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New Insights on the Evolution of the Sweet Taste Receptor of Primates Adapted to Harsh Environments

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Simple Summary: A sense of taste is vital to an animal's fitness. It enables animals to select and ingest beneficial foods and avoid harmful substances in their daily lives. There have been relatively few studies regarding the evolution of the taste receptor gene for sweetness, particularly in regard to endemic Bornean primates. We constructed *TAS1R2* gene phylogenies for 20 anthropoid primate species using four different methods as well as established the phylogenic time divergence. The phylogenetic analysis successfully separated the primates into their taxonomic groups and as per their dietary preferences. Of note, the estimated time of divergence for the primate speciation pattern in this study was more recent than the previously published estimates. This difference may have been due to environmental changes, such as food scarcity and climate change, during the late Miocene epoch, which likely forced primates to adapt their dietary preferences. These findings establish a foundation for further investigations.

Abstract: Taste perception is an essential function that provides valuable dietary and sensory information, which is crucial for the survival of animals. Studies into the evolution of the sweet taste receptor gene (*TAS1R2*) are scarce, especially for Bornean endemic primates such as *Nasalis larvatus* (proboscis monkey), *Pongo pygmaeus* (Bornean orangutan), and *Hylobates muelleri* (Muller's Bornean gibbon). Primates are the perfect taxa to study as they are diverse dietary feeders, comprising specialist folivores, frugivores, gummivores, herbivores, and omnivores. We constructed phylogenetic trees of the *TAS1R2* gene for 20 species of anthropoid primates using four different methods (neighbor-joining, maximum parsimony, maximum-likelihood, and Bayesian) and also established the time divergence of the phylogeny. The phylogeny successfully separated the primates into their taxonomic groups as well as by their dietary preferences. Of note, the reviewed time of divergence estimation for the primate speciation pattern in this study was more recent than the previously published estimates. It is believed that this difference may be due to environmental changes, such as food scarcity and climate change, during the late Miocene epoch, which forced primates to change their dietary preferences. These findings provide a starting point for further investigation.

Keywords: primate; phylogenetic; sweet taste receptor gene; diet preference; divergence date; late Miocene

1. Introduction

Taste is a vital component of an animal's fitness. It facilitates animals in making decisions about the ingestion of beneficial foods and avoiding harmful substances in their daily life. Taste evolved to ensure animals choose the appropriate foods for their survival. Taste sensations can be divided into five basic elements: sweet, umami, bitter, salty, and sour [1,2]. Bitter and sour tastes usually warn against hazardous substances, whereas sweet and umami tastes indicate foods that are rich in carbohydrates and proteins, respectively [3]. Salty tastes indicate foods that are rich in sodium and other minerals that are required by animals for optimum biological function.

Sour and salty tastes are conferred by taste receptor cells, which use ion channels, whereas sweet, umami, and bitter tastes are conferred by G protein-coupled receptors (GPCRs) [2,3]. GPCRs comprise two families: taste 1 receptors (TAS1Rs) and taste 2 receptors (TAS2Rs), which function as sweet or umami and bitter taste receptors, respectively [4]. The *TAS1R* gene has a smaller gene repertoire compared with the *TAS2R* gene and comprises three genes in most mammals, namely, *TAS1R1*, *TAS1R2*, and *TAS1R3* [5]. These receptors only function as heterodimers, with *TAS1R3* an obligate partner of both the umami and sweet receptors. The dimer *TAS1R1* + *TAS1R3* acts as the main receptor for umami, whereas *TAS1R2* + *TAS1R3* respond to a variety of natural and artificial sweet ligands [6]. Thus, we can conclude that *TAS1R2* is probably the sole sweet-specific taste receptor gene.

The evolution of *TAS1R* has been less well-studied and characterized compared with the evolution of *TAS2R* because the sweet and umami taste genes are believed to be conserved among species as these genes are necessary for nutrient uptake [7]. However, recently, several studies have demonstrated that the *TAS1R* genes undergo major mutations, revealing new insights regarding the evolution and function of the gene. For example, *TAS1R1* is pseudogenized in the giant panda [8], *TAS1R2* is inactivated in the cat family Felidae [9], and *TAS1R2* is pseudogenized in vampire bats [5]. Consequently, the *TAS1R* gene repertoire is not conserved as predicted. To better understand the evolutionary dynamics of the *TAS1R2* gene, examining species that are closely related to humans that have diverse dietary preferences is necessary.

To obtain a deeper understanding of the phylogenetic relationship between primates' sweet taste perception, a study of the molecular phylogenetics of the *TAS1R2* gene in primates was conducted. We chose primates because their diets are hugely diverse and include shoots, leaves, plants, fruits, gums, nectars, insects, invertebrates, small mammals, and amphibians (Table 1) [10–15]. For simplicity, we classified primates into four main dietary groups, namely, frugivores, folivores, omnivores, and gummivores, to discuss the possible environmental factors and diet preferences that have influenced the evolution of *TAS1R2*.

Table 1. Food preferences of primates found mainly in Southeast Asia and Borneo.

Dietary Groups	Primate	Preferred Diet
Gummivore	Marmosets	Gum, sap, latex, and resin
Folivore	Langurs, snub-nosed monkeys, proboscis monkeys	Shoots, young leaves, and unripe fruits
Omnivore	Macaques, tarsiers, slow lorises, humans, baboons, Patas monkeys, gorillas, chimpanzees	Flexible diets including fruits, leaves, insects, bird eggs, small mammals, and amphibians
Frugivore	Squirrel monkeys, siamangs, gibbons, orangutans	Ripe fleshy fruits and mature leaves