# INFLUENCE OF ISOCALORIC HIGH ENERGY CARBOHYDRATE AND FAT DIETS ON GROWTH RELATED HORMONE PROFILES IN THE YEARLING HORSE

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## Introduction

Growth is defined as an anabolic advantage over catabolic processes (Van Sickle, 1985). This definition implies the existance of an equilibrium and a control mechanism for its maintenance. Postnatal bone growth is controlled, in part by the hormones insulin, thyroxin ($T_4$), triiodothyronine ($T_3$), cortisol, growth hormone, somatomedins/insulin-like growth factors (Sm/IGF) (Hoskins and Asling, 1977, Glade, et al. 1983, Glade and Reimers, 1984, Glade, 1986).

Many hormones have local effects on bone development (Canalis et al. 1988) although there also seems to be evidence for a systemic endocrine regulatory mechanism. This endocrine regulation influences growth through directing the flow of nutrients through various metabolic pathways (Bauman et al. 1982). Ample evidence also exists to demonstrate that the nutrients, themselves, affect metabolic pathways and perhaps influence hormone profiles. (Danforth et al, 1979, Blum et al. 1980, Glade and Reimers, 1984, Topliff et al. 1985, Pagan et al. 1987).

In order to better understand nutritional influences on bone growth and development in horses the effects of nutrients on hormone profiles must be determined. High energy carbohydrate diets have been shown to alter hormone profiles and affect bone development in horses (Glade et al. 1983). The objective of this study is to determine if high carbohydrate or high fat diets affect certain hormone profiles associated with growth in horses.

## Materials and Methods

Eleven yearlings of Thoroughbred, Quarter Horse and Arabian breeding between 9 and 10 months of age were randomly assigned to two groups. In a cross-over arrangement the horses were fed either high energy carbohydrate (HC) or fat (HF) diets.

An oats, barley, and soybean basal diet was supplemented with corn or soybean oil to approximate isocaloric and iso-nitrogenous rations for both groups. The HF diet was supplemented with 10% soybean oil, by weight, of the total grain portion of the ration. The oil was added to grain ration at each feeding. The HC diet was made isocaloric to the fat diet by addition of corn to the basal diet.

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Alfalfa hay was fed at 0.75% BW only in the evenings. Concentrates were fed twice daily. The diets were fed at 120% of NRC energy requirements. All other nutrients were fed to meet 100% of NRC recommendations (Table 1). Water and salt blocks were available ad libitum. In the cross-over arrangement diets were exchanged after 3 wk with a 1 week adjustment period. Horses were housed in stalls overnight and turned out on a dry lot for exercise after the morning feeding.

Horses were evaluated for obvious growth abnormalities at the beginning, exchange of diets and end of the trial. Feed intake was measured daily. Horses were weighed and measured weekly. Measurements included body weight (BW), height at withers (WH) and hip (HH) and heart girth (GH).

One day per week the yearlings were sampled via jugular venous puncture at 30 min before feeding. Samples were also taken at 30 min and 90 min after all feed had been consumed or horses had stopped eating. Refusals were removed from stalls. Plasma and serum were collected for glucose, insulin, $T_3$, $T_4$ and cortisol analysis. Plasma glucose was assayed using hexokinase and glucose-6-phosphate dehydrogenase Assay Kit No. 16-uv. (Sigma Chemical, St. Louis). Serum insulin, $T_3$, $T_4$, and cortisol were determined by equine-validated radioimmunoassays (Reimers et al., 1981, 1982).

The production data were analyzed according to a completely randomized design separately for each phase. Treatments were either high carbohydrate or high fat. Hormone data were analyzed separately from each phase and pooled across phase using a repeated measures design. The model included diet, horse within diet, week, hour and interactions. All analyses were done using SAS (SAS, 1979).

## Results

### Growth

During phase 1 no differences were seen in feed intake, feed efficiency or average daily gain (Table 2). During phase 2 the HC group had a higher feed intake, ($P<.05$) 136 kg versus 116 kg for the HF group. No differences were found in HG, WH or HH due to diet. There was no visual evidence of bone development problems during the trial.

### Glucose

There were no differences in glucose concentrations between diets in phase 1 (Table 3). However, there were significant week and hour effects ($P<.05$) and interactions between diet and hour and week and hour ($P<.05$). In phase 2 glucose concentrations for the HC diet were higher (HC 156 mg/dl vs HF 130 mg/dl) than for the HF diet ($P<.05$).

Hormone data were pooled across phase and there were no significant differences at the 0 sampling time (Table 5). Glucose concentrations for the horses fed the HC diet were higher at the 30 and 90 minute sampling times ($P<.05$).

Insulin

Insulin concentrations were similar for both diets in both phases before feeding (Table 3). After feeding insulin values rose. There were no differences in insulin concentrations when they were pooled across sampling times in phase 1. In the second phase the HC diet had significantly higher (58.37 $\mu$IU/ml vs. 21.46 $\mu$IU/ml) average insulin concentrations than the HF diets ($P<.05$).

Insulin concentrations pooled across phase (Table 5) were higher for the HC diet at 30 and 90 min. after feeding ($P<.05$).

Triiodothyronine and Thyroxine

Diet affected $T_3$ concentrations in phase 1 ($P<.05$). The HF diet lowered $T_3$ concentrations (Table 4).

Data were pooled over phases and analyzed and $T_3$ did not show any significant dietary effects (Table 5). However $T_4$ was higher in the HC group at the 0 and 90 min. sampling times ($P<.05$).

Cortisol

There were no significant differences in cortisol concentrations between diets within phase (Table 4). Cortisol was higher before feeding and continued to decrease or remain lower than prefeeding values through 90 min. after the meal.

When data were averaged across phases there was a dietary effect on cortisol (Table 5). Cortisol concentrations were lower in the HF groups before feeding ($P<.05$).

## Discussion

The effects of fat and carbohydrate diets on growth in the horse has recently received attention (Glade et al. 1984, Ott et al. 1986, Scott et al. 1987). The higher growth rates in this trial for horses fed HC diets versus HF diets are not in agreement with Scott et al. (1987). The crossover nature of this trial may be responsible for some of the inconsistency. While inconclusive, it appears that an adaptation period or interaction between diet and time may be important for the increased intakes.

Higher glucose and insulin values corresponded to higher intakes and weight gains in horses fed HC diets following crossover from HF diets. This may have been related to carryover or other metabolic effects of the HF diet.

Stull et al. (1987) reported that peak insulin values were higher in 2 year old horses fed carbohydrate diets than in those fed fat diets (10% corn oil). Higher insulin concentrations observed in phase 2 when horses received HC diets agree with the findings of Stull et al. (1987). Elevated glucose and insulin in the growing horse has the potential of dramatically affecting

growth. Insulin stimulates protein, DNA, proteoglycan and RNA synthesis during in vitro cartilage growth (Cook and Nicoll, 1984; Glade 1986). The most important function of insulin may be its ability to regulate carbohydrate, protein and fat metabolism leading to changes in flow of nutrients through metabolic pathways. However the metabolic effect of insulin may be under the systemic endocrine control of growth hormone, thyroid hormones, cortisol and catechcholamines (Bauman et al. 1982).

Biesik and Glade (1985) and Glade and Reimers (1984) suggest that $T_3$ and $T_4$ concentrations in 6-8 month old horses are sensitive to dietary carbohydrate. The results of this experiment indicate that $T_3$ and $T_4$ concentrations in yearlings may be sensitive to dietary energy source.

Cortisol concentrations have been reported to be unaffected by diet in the mature horse (Stull et al. 1987). There was a treatment effect on cortisol in this study.

In conclusion, growth in horses may be influenced by dietary energy source (carbohydrate vs fat) and this effect may be mediated by the endocrine system and its regulatory effects on metabolic pathways. Additional study is required before dietary manipulation of growth in horses can be achieved.

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KEY WORDS: Growth, Hormones, Carbohydrates, Fat

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TABLE 1. CONCENTRATE COMPOSITION AND ANALYSIS

| | High Carbohydrate | High Fat |
|---|---|---|
| Barley, Rolled | 10.00 | 25.00 |
| Corn, Rolled | 57.18 | |
| Oats, Rolled | | 36.55 |
| Trophy Gold FX* | 15.00 | 16.65 |
| FX Nat Pro 30 Pa* | 10.15 | 10.00 |
| Premix Vit-TM* | 3.67 | 7.35 |
| Molasses, Cane | 4.0 | 4.45 |
| | 100.00 | 100.00 |
| Soybean Oil | | Added at 10% Conc. by weight |
| Crude Protein %** | 14.00 | 17.00 |
| Digestable Energy Mcal/kg** | 3.07 | 2.85 |
| Ca % | 0.78 | 0.72 |
| P % | 0.67 | 0.67 |
| Mg % | 0.11 | 0.11 |
| Cu ppm | 14.00 | 16.98 |
| Zn ppm | 69.23 | 70.06 |
| Mn ppm | 78.65 | 60.09 |

* Concentrates supplied by Manna Pro, Los Angeles, Ca 90010
** DE and CP values before 10% added soybean oil to high fat diet.

TABLE 2. EFFECT OF DIETARY FAT AND CARBOHYDRATE ON PERFORMANCE IN GROWING HORSES.

| Diet | No. of Animals | Initial Wt. kg | | Total Feed Intake kg | | Average Daily Gain kg | | Feed Efficiency Feed/Gain | |
|---|---|---|---|---|---|---|---|---|---|
| **Phase 1** | | | | | | | | | |
| High Carbohydrate | 6 | 290[a] | ±55.4 | 113[a] | ±13.2 | 0.32[a] | ±0.14 | 19[a] | 6.6 |
| High Fat | 5 | 267[b] | ±28.2 | 105[a] | ±6.4 | 0.36[a] | ±0.25 | 24[a] | 20.0 |
| **Phase 2** | | | | | | | | | |
| High Carbohydrate | 5 | 274[a] | ±27.0 | 136[a] | ±6.4 | 0.50[a] | ±0.08 | 13[a] | 2.2 |
| High Fat | 6 | 297[b] | ±57.8 | 116[b] | ±15.9 | 0.29[a] | ±0.22 | 40[a] | 42.0 |

[a,b]Means in same columns within phases with different superscript letters differ (P<.05).

TABLE 3. EFFECT OF DIETARY FAT AND CARBOHYDRATE ON GLUCOSE AND INSULIN CONCENTRATIONS BEFORE AND AFTER FEEDING GROWING HORSES.

| Diet | Sampling Time[a] | Glucose mg/dl | | Insulin μIU/ml | |
|---|---|---|---|---|---|
| **Phase 1** | | | | | |
| High Carbohydrate | 0 | 109 | ±8.8 | 2.4 | ±1.3 |
| | 1 | 122 | ±17.2 | 6.3 | ±5.5 |
| | 2 | 130 | ±23.9 | 12.5 | ±13.2 |
| Pooled[b] | | 120[c] | ±19.3 | 7.0[c] | ±9.0 |
| High Fat | 0 | 114 | ±12.2 | 2.8 | ±2.1 |
| | 1 | 132 | ±16.9 | 11.2 | ±8.4 |
| | 2 | 119 | ±10.8 | 9.8 | ±9.7 |
| Pooled[b] | | 121[c] | ±15.3 | 8.0[c] | ±8.2 |
| **Phase 2** | | | | | |
| High Carbohydrate | 0 | 110 | ±28.1 | 1.8 | ±1.2 |
| | 1 | 167 | ±17.5 | 24.3 | ±18.6 |
| | 2 | 190 | ±36.6 | 51.7 | ±29.3 |
| Pooled[b] | | 156[c] | ±43.9 | 25.9[c] | ±28.5 |
| High Fat | 0 | 116 | ±44.2 | 1.4 | ±0.14 |
| | 1 | 123 | ±12.5 | 5.6 | ±4.9 |
| | 2 | 151 | ±28.7 | 10.1 | ±8.1 |
| Pooled[b] | | 130[d] | ±36.4 | 5.7[d] | ±6.4 |

[a]Sampling times: 0-30 min. before feeding, 1-30 min. after feeding and 2-90 min. after feeding.
[b]Data averaged across sampling times.
[c,d]Means in same columns with different superscript letters differ (P<.05).

TABLE 4. EFFECT OF DIETARY FAT AND CARBOHYDRATE ON SERUM THYROXIN ($T_4$), TRIIODOTHYRONINE ($T_3$) AND CORTISOL BEFORE AND AFTER FEEDING GROWING HORSES.

| Diet | | $T_4$ ng/ml | | $T_3$ ng/ml | | Cortisol ng/ml | |
|---|---|---|---|---|---|---|---|
| **Phase 1** | | | | | | | |
| High Carbohydrate | 0 | 15.3 | ±6.8 | 0.38 | ±0.40 | 42.5 | ±20.9 |
| | 1 | 16.0 | ±6.3 | 0.31 | ±0.33 | 35.6 | ±15.4 |
| | 2 | 17.5 | ±8.8 | 0.20 | ±0.22 | 35.0 | ±16.2 |
| Pooled[b] | | 16.2[c] | ±7.2 | 0.29[c] | ±0.32 | 37.8[c] | ±17.7 |
| High Fat | 0 | 12.1 | ±6.0 | 0.46 | ±0.28 | 44.8 | ±24.1 |
| | 1 | 15.2 | ±6.9 | 0.56 | ±0.38 | 40.8 | ±27.0 |
| | 2 | 14.3 | ±6.8 | 0.45 | ±0.26 | 41.8 | ±16.1 |
| Pooled[b] | | 13.9[c] | ±6.5 | 0.49[d] | ±0.31 | 42.5[c] | ±22.4 |
| **Phase 2** | | | | | | | |
| High Carbodyrate | 0 | 20.5 | ±3.4 | 0.60 | ±0.27 | 56.6 | ±13.8 |
| | 1 | 23.1 | ±7.0 | 0.94 | ±0.55 | 43.5 | ±12.4 |
| | 2 | 23.3 | ±4.3 | 0.76 | ±0.27 | 41.7 | ±14.3 |
| Pooled[b] | | 22.4[c] | ±5.2 | 0.76[c] | ±0.40 | 47.3[c] | ±14.8 |
| High Fat | 0 | 16.5 | ±7.0 | 0.60 | ±0.70 | 38.5 | ±15.1 |
| | 1 | 18.9 | ±6.4 | 0.59 | ±0.34 | 37.0 | ±15.0 |
| | 2 | 20.0 | ±8.1 | 0.56 | ±0.33 | 30.0 | ±15.3 |
| Pooled[b] | | 18.5[c] | ±7.2 | 0.58[c] | ±0.48 | 35.2[c] | ±15.3 |

[a]Sampling times: 0-30 min. before feeding, 1-30 min. after feeding, and 2-90 min. after feeding
[b]Data averaged across sampling times.
[c,d]Means in same columns with different superscript letters differ (P<.05).

TABLE 5. EFFECT OF DIETARY FAT AND CARBOHYDRATE ON $T_4$, $T_3$, CORTISOL, GLUCOSE AND INSULIN BEFORE AND AFTER FEEDING GROWING HORSES.

| Diet | $T_4$ ng/dl | $T_3$ ng/dl | Cortisol ng/ml | Glucose mg/dl | Insulin μIU/ml |
|---|---|---|---|---|---|
| | | Sampling time[a] 0 | | | |
| High Carbohydrate | 17.6[b] | 0.47[b] | 48.9[b] | 112[b] | 2.1[b] |
| High Fat | 14.6[c] | 0.53[b] | 41.3[c] | 113[b] | 2.0[b] |
| | | Sampling time 1 | | | |
| High Carbohydrate | 19.2[b] | 0.59[b] | 39.2[b] | 149[b] | 14.5[b] |
| High Fat | 17.2[b] | 0.58[b] | 39.0[b] | 122[c] | 8.0[c] |
| | | Sampling time 2 | | | |
| High Carbohydrate | 20.3[b] | 0.46[b] | 38.1[b] | 154[b] | 30.9[b] |
| High Fat | 17.5[c] | 0.51[b] | 35.2[b] | 140[c] | 10.0[c] |

[a]Sampling times: 0-30 min. before feeding, 1-30 min. after feeding and 2-90 min. after feeding.
[b,c]Means in same columns with different superscripts letters differ (P<.05).