Skeletal changes in the skull of the genus *Sus sp.* as a result of domestication

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Abstract. The subject of this paper is the analysis of the skull characteristics of the specimens of the genus Sus sp. belonging of different historical contexts preserved at the Laboratory of Archeozoology and Veterinary Anatomy Museum of the University of Pisa, and the morphological changes occurred between wild and domestic forms in relation to the adaptive bone remodeling due to domestication processes.

Keywords: *Suidae*, Skull, Domestication, *Sus sp.*

INTRODUCTION

The process of domestication began during the Neolithic Revolution in the ancient Near East (from Southwest Asia, eastern Mediterranean and Arabian Peninsula to Iran), and then developed into different forms and times in other areas owing to cultural osmosis and ethnic contribution. On the basis of relative dating, these process dates back to 7th millennium B.C. as concerns the Mediterranean and Eastern areas.

Domestication lead to the development of a symbiotic relationship between man and animal: when humans learned the advantages of driving out animals from their natural habitats, they also understand how to control animal's nutrition and reproduction in order to satisfy their own needs.

Animals that are domesticated have a lower risk of becoming victims of predators, and a higher protection against environmental hardships. In addition, under domestication and favorable conditions animals have a better chance to grow and reproduce. However, for true domestication of animals, also of different species, basic criteria are required.

First, the animal must be able to survive separation from its mother before weaning adapting to a new diet, new environment and climate conditions. Secondly, to be suitable for domestication it has to recognize social hierarchy and man leadership, and not to be inclined to spontaneous escape. And last, but not least, it has to be able to reproduce in captivity, to survive unknown parasitic infections, and easy to feed (also with human waste).

Hence, it could be defined domestic a species *"bred in captivity for purposes of economic profit to a human community that maintains total control over its breeding, organization of the territory and food supply"* (qtd. in Clutton-Brock, 1999).

Involving both cultural and biological processes, domestication led to the following physical variations: changes in body size, that usually are a reduction of size (Darwinian selective processes clearly explain the reasons for which individuals become larger or smaller); change in appearance and coat, with wide variability due to human preferences; anatomic

modifications, especially in teething often accompanied by a remarkable tendency to deposition of fat in the subcutaneous tissue, and between muscle bundles.

Anatomic modifications are more evident in the skull: at the level of the splanchnocranium, the jaw is shortened and the teeth decrease in size.

Domestication of pig

The domestication of pig began when it was realized that its advantages overwhelm the disadvantages.

This animal species could provide a great deal of meat with minimum of care (pigs can be efficiently bred with waste food or spontaneous natural products from the forest); bones and teeth were used for practical or decorative purpose (such archeological finds occur frequently during the Cupper and the Bronze Age).

One of the disadvantages of the domestication of pig was related to the sedentary lifestyle typical of this species, so that these animals cannot be transferred over long distances. In fact, the presence of pig remains in archaeological sites is a sign of the sedentary lifestyle of the population who lived there. In addition, a large number of important pig diseases are transmissible to humans, e.g. zoonotic diseases.

Boar is the species from which all domestic pigs were originated, with a large distribution extending from Eurasia and North Africa through the Far East. Domestic pigs are native to the Balkan Peninsula and the Far East. The archaeological data suggest that the domestication of the species has taken place in unconnected geographical regions (Near East, Europe and China). At the present time, the oldest archaeological finds dating to the 8th millennium B.C. have been found in the South-East Asia.

In the Middle Ages, the domestic pig had a primary role in the Italian peninsula economy. The crisis of the III-IV century A.D., characterized by the expansion of overgrown forest areas unsuitable for sheep breeding, and the gradual assimilation to the ways of life of the Germanic peoples, especially to the Langobards, caused the development of domestic pig farming. In facts, pigs became so important that a forest was measured calculating the number of animal that it can feed.

In ancient iconography, pigs are presented in a very different manner, like wild boar, with which are attested spontaneous crossings (subjects with large and elongated skull, snout-necked, short and erect ears, well-pronounced canines or fangs).

The aim of the present paper is the study of transition from the condition of wild to domestic *Sus sp*. focusing the investigation on the relationship between masticatory muscle activity, and the remodeling of the skull in relation to the drastic change in feeding between wild and domestic species.

MATERIALS AND METHODS

We studied specimens of wild boar skulls from the Archeozoological Laboratory of the University of Pisa and specimens of domestic pig skulls from the Osteological Collection of Veterinary Anatomy Museum, University of Pisa. Some landmarks related to the attack of the following muscles of mastication were highlighted: masseter muscle (a strong elevator of the jaw which originates from the zygomatic arch and the facial ridge, and ends on the masseteric fossa and on the angle of the jaw), and temporal muscle (another strong elevator of the jaw

that occupies the temporal fossa, and ends on the coronoid process and the rostral margin of the jaw branch)(Fig. 1).

RESULTS

The forces exerted by the myological component are closely related to the type of chewing, and consequently to the type of food taken. As regards the action of the myological component on the bones of the splanchnocranium we can observe that the zygomatic arch is deformed by the action of forces acting at the level of the suture between the zygomatic process of the temporal and frontal bones. Muscle contraction causes a compression in the vertical plane and a stretch action on the horizontal plane. As regards the action of the myological component on the bones of the neurocranium (the elevators muscles of the jaw exert a torsion action on the outer surface particularly of the frontal and parietal bones. The direction of the axis of torsion corresponds to a pair of muscles placed diagonally (e.g. right masseter muscle and left temporal muscle) with alternating contraction. The suture between the frontal and parietal bones (called coronal) undergoes the forces of these muscles during masticatory movements of the mouth. The sutures cranial to this one is not involved in the activities of chewing, and can be influenced only indirectly by the closing and opening of the oral cavity. The action of the myological component on the jaw is configured as pull forces that insist on the outer side of the jaw condyle, with a predominance of compression on the tension. The axis of compression is orientated dorso-ventrally or dorso-rostrally. The orientation of the axis of compression is the same as the carrier of the masseter muscle (Herring et al., 2001). Taking into account the assumption that the bones, as mutable structures, respond to biomechanical stress caused by external changes (Wolff's Law, or law of bone remodeling), the activation of the masticatory muscles and their coordination determine the direction of the jaw movements, the control of occlusive forces, and then the deformation of the skull. Consequently, it can highlight a relationship between masticatory muscle activity, and remodeling of the skull and jaw. From the results of our investigation it is pointed out (Fig. 2) that in the skull of wild boar the angle between the frontal and nasal bones is flat; the zygo-

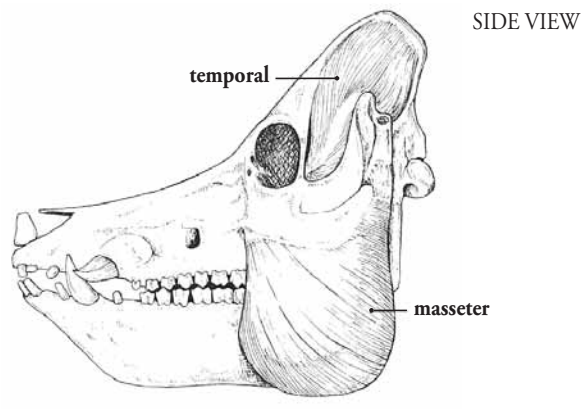

Fig. 1 – Localization of masseter and temporal masticatory muscles (from: Barone, R. 1981, Anatomia comparata dei mammiferi domestici).

Fig. 2 – Neurocranium and splanchnocranium of wild boar (sx) and domestic pig (dx) (A); jaw of wild boar (sx) and domestic pig (dx) (B), lateral viewo (Laboratory of Archeozoology and Veterinary Anatomy Museum).

matic process of temporal and frontal bones are localized on the same plane; the orbital cavity, which is spherical, is positioned more laterally (as for many wild animals that must control a large area in front and behind them); the external occipital protuberance is aboral to the profile of the cranium (Fig. 2).

The same investigation on the skull of domestic pigs shows different features: the angle between the frontal and nasal bones is less than 180°; the zygomatic process of the temporal bone is vertical while the frontal one is laterally directed; the orbital cavity, oval in shape, moved orally (as for many domestic animals that should not control a large area around them as kept on the farm); the external occipital protuberance is integral to the profile of the neurocranium.

The study of the boar's jaw in lateral view (Fig. 3) showed an obtuse angle of the jaw (between the body and branch); the profile of the mandibular condyle is outer to the same jaw branch; the coronoid process is projected caudally; the prominence of the chin is just present and dorso-ventrally compressed; the angle between the two branches of jaw is acute and the incisive portion is narrow and stretched orally. In the domestic pig's jaw we have revealed a rectum angle of the jaw, and the profile of the mandibular condyle is integral with the same jaw branch; the coronoid process is vertical; the prominence of the chin is highly pronounced and laterally compressed; the angle between the two branches of jaw, always acute, is wider than in the wild progenitor and the incisive portion is thick and strong, stretched dorsally.

CONCLUSIONS

From wild to domestic pig the bone remodeling of the skull is visible in the splanchnocranium, in particular at the level of the zygomatic arch and the ascending branch of the

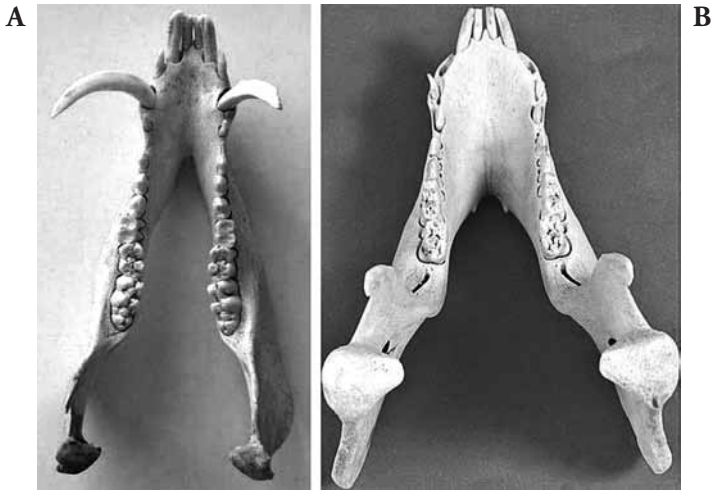

Fig. 3 – Wild boar jaw (A) and domestic pig jaw (B), dorsal view (Laboratory of Archeozoology and Veterinary Anatomy Museum).

jaw, and in the neurocranium, at the level of the external occipital protuberance. The frontal and parietal bones tend to assume a vertical profile. Since the type of food influences the duration of the myological activities of chewing, it follows that in the wild pig, such as wild boar, which has a diet rich in tough foods, the contraction of the masticatory muscles with the movement of the jaw causes a strong influence on deformation of the bones of the skull. In domestic pigs, which are fed by humans with food or sometimes with food waste, the drastic change in the vector forces determined by the myological component suggests a reduction in the effectiveness of the masseter and temporal muscles on osteological component (Fig. 4). From this we can point out that a possible hybridization between wild boar and domestic pig, characterized by the same number of chromosomes, could determine subjects with intermediate features, relative to the skull and jaw, between the two variants of the genus *Sus sp*.

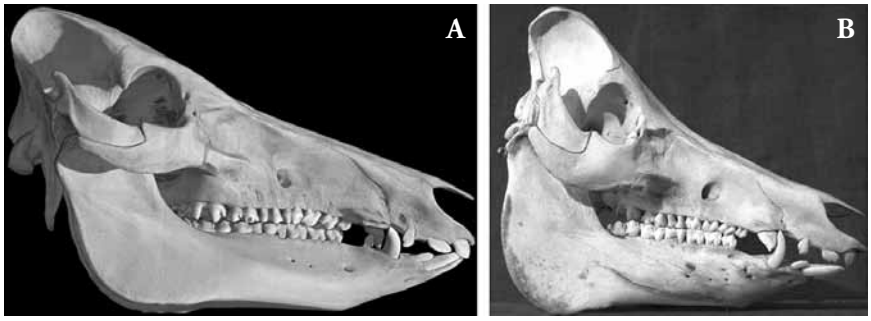

Fig. 4 – Wild boar cranium (A) and domestic pig cranium (B), lateral view. (Laboratory of Archeozoology and Veterinary Anatomy Museum).

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RIASSUNTO

Variazioni scheletriche del cranio di *Sus sp.* come risultato del fenomeno di domesticazione

Si presentano i risultati di uno studio su reperti osteologici di *Sus sp*. provenienti dalle collezioni del Laboratorio di Archeozoologia e del Museo Anatomico Veterinario, Università di Pisa, riferiti a soggetti domestici e selvatici, risalenti a vari contesti cronologici, provenienti da tutta Italia. Mediante analisi macroscopica degli elementi costituenti le ossa del cranio si evidenziano le variazioni morfologiche scheletriche che intercorrono tra la forma selvatica e quella domestica in relazione al processo di rimodellamento osseo ed adattativo determinato dalla domesticazione. A livello dello splancnocranio la contrazione muscolare ha come esito la deformazione dell'arcata zigomatica a partire dal suo punto più debole (la sutura tra processo zigomatico del temporale e del frontale) per una azione compressiva sul piano verticale. A livello del neurocranio, i muscoli masticatori esercitano un'azione di torsione particolarmente sull'osso frontale e parietale corrispondente ad una coppia di muscoli in contrazione diagonale. Tenendo in considerazione la legge di Wolff o del rimodellamento osseo, gli Autori hanno studiato la relazione tra l'attività masticatoria ed il rimodellamento del cranio e della mandibola. Sui reperti di splancnocranio e neurocranio di cinghiale l'analisi morfologica ha evidenziato notevoli variazioni riguardanti il profilo dell'osso frontale, la posizione del processo zigomatico del temporale e del frontale, la forma e posizione della cavità orbitaria, il profilo della protuberanza occipitale esterna rispetto ai medesimi reperti di suino domestico. Anche lo studio della mandibola di cinghiale (ampiezza dell'angolo tra corpo e branca della mandibola, posizione del condilo mandibolare e del processo coronoideo rispetto al piano dell'angolo precedentemente citato, morfologia ed estensione della prominenza mentale, ampiezza dell'angolo tra le due emimandibole, ampiezza e posizione della porzione incisiva) ha confermato che intercorrono notevoli differenze con la forma domestica della stessa specie. Gli Autori ritengono che, con il processo di domesticazione ed il passaggio da una dieta onnivora, ricca di cibi di notevole consistenza, a una dieta derivante da scarti dell'alimentazione umana, si modifica la forza e la durata dell'attività dei muscoli masticatori tanto che nei suidi selvatici, come il cinghiale, la direzione vettoriale delle forze di compressione e torsione hanno influenza sulla deformazione delle ossa del cranio. Nei suini domestici la riduzione dell'efficacia dei muscoli masticatori sulla componente osteologica esita in una diversa direzione vettoriale di tali forze. Una possibile ibridazione in natura di cinghiali e suini domestici, caratterizzati dallo stesso numero ci cromosomi, potrebbe determinare soggetti con caratteristiche intermedie, relativamente al cranio ed alla mandibola, tra le due varianti del genere *Sus sp*.

REFERENCES

Albarella, U. Dobney, K. & Rowley-Conwy, P. (2006) The domestication of the pig (*Sus scrofa*) : new challenges and aproaches. In: Documenting domestication: new genetic and archaeological paradigms. Berkeley, University of California Press, pp 209-227.

Albarella, U., Dobney, K., & Rowley Conwy, P. (2009) Size and shape of the Eurasian wild boar (*Sus scrofa*), with a view to the reconstruction of its Holocene history. Environmental Archaeology **14** (2): 103-136.

Apollonio, A. Randi, E., & Toso S. (1988). The systematics of the wild boar (*Sus scrofa* L.) in Italy. Bolletino di zoologia **55** (1-4): 213-221.

Amills, A. (2011) Biodiversity and Origin of Pig Breeds. Bulletin UASVM Animal Science and Biotechnologies **68**:1-5.

Aravena, P., & Skeves, O. (2007) European wild boar and sus scrofa intercrosses. Discrimination proposal. A review. Agro Ciencia **23**(3): 133-147.

Barone, R. (1981) Anatomia comparata dei mammiferi domestici. Edizione Edagricole, **3**:115-136.

Baruzzi M., & Montanari M. (1981) Porci e porcari nel Medioevo. Paesaggio, economia alimentazione, CLUEB, Bologna, pp 54-65.

Celio Alves,P., Pinheiro, I., Godinho, R.; Vicente, J:, Gortazar, C., & Scandura, M. (2010) Genetic diversity of wild boar populations and domestic pig breeds (Sus scrofa) in South-western Europe. Biological Journal of the Linnean Society **101**: 797-822.

Chaix L., & Meniel P. (2001) Archeozoologie, les animaux et l'archeologie. Editions Errance, Paris, pp 240

Clutton-Brock J. (1999) A natural History of domesticated mammals, Cambridge University Press, Cambridge (UK) pp 235.

De Grossi Mazzorin J. (2008) Archeozoologia. Lo studio dei resti animali in archeologia, Editori Laterza, pp 255

Dinu, A. (2009) The action of the masticatory muscles and cranial changes in pigs as results of domestication. Documenta Praehistorica **36**: 207-218.

Herring, S.W., Rafferty, L., Liu, Z.J. & Marshall, C.D. (2001) Jaw muscles and the skull in mammals: the biomechanics of mastication. Comparative biochemistry and physiology, Part A, **131**: 207-219.

Hyams E. (1973) E l'uomo creò le sue piante e i suoi animali. Storia della domesticazione, Mondadori Milano, pp 337.

Montanari M. (1997) La fame e l'abbondanza. Storia dell'alimentazione in Europa, Editori Laterza, pp 270.

Montanari M. (2008) Alimentazione e cultura nel Medioevo, Editori Laterza, pp 236

Rosell, C., Fernandez-Llario, P., & Herrero, J. (2001). El Jabalì (Sus Scrofa Linnaeus, 1758), Galemys,**13** (2): 1-25.

Vigne, J.D., Peters, J., & Helmer D. (2005) First Steps of Animal Domestication. New archaeozoological approaches. Proceedings of the 9th ICAZ Conference, Durham 2002, Oxbow Book, pp 86-95.

Von den Driesch A. (1976) A guide to the measurement of animal bones from archeological sites. Peabody Museum, Bulletin 1, Harvard University Press, Cambridge.

Wilson B., Grigson C., & Payne S. (1982) Ageing and sexing animal bones from archeological sites. British Archaeological Report International Series, pp 109.

Zeuner, F. E. (1963) A history of domesticated animals, Harper & Row Publishers, New York and Evanston, pp. 271.