficulties would then depend on the ratio of calf weight to a linear dimension which of necessity increases very much more slowly than body weight, so that calving difficulties must be expected to be greater for larger breeds.

Selection to decrease calving difficulties might therefore aim to increase the ratio of pelvic size relative to calf birth weight. A more attractive alternative would be to use pelvic size relative to body weight in the form (pelvic size)/(body weight)$^{0.4}$ or with separate exponents for height and width. Such an index could be used irrespective of age and breed and with a 10 p. 100 correction for the effect of a first parturition. A restricted selection index may be necessary to prevent selection reducing body weight but no valid assessment can be made without information on heritabilities and genetic correlations both within and between breeds.

Another conclusion also appears to be that a *linear* pelvic measurement is more relevant and critical in relation to calving difficulties than is the area of the pelvic opening.

All conclusions from the present data are very tentative, but they point to the potential value of an index based on pelvic size and body weight and hence to the need for more accurate estimates of both the allometric and interbreed relationships of pelvic size and body weight.

Reçu pour publication en janvier 1975.

ACKNOWLEDGEMENTS

RÉSUMÉ

POSSIBILITÉS D'AMÉLIORATION DES CONDITIONS DE VÊLAGE PAR SÉLECTION.
III. — NOTE SUR LA RELATION ENTRE L'OUVERTURE PELVIENNE ET LE POIDS CHEZ LES BOVINS

Les mensurations internes de hauteur sacro-pubienne et largeur *bis*-iliaque ont été faites sur 33 femelles nullipares ou multipares de 10 types génétiques, d'âge variant de 8 mois à 6 ans ; elles ont été élevées soit avec une alimentation traditionnelle (aliment conventionnel) soit avec une alimentation complète standardisée (aliment complet).

La relation d'allométrie entre la hauteur et la largeur de l'ouverture pelvienne avec le poids après ajustement pour l'effet du vêlage et de l'alimentation, donne des coefficients de croissance de 0,35 ± 0,04 et 0,40 ± 0,05 respectivement pour la hauteur et la largeur.

Les régressions entre races du logarithme de l'ouverture pelvienne ajustée pour le degré de maturité sur le logarithme du poids moyen adulte, sont de 0,46 ± 0,08 et 0,37 ± 0,10 pour la hauteur et la largeur respectivement. Donc, dans la limite de notre information, l'ouverture pelvienne pourrait être estimée à un stade quelconque de maturité avec une erreur de ± 7 p. 100 (ou de ± 4 à 5 p. 100 si les données sont ajustées pour les effets de vêlage, de l'alimentation et de la race), par les équations suivantes :

$$\text{hauteur sacro-pubienne (cm)} = 1,63 \text{ (poids en kg)}^{0.4}$$
$$\text{largeur } \textit{bis}\text{-iliaque (cm)} = 1,22 \text{ (poids en kg)}^{0.4}$$

L'effet d'un ou plusieurs vêlages accroît la hauteur sacro-pubienne *espérée* de 9 à 15 p. 100 et la largeur *bis*-iliaque *espérée* de 3 à 12 p. 100. L'effet d'un élevage intensif réduit la hauteur *espérée* de 10 à 14 p. 100 et la largeur *espérée* de 4 à 7 p. 100.

De ces résultats nous déduisons que dans l'index de difficultés de vêlage établi par MONTEIRO (1969), l'exposant (0,4) du poids des mères et l'effet (10 p. 100) du vêlage servent tous deux de prédicteurs des mensurations linéaires de l'ouverture pelvienne. Le rapport de l'ouverture pelvienne ou poids à la puissance 0,4 pourrait être un index de sélection approprié contre les difficultés de vêlage.

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