THESES OF DOCTORAL (PhD) DISSERTATION

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CORRELATION BETWEEN S/EUROP QUALIFICATION AND THE SLAUGHTER VALUE OF SHEEP

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1. ANTECEDENTS AND OBJECTIVES OF THE RESEARCH

Since 1 January 2001, low-weight (*<13 kg*) and high-weight (*>13 kg*) sheep carcasses have to be qualified in conformity with the standard (*Règlement, CEE n^{o}2137/92; n^{o}461/93*) currently in force in countries of the European Union (*further on:* EU). Since 1 January 2002, a decree [*Decree No. 16/1998 (IV. 3.) FM of the Ministry of Agriculture*] has been in force also in Hungary that regulates the application of a qualifying system identical with the quality certification system of the EU. From the aspect of breeding, the disadvantage of this so-called S/EUROP sheep carcass qualifying system is that it allows the qualification of animals only in slaughtered state; as a result, valuable breeding animals may be lost when determining body conformation and fatness characteristics individually.

In recent decades, the advent of computed tomography (CT) has opened up new paths in the field of animal studies by facilitating *in vivo* measurement of tissue composition of the body.

Like in other animal species, also in the case of sheep it would be desirable to judge breeding animals in live state, on the basis of the valid slaughterhouse qualification, in order to move towards the quality demanded by consumers also in the field of breeding. For this, we must first determine the correlation between the S/EUROP qualification categories and the anatomic structure of live animals. When this is done, such measurement methods will have to be developed which can predict the S/EUROP carcass quality from results of the CT examination of live animals with sufficient accuracy.

The objective of this Ph.D. dissertation was to answer the following questions:

1. What correlation exists between parameters measured and calculated *in vivo* by CT and S/EUROP conformation and fatness characteristics?

2. Which of the tissue areas, body measures and pixel frequency values measured by CT and which of the indices derived from them are the most suitable for *in vivo* estimation of the S/EUROP quality of sheep (*or of the Australian EUROP fatness condition*)?

3. Can the S/EUROP conformation and the Australian EUROP fatness categories be depicted with the help of three-dimensional (3D) diagrams? Can the differences between categories be measured numerically on these diagrams?

4. As S/EUROP qualification is based on the judgement of carcass conformation, my aim was to identify those parameters measurable on the carcass and those indices derived from the former which showed the closest correlation with the quality categories used in S/EUROP qualification.

5. I also wished to determine whether the data obtained during slaughtering, dressing and boning support the subjective estimations made during S/EUROP qualification.

6. The final objective was to determine whether the method based on the established correlations was suitable for preparing a CT-based S/EUROP qualification.

2. MATERIALS AND METHODS

During the experiment, a total of 87 lambs (*42♂, 45♀*) belonging to 5 different breeds or genotypes (*Ile de France, Hungarian Merino, British milk sheep, British milk sheep x Ile de France, British milk sheep x Suffolk*) were examined by CT for *in vivo* determination of the S/EUROP qualification category of individual sheep (Table 1) and for the performance of probationary (test) slaughtering (*n=87*). The different genotypes served only as a means of providing the widest possible range of S/EUROP sheep carcass qualification categories and for demonstrating the validity of the calculated indices.

With the purpose of approaching the S/EUROP carcass conformation and fatness characteristics qualification system, I searched for fixed anatomical points that represented the body parts having a decisive role in this qualification and the examination of which can be repeated in a reliable manner at any age or liveweight. Subsequently, of the spiral CT images taken in the entire length of the body I used those images that covered the carcass. After CT examination and slaughtering the lambs were qualified according to the regulations of S/EUROP qualification. The carcasses were chopped and finally the chopped carcass parts were boned.

The correlations were analysed according to the following criteria (Fig. 1):

- Comparison of the processed data of *CT examinations* with the estimated numerical values of S/EUROP qualification and with the test slaughtering results of individual lambs (*n=57*).
- Comparison of the results of *test slaughtering* with the estimated values of European S/EUROP qualification and with the measured values of Australian EUROP qualification, as well as those measured on and calculated from CT images.

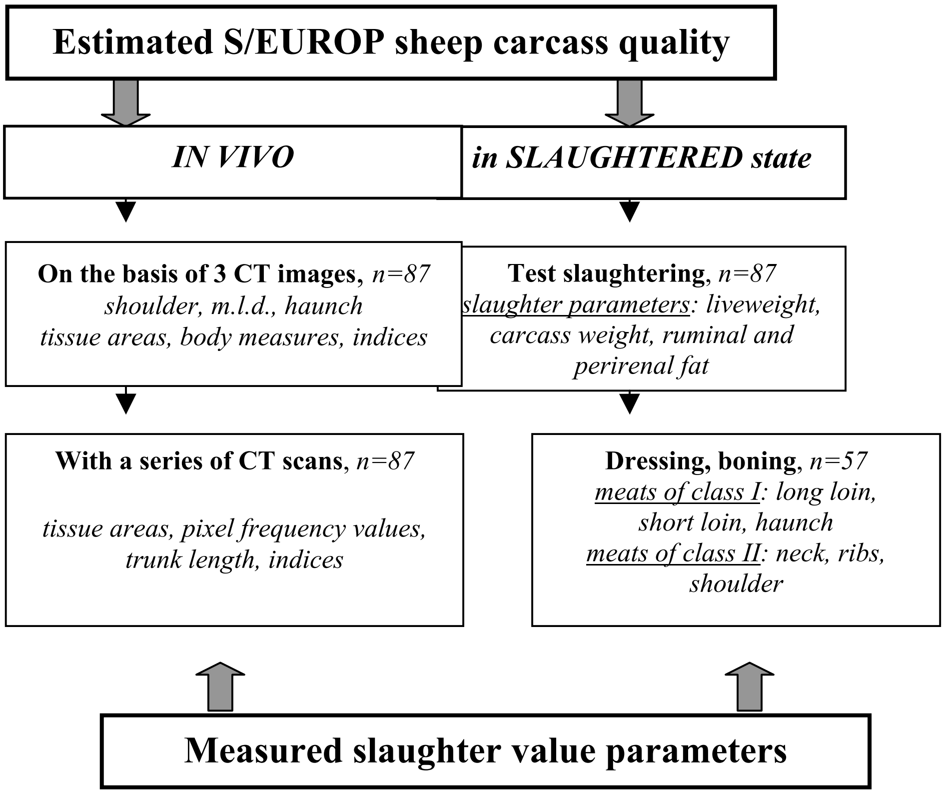

Figure 1. Methodological design of the experiment

The computed tomographic studies were carried out in the Institute of Diagnostic Imaging and Radiation Oncology of the University of Kaposvár. After preparation of the animals to be examined, in order to approach the principles of S/EUROP carcass conformation and fatness characteristics qualification, from the series of CT images covering the carcass (40-60 section images) I selected those three sections for S/EUROP qualification by CT which have a decisive role in the subjective qualification of two S/EUROP categories (*body conformation, fatness characteristics*). Accordingly, for the estimation of body conformation and fatness characteristics, from the series of spiral CT images I selected three (*3*) CT images taken at the junction of the humerus and the scapula, that taken of the longissimus dorsi muscle (m.l.d.) after the 13th rib, and at the junction of the femur and the pelvic bone, respectively.

My assumption was that from these three CT images it would be possible to evaluate muscle tissue deposition in the trunk, extremities and spine, as well as the fatness characteristics of those muscles.

In the hope of determining the correlations more accurately, I performed studies of materials of fat, muscle, bone and water density, their areas (*cm^2*) and pixel frequency values by the use of a series of CT images covering the carcass.

According to the technique described by MEZŐSZENTGYÖRGYI (2000), using a predetermined slice gap (*20 mm*) and slice thickness (*10 mm*), I made cross-sectional images along the body length of the lambs examined, from the atlanto-occipital junction to the tarso-metatarsal joint (*zoom factor: 1.4; tube voltage: 120 kV; radiation dose: 210 mAs*). The obtained images were stored on CD. The CT images were evaluated with the help of the CTPC (BERÉNYI, KÖVÉR, 1991) computerised image analysis programme. The data thus obtained included the areas of the tissues indicated (*cm^2*) as well as the frequency distribution of X-ray absorption values belonging to the pixels constituting the images.

In order to determine the tissue composition of the carcass, first the area data concerning the entire body, then those concerning the abdominal organs or the body parts removed during slaughter were recorded. The surface of the carcass (*cm^2*) was calculated as the difference of the two area data. For evaluation of the CT images, from the 400 data of the studied (*fat, water and protein*) density range (*from –200 to +200*) 40 variables were formed by pooling 10 neighbouring values each, according to ROMVÁRI et al. (1993). Pooling of data was performed by the HISTOCUT V1.1 programme (ZÁVODA and ROMVÁRI, 1996).

The class values of S/EUROP qualification were determined as proposed by DUMONT (1971), in the form of a series of numbers increasing in a linear manner, which corresponded to the qualification categories and indicated the change of the given trait. The original main classes and subclasses were expressed by discrete numbers ranging from 1 to 16 for body conformation and from 1 to 15 for fatness characteristics. This operation was required for the statistical analysis.

Dressing and boning of the carcass were performed in the experimental slaughter premises of the institute. Of the 87 lambs examined by CT and then slaughtered, 57 animals (*Ile de France, n=28; Merino, n=29*) were examined further. The right half of the carcass was cut up into units corresponding to class I, i.e. 'roast-quality', and class II, i.e. 'non-roast quality" parts, then these parts were boned. The measured data were recorded on the spot.

Data of the CT images as well as those of slaughtering, dressing and boning were systematised and the basic statistical values were calculated by the Excel programme of Windows XP, Microsoft Office 2002. The statistical analyses were carried out with the help of the SPSS® for Windows™ 10.0 programme package. Comparison of two groups was done by the *t*-test, while the significance of differences among several groups by one-factor analysis of variance. To reveal correlations between trait pairs, pair-wise correlation was calculated according to *Pearson.* To identify function-like correlations and to obtain the judging equations, multivariate regression analysis was performed, by *Stepwise* method. 3D histograms illustrating differences in body composition were constructed using the SYSTAT 5.0.1. (1990) software. To illustrate muscle tissue deposition and fat tissue deposition by S/EUROP qualification system category, contour diagrams were also prepared by the use of the same software. Further analysis of the contour diagrams was done with the Photoshop 6.0 (2000) image processing programme. Using the same programme, I counted the pixel values of areas in the different subclasses that were characterised by different pixel frequency ranges. This procedure enabled me to express the differences in numerical terms and to subject the data thus obtained to further statistical analysis.

3. RESULTS

Results obtained by the use of CT images taken of three anatomical units

The three sections used for the study of S/EUROP **conformation** provided favourable results for detecting correlations that existed with the CT images. Although the highest correlation (*r=0.771*) was demonstrated between the study parameter and *liveweight (kg),* from the technical point of view the correlation obtained between the *liveweight (kg) / trunk length (cm)* index *(r=0.749)*. As the liveweight involves distortion factors such as variations in the fullness of viscera and other body parts not suitable for consumption, the comparison of trunk length to *carcass weight* or, in the absence thereof, to the *3 CT images* can be expected to provide a more reliable picture on carcass quality. This latter statement justifies why I used the total area of the 3 CT sections, rather than the co-parameters showing a higher *r value*, for calculating the CT conformation index.

For the numerical expression of conformation an index was constructed, by the use of which individuals having different degrees of muscle tissue deposition can be ranked.

CT conformation index = *total area of the 3 CT sections, cm^2*

trunk length, cm

Using the *Stepwise* method of multivariate regression analysis, I set up a judging equation for the determination of S/EUROP conformation. The obtained equation was

$$\mathbf{Y_{t1} = 0.192\ x_1 + 0.287\ x_2 - 5.332}$$

($R^2=0,643$), where Y_{t1} = S/EUROP conformation, x_1= liveweight (*kg*), x_2= haunch thickness (*cm*).

I did not find a close correlation between the estimated values of S/EUROP **fatness characteristics** and the 3 CT images; therefore, it was not possible to set up a judging equation.

Results obtained by the use of spiral CT image series

To reveal the correlations more precisely and reliably, I analysed the complete spiral CT image series covering the carcass of the examined animals, instead of the former 3 CT images.

During the analysis of the **conformation** trait, I have confirmed the previously revealed correlations and demonstrated new ones.

I consider it an important finding that the correlation between the index formed by the total area of the 3 CT images (i.e. the shoulder, the m.l.d. and the haunch sections) with the trunk length and the S/EUROP conformation did not improve further as a result of adding the additional information derived from the spiral CT images ($r=0.735$). The principle of creating these indices was directed by the correlation between the largest possible total area that falls to 1 cm of trunk length (cm^2) and the conformation that improved in a linear relationship with the former.

In the possession of the additional information provided by CT images covering the whole carcass, by the introduction of four (4) independent variables and by the exclusion of liveweight as a single parameter, I set up a new judging equation using the *Stepwise* method. The result I obtained was the regression equation

$$\mathbf{Y_{t3} = 10.452\ x_1 + 0.455\ x_2 - 0.24\ x_3 - 13.026\ x_4 - 2.701}$$

($R^2=0,682$), where Y_{t3} = S/EUROP conformation, x_1= liveweight (*kg*) / trunk length (*cm*), x_2= haunch thickness (*cm*), x_3= CTIF index (*cm*^{2}), x_4= haunch thickness (*cm*) / trunk length (*cm*).

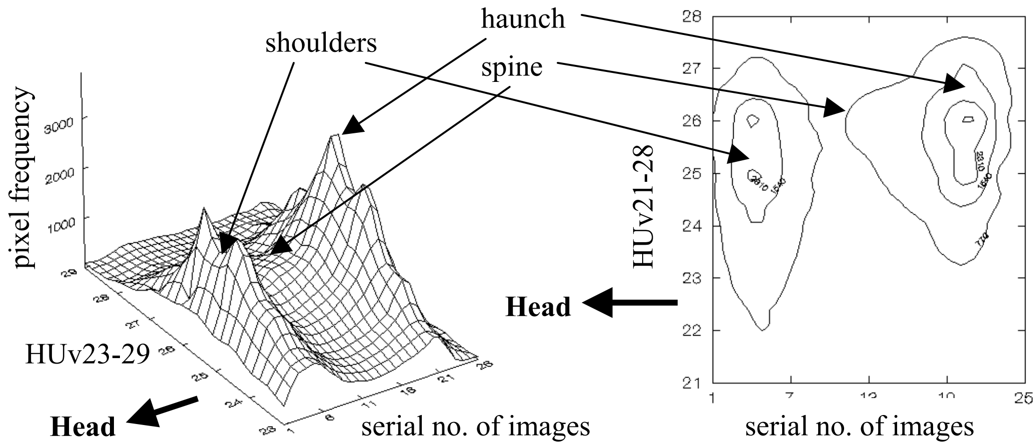

Figure 2. S/EUROP conformation, muscle-tissue deposition rate in subclass R$^+$

By processing the pixel frequency values belonging to the CT images of animals representing the main classes and subclasses of S/EUROP conformation and by excluding and narrowing the density ranges of muscle (HUv23-40), I constructed 3D histograms (HUv23-29) and contour diagrams (HUv21-28) (*Fig. 2*). I also illustrated differences manifested in muscle tissue deposition among the main S/EUROP classes.

As regards **fatness,** I could not demonstrate an essential relationship between the estimated S/EUROP fatness values and the data obtained by computed tomography even if the processed results of the entire CT image series were used. I attribute this failure to the narrow fatness range of the studied stock (*9 subclasses instead of 15*), to the low number of individuals representing the extreme values, and to the subjective bases of the S/EUROP qualification system.

To characterise the fatness degree of the carcass, I created a so-called CT-carcass fat % index expressing the degree of tallow deposition, by the utilisation of spiral CT image series covering the carcass. I find this index suitable for the determination of tallow rate of the carcass *in vivo* and for setting up an order of rank among the animals.

$$\textbf{CT-carcass fat \%} = \frac{\Sigma \textit{ fat area of carcass sections } (cm^2) \times 100}{\Sigma \textit{ area of carcass sections } (cm^2)}$$

With the help of the method of the **Australian EUROP qualification** for determining the **fatness** condition, I performed additional studies to detect correlations and functional connection between the tallow rate and the data recorded on the CT images. I have confirmed that the tallow thickness measured above the 12th rib on the CT images is in a close correlation with the *'fat areas of carcass sections (cm^2) / cold carcass weight (kg)'* index *(r=0.869) as well as with the CT-carcass fat %* (*r=0.870*).

To estimate the Australian EUROP tallow thickness grade as dependent variable, I again attempted to set up a judging equation by *Stepwise* selection method. As a result, I obtained

$$\mathbf{Y_{2f} = 0.00681\ x_1 - 0.111\ x_2 - 0.155\ x_3 - 29.931\ x_4 + 21.21}$$

judging equation ($R^2=0.867$), where Y_{2f}= Australian EUROP tallow thickness, x_1= CT-carcass Σ fat area (*cm^2*), x_2= trunk length (*cm*), x_3= water-density substances of shoulder section (*cm^2*), x_4= trunk length (*cm*) / area of shoulder section (*cm^2*). The above equation seemed to be suitable for ranking the studied genotypes in a valid manner in terms of the tallow rate of the carcass.

I illustrated the differences among the individual subclasses also with

3D diagrams.

During the **test slaughtering,** 57 animals having undergone CT examination were slaughtered, dressed and boned at the experimental slaughterhouse of the Faculty of Animal Science. The recorded data were compared with the 3 CT images representing the three main anatomical units of S/EUROP high-weight carcass qualification, with the parameters measured by the CT image series covering the entire carcass, and with the indices calculated from them. The 'roast-quality' meat parts showed a moderately high correlation (*r=0.557*) with the S/EUROP *conformation,* but this correlation was higher than that shown by the 'non-roast quality' part (*r=0.546*). For the 'roast-quality' meat parts the highest correlation was obtained for the haunch meat weight (*r=0.621*) while for the 'non-roast quality' meat parts the highest correlation was found for the shoulder meat weight (*r=0.546*). Of the carcass parameters, the abdominal fat (*r=0.679*) and the perirenal rat (*r=0,632*) showed the highest correlation with the Australian EUROP *fat thickness*.

During this latter phase of the study, I revealed several correlations between the measured slaughter parameters and the S/EUROP sheep carcass conformation and fatness values. These correlations support the suitability of CT images for *in vivo* estimation corresponding to the EU qualification system.

4. CONCLUSIONS AND RECOMMENDATIONS

The results presented in the framework of the dissertation render possible the *in vivo* S/EUROP qualification of high-weight lambs.

By the computed tomographic determination of body composition, the quantity and proportion of fat, muscle and bone tissues constituting the carcass (*cm^2, pixel frequency*) can be estimated with high accuracy.

On the basis of the above data a regression equation can be set up, which can enable us to estimate the hot carcass weight and the carcass fat percentage *in vivo* and to rank (select) potential breeding animals according to that trait.

The data obtained on the basis of the CT images and the indices derived from them are suitable for expressing the conformation and fatness values, which are important indicators of the carcass value, in numerical terms.

The results of this study prove that conformation can be expressed numerically, in the form of an index, also on the basis CT images taken of 3 specific anatomical units, instead of 40-60 CT images. The close correlations of the parameters based on these three CT images and the indices derived from them with the slaughter parameters demonstrate the suitability of computed tomography for the *in vivo* determination of body composition. The repeatability of the method restricted to 3 CT images independently of age and liveweight should be taken into consideration during the further development of less expensive CT examination methods.

The correlation calculated between the conformation index and S/EUROP conformation could not be increased further with the help of spiral CT images.

Further studies are needed for elucidating the relationship between the lumbar part of the longissimus dorsi muscle (*m.l.d.*), i.e. the short loin, and body conformation.

During the study of fatness as a parameter of S/EUROP qualification, I could not demonstrate an essential correlation between the values of subjective estimation and the area data pf CT images or the values measured during test slaughtering. In future studies, efforts should be made to draw under examination a larger number of animals representing all subclasses of the S/EUROP fatness category.

The method applied in the Australian EUROP qualification seems to be suitable for the objective determination of fatness. The correlation revealed between the data recorded on the CT images and those obtained during test slaughtering on the one hand and fat thickness measured above the 12th rib on the other makes it possible to set up a judging equation. Using that equation, the studied animals can be ranked in a reliable manner according to the principles of Australian EUROP qualification for fatness.

Of the different carcass parameters and indices derived from them, the body weight (*kg*), the fresh (hot) carcass weight (*kg*), the shoulders and their meat (*kg*), the haunch and its meat (*kg*), the loin and its meat (*kg*), and the lean meat (*kg*) proved to be the most suitable for determining the conformation categories of S/EUROP qualification. The measured and calculated values of the 3 CT images and the spiral CT images are also in a moderate or higher correlation with the above slaughtering parameters.

The body measures recorded on, or with the help of, the CT images (*shoulder width, haunch width, trunk length*) can play an important role in the calculation or estimation of the conformation index. Ensuring the standard body posture of animals for examination continues to pose a problem.

The 3D histograms and contour diagrams can be used successfully for the detection of differences between individuals and genotypes. These diagrams clearly illustrate the differences manifested in both muscle-tissue and fat deposition. With the contour diagrams the changes in muscle-tissue and fat deposition by body region can be mapped and expressed in numerical terms.

The parameters calculated and indices derived on the basis of the CT images and the estimated values of S/EUROP conformation indicated higher correlations with the units of the 'roast-quality' meat parts and with their entirety than with the units of 'non-roast quality' meat parts and their entirety. The dominant role of the shoulder meat within the 'non-roast quality' parts and that of the haunch within the 'roast-quality' parts is consistent with the principles determining conformation within the S/EUROP qualification system. The same tendency can be demonstrated between the studied CT parameters and the above slaughter parameters.

In my view, the results obtained and the methods developed are suitable for judging the slaughter value of sheep in vivo. By continuing these studies on the largest possible number of animals representing the entire range of S/EUROP conformation and Australian EUROP fatness categories, the reliability of my judging equations can be improved further. Owing to the correlations and functional connections revealed, the application of this method could provide an opportunity for the qualification of the S/EUROP conformation and Australian EUROP fatness characteristics of breeding animals (♂) and for a more precise determination of their breeding value in vivo.

5. NEW RESEARCH RESULTS

1. The conformation categories of S/EUROP high-weight sheep carcass qualification can be determined *in vivo* with the help of CT images taken of three (3) anatomical points.

2. The fat thickness categories of the Australian EUROP high-weight sheep carcass qualification can be determined with high accuracy by CT.

3. The three-dimensional histograms prepared on the basis of the CT images and their contour diagrams made in a view from above are suitable for demonstrating and expressing in numerical terms the subclasses of S/EUROP conformation and fatness categories and the differences existing between them.

6. PUBLICATIONS WRITTEN ON THE SUBJECT OF THE DISSERTATION

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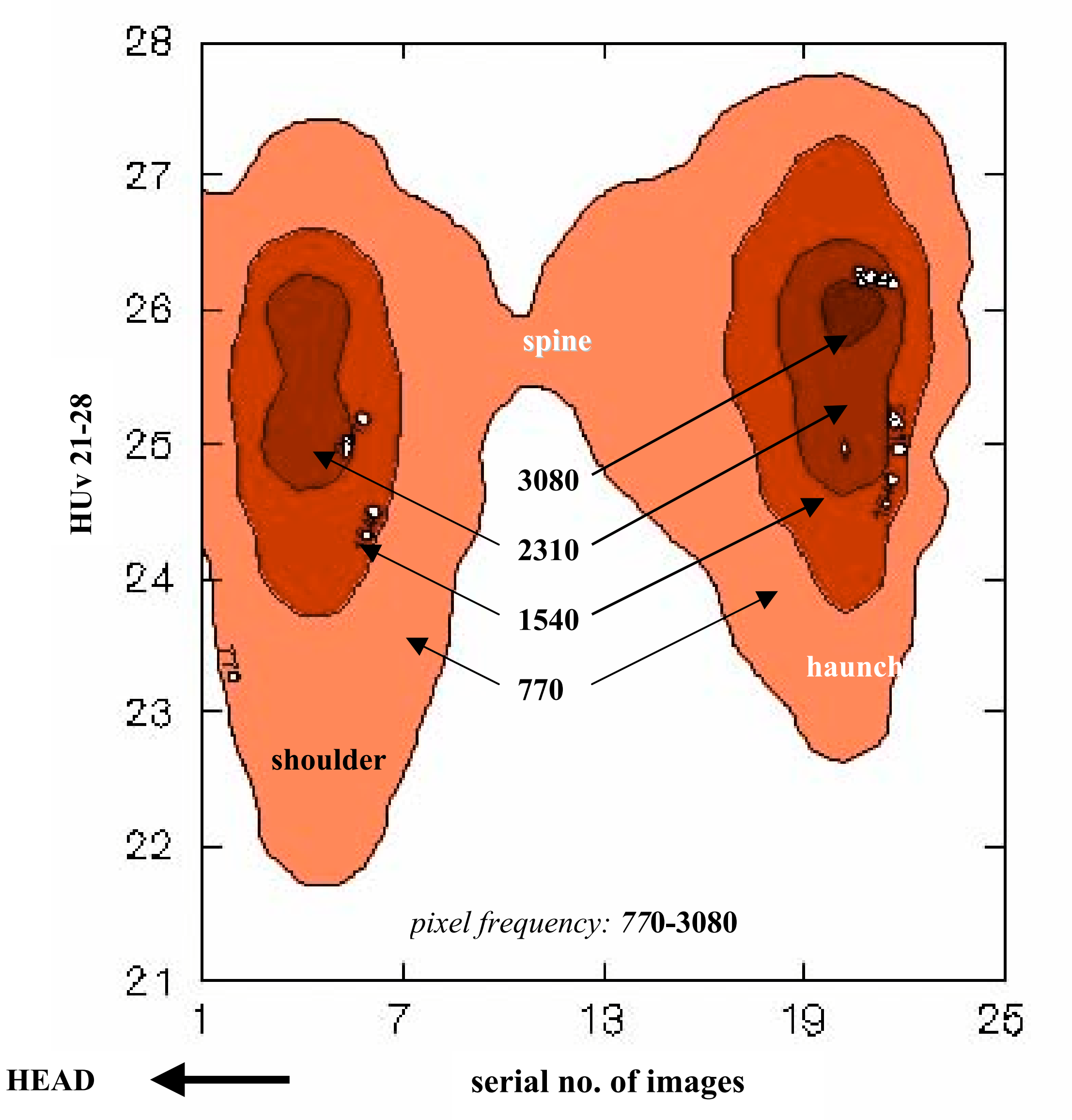
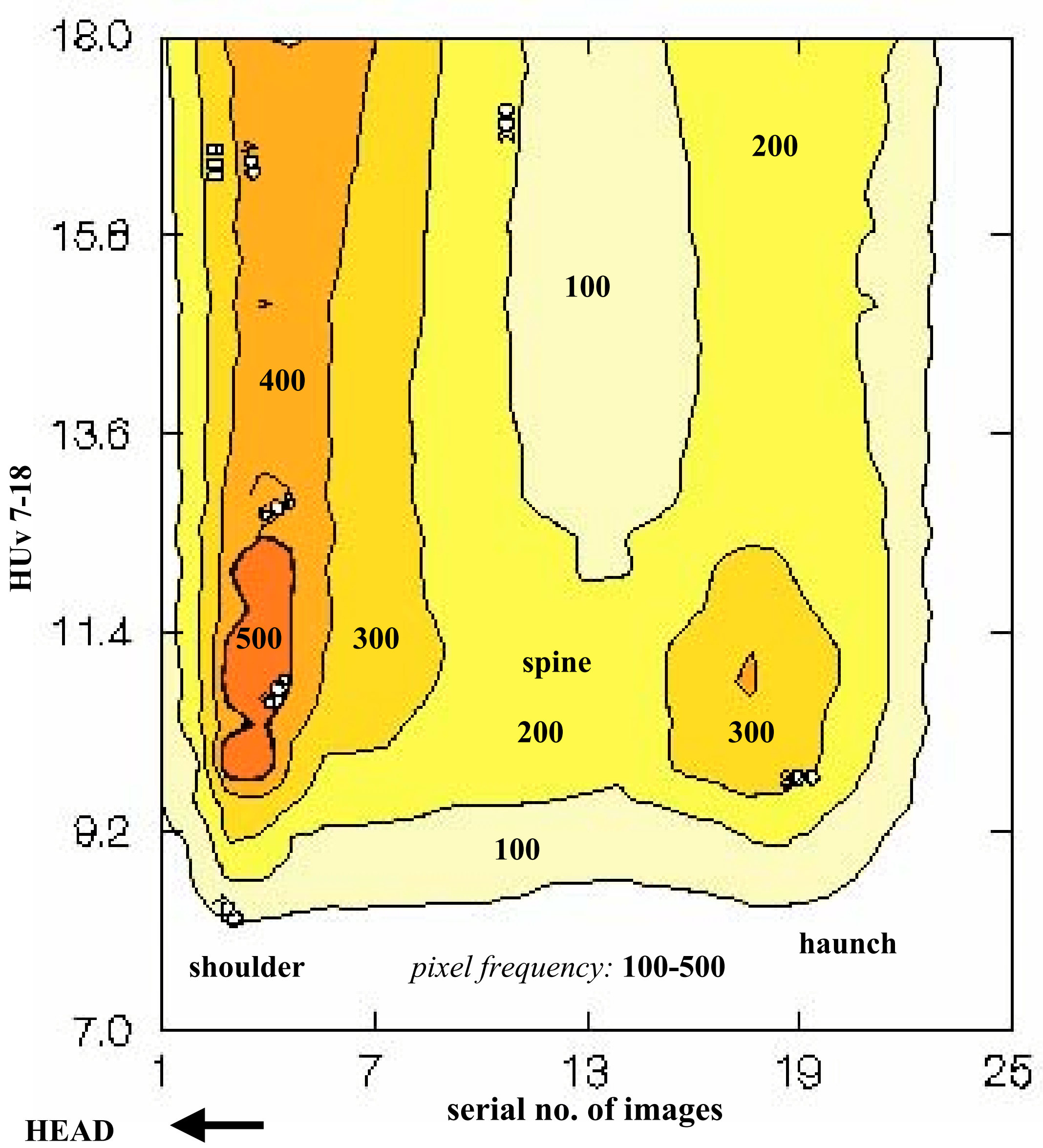
4. Annexes



S/EUROP, conformation, U⁻, contour diagram



S/EUROP, fatness, 3$^+$, contour diagram