EXPERIMENTS IN BONE BOILING: NUTRITIONAL RETURNS AND ARCHAEOLOGICAL REFLECTIONS

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Summary

Boiling bones with adhering meat is a common processing technique utilized by contemporary and prehistoric human populations. Although most scholars agree that this is a time-intensive process, little quantitative data exists on the time or effort involved or the amounts and types of nutrients that can be extracted by this technique. This paper presents data on the efficiency of boiling animal bones in relationship to processing carcasses without the aid of fire. These data are the results of recent butchering experiments involving impala, wildebeest, and zebra carcasses. Carcasses of some medium-sized taxa can be quickly butchered and almost completely processed without the aid of fire. Boiling bones is very time consuming but aids in the removal of bone grease and improves the quality of lean meat. Given these results, we question how often pre-fire hominids would transport the bones of medium and larger-sized prey for culinary purposes. We also suggest that boiling should be adopted as a bone processing technique as soon as the use of fire emerges and may be reflected by specific types of bone damage patterns.

Résumé

Expérimentations consistant à faire bouillir des os : rendements nutritionnels et considérations archéologiques.

Bouillir des os avec la viande attenante est un traitement couramment utilisé par des populations humaines contemporaines et préhistoriques. Quoique la majorité des chercheurs convienne que ce traitement prend beaucoup de temps, il y a peu de données quantitatives concernant la durée et l'effort nécessaire à ce traitement ou encore les quantités et types de nourriture obtenus par cette technique. Cet article présente des données concernant l'efficacité de bouillir les os animaux en comparaison avec le traitement de carcasses sans l'aide du feu. Ces résultats ont été obtenus lors d'expérimentations récentes de boucherie sur des carcasses d'impalas, gnous et zèbres. Les carcasses des taxons de tailles moyenne peuvent être traitées presque entièrement sans l'aide du feu. Bouillir les os prend beaucoup de temps mais est très utile dans l'extraction de la graisse des os et améliore la qualité de la viande maigre. Compte tenu de ces résultats, nous nous posons des questions sur la fréquence avec laquelle les hominidés d'avant l'ère du feu ont transporté les os des proies de tailles moyenne et grande à des fins de consommation. Nous proposons également que la technique de bouillir les os aurait dû être adoptée dès l'apparition du feu. Bouillir ne nécessite pas l'usage de récipients non-périssables, tels que ceux en métal ou céramique, et pourrait se refléter dans des types spécifiques de marques d'endommagement des os.

Zusammenfassung

Versuche zum Sieden von Knochen: Überlegungen zur Bedeutung für die Archäologie.

Das Sieden mit Fleisch umgebener Knochen ist eine gebräuchliche Verarbeitungsmethode moderner und prähistorischer Menschen. Obwohl sich die meisten Wissenschaftler in der Annahme, daß dieser Vorgang sehr zeitaufwendig ist, einig sind, gibt es nur wenige Daten bezüglich des Zeit- und Arbeitsaufwandes oder der Mengen und Bestandteile von Nährstoffen, die durch das Sieden gewonnen werden können. In diesem Beitrag wird der Nutzen des Knochensiedens gegenüber der Verarbeitung von Kadavern ohne die Zuhilfenahme von Feuer beschrieben. Die verwendeten Daten sind das Ergebnis kürzlich durchgeführter Schlachtexperimente an Impala-, Gnu- und Zebrakadavern.

Die Kadaver einiger mittelgroßer Taxa können sehr schnell geschlachtet und fast vollständig ohne Zuhilfenahme von Feuer verarbeitet werden. Das Sieden von Knochen ist sehr zeitaufwendig aber beim Extrahieren von Knochenfett sehr hilfreich; außerdem verbessert es die Qualität mageren Fleisches. In Anbetracht dieser Resultate stellen wir uns die Frage, inwiefern Hominiden vor dem Gebrauch von Feuer das Fleisch mittelgroßer und großer Beutetiere zu Ernährungszwecken transportiert haben. Wir gehen davon aus, daß die Technik des Knochensiedens sehr bald nach der "Erfindung" des Feuers praktiziert worden ist. Zum Knochensieden sind keine haltbaren Behälter nötig. Möglicherweise zeigt sich diese Technik auch in bestimmten Bruchmustern der Knochen.

Key Words

Carcass butchering, Bone boiling, Nutritional value, East Africa, Taphonomy.

Mots clés

Découpe de carcasses, Bouillir des os, Valeur nutritive, Afrique de l'Est, Taphonomie.

Schlüsselworte

Schlachten von Tierkörpern, Sieden von Knochen, Nährwert, Ostafrika, Taphonomie.

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Introduction

Boiling meat and bones is a common culinary technique utilized by both modern and prehistoric human populations around the world. Recent observations of East African Hadza hunter-gatherers are illustrative of the technique utilized by other subsistence hunters (Bunn *et al.*, 1988; O'Connell *et al.*, 1988). The Hadza field process some medium to large-sized prey by stripping most of the meat, removing the marrow from some elements, and transporting both loose meat and some of the stripped bones to residential camps where they are often processed by boiling. This paper examines the efficiency of boiling as a meat and bone processing technique. Experimental data we report here suggest that for some animals, most edible products can be quickly extracted with little effort during initial field processing and without the use of boiling. Boiling is a high cost processing technique but facilitates the removal of bone grease, increases the efficiency with which residual meat can be stripped from bones, and structurally alters some animal products, thus improving the nutritional quality of lean meat.

The efficiency of boiling and other food processing techniques that utilize heat is of interest because the use of fire is a relatively recent innovation in human prehistory (James, 1989). Some argue that the emergence of boiling resulted in changes in the skeletal composition of faunal assemblages because body part transport decisions are influenced by the available technology (Speth, 1989; Bunn *et al.*, 1988; Marshall and Pilgrim, 1991). Economic data presented here may help to better identify the types of changes that might have occurred with the emergence of boiling.

Experiments in carcass butchering and processing

In the summer of 1992, we conducted butchering experiments in Kenya on 17 animal carcasses representing four East African taxa. The sample included both male and female adult impala (*Aepyceros melampus*), hartebeest (*Alcelaphus buselaphus*), zebra (*Equus burchelli*), and wildebeest (*Connochaetes taurinus*). These animals were killed as part of a cropping scheme initiated by the Kenya Wildlife Service and designed to control animal populations. Our principal goal was to measure the efficiency of field processing different prey animals. Efficiency was measured by conventional units used in optimality models to evaluate the costs and benefits of pursuing different activities (Smith, 1983). Benefits were measured by the amount of edible nutrients (e.g., meat, marrow, and grease) and the costs in amount of time needed to accomplish different tasks. All carcasses were butchered in a uniform manner by a professional butcher and one assistant using metal knives (see Blumenschine and Caro, 1986, for a description of similar methods). Carcasses were eviscerated and skinned, the meat was stripped from all body parts, and major joints were dismembered. The marrow was then removed from all marrow-bearing bones. Bones from a sample of three animal carcasses, one impala, one wildebeest and one zebra, were stripped, chopped, and further processed by boiling. Residual meat was picked off the bones after they were boiled and some were rendered for grease. All activities were timed with a stop-watch and all extracted nutrients were weighed. Table 1 enumerates the tasks and time involved in processing complete animal carcasses. Note that the time required to complete these tasks is a function of carcass size. That is, the larger the animal, the longer it takes to butcher the carcass.

Processing carcasses by boiling involves additional effort which often is difficult to estimate. In our experiments, carcass body parts were boiled for varying lengths of time in a metal pot over a charcoal grill. Because we used modern cooking instruments, these times may be under-estimations of the efforts put forth by more traditional subsistence societies. Before axial elements were boiled, many were chopped into smaller pieces to fit them into the pot. Actual cooking time involved little effort, primarily monitoring the pot's progress and adding fuel when necessary. For simplicity, we assume that most cuts of meat can be cooked in one hour, although the actual time involved depends upon the amount of meat and pot size. To a certain extent the quality and cut of the meat also will influence cooking time. For example, the meat of older animals contains more connective tissue than that of younger animals, thus it will take longer to cook (Robertson *et al.*, 1986). Regardless of prey condition, grease rendering from stripped bones takes considerably longer, and our experimental times represent maximum approximations. Removing cooked meat involved picking residual tissue from the bones. As with the initial butchering times, the effort involved increased as a function of carcass size.

Among the costs associated with boiling for which we have no information is the gathering of fuel. The actual amount of fuel necessary to boil meat varies as a function of the type of cooking vessel used, the availability of natural fuels (Shellie-Dessert and Hosfield, 1990) and size of bone fragment.

Table 1: Time of different activities involved in butchering and processing complete carcasses. [(a)]: Based on average rate for removing cooked meat from selected elements. * Missing or unknown values. Data reported here is based on a sample of 3 carcasses: 1 male impala, 1 female wildebeest and 1 female zebra (Carcasses 15, 11 and 14, Lupo n.d.).

Activity	Impala		Wildebeest		Zebra	
PRE-BOIL ACTIVITIES	Hour	Minute	Hour	Minute	Hour	Minute
Evisceration		3		1		3
Skinning		10		13		23
Dismemberment		10		12		24
Filleting		15		34		36
Marrow extraction		27		28		31
Time in hours	1	5	1	28	1	57
BOILING ACTIVITIES	Hour	Minute	Hour	Minute	Hour	Minute
Chopping bones (axial parts only)		*		3		6
Cooking, meat	1		1		1	
Cooking, grease rendering	4		3		12 +	
Removing cooked meat [(a)]		36		55	3	15
Fuel gathering *						

Nutritional returns and implications of boiling

In these experiments most, but not all, of the meat was rapidly stripped from the animal carcasses during initial field butchering (fig. 1). The relative proportion of meat removed from different elements varies taxonomically but is uniformly very high and consistent for almost all body parts. However, those elements that are oddly shaped and difficult to strip (e.g., vertebrae) tend to retain more meat after initial stripping than do appendicular elements; even so, about 70% of all meat can be stripped off vertebrae during initial field butchering. Only the cranium (for all taxa) retained large amounts of meat and tissue within the bone after initial field stripping. Similarly, most marrow can be rapidly removed during field butchering. Of the taxa examined, only zebra limb bones, which are comprised largely of cancellous bone that entraps most of the marrow and bone grease, are exceptions (tab. 2).

Processing stripped animals bones by boiling yields two types of products: residual meat and bone grease. Since most raw meat can be quickly stripped from the carcass in the field, only small amounts of meat are left adhering to bones when they are boiled. Bone grease is the only animal product that cannot be efficiently removed without the use of heat. Here, bone grease refers to the grease, fat, and small amounts of marrow trapped in the cancellous bone. Table 3 shows the amount of grease associated with each taxon. These are estimations only, since it is impossible to remove all of the grease contained in the bones of some taxa. The degree to which grease can be completely and efficiently removed is a function of animal size and bone structure. For impala, the smallest-sized animal in this sample, most of the bone grease could be removed by boiling the bones for 1-2 hours. A similar situation characterized the wildebeest bones, although some grease still remained trapped within the dense articular limb bone ends even after several hours of boiling. Zebra bone grease was extremely difficult to extract; after 12 hours of boiling much of the grease was still trapped within the bones and grease continued to seep from the bones for several days.

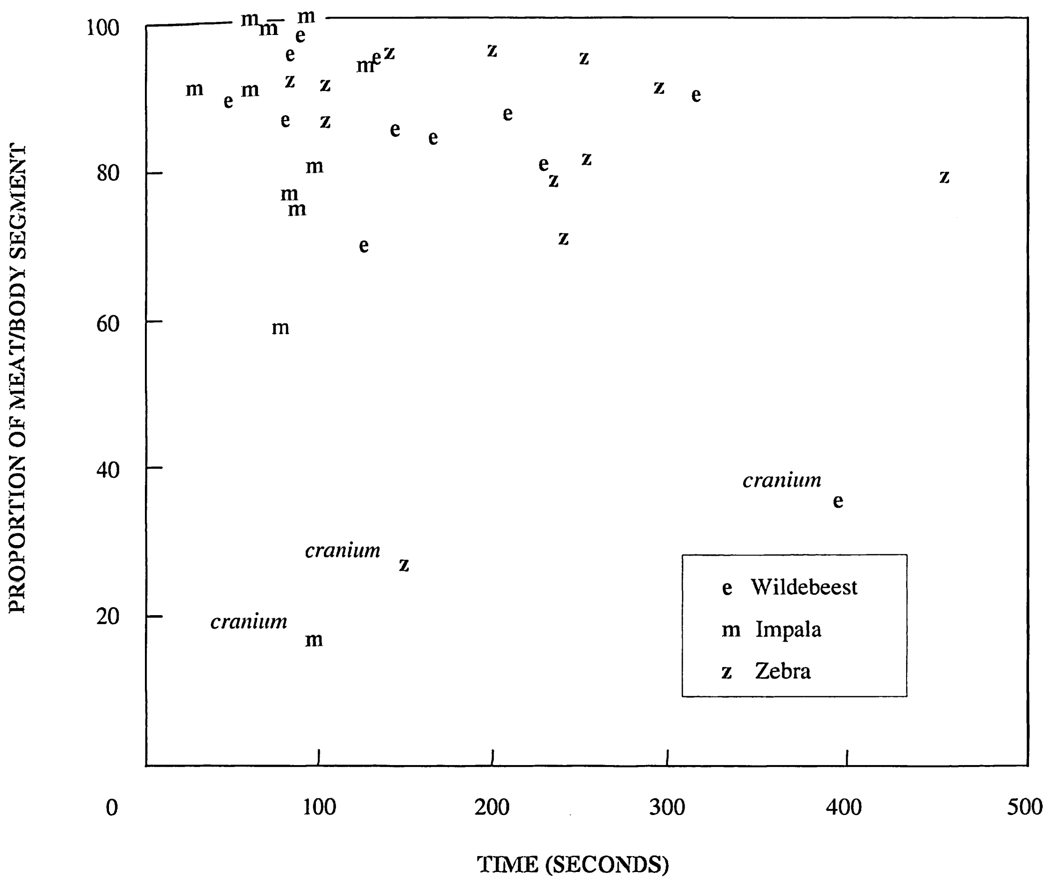

Fig. 1: Scatterplot illustrating the proportion of available meat removed and time invested in the initial field stripping of impala, wildebeest, and zebra body segments.

The caloric values for the nutritional products extracted at different stages of processing are compared in table 4. Caloric returns are measured in the number of kilocalories obtained per hour for each activity. For all taxa considered here, the best return is from stripping raw meat before it is boiled and the worst return is from grease rendering. For all taxa, the value of stripping residual meat and removing marrow is similar. But only for impala and wildebeest are marrow yields higher than stripping residual meat. However, it should be noted that meat and fat have different nutritional values. Meat, especially that from wild animals, is notoriously lean, and in East African animals the total fat content of meat may be less than 5% (Ledger, 1968). Depending upon the health, season, sex and reproductive status of the animal, marrow and grease can be quite high in lipids that are nutritionally important to human populations, especially children and lactating females (Hill *et al.*, 1987). Consequently, products higher in fat such as marrow and grease have a higher nutritional value irrespective of their caloric value. As a result, the best nutritional return may be contained in bone marrow and grease.

Another benefit resulting from boiling is the structural changes that meat and animal tissue undergo when exposed to heat and which is immeasurable in kilocalories. Connective tissue which on average comprises about 20% of the muscle mass is denatured when exposed to temperatures in excess of 70° C (Sims and Bailey, 1992). Prolonged heat exposure causes the collagen in connective tissue to turn into a gelatin that is more easily digested by humans. This same phenomenon explains why stripping cooked meat from bone is easier than removing meat that is raw. Cooking also reduces the moisture content of meat, thereby concentrating the nutrients (Mustafa, 1988). At temperatures in excess of 80° C the surrounding fatty deposits melt and

Table 2: Amount of marrow (in gms) removed from marrow-bearing parts and time required (in seconds) to break bones and remove marrow. All marrow weights (except the mandible) are averages derived from paired elements (left and right) from 1 individual. Marrow weights represent amount of marrow easily removed from medullary cavity; marrow in the cancellous bone of the articular ends was not removed. All limb bones were slightly roasted before being broken open. For impala and wildebeest, marrow-bearing bones were broken open with a hand-held hammerstone and anvil; for zebra, a panga (large bush knife) was used. [(a)]: Time required to break bones and remove marrow. [(b)]: This is the marrow from the first phalanges of one foot.

	Impala		Wildebeest		Zebra	
Element	Marrow	Seconds[(a)]	Marrow	Seconds[(b)]	Marrow	Seconds[(b)]
Mandible	2	150	14.6	263	10.9	133
Humerus	8.2	117	38.75	116	20.85	163
Radioulna	3.8	115	30.2	181	10.15	150
Metacarpal	3.45	68	6.8	86.5	5.85	91.5
Front phalanx[(b)]	1.7	46	2.7	68		
Femur	14	125	36.8	67.5	21	174
Tibia	19.5	95	81.75	97	24.65	186.5
Metatarsal	4.6	94	11.5	102.5	10.65	110
Hind phalanx[(b)]	1.64	80.5	2.1	28		

Table 3: Estimated total amount of bone grease for East African taxa.

Taxon	Bone Grease * (in grams)
Impala	142.53
Wildebeest	387.18
Zebra	653.78

* Estimates based upon grease content reported for American bison (*Bison bison*) by Emerson (1990). These are minimum estimates.

penetrate the lean meat, thus increasing its fat content and improving its overall quality (Coleman *et al.*, 1988).

Archaeological implications

The technology to boil food is a relatively recent innovation that may have only emerged with anatomically and behaviorally modern humans (Stiner, 1993). Many have speculated about changes in prey body part composition and bone damage patterns that resulted from the advent of boiling (Speth, 1989; Bunn *et al.*, 1988; Marshall and Pilgrim, 1991). Experimental data presented here provides some quantitative basis for evaluating how this processing technique might have changed faunal assemblages.

Our data suggest that prey carcasses can be quickly processed and their products nearly or completely exhausted without the use of fire. It is possible that some pre-modern humans could have been as efficient in processing animal carcasses with simple stone tools and without the aid of fire. Under these circumstances, and if transport capacity was limited, it might be expected that few, if any, bones of medium and large-sized prey were transported from carcass acquisition sites for subsequent culinary purposes. For pre-fire hominids, a small caloric advantage might be gained by transporting stripped bones with residual bits of meat, but two constraints might have limited this activity: the time it takes to remove raw residual meat and the costs of transporting stripped bones.

Raw residual bits of meat are difficult to strip from bones. Impala and wildebeest raw residual meat takes almost twice as long to remove as does cooked meat (tab. 5). The

Table 4: Kilocalories obtained per hour for different processing activities. [a]: Caloric values of impala and wildebeest meat approximated by antelope meat (114 Kilocals per 100 grams of meat). Caloric value of zebra meat approximated by horse meat (133 Kilocals per 100 grams) (U.S.D.A., 1989). [b]: Proportion of fat is based upon assumption that animals were in good physical condition and that the nonfat residue accounted for 7% of the wet marrow weight (after Blumenschine and Madrigal, 1993). [c]: For simplicity, it is assumed that grease is comprised of 100% fat.

Activity	Impala	Wildebeest	Zebra
Pre-boil nutrients			
Meat[a]	35,730	71,592	98,268
Marrow[b]	2,244	8,098	3,325
Boiling nutrients			
Residual meat[a]	1,847	5,101	4,530
Grease[c]	321	1,210	490

Table 5: Comparison of rates at which raw and cooked residual meat can be removed. Rates reflect grams of meat removed per second.

Condition of Meat	Impala	Wildebeest	Zebra
Raw residual meat	.55	.68	1.3
Boiled residual meat	1.2	2.6	1.2

same results were not obtained for zebra where raw meat was removed at about the same rate as cooked meat. Since only one zebra was analyzed in our experiment, we acknowledge that these results may be a product of sample size.

A larger consideration for pre-fire hominids would be transport costs. The costs of transporting stripped bones only for their returns in residual meat may have been quite high. A large proportion of the weight of some stripped bone is comprised of the unusable mineral component. Some elements (e.g., vertebrae) have relatively low proportion of dry unusable bone weight. Of the three taxa discussed here, an average of 40% of the stripped bone weight of a complete carcass was comprised of mineral bone. If transport was constrained, the costs in transporting stripped bones may have been prohibitive. However, this does not rule out the possibility that bones of medium and large-sized prey were transported for nonconsumptive purposes, such as for use in the manufacture of tools or ornaments.

With the advent of boiling, the transport of stripped bones became more feasible, due to the potential nutritional returns, especially in fat. In particular, bones with high grease content would be selectively transported and boiled, such as upper limb bones, especially the articular ends, and some of the vertebrae.

Our experimental data suggest that boiling is a high cost processing strategy, but these methods do not parallel those used by many prehistoric populations lacking modern metal vessels, and our data probably offer inflated caloric returns. Ethnohistoric observations of hunters in both the Old and New World suggest that in the absence of durable vessels, boiling meat and bone was achieved by dropping heated rocks into containers of water (Russell, 1963; Vehik, 1977). The hot-rock method could be used with vessels constructed of wood, hide, or basketry because it precluded exposing the container directly to flames. An example of hot-rock boiling is reported by Binford (1978) who observed Nunamiut Eskimo women rendering grease from caribou bones. Binford reported that 3 backloads of wood were required to heat 27 kilograms of stone which were repeatedly heated and dropped into a 23 litre kettle of water and pulverized bone. Binford reported that the whole process took approximately two hours to produce a grease cake weighing only 198 grams. Historical sources suggest that far fewer stones were needed to simply cook meat (Russell, 1963). However, this illustrates that traditional hot-rock boiling methods are far more time intensive than the methods used in our experiments.

Many have argued that boiling bones requires specific types of technology and it could not have been practiced without durable ceramic vessels and the controlled use of fire (e.g. Shipman and Rose, 1983). However, historical accounts of New and Old World hunter-gatherers describe bone boiling with less sophisticated technology. In the New World, bones were frequently boiled in pouch skin bags or baskets using the hot-rock method described above (see Lupo, 1993, and the references therein). Furthermore, if animal fat possesses the high nutritional value that many have suggested, grease extraction by way of bone boiling should have maturated shortly after the emergence of fire.

In addition to changes in the skeletal composition of faunal assemblages, at least two types of bone damage patterns resulting from preparing bones for boiling have been identified. Pulverized large mammal bones are often associated with grease rendering activities (Binford, 1978; Vehik, 1977). Bones are broken into small pieces to facilitate grease extraction, and the rendered grease is often cooled, formed into cakes, and used as supplement for dried meat. Additionally, chopped bones in uniform "pot-sized" pieces may reflect meat and stripped bone boiling (Crader, 1981; Lupo, 1993). In this circumstance both meat and stripped bones may be cooked together to improve the quality of lean meat. In addition to the structural changes that meat undergoes when cooked, small chunks of meat added to a pot more efficiently absorb fat and grease contained within the broth.

Conclusions

These are only some preliminary results from experiments in butchering and processing the carcasses of some East African taxa. The experiments did not simulate conditions experienced by pre-modern humans. We used modern technology, such as metal knives and kettles, and our materials and methods ultimately affected our results. The use of metal blades in our experiments, for example, probably resulted in efficiency levels seldom attained by pre-modern stone tool populations. However, our intent was to collect some base-line data from which different carcasses processing activities could be evaluated and to offer some preliminary inferences on the costs and benefits of pursuing these activities.

We examined the efficiency of bone boiling by comparing it with carcass butchering and processing without the aid of fire. The results suggest that butchering and processing some carcasses in the field can be accomplished quite quickly and that the yields generally are great. Except for grease, most animal products can be removed in the field without the aid of fire. As a result, we suspect that when transport was constrained early hominids rarely transported the bones of large taxa for culinary purposes. With the advent of fire, our data indicate that extracting residual meat and grease via boiling is costly and affords only a small amount of the available calories in prey carcasses. However, despite the low caloric returns and amount of effort it requires, the nutrient yield in fat and grease may have out-weighed the effort. Although not discussed in detail here, the addition of meat and bones to a stew pot containing vegetables may have increased the nutritional value of plant foods (see Stahl, 1989, for a discussion on cooking and plant products). Finally, an important benefit of boiling, and one that often is overlooked, is that it structurally changes meat by improving its quality and extends its use-life.

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Bibliography

BINFORD L., 1978.– *Nunamiut Ethnoarchaeology*. New York : Academic Press.

BLUMENSCHINE R. and CARO T., 1986.– Unit flesh weights of some East African bovids. *African Journal of Ecology*, 24 : 273-286.

BLUMENSCHINE R. and MADRIGAL T., 1993.– Variability in long bone marrow yields of East African ungulates and its zooarchaeological implications. *Journal of Archaeological Science*, 20 : 555-587.

BUNN H., BARTRAM L. and KROLL E., 1988.– Variability in bone assemblage formation from Hadza hunting, scavenging, and carcass processing. *Journal of Anthropological Archaeology*, 7 : 412-457.

COLEMAN M., RHEE K. and CROSS H., 1988.– Sensory and cooking properties of beef steaks and roasts cooked with or without external fat. *Journal of Food Science*, 53 : 34-39.

CRADER D., 1981.– *Hunters alongside farmers : faunal remains from Chencherere II Rockshelter, Malawi*. Ph. D. dissertation. University of California, Berkeley.

EMERSON A., 1990.– *Archaeological implications of variability in the economic anatomy of* Bison bison. Ph. D. dissertation. Washington State University, Pullman.

HILL K., HAWKES K., KAPLAN H. and HURTADO A., 1987.– Foraging decisions among Ache hunter-gatherers : new data and implications for optimal foraging models. *Ethnology and Sociobiology*, 8 : 1-36.

JAMES S., 1989.– Hominid use of fire in the Lower and Middle Pleistocene. *Current Anthropology*, 30 : 1-25.

LEDGER H., 1968.– Body composition as a basis for a comparative study of some East African mammals. *Zoological Society of London Symposia*, 21 : 289-310.

LUPO K., 1993.– *A taphonomic analysis of Hadza-produced bone assemblages*. Ph. D. dissertation. University of Utah, Salt Lake City.

LUPO K., n. d.– The economic anatomy of selected East African taxa. Manuscript in possession of the Author.

MARSHALL F. and PILGRIM T., 1991.– Meat versus within-bone nutrients : another look at the meaning of body part representation in archaeological sites. *Journal of Archaeological Science*, 18 : 149-163.

MUSTAFA F., 1988.– Moisture, fat and cholesterol content of some raw, barbecued and cooked organ meats of beef and mutton. *Journal of Food Science*, 53 : 270-271.

O'CONNELL J., HAWKES K. and BLURTON JONES N., 1988.– Hadza hunting, butchering, and bone transport and their archaeological implications. *Journal of Anthropological Research*, 44 : 113-161.

ROBERTSON J., RATCLIFF D., BOUTON P., HARRIS P. and SHORTHOSE W., 1986.– A comparison of some properties of meat from young buffalo (*Bubalus bubalus*) and cattle. *Journal of Food Science*, 51 : 47-50.

RUSSELL H., 1963.– Pot boiling with red-hot stones. *Massachusetts Archaeological Society*, 24 : 58-59.

SHELLIE-DESSERT K. and HOSFIELD G., 1990.– Implications of genetic variability for dry bean cooking time and novel cooking methods for fuelwood conservation in Rwanda. *Ecology of Food and Nutrition*, 24 : 195-211.

SHIPMAN P. and ROSE J., 1983.– Early hominid hunting, butchering, and carcass-processing behaviors : approaches to the fossil record. *Journal of Anthropological Archaeology*, 2 : 57-98.

SIMS T. and BAILEY A., 1992.– Structural aspects of cooked meat. *In* : D. E. Johnston, M. K. Knight and D. A. Ledward eds., *The Chemistry of Muscle-based Foods*. Cambridge : Royal Society of Chemistry, p. 106-127.

SMITH E., 1983.– Anthropological applications of optimal foraging theory : a critical review. *Current Anthropology*, 24 : 625-651.

SPETH J., 1989.– Early hominid hunting and scavenging : the role of meat as an energy source. *Journal of Human Evolution*, 18 : 329-343.

STAHL A., 1989.– Plant-food processing : implications for dietary quality. *In* : D. R. Harris and G. C. Hillman eds., *Foraging and farming : the evolution of plant exploitation*. London : Unwin Hyman.

STINER M., 1993.– Modern human origins-faunal perspectives. *Annual Review of Anthropology*, 22 : 55-82.

U.S.D.A., 1990.– *Composition of foods : lamb, veal, and game products*. Agriculture Handbook 8-17. Washington D.C. : United States Department of Agriculture.

VEHIK S., 1977.– Bone fragments and bone grease manufacturing : a review of their archaeological use and potential. *Plains Anthropologist*, 22 : 169-182.