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Review Article

The Truth: Are Humans Vegetarian, Carnivore, or Omnivore? A Review Based on the Anatomy and Physiology of the Human Digestive Tract

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Abstract

The anthropological aspect of food studies is a fascinating segment of food science. The modern-day food study comprises the culinary arts, nutrition, gastronomy, and more. Anthropologists seek to know the food habits of human ancestors and the evolutionary transformations that occurred in the human diet. Different schools of thought exist regarding the original human diet. Some claim that *Homo sapiens* were herbivorous, mainly evidenced by gut morphology. Others study tribal communities and compare them with the stone age, concluding that human ancestors were omnivorous. The literature is scattered with only theories and shreds of evidence. This review aims to collate the evidence present in the literature to understand if the original human diet was omnivorous, carnivorous, or herbivorous. The presence of fire and butchery marks on animal bones retrieved from archeological sites points towards the hunting habit of humans. Early humans also domesticated animals and cultivated crops. The knowledge of agriculture made it possible for them to inhabit wider regions across the globe. Now that humans' horizons had broadened, also did their dietary habits. The overall inference could be that early human consumed a mixed diet at some point in time. However, the timeline of events that brought about dietary changes remains an enigma. It is possible that the addition of meat to their diet occurred at a later stage as part of a survival strategy. The harsh winters must have compelled them to rely on animal food because plants were buried under snow. Much more inestigation regarding early humans' dietary habits is needed, and would prove helpful in better understanding human nutrional needs, dietary demands, and their inherent digestive process as they relate to health and disease. Researchers need to weave more evidence and pursue various leads to solve human's complex dietary history and reach a definitive conclusion—are humans fundamentally herbivores, carnivores or omnivores?

Keywords: *Flesh; Microbiome; Plants; Protein; Survival*

Abbreviation

Ma: Mega Annum (One Million Years Ago)

Introduction

"It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change" (Attributed to Charles Darwin).

Homo sapiens are said to have originated in the Sub-Saharan Region, approximately 200,000 years ago. *Homo erectus* is the first member of the genus *Homo* that existed about 2 million years ago [1]. Humans assimilation of cultural values, developing and using tools, and communicating with each other using verbal language has made them evolutionarily superior to animals. Nevertheless, there are few differences between humans and animals [2].

Quantitatively, among different species, dietary needs vary due to the inherent differences in physiology, size, habitat, physical activity, and other factors. The discussion on human evolution would be incomplete without a discourse on dietary changes that have occurred over millions of years. Anthropologists have always been intrigued by the food habits of our human ancestors, such as what they ate, how did they cooked, and were they herbivores, carnivores, or omnivores? Interestingly, human food habits vary because of diverse cultural and geographical differences; however, this variation is rarely seen among other species. For example, the Japanese and French diets are composed of more vegetables than the North American diet. The North American diet mainly revolves around rice, potatoes, corn, and wheat [1]. Feeding habits rarely change among animals unless driven by environmental pressures.

The debate about the original food habits of primitive humans seems unresolved. According to some scholars, the human diet consisted of both vegetables and meat. Being omnivorous, humans could adapt to and evolve from changing conditions. Researchers, like Milton (2000), believe that the primitive human diet consisted more of vegetables than meat, while other researchers hold the opposite opinion [3,4]. The tribal communities and populations residing in snowy conditions in the current era are more dependent on meat. Since such contemporary climatic conditions are similar to those in the Paleolithic era, it can be assumed that meat formed a significant portion of the diet in early human evolution.

Discussion

The evolution of human food habits

It is plausible that early humans leaned towards meat during harsh winters when the plants were buried under snow. Moreover, meat can be stored for a longer period than plants and vegetables, making it possible for humans to avoid seeking food during harsh weather. There is sufficient evidence indicating that our human ancestors had sharp tools (suitable for hunting) and knew how to use fire to cook. Goren-Inbar., *et al*. (2004) wrote about the controlled use of fire at hearths, evidenced in an archeological site in Israel. This site revealed burnt seeds, wood, and flint, dating about 790,000 years ago [5]. The authors eliminated the possibilities of natural fire and volcanic eruptions in the location where burned flint and wood were found, thus concluding that these were products of hominin activity.

When primitive humans learned to use fire to cook, it substantially modified human food habits and lifestyles [1]. Although there are opposing theories about fire's origin, some researchers opine that it was not discovered by *H.erectus* (ancestors of *H. sapiens*), but that *H. erectus* could control fire [1]. Whoever created fire, primitive human certainly knew how to use fire to cook food.

During food scarcity, remnants of animal carcasses served as a source of nutrition for early humans. These carcasses provided bone marrow and underground plant storage during the dry season [6,7]. Later, humans learned to process food and convert the complex starches of plant food into easily digestible components [8].

The butchery marks on bones found in the fossils belonging to the early stone age support the theory that human ancestors hunted for meat. Typically, these marks are formed when carcasses are skinned, disarticulated, or bones are fractured [9,10]. This prehistoric evidence of human carnivory has been recognized by researchers from as early as the 1980s. The stone tool butchery marks support the theory that early African hominins were carnivorous from as early as 2.6 Ma (mega annum) [11].

However, it is unclear when meat and bone marrow entered the human diet. Nevertheless, evidence shows that gene selection may have helped in adapting to dietary changes [12]. The human gut has some anatomical differences from apes [13], which is dealt with in more detail later in this article.

The debate regarding the true dietary nature of humans

Anthropologists have studied the Paleolithic Era ("Stone Age") trying to ascertain the history of human food and feeding habits. Some researchers believe that most human nutrition was gained from fruits and nuts during the early days, whereas meat was obtained from occasional hunting excursions. Investigations have strongly suggested that the Neanderthal diet was composed mainly of plants. In contrast, however, some authors believe that human ancestors were hunters while also being "occasional berry chasers". Nevertheless, these human ancestors experienced specific and fundamental changes in diet or feeding habits to survive harsh environments and cycles of "abundance and starvation" [14]. In the current epoch of widely available food and farming, husbandry, food processing, and food storage, starvation is likely much less frequent than in the Paleolithic Era, per capita.

In the early 20th century, research on inhabitants in marginal areas revealed that the constant fear of food shortages might have made early humans hunter-gatherers. However, researchers point out that these areas had plentiful food sources when the first human tribes arrived there. Thus, the origin and reason behind how meat made it to the human diet remain controversial [15]. Presumably, hunter-gatherer feeding has always existed and is not related to food shortages. The food supply was positively impacted only after the agriculture's advent [16,17].

Another argument against food scarcity is that early humans could use fire to cook food. They could even process food, and limitations in supply might not have been a reason to opt for meat [1]. However, food shortages may have occurred when the human population started to move into different locales and regions. Before applying agriculture, feeding habits may have changed depending upon the location and availability of food in a specific region to where the growing tribes migrated [18]. This hypothesis makes sense when considering the evolution of humans due to phenotypic plasticity—the adaptation of an organism to environmental conditions without undergoing genetic changes.

Due to humans changing locales and spreading across the globe, the circumstances likely demanded a change in feeding practices. Nature may have supported those who had a better physiological ability to preserve calories. Furthermore, this habitat change might have brought about physiological changes in metabolism, depending upon food availability [1].

The decreasing gut size of humans and increasing brain size during their evolution are essential evidentiary pieces to the early human dietary habits puzzle—for those who claim that meat in the diet led to this vital evolutionary step. However, there is no conclusive research to ascertain if this development occurred due to a dietary change, usage of fire in cooking, or advancement in tools [19].

Were human ancestors omnivores?

It is argued that early hominins (human evolutionary group of species) had an omnivorous diet similar to chimpanzees (food, leaves, insects, and meat). Odontological studies revealed that later larger animals formed part of the diet [20]. Fossils show that, out of the three hominins, *H. sapiens* were the only meat-eaters—based on anatomical features, such as small teeth and gut size, and increased body and brain size [21]. The limitations of exploiting the vast African grasslands may have compelled them to turn to meat. Advancing hunting strategies and butchery techniques may have brought meat into the human diet in more significant proportions than before.

The essential amino acids from meat (and aquatic fauna) helped their brain development and increased body size [22]. Zucoloto (2011) wrote that agriculture introduced cereals to the human diet, which was previously composed of meat [1]. Dr. T. Colin Campbell, a professor at Cornell University, New York, also supports the theory that only after *H. sapiens* learned to cultivate, did they start eating meat [23]. Gaining the skill of growing their food also brought in the possibility of migration. They no longer needed to remain nomads for sustenance, since they could grow food near their habitat.

Omnivory was a boon for *H. sapiens* because they could stay put or relocate, consuming meat and plant products provided by geographical or climatic conditions. Exclusive herbivory would not have permitted them to survive in extremely cold termperatures, like current-day Alaska where animal food is the predominant source of nutrition. However, exclusive carnivory would also have made survival equally problematic because they were not natural hunters [1,24].

Vitamin B12 is an essential nutrient for humans and is found only in animal-derived food sources. Milk supply was absent in the Paleolithic era, so it is highly possible that humans derived vitamin B12 from animals. Nevertheless, the amount of meat consumption must have varied, depending upon the requirement, location, or hunting conditions.

Zaraska (2016), in her book on human ancestral history, stated that a change of climate approximately 2.5 million years ago, must have provided the required dietary modifications to *H. sapiens*. With the decrease in rainfall, forests converted into grasslands, resulting in an increase in grazing animals and a decrease in fruits, leaves, and flowers. To survive food scarcity, humans turned to meat-eating [25].

At Kanjera (Kenya), fauna fossils were excavated; stone tools dated back to 2.0 Ma. This discovery also supports the carnivory of Hominins [26]. Anthropological and archeological sites at Koobi Fora, Kenya, provide evidence showing aquatic animals were also a part of the hominin diet since about 1.95 Ma [21]. In his research paper, Landt (2007) discussed discoveries from the Central African Republic that found human teeth marks on bones of small mammals.

Scholars believe that three hominin species existed between 2.6 and 2.5 Ma [27]. However, when considering the period that relates to stone tools and the anatomical evidence of meat-eating, only the Homo genus (especially *H. erectus*) closely fits this era. Hence, it is believed that human ancestors chewed on bones [21].

This group of believers in the omnivorous nature of humans is further divided into those who have differences in opinion about the quantity of meat that *H. sapiens* consumed. Milton (2000) advocated that human omnivorous ancestors consumed more vegetables than meat [3], whereas Cordain (2000) claimed that meat formed a significant portion of their diet—or, at least, it was equal to vegetables [28].

Carbon isotope analysis of the early human fossil remains points to omnivory. According to Sponheimer and Lee-Thorp (1999), about 3 million years ago, when the hominid *Australopithecus africanus* existed, their food was composed of more fruits and leaves and less meat. The grasses and herbivores were found to have more carbon-13 than leaves and fruits. The hominids also showed carbon-13, which must have been derived from the meat of herbivores [29].

Whatever the principal diet component, the concept that early humans were omnivorous comes from a comparison to present-day hunter-gatherer tribes. These tribes resemble the primitive *H. sapiens* belonging to the Paleolithic era. The tribes living in the tropics (Kung) eat more vegetables than meat, whereas the tribes from colder regions (Inuits) eat more meat [30].

Were human ancestors herbivores?

There is another theory stating that humans are "committed" herbivores [31]. This supposition is supported by Dr. Milton Mills, a well-known name in the field of nutrition research.

The human digestive system resembles the digestive system of herbivores more than carnivores. The human's small intestine is longer like herbivores so that the bolus remains for a longer time in the system to undergo digestion.

Carnivores have a larger stomach and a shorter small intestine [23]. Hunters, like lions and tigers, pursue a kill once every few days. The large stomach stores food that these animals digest while resting. The stomach is highly acidic in these animals, unlike the human stomach that shows mild acidity. The carnivores need hydrochloric acid to digest meat protein and kill harmful bacteria in the meat. The view that humans are not natural hunters is also supported by Dr. Neal Barnard, founder and president of the Physicians Committee for Responsible Medicine. He supports this view by saying that humans lack the instincts of a good hunter, in that: "we are not quick, like cats, hawks, or other predators [23]".

Anthropologists argue that human dentition resembles herbivores more than carnivores. The human molars are flat (to help in grinding plant products). Incisors are spade-like (to help in peeling and biting soft food). Premolars are flat and nodular (to help in "mulching" soft and smooth food).

The differences in anatomy, gut microbiota and enzymes

The gut morphology depends on the need, shape, and size of the body, the nature and frequency of food, and the requirement for food storage. The digestive systems show substantial differences among herbivores, carnivores, and omnivores. The human alimentary canal is significantly extended, evincing more extensive surface for more complete digestion. Thus, more nutrition can be extracted. Simple foods are metabolized early in the tract, whereas the complex foods are degraded in the large intestine.

Due to the animal kingdom's diverse food sources and dietary habits, features of the gastrointestinal system vary. Before knowing the fundamental differences, there should be consideration of the physiological balance that nature has maintained within creatures. Caloric requirement, retention time of food in the stomach, enzymatic and absorptive capacity, and food chemistry are interrelated. For example, if the retention time is prolonged, it would limit food intake or enlarge the gastrointestinal tract [33]. As part of this mechanism, the digestive system enlarges or diminishes in size, depending on the dietary requirement or food habits of seasonally-hibernating animals [33], reptiles [34], and fishes [35].

Another striking feature is the phenomenon of lactose intolerance—typical among humans. At birth, mammals have high lactase that helps them digest milk. This enzyme declines after the weaning period, and if later in life a large quantity of lactose is ingested, it might lead to the production of harmful gases and cause osmotic diarrhea [32].

The gut microbiota composition is related to the animal's phylogenetic status and digestive tract [36,37]. In humans, this composition varies depending upon age [38], diet [37], and medical conditions [39].

Herbivores are most efficient in digesting plants and plant fibers—and carnivores the least. In contrast, microbes in the digestive system are most prominent in carnivores because they are needed to digest meat [40]. When comparing humans and mammals, such as apes, the latter have a proportionally larger intestine. The small intestine and lack of cellulase make humans incapable of extracting plant nutrition [14]. Another significant difference between herbivores and humans is the presence of foregut or hindgut in the herbivores.

Herbivorous mammals are further differentiated into non-ruminant or ruminant foregut fermenters and non-coprophagous and coprophagous (consumption of feces) hindgut fermenters [41]. Herbivores have a particular enzyme, cellulase, to break down cellulose, which is the primary component of plant cell walls. In herbivorous ruminants, bacterial fermentation occurs in the rumen. The rumen is an anaerobic cavity in which the food gets hydrogenated.

This surplus hydrogen forms saturated fatty acids, which in turn cause an increase in body fat deposition due to beef containing more fat than chicken meat. On the other hand, hindgut fermenters (such as rabbits and horses) are more agile and less bulky. Maximum digestion in these animals occurs in the small intestine. Any undigested food undergoes fermentation in the cecum and then moves to the large intestine, where fatty acids and water are absorbed from the ingested food [42].

Carnivores eat animal protein that is easily broken into amino acids by digestive enzymes. Hence, they have a relatively simple digestive tract, unlike herbivores. Moreover, there are obligate carnivores (carnivorous because of physiological limitations) like the cat family that takes all necessary nutrients out of their carnivorous diet [42].

Humans are "autoenzyme digesters" who digest food in the foregut and midgut, using self-produced enzymes and not bacterial enzymes [43]. The digestive process in this species starts in the oral cavity where food is masticated, and salivary enzymes act on the bolus. The stomach releases acids and enzymes that hydrolyze the food while also killing most bacteria in it. Among the omnivores that are autoenzyme digesters, there are variations in the large intestines, e.g., the large intestine is spacious in pigs. Differently, carnivores have a shorter hindgut, often contiguous with the small intestine [44].

Interestingly, humans have also been classified as cucinivores. This classification is due to the knowledge of cooking food, which is unique to this species.

Different modes of cooking and processing enhance palatability and digestibility—a probable reason for the difference between human and primate gut systems. The human colon makes up 20% of the total volume of the digestive tract compared to 50% in apes [45]. The more extensive colons in large primates enable them to use plant fibers as a source of energy, unlike humans [46].

Carnivorous vertebrates lack enzymes to digest cellulose, which is primarily found in plant food. Herbivores have microflora that ferment fibrous plant components facilitated by gut specializations, which retain the food for a longer time in the gut—thus enhancing the digestion of complex compounds [47].

Another difference between herbivores and carnivores is that the large intestine is longer and voluminous in herbivores than carnivores. Additionally, herbivores possess gut specializations absent in carnivores, such as a cecum, intestinal valves, and hindgut nematodes [44].

Conclusion

It is challenging to assert whether or not human ancestors were exclusively herbivores or carnivores conclusively. The statements by archeologists and scholars are dichotomous and lack adequate theoretical support. However, the evidence pivots toward an evolutionary pattern that caused herbivorous *H. sapiens* to become omnivores. There is a definite association between anatomical and physiological changes to dietary evolution.

Conflict of Interest Statement

The authors declare that this paper was written in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

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