

DO NEW WORLD PRIMATES REALLY HAVE ELEVATED NEEDS FOR PROTEIN AND VITAMIN D?

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Phylogenetic variation in nutrient requirements is of both theoretical and practical interest. Although all vertebrates are thought to require a similar set of nutrients, quantitative needs can vary in relation to digestive, physiologic and reproductive performance (Allen and Oftedal, 1996). For example, among primates it is likely that the nutrient requirements of colobine monkeys such as colobus (*Colobus*) and langurs (*Presbytis*) are modified by the microbial fermentation that occurs in the enlarged and sacculated foregut (Bauchop and Martucci, 1968). In bushbabies (*Otolemur*) maternal nutrient needs are undoubtedly influenced by the relatively high rates of milk nutrient transfer (Tilden and Oftedal, 1996). All primates need not have the same quantitative nutrient requirements, even if differences in body size are taken into account.

The possibility that New World monkeys of the families Cebidae and Callitrichidae have higher protein requirements than Old World monkeys (Cercopithecidae) gained credence when it was suggested in a report of the Committee on Animal Nutrition (National Research Council, 1978). Manufacturers of formulated primate feeds developed 15% protein diets for Old World monkeys and 25% protein diets for New World monkeys, and many zoos and primate research centers have followed this lead.

A more recent review of studies on the protein requirements of common marmosets (*Callithrix jacchus*), squirrel monkeys (*Saimiri sciureus*), cebus monkeys (*Cebus albifrons*) and rhesus macaques (*Macaca mulatta*) did not support the hypothesis that New World monkeys had higher protein requirements (Oftedal, 1991). However, few studies had looked at protein requirements of adult primates, and even fewer at requirements for reproduction. If New World monkeys produce more milk of higher protein content than do Old World species, then lactating females might have higher protein needs.

To examine the protein hypothesis, we examined reproductive performance of common marmosets fed diets that differed in the amount of estimated metabolizable energy (ME) supplied by protein: 15% of ME from protein (LP diet) or 25% of ME (HP diet). These diets were based on purified ingredients, including a high quality protein (lactalbumin) and agar as a gelling agent. The diets were moistened, allowed to set up under refrigeration and cut into cubes for feeding. After an adaptation period, the experimental diets were the sole foods offered, and most females bred while fed these diets. Ultrasound images were used to measure prenatal growth in body length (crown-rump) and head width (biparietal diameter or BPD) in 59 pregnancies in 13 females. Of these 54% proceeded to term deliveries. At least one infant survived beyond 7 days of age in 24 litters. Postnatal growth was measured before, during and after the weaning transition. Milk samples were collected and assayed for major constituents and milk production was estimated by an isotope dilution procedure.

There was no evidence of improvement in prenatal or postnatal growth or survival in marmosets fed the HP diet. In fact, a smaller number of litters were produced in females fed the HP diet, and among those including viable young, the newborn HP infants were significantly smaller in biparietal diameter than were the LP newborns. BPD appears to be a valuable indicator of skeletal development and subsequent survivorship. Milk composition did not differ between the diets; milk yield data have yet to be completed. We concluded that 15% protein (on a dry matter or ME basis) is adequate for successful reproduction and growth of common marmosets, at least when a high quality protein such as lactalbumin is used. However, a higher protein content may still be appropriate in manufactured feeds for captive primates if protein quality is lower, especially if the ingested diet is diluted by inclusion of fruits, treats or other low protein foods.

Another practical concern in the feeding of New World primates is the amount of vitamin D that the diet must supply. Primates, like many other mammals, can synthesize vitamin D from precursors in the skin if sufficient radiation in the ultraviolet B (UV-B) range is available. However, in captivity animals may not have access to unfiltered sunlight or artificial sources of UV -B, and must rely on dietary sources. It is commonly thought that the vitamin D requirements of New World monkeys, and especially of callitrichids, are especially high. Early work demonstrated that some New World species did not utilize the plant form (ergocalciferol) of vitamin D effectively, and more recent studies have documented high circulating levels of vitamin D metabolites (such as 25-OH cholecalciferol or calcidiol) in both captive and wild callitrichids (Adams et al., 1985; Power et al., 1997). It is possible that high circulating levels of calcidiol must be maintained due to target organ resistance, and that maintaining these high levels in callitrichids requires greater dietary supply of vitamin D than is required in other primates. Unfortunately, there have been few long-term studies that can be used to define vitamin D requirements of callitrichids. The Committee on Animal Nutrition recommend 2170 IU cholecalciferol per kg diet dry matter (DDM) for all primates (National Research Council, 1978), but commercial diets formulated for callitrichids often contain many times this amount.

In the common marmoset project, we opted for a dietary level of 3000 IU/kg DDM; a higher level was not chosen due to concern about the potential toxicity of vitamin D, especially when only a single food is offered. Three of the females that served as founders of our colony displayed evidence of possible vitamin D deficiency shortly after arrival, including one animal that suffered a lumbar vertebral fracture and reluctant to move until treated therapeutically with vitamin D. To determine whether our diets were alleviating or exacerbating possible marginal vitamin D status, we collected blood samples 2-4 times per year from breeding adults and on an occasional basis from young animals. These were assayed for calcidiol concentration by the Skin Laboratory of the Boston University School of Medicine. Calcidiol values of less than 20 ng/ml were considered potentially deficient; in wild cottontop tamarins (*Saguinus oedipus*) 25 ng/ml was the lowest value observed (Power et al., 1997).

Over a period of about 2 years, potentially deficient calcidiol levels were observed in 31% of the samples (n=108 from 30 animals), but the distribution of these low values was not uniform. For example, potentially deficient levels were found in only 10% of adult male samples, but in 47% of the adult female samples. Although some females showed a decline in circulating calcidiol levels over the course of repeated reproductions, others did not or appeared to rebound subsequently to higher circulating levels. It appears that factors other than diet may affect vitamin

D status, at least as assessed by circulating calcidiol. Power et al. (1997) noted that in a wild cotton-top tamarin population, pregnant females had lower calcidiol concentrations than nonpregnant females, even though these animals had regular exposure to the sun.

Our calcidiol data are consistent with the hypothesis that callitrichids may require more than 3000 IU vitamin D per kg DM to sustain high circulating calcidiol levels. However, we did not see frank cases of rickets in young monkeys as one would expect in a vitamin D-deficient population. In 1996 we began to use experimental diets containing 9000 IU/kg DDM and will examine calcidiol responses over time.

In conclusion, New World monkeys do not appear to have elevated needs for protein, but at least the callitrichids may have elevated requirements for vitamin D. Further research is needed to determine how high these requirements actually are, and whether they differ between adult males and females.

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