VARIATION OF THE SKELETAL MATURITY IN BEEF CARCASES AND RELATIONSHIP WITH AGE.

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INTRODUCTION
With age the body components undergo continuous changes which concern both anatomical structure and physiology. This "ageing" process affect many aspects of the texture and the composition of the different tissues.
The meat industry is directly interested by this biological phenomenon as quality traits of meat are largely dependent of the age of the animal, namely as tenderness or colour are concerned. This is of special importance in beef where the age at slaughter may be very variable, specially in females were all the intermediate exist between the young heifer and the very old cull cow.
The main problem involved in the management of animal age in beef industry comes from its determination.
Most of time, age is not exactly known at the slaughter-plant and one must assess it from some of the changes produced by ageing on the morpho-anatomical structure of the animals at various locations in the body. The variation in the shape of bones (during growth) and mainly the variation in their structure (resulting at first from ossification and, later on in the senile bones, of the decrease of the organic matter) may be used to judge the age of cattle at slaughter.
The parts of skeletal system visible in the split carcase offers thus many sites which are commonly used by the trade to get indication of the animal's age.

To assess the skeleton ossification, a standardized method of visual assessment using descriptive scale for different sites has been proposed by ROY *et al* (1970). The visual assessment of the stage of ossification by some other specific methods was also used by LEACH and AKERS (1972) and by KLASTRUP and SØRENSEN (1987) who also considered the relation between age and ossification at four sites in the carcase.

This papers presents the results of a study conducted on a large sample of beef carcases of various types to study the relationship between age and the morpho structural characteristics of the split bones visible in a beef side.

MATERIALS AND METHODS
The study has been conducted in two parts :
1) in a first part a sample of 506 beef carcases of different commercial types was used, by considering animals of the four sexual types [young bulls (N=240), steers (N=51), heifers (N=65), cows (N=150)] and of different genetic types [from beef type (Charollaise, Limousine, Maine Anjou, Hereford) to dairy type (Frisonne Pie Noire, Tarine, Abondance...) or dual purpose (Normande, Salers...)].
At the slaughter-house, 24 hours *post mortem*, on chilled carcases, assessment of ossification of the skeleton was carried out using the method of ROY *et al* (1970) which involved an examination of :
a) the profile of the pelvic symphysis (PSP) (11-points scale),
b) the shape of the ventral pubic tubercle (VPT) (8-points scale),
c) the degree of ossification and fusion of the bones of the sternum (STE) (12-points scale),

d) the degree of fusion of the bodies of the sacral vertebrae (SVB) (13-points scale),
e) the degree of fusion of the spinous processes of the sacral vertebrae (SVP) (10-points scale),
f) the degree of ossification of the spinous processes of the thoracic vertebrae (TSP) (13-points scale).
2) In a second part the same procedure has been applied on one sample of N=337 carcases which was one sub-set of the sample used in 1). For these animals the chronological age at slaughter (CA, in days) was known.
For the statistical treatment, the scores of the individual sites were considered as variables. In addition, for each carcase were calculated :
a) the values of the sum of five out of the six scores (named respectively psp, vpt, ste, svb, svp, tsp and considered as partial index of skeletal maturity), with :

psp : = VPT+STE+SVB+SVP+TSP
....
....
tsp : = PSP+VPT+STE+SVB+SVP

b) the values of the sum of the six scores considered as the total maturity index of the skeleton (MAT) :

MAT=PSP+VPT+STE+SVB+SVP+TSP

In each study for the whole population, the mean and coefficient of variation of the variables defined above were calculated as well as the correlations between variables.
In the second study it was possible to make this calculation for some sub-samples of carcases (e.g. for carcases of the same type of cattle, as sex and breed were concerned).
A progressive regression analysis was conducted to calculate the percentage of the CA variation which was explained by different combinations of variables.

RESULTS

Study 1

The mean and coefficient of variation of the individual scores of maturity and of MAT are given in Table 1 in wich is also indicated the range observed.

Table 1

Level	Mean	C.V(%)	range min.	range max.
PSP	3.28	58.8	1	11
VPT	2.82	60.6	1	8
SVP	3.20	65.7	1	10
SVB	2.81	78.0	1	13
TSP	3.35	65.4	1	13
STE	2.71	60.3	1	12
MAT	18.17	59.9	8	64

The inter corrrelations between scores are given in Table 2 and the correlations between scores and the partial maturity index are in Table 3.

Table 2

	PSP	VPT	SVP	SVB	TSP	STE
VPT	.838					
SVP	.826	.856				
SVB	.790	.839	.907			
TSP	.812	.821	.889	.863		
STE	.723	.786	.785	.809	.807	
MAT	.899	.923	.954	.944	.941	.879

Table 3

psp/PSP	0.855
vpt/VPT	0.894
svp/SVP	0.930
svb/SVB	0.913
tsp/TSP	0.909
ste/STE	0.836

Study 2

The mean and coefficient of variation of the individual scores of maturity, MAT and CA are given in Table 4.

Table 4

Level	Mean	C.V.(%)	range min.	range max.
PSP	3.10	59.28	1	9
VPT	2.60	61.47	1	8
SVP	2.90	65.58	1	9
SVB	2.40	78.98	1	9
TSP	3.00	62.12	1	8
STE	2.60	56.05	1	7
MAT	16.68	59.21	8	44
CA	935.6	72.32	412	2537

The intercorrelations between variables are given in Table 5.

Table 5

	PSP	VPT	SVP	SVB	TSP	STE	MAT
VPT	.850						
SVP	.854	.835					
SVB	.854	.843	.943				
TSP	.824	.788	.884	.873			
STE	.734	.774	.807	.832	.794		
MAT	.921	.911	.960	.963	.930	.879	
CA	.862	.856	.926	.918	.921	.821	.954

The multiple regression analysis of CA variation shows that when considering all the six variables, one can explain 92.1 p. cent of the CA variation (P < 0.001). In table 6 are given the percentages of explanation given by different variables or set of variables.

Table 6

Variables	Explanation of the variation of CA(%)
SVB	84.3
SVB,SVP	87.5
SVB,TSP	90.2
SVP,TSP	90.5
SVB,TSP,SVP	91.1
all	92.1
MAT	91.1

The relationship between CA and MAT can be expressed by the two equations :

$$CA = 65.405\ MAT - 155.06$$
with residual s.d. = $\pm$ 202.2

or

$$MAT = 0.014\ CA + 3.65$$
with residual s.d. = $\pm$ 2.95.

DISCUSSION

The first conclusion that one can draw from the experience 1 is that in one large commercial sample of beef carcases one finds a wide range of state of maturity of the skeleton (table 1). The overall variation is high but SVB is, by far, the site the most variable.

The variability observed in MAT (which summarizes the skeletal maturity taken as a whole) suggests that the different sites react in a similar way to the influence of a common or unique factor of variation. It is clear that we may easily suppose that the differences in age existing between individuals can be considered as that one. The correlations between the scores at different sites (table 2) are rather high, highly significant, and lead to suppose that each site is very largely affected in the same manner by the variation of age.

The close relationship existing between sites is also demonstrated by the data of table 3 which clearly show that the variation of any site explains a very great part of the variation of the sum of the others (from 69.89 for STE to 86.49 p. 100 for SVP).

The close relation between the degree of evolution of the stage of ossification and the age of cattle at slaughter appears clearly from the results of the second part of the trial in which the date of birth of the animals was known. CA is very closely related to the degree of evolution of the skeletal changes assessed at each site and, here, the variation of CA explains ($P < 0.001$) from 67.4 (for STE) to 85.7 p. 100 (for SVP) of the variation of the maturity scores. When considering combinations of sites one improves the percentage of explanation, which suggests that in addition to the common effect of age, each site reacts in a specific way to the variation of age.

One could try to state the best mathematical model (other than the multiple linear regresion model) which would maximize the percentage of explanation of CA from the different maturity scores.

At the moment, in our opinion, MAT yet offers a fair estimation of CA (and reciprocally). The relationship between CA and MAT is highly significant ($P<0.001$). In the range of CA considered here it is thus clear that the skeletal changes revealed by the increase of MAT are one of the essential manifestation of the general processus of ageing in cattle.

The practical application of the CA/MAT relationship must be considered in two directions :

a) how is it possible to estimate CA from MAT assessment ?

b) for a given CA, which is the probable MAT?

Before discussing these aspects the accuracy of MAT assessment must be borne in mind.

MAT is the sum of the six individual scores, each of one being estimated with an absolute error of $\pm$ 0.5 scale unit. The maximum absolute error of MAT (**e**) is $\pm$ 3 scale units. MAT assessment is thus relatively more accurate the MAT value is higher. From this consideration it is evident that as **e** is quite of the same magnitude whatever the scaling system, systems which use numerous points for scoring each site (such as the ROY's system does) are better than those which are more restrictive.

The possible error in MAT assessment is supposed to be limited to **e** only, being considered, by own experience, that the visual assessment has been proved to be highly reproducible and to show a very high repetability.

Another source of error in MAT appraisal can come from that, for any carcase of a given CA, the appearance of the different sites may be altered by the dressing conditions and specially by the splitting.

The description of the definition of the stage of ossification at each site is based on the hypothesis that the plane of examination is the medial plane of the carcase. Artificial variations in splitting the carcase may result in changing pattern of ossification being uneven distritubed between the two sides and that the apparent medial pattern being not the "normal" one. This seems more frequent for the distal sites (PSP, VPT...) than for the others. It is clear that the consequences of such variations on the assessment of the maturity are also more important in systems based on two few sites of examination (3 or 4) for which the error is relatively greater.

The residual standard deviation in the relation (MAT/CA) could also be explained by the existing biological variation existing between animals in the pattern of ossification changes with age. Some informations on this point may be found in this study from the variation existing :

- within animals of the same sex, age, breed and system of management (table 7),
- or between groups of animals of the same sex and CA, but of different breeds (table 8).

Table 7

	n	CA*	PSP	VPT	SVP	SVB	TSP	STE	MAT
Young bulls									
AB	10	480	2.6	1.9	2.1	1.4	2.6	2.1	12.7
HN	15	482	2.0	2.0	1.4	1.1	1.9	1.5	9.8
HC	10	483	2.3	1.8	1.7	1.3	1.9	2.1	11.2
Hn	21	487	1.7	2.3	1.7	1.4	1.8	1.8	10.6
NO	32	489	2.2	1.8	1.8	1.4	1.9	2.0	11.0
HH	17	491	2.0	1.9	1.7	1.3	1.9	1.8	10.6
TA	10	491	2.8	1.7	1.8	1.5	2.3	2.3	12.4
FF	13	492	1.8	1.5	1.7	1.2	1.5	2.1	9.8
HF	12	492	1.9	1.2	1.8	1.3	1.6	2.1	10.0
MB	9	495	1.9	1.2	2.1	1.9	2.4	2.1	11.7
SA	10	509	2.6	1.8	1.8	1.5	2.1	1.9	11.7
Cows									
CH	16	1718	4.4	3.7	4.8	3.9	4.9	2.6	24.3
LI	12	1715	4.5	3.3	4.9	4.3	5.2	2.9	25.2
HE	6	1690	6.2	5.5	5.5	5.0	5.0	3.0	30.2
MA	12	1724	5.8	3.7	4.8	4.1	5.6	2.8	26.7

AB = Abondance / CH = Charollaise / FF = Française Frisonne pie-noire / HC = Holstein x Charollais / HE = Hereford / HF = Holstein x Française Frisonne Pie noire / HH = Holstein / HN = Holstein x Normand / Hn = 3/4 Holstein x 1/4 Normand / LI = Limousine / MA = Maine-Anjou / MB = Montbéliarde / NO = Normande / SA = Salers / TA = Tarine.
* in days

From table 8 it seems that some differences between breeds could exist in the average level of ossification of the various sites at the same age. It thus appear that in cows of about 1700 days skeletal maturity is earlier in Hereford cattle that in the French native beef breed. Similar conclusions may be suggested from the comparisons of other breeds in the case of young bulls. This point might be studied in the future on larger sample of animals to set exactly which importance must be put on taking in consideration any breed effect in the MAT/CA relationship.

Table 8

		CH	LI	MA	NO
		n=16	n=12	n=12	n=23
CA*	x	1718	1715	1724	2432
	CV%	2.1	1.7	2.5	2.0
PSP	CV%	20.2	32.1	26.9	16.0
VPT	CV%	24.8	41.1	21.2	15.6
SVB	CV%	23.6	26.6	35.3	11.3
SVP	CV%	14.4	23.7	27.7	10.6
TSP	CV%	16.5	23.1	20.9	13.1
STE	CV%	23.6	22.9	25.3	12.9
MAT	CV%	11.41	20.1	18.9	4.4

CH = Charollaise / LI = Limousine / MA = Maine-Anjou / NO = Normande
* in days

One possible way to improve the estimation of CA from MAT (or inversely), by reducing the residual standard deviation, would probably result from a more complete quantification of the ossification process with age. The quantitative evaluation by description is necessarily limited and the objective might be to substitute description for direct measures of the morphological changes taking place during ageing at the different sites. The automation of assessment of skeletal maturity which seems to be one of the aim of carcass grading system in the future will oblige to translate the actual definition of the stage of maturity into terms of biometrical morpho-anatomy. For instance it is suggested to measure the variation of PSP by considering the shape of both proximal (or cranial) and distal (or caudal) profiles of the symphysis at the same time as its depth at different locations. In the same way one may measure the variation of VPT by considering the area and shape (e.g. from a flatness ratio) of the pubic tubercle. Likewise the difference of color between cartilage and spongy and compact bone substance could be used to quantify the ossification pattern of the thoracic vertebrae by measuring the relative part of each spinous process which is affected by the progressive ossification. All the progress in that field relies on the accurate definition in morpho-anatomical terms, by appropriate measurements, of the variation of maturity and its translation into an adequate programme of image analysis.

CONCLUSION

From the data obtained in this study one may draw the general conclusion that in the range from 400 to 2500 days the stage of ossification of the whole skeleton and age are highly related, being considered that the overall skeletal maturity was assessed in several sites and by using a rather large and detailed scale. For some sites it seems possible to pass from one visual descriptive assessement to image analysis of the quantified changes. Such quantification would probably be very useful to state how could be interesting for the trade - which can only consider the predicted age from the skeletal maturity - the study of the relationship existing between the age of the animal, its skeletal maturity and the age - related changes in meat quality, as those concerning meat toughness (which were yet considered by BALAND in rather young cattle and by KLASTRUP and SORENSEN in cows) or the amount of haem iron which seems to be a very age - dependent trait (BOUSSET and DUMONT).

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