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The significance of cooking for early hominin scavenging

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ABSTRACT

Meat scavenged by early *Homo* could have contributed importantly to a higher–quality diet. However, it has been suggested that because carrion would normally have been contaminated by bacteria it would have been dangerous and therefore eaten rarely prior to the advent of cooking. In this study, we quantified bacterial loads on two tissues apparently eaten by hominins, meat and bone marrow. We tested the following three hypotheses: (1) the bacterial loads on exposed surfaces of raw meat increase within 24 h to potentially dangerous levels, (2) simple roasting of meat on hot coals kills most bacteria, and (3) fewer bacteria grow on marrow than on meat, making marrow a relatively safe food. Our results supported all three hypotheses. Our experimental data imply that early hominins would have found it difficult to scavenge safely without focusing on marrow, employing strategies of carrion selection to minimize pathogen load, or cooking.

1. Introduction

The emergence of the genus *Homo* from australopithecines was characterized by the appearance of several distinctly human traits including increased body mass, reduced masticatory structures, narrower rib cage, longer lower limbs, increased commitment to bipedalism, and increased absolute and relative brain size (Eng et al., 2013; Antón et al., 2014). These traits became pronounced with the evolution of *Homo erectus* around 1.9 million years ago and are considered to reflect a concomitant increase in energy use and dietary quality (Wood, 1992; Aiello and Wheeler, 1995; Wrangham and Carmody, 2010).

Increased meat–eating is widely thought to have been an important contributor to increases in energy use and dietary quality. Persistent carnivory has been confidently dated to 2.0 million years ago (Ferraro et al., 2013). Occasional carnivory, by contrast, is shown by stone tools and cut–marks dated to between 2.6 and 2.5 million years ago (Domínguez-Rodrigo et al., 2010), or possibly by cut–marks at 3.4 million years ago (McPherron et al., 2010). The original meat–eating models featured hunting as the source of meat, evidenced by animal bone assemblages exhibiting stone–tool cut marks (Dart, 1953, 1959; Washburn and Lancaster, 1968; Bunn, 1981; Potts and Shipman, 1981). Later authors noted the co–occurrence on animal bones of marks made not only by stone tools but also by carnivores, and therefore suggested that scavenging was a main strategy of obtaining meat (Binford, 1981; Brain, 1981; Bunn et al., 1986; Blumenschine, 1987; Cavallo and Blumenschine, 1989).

Attempts have therefore been made to use the archaeological record to determine hominin carcass acquisition strategies based on data such as the frequency of carnivore tooth marks and the presence or absence of skeletal elements that tend to be removed by carnivores. Some results suggest that early hominins were primarily engaged in hunting activities (Domínguez-Rodrigo et al., 2005, 2009; Pobiner et al., 2008), or that both hunting and scavenging were important (Ferraro et al., 2013). Others point to a dominant role for scavenging (O'Connell et al., 2002), but while assemblages and marks on bones are often consistent with scavenging (of both meat and marrow), none of the signals are certain (Lupo, 1998; Pante et al., 2012). The extent of scavenging by early *Homo* thus remains undecided.

Scavenging has received increased attention over the years partly because it has been observed among African foragers, especially in open habitats. O'Connell et al. (1988a,b) reported that the Hadza obtained 14% of their meat from scavenging, with 20% of the 54 carcasses that provided meat over a one–year period having been scavenged. Yellen (1991) reported that 9% of 143 small antelope eaten by !Kung San during the dry season were scavenged, and indicated an even stronger role for scavenging in the rainy season. By contrast, the forest–living Bofi and Aka of Central Africa scavenge only "on rare occasions," i.e., 0.3% of 650 mammals and birds eaten over a four–year period (Lupo and Schmitt, 2005: 337).

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There are fewer carcasses, and therefore fewer scavenging opportunities, in humid forests than in open savannas (Watts, 2008). Meat scavenged by tropical hunter–gatherers is apparently always cooked.

Although scavenging by open–country hunter–gatherers is informative by showing that significant amounts of meat can be obtained, Ragir et al. (2000) suggested that scavenged meat would be a costly food. When an animal is killed and its flesh exposed, bacteria accumulate on the meat (Janzen, 1977). Ragir et al. (2000) argued that bacteria are likely to be pathogenic and produce toxins. These can indeed be costly. Even in the relatively hygienic conditions of the United States, gastroenteritis (i.e., food–poisoning) annually affects 48 million people, hospitalizes 128 thousand, and kills three thousand (Centers for Disease Control, 2014). Basing part of their argument on the fact that chimpanzees normally fail to take advantage of scavenging opportunities, Ragir et al. (2000) suggested that all hominoids lack the gut morphology and digestive kinetics to cope with these pathogens in an energetically feasible manner. They therefore proposed that cooking would be required to minimize the risk of ingesting pathogenic bacteria on meat, and therefore that carcasses exploited before the advent of cooking must have been primarily hunted rather than scavenged.

The time when cooking was first practiced is not known. One possibility is that it was initiated by early *Homo*, as predicted from biological evidence (Wrangham et al., 1999; Wrangham and Carmody, 2010). Cooking increases the effective energetic value of meat (Carmody et al., 2011), and cooked meat is spontaneously preferred to raw meat by living hominoids (Wobber et al., 2008). Therefore, hominins who cooked scavenged meat could have increased their overall energy gain by increasing their access to another high–quality source of food. However, the extent to which they would have benefited from the anti–bacterial properties of fire is unclear because to date there has been no study quantifying the bacterial loads of meat and marrow in an environmentally relevant scavenging scenario. Nor has there been any quantification of the effect of a simple cooking method that might have been available to ancestral *Homo* (open–flame roasting) on these bacterial loads. It is therefore uncertain how predictably bacteria accumulate on raw wild meat, and how effectively *Homo* could have made scavenged meat safe with early methods of cooking.

In this paper we describe two tests of Ragir et al.'s (2000) hypotheses. First, we conducted experiments to assess how rapidly bacterial populations grow on freshly killed meat in the wild, and whether open–flame roasting reduces those populations. Second, we compared the densities of bacteria on meat versus bone marrow. Hadza hunter–gatherers of northern Tanzania consume raw marrow regularly, though how often it comes from scavenged or hunted carcasses has not been reported (Oliver, 1993). From a microbiological perspective, marrow could be relatively safe compared with meat because the bone casing is expected to offer protection from microbes, even though bacteria injected into the circulatory system could in theory enter the bone through the nutrient artery (Trueta, 1959).

Accordingly, we designed an experiment in which meat and defleshed, intact bones from wild animals were allowed to decompose in a controlled environment, after which their bacterial loads were compared with those of roasted counterparts. We tested three hypotheses: (1) exposed meat surfaces accumulate higher bacterial loads with increasing time after death, (2) cooking reduces the bacterial load on meat, and (3) for matched samples of meat and of bone marrow, the bone marrow has a lower bacterial load due to the protection conferred by the bone casing.

2. Materials and methods

Research was conducted from June 15 to August 5, 2013 in Graford, Texas (32°56′ N, 98°14′ W) at the Wagley Ranch, owned and operated by Jay and Sue Wagley. Feral Eurasian boar (*Sus scrofa*) cause property damage on the ranch, and are therefore regularly culled ([1]see note below). The Wagleys donated fresh carcasses. We received exemption from the oversight of IACUC (the Institutional Animal Care and Use Committee) in utilizing them.

2.1. Preparation of meat and marrow samples

After ranch workers shot and killed an adult boar, they immediately brought the whole carcass to our experimental station. The time to arrival was never more than 30 min after death. Butchering began at once. The four limbs of each carcass were not touched by bullets and were the sources of meat in this experiment. Initial butchering was performed with a large knife that was sterilized with 70% ethanol before and after the cutting of each individual limb. To butcher the hind limbs, we cut across the exterior surface to the acetabulofemoral joint, freeing the femoral head from the acetabulum. To butcher the forelimbs, we cut across the glenohumeral joint, freeing the humeral head from the glenoid fossa. Great care was exercised to ensure that the intestines and other organs were not punctured and that there was no contact between the meat and the anus, feces, or other sources of contamination.

Using a new, sterile scalpel for each cut, three incisions were made in each limb from skin to bone. One was a transverse cut across the top of the limb, another was longitudinal down the femur or humerus (through either the biceps femoris or triceps, respectively), and the third was the same as the first (transverse) except at the bottom of the longitudinal cut (Fig. 1). The sample was then 'butterflied' so that the two halves of muscular tissue were pulled open from the longitudinal cut, exposing the adjacent surfaces of muscle that were originally divided by the longitudinal cut. Marrow samples came from distal limb bones, which were disarticulated and defleshed using a sterilized knife.

The limbs and bones were placed in individual, large tupperware containers ('boxes,' 72 cm L × 46 cm W × 16 cm H) for decomposition, the aim being to protect the samples from scavenging vertebrates or insects (a method adapted from Carter and Tibbett, 2006; Spicka et al., 2011). There is no doubt that insects play an important role in the decomposition process. By transporting microbes and producing offspring that tunnel and aerate carcass tissues, insects alter the microbial and physical nature of the carrion source in ways that are expected to promote bacterial growth (Payne, 1965; Putman, 1978; DeVault et al., 2003). However,

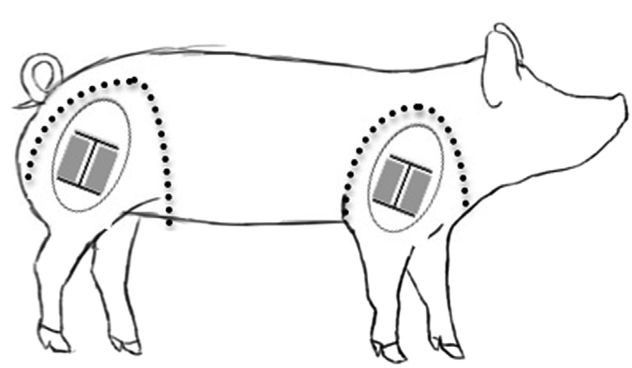

Figure 1. Schematic representation of butchery and sample preparation. Black lines indicate transverse and longitudinal cuts. The gray portions indicate the actual samples of meat gleaned from the limb. Dotted lines indicate where the limbs were removed from the torso.