COLD HOUSING EFFECTS ON GROWTH AND NUTRIENT DEMAND OF YOUNG HORSES\textsuperscript{1}

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ABSTRACT

Housing temperature effects on growth, feed utilization and feed digestion of 12, 7-mo-old Standardbred colts were evaluated for 22 wk beginning in late November. Colts were assigned to one of two treatments: housed in a barn heated at 10°C (warm) or housed in a barn with no external heat supply (cold). All horses were allowed outdoors for 4 h daily. Mean temperatures of the warm and cold barn from November to April were 10.9 ± .66 and −5.2 ± 1.72°C, respectively. Hair coat weight of cold-housed colts was 1.4- to twofold ($P < .05$) that of warm-housed colts from December through April but declined for both groups from fall to spring. All colts were fed a pelleted diet to meet National Research Council (1989) energy guidelines for moderate gain (0.67 vs 0.52 kg/d). Skeletal growth, measured by cannon bone circumference, wither and croup height, was not affected by housing temperature. Nutrient digestion by both groups of colts was compared to that of mature, warm-housed ponies. Ponies had longer ($P < .05$) digestive tract retention times and higher digestibilities for every nutrient than the young horses did. Although retention times by all colts were similar, cold-housed colts digested more ADF and less phosphorus ($P$) than did warm-housed colts ($P < .05$). Over time, digestibilities of DM, NDF and P declined ($P < .05$) for colts but not for ponies. Maintenance energy needs were estimated at 34.6 kcal/kg BW for cold-housed colts vs 26.3 kcal/kg BW for warm-housed colts. Young horses need 1.3% more maintenance energy per Celsius degree decrease in temperature below 0°C. To sustain a constant moderate gain, daily DE intake needs to be increased .7% per Celsius degree decrease in ambient temperature below 0°C. (Key Words: Horses, Growth, Cold, Digestibility, Hair, Retention Time.)

Introduction

Winter temperatures in western Canada can reach −40°C (Hare and Thomas, 1979). Intense cold reduces productivity of feedlot cattle (Milligan and Christison, 1974). Although horses are successfully reared and worked at or below −20°C (Dahl et al., 1986; Cymbaluk and Christison, 1989), impaired productivity by cold horses would be expected at these temperatures based on data for other domestic livestock (NRC, 1981).

Cold weather increases the energy needed for maintenance of cattle and swine (NRC, 1981), but only minimal data are available for horses. Consequently, the 1989 NRC \textit{Nutrient Requirements of Horses} does not modify energy requirements for horses exposed to cold weather. However, cold-adapted, mature horses use 2.5% more energy for maintenance per Celsius degree below their lower critical temperature (McBride et al., 1985), and growing horses may need 23 to 64% more total energy for maintenance at temperatures below −10°C (Cymbaluk and Christison, 1989; Cymbaluk et al., 1989a).

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Baseline digestion data for horses often have been inferred from studies using ponies. Yet, few studies have been conducted to confirm that growing horses and mature ponies use feed similarly, nor have the effects of ambient temperature on feed digestibility by horses been examined.

The objectives of this study were to assess the effects of housing temperature on growth and feed utilization of overwintered, young horses and to compare digestibility by these growing horses and mature ponies.

**Experimental Procedure**

A split-plot design was used to examine effects of housing temperature on growth of 7-mo-old horses over 22 wk starting in late November. Colts were assigned to treatments as a randomized complete block after stratification by sire. Two colts from each of three sires were assigned to each group. The treatments consisted of a control group (warm) housed in a barn set for a mean ambient temperature of 10°C and a treatment group (cold) kept in an uninsulated barn with no external heat supply. Four mature ponies were compared with these growing horses with regard to diet digestion and 80% feed retention time. The treatments evaluated for digestion studies included cold-housed colts, warm-housed colts and mature, warm-housed ponies. Ponies were fed the same diet as the colts but at a rate to meet maintenance energy needs. The ponies were kept in the heated barn and exercised similarly to the colts.

**Animals and Housing.** Twelve Standardbred colts were used. Colts were kept outdoors with access to an unheated barn and a straw-bedded shed during an adaptation period from October to November. A pelleted diet (Table 1) was fed at 1.25 kg/100 kg BW and brome-alfalfa hay was available ad libitum during this period. Warm-housed colts were moved into the heated barn 1 wk prior to the start of the study. Colts were dewormed with an ivermectin paste at 3-mo intervals.

Horses were kept in concrete-floored box stalls within each barn. The box stall areas were 6.80 m² in the heated barn and 8.1 m² in the unheated barn. These comply with the recommended area of 1.8 m²/100 kg BW given for horses (Consortium, 1988). Each box-stall had a 2.2-m² rubber mat affixed to the floor that accommodated the colt while it was recumbent. The floor and mat surfaces also were bedded with wood shavings. In addition to barn space, each group of horses could exercise 4 h daily in a 200-m² paddock. Horses were outdoors from 1000 to 1400 each day.

The heated barn was ventilated by a temperature-controlled exhaust fan. The unheated barn was passively ventilated. Maximum and minimum barn temperatures of the previous day were recorded daily at 0800 and 1600. Feed refusals were uncommon, but two horses in the unheated barn occasionally left small amounts of feed (less than 200 g).
Hair Samples. Clean, dry hair was collected mid-neck about 7 cm below the base of the mane at 3, 11 and 19 wk after the start of the study. Care was taken in subsequent samplings not to overlap on the previous sampling area. A 5.2-cm × 7-cm template was constructed from flexible plastic. A hair clipper with a #30 blade was used to clip all the hair within this template. The hair was collected into a plastic bag, air-dried at 25°C, and weighed.

Morphometric Measurements. Body weight was measured using an electronic scale. Total BW was recorded for each horse on the main platform, which was fastened over metal bars enclosing four load cells. Level platforms extending on either end of the main platform allowed fore and hind BW measurements to be taken directly. Weights were measured weekly and recorded to the nearest .5 kg. Wither height was measured at the level of the fifth thoracic vertebra; croup height was measured at the maximal point of the gluteal muscle using a horizontal level attached to a vertical scale. Measurements were made every 14 d. Cannon bone circumference was taken at the mid-point of the left metacarpal bone every 2 wk; values were recorded to the nearest .25 cm.

Digestion Trials. Total fecal collections of 72-h duration were made at 3, 11 and 19 wk after the onset of the study (periods 1, 2 and 3, respectively). Colts were placed in wooden metabolic crates that allowed the separate collection of feces and urine. Pellets containing chromium sesquioxide (Cr₂O₃; Table 2) were fed at the initial meal of each collection to provide 10 g Cr₂O₃/100 kg BW. The time taken to consume the Cr₂O₃ pellets was recorded. All colts except two ate the allotted Cr₂O₃ pellets within 15 min of feeding. The two exceptions ate their required amounts within 1 h. The remainder of the meal, pellets and hay, was given after the Cr₂O₃ pellets were eaten. Horses were watered three times daily and the volume of water consumed was recorded. The same protocol was used for the ponies except that collection periods were 96 h in duration.

Total feces production was measured at 12-h intervals. Subsamples were taken in each interval for Cr₂O₃ determination and for nutrient analyses. Total urine volumes were recorded. Pellets and hay were subsampled daily and composited for each trial. In addition, the pelleted diet was sampled and analyzed at 4-wk intervals.

Feed and Fecal Analyses. Feeds and feces were analyzed for moisture, GE, CP, ADF, NDF, calcium (Ca), phosphorus (P) (AOAC, 1985) and Cr₂O₃ content (Fenton and Fenton, 1979). The 72-h cumulative excretion of Cr₂O₃ was evaluated for linear, log and quadratic components. The highest R² (>.90) was obtained using a quadratic equation. An 80% feed retention time was calculated for each group in each period from individual and pooled quadratic equations. Ponies excreted 100% of the Cr₂O₃ within 72 h. Thus, quadratic equations for ponies also were based on 72-h collections.

Statistical Analyses. Statistical analyses included analyses of variance and covariance of balanced and unbalanced data, repeated measures analyses of variance, correlation and regression analyses. Initial hair weight (December sample) was used as a covariate to compare February and April samples. Daily gains for weight and height growth were based on regression analyses of individual data against days on test. The intercept represented initial measurements and the regression coefficient represented ADG. Mean comparisons of digestibility data compared warm to cold-housed colts and colts to ponies. Orthogonal comparisons of period (age) means compared period 1 versus 2 and period 1 and 2 versus 3. In evaluation of water and temperature responses, daily free water consumption per
kilogram of DM intake was regressed on mean ambient temperatures for each day in each digestion trial.

Results and Discussion

Ambient Temperature. The mean temperatures of the heated and unheated barns over 22 wk were 10.9 ± 0.66 and -5.2 ± 1.72°C, respectively. Mean weekly temperatures for each barn and outdoors are shown in Figure 1. During extremely cold or warm weather, temperatures in the heated barn could not be closely controlled. The mean daily temperature for the heated barn ranged from 3 to 18°C and for the unheated barn, -26 to 24°C.

Hair Growth. The duration of daylight in mid-December, February and April in Saskatoon is 7.8, 10 and 14 h, respectively (Hare and Thomas, 1979). Hair weight of cold-housed horses was 1.46, 1.43 and 2.05-fold (P < .05) that of warm-housed horses in respective periods (Table 3). The differences between groups in haircoat weights in February and April were present after covariate adjustment for initial hair weight. The heaviest

TABLE 3. EFFECTS OF ACCLIMATION HOUSING TEMPERATURE (°C)° ON HAIR COAT WEIGHT (mg/cm²) OF GROWING HORSES

<table>
<thead>
<tr>
<th>Wk on test</th>
<th>Month</th>
<th>Warm</th>
<th></th>
<th></th>
<th>Cold</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Hair weight</td>
<td>Mean</td>
<td>Hair weight</td>
<td>Mean</td>
<td>temperature</td>
</tr>
<tr>
<td>3</td>
<td>December</td>
<td>27.8&lt;sup&gt;c&lt;/sup&gt;</td>
<td>9.4</td>
<td>40.4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-4.6</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>February</td>
<td>20.4&lt;sup&gt;d&lt;/sup&gt;</td>
<td>8.5</td>
<td>29.2&lt;sup&gt;d&lt;/sup&gt;</td>
<td>-10.9</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>April&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.7&lt;sup&gt;e&lt;/sup&gt;</td>
<td>10.8</td>
<td>15.8&lt;sup&gt;e&lt;/sup&gt;</td>
<td>-5.9</td>
<td></td>
</tr>
<tr>
<td>Pooled SE</td>
<td></td>
<td>2.21</td>
<td>2.28</td>
<td>3.01</td>
<td>0.70</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Values are mean daily temperatures for 3 wk preceding the December sampling and for 8 wk preceding the February and April sampling.

<sup>b</sup>Hair weights of warm and cold-housed colts differ (P < .01).

<sup>c,d,e</sup>Within treatment or column, means with different superscripts differ (P < .01).
Hair coat for both groups of horses occurred in December ($P < .05$), which did not coincide with the coldest ambient temperature but did correspond to the shortest daylength.

Hair shedding was evident in warm-housed horses at wk 11 (mid-February) and substantial hair loss had occurred by wk 15 (mid-March). By wk 15, only two colts in the unheated barn had shed any hair; this was localized to the face. By wk 19 (April), all warm-housed colts had shed their winter hair coats. Cold-housed colts had not completely shed their winter coats by the final week of the study (May).

Hair growth and shedding by horses varies with photoperiod (Kooistra and Gmther, 1975). Both groups of colts were exposed to similar lighting regimens. Light intensity ranged from 10 to 100lux in different areas of the pens at night, and, during the day, natural light exceeded these values. Thus, the differences in hair coat weight between cold- and warm-housed colts indicate that ambient temperature in addition to photoperiod may regulate hair cover and hair shedding in horses. Initial haircoat weight likely differed because warm-housed colts were exposed to 10°C temperatures for 4 wk preceding hair sampling. Greater haircoat depth in cold-exposed cattle arises from reduced shedding rather than from activated growth (Webster et al., 1970). This may have occurred here as well. Yearling and adult horses exposed to a mild western Canadian winter had haircoat depths and weights similar to those reported here, but mature horses may develop a lesser haircoat depth due to a greater skin thickness (Young and Coote, 1973; McBride et al., 1985).

**Morphometrics.** Growth data of colts reared in unheated and heated barns in a prairie winter are given in Table 4. Total BW of these Standardbred colts as yearlings were consistent with published values (Willoughby, 1975). Warm-housed colts gained weight at the rate of .67 kg daily. The nutrient intake was chosen to support an ADG of .65 kg, which is designated as moderate growth for this class of horse (NRC, 1989). Notably, the ADG of warm-housed colts was 28.8% more rapid ($P < .01$) than that for cold-housed colts (Figure 1). Gains in fore and hind BW depended directly ($r = .96$) on ADG in total BW. Gains in fore BW were about 60% of total BW gain for both groups, but because total ADG was lower for cold-housed horses, fore body ADG also was lower ($P < .01$) than for warm-housed horses. The proportion of fore and hind BW to total BW for both groups remained at about 57 and 43%, respectively, throughout the study. This agrees with values for young Quarter horses (Cymbaluk et al., 1990) and adult draught horses (Bjorck, 1958) but disagrees with the extreme divergence in body mass proportions of growing horses implied by Willoughby (1975).

Gains in chest girth by warm-housed horses were greater ($P < .05$) than for cold-housed colts (Table 4), but because chest girth and total BW were directly related ($r = .96$), no differences existed between groups in the association of chest girth to total BW. Total BW (BW, kg) could be predicted from chest girth ($X$, cm) by the equation, $BW = -476.5 + 5.01X$ ($R^2 = .90$; $SE_{yx} = .142$). A similar relationship was found between total BW and chest girth for Standardbred foals older than 100 d (Persson and Ullberg, 1981).

Skeletal growth, as inferred from measurements of wither height, croup height and cannon bone circumference, was not affected by housing temperature (Table 4). Rates of

### Table 4. Initial and Final Morphologic Measurements and ADG of Cold and Warm-Housed Horses

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Warm Initial</th>
<th>Warm Final</th>
<th>Warm ADG</th>
<th>Cold Initial</th>
<th>Cold Final</th>
<th>Cold ADG</th>
<th>Cold ADG SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total body wt, kg</td>
<td>215.2</td>
<td>318.0</td>
<td>.67a</td>
<td>224.8</td>
<td>304.8</td>
<td>.52b</td>
<td>.026</td>
</tr>
<tr>
<td>Fore body wt, kg</td>
<td>121.7</td>
<td>184.5</td>
<td>.41a</td>
<td>127.7</td>
<td>172.7</td>
<td>.29b</td>
<td>.019</td>
</tr>
<tr>
<td>Hind body wt, kg</td>
<td>92.0</td>
<td>133.6</td>
<td>.27</td>
<td>97.0</td>
<td>130.7</td>
<td>.22</td>
<td>.016</td>
</tr>
<tr>
<td>Chest girth, cm</td>
<td>140.1</td>
<td>156.0</td>
<td>.103c</td>
<td>139.9</td>
<td>154.1</td>
<td>.092d</td>
<td>.003</td>
</tr>
<tr>
<td>With height, cm</td>
<td>129.7</td>
<td>142.9</td>
<td>.086</td>
<td>128.5</td>
<td>141.4</td>
<td>.083</td>
<td>.003</td>
</tr>
<tr>
<td>Croup height, cm</td>
<td>134.2</td>
<td>147.2</td>
<td>.085</td>
<td>132.6</td>
<td>145.2</td>
<td>.082</td>
<td>.003</td>
</tr>
<tr>
<td>Cannon bone circumference, cm</td>
<td>16.5</td>
<td>18.6</td>
<td>.014</td>
<td>16.8</td>
<td>18.8</td>
<td>.013</td>
<td>.001</td>
</tr>
</tbody>
</table>

*a,b* Treatment means in a row with different superscripts differ ($P < .01$).

*c,d* Treatment means in a row with different superscripts differ ($P < .05$).
interaction concurrently for ponies. A treatment utilizations by 12-mo-old colts than by housed colts or ponies until period 3. Dry GE digestibility by warm-housed colts at 10 mo of age; this was not observed in cold-housed colts or ponies until period 3. Dry matter and GE digestion by warm-housed colts decreased (P < .05) 8 to 10% from 8 to 10 mo of age but remained unchanged in cold-housed colts. At 12 mo of age, both groups digested DM and GE similarly. Ponies digested dietary energy 4 to 7% more efficiently than young horses did.

Dietary DM digestibility by ruminants decreases about .2% per Celsius degree drop below 20°C (Westra and Christopherson, 1976). Unlike for ruminants, diet digestibility did not decrease for cold-housed, growing horses. However, factors including processing, diet composition, duration of cold, age and size of animal can modify the extent that cold temperatures affect diet digestion by ruminants (Christopherson and Kennedy, 1983). Cold-exposed ruminants fed diets with a high concentrate content had only minimal changes in DM digestion (McBride and Christopherson, 1989a). The colts herein were fed a similar DE intake and kept in the same unheated barn (Cymbaluk et al., 1989b). Ponies digested forage diet in which the forage was chopped coarsely or ground finely (Schryver et al., 1981). These data emphasize the importance of breed, nutritional management and husbandry in the definition of growth and nutritional data for horses.

**Nutrient Utilization.** Treatment (P < .05) affected dietary DM and GE digestion and was ascribed to higher (P < .05) DM and GE digestibilities by ponies than colts (Table 5). A period effect (P < .05) occurred for DM and GE digestibility and was attributed to lower utilizations by 12-mo-old colts than by 8- and 10-mo-old colts. A decline occurred concurrently for ponies. A treatment × period interaction (P < .05) was related to a decline in GE digestibility by warm-housed colts at 10 mo of age; this was not observed in cold-housed colts or ponies until period 3. Dry matter and GE digestion by warm-housed colts decreased (P < .05) 8 to 10% from 8 to 10 mo of age; perhaps due to their lower feed intake. Although insignificant, ponies tended to have higher energy digestibilities than horses when

**TABLE 5. DIETARY NUTRIENT DIGESTIBILITIES (%) AND 80% RETENTION TIME (h) BY WARM-HOUSED OR COLD-HOUSED COLTS AND BY MATURE, WARM-HOUSED PONIES**

<table>
<thead>
<tr>
<th>Item</th>
<th>Warm, 8 mo</th>
<th>Cold, 8 mo</th>
<th>Ponies, 6 yr</th>
<th>Warm, 10 mo</th>
<th>Cold, 10 mo</th>
<th>Ponies, 6 yr</th>
<th>Warm, 12 mo</th>
<th>Cold, 12 mo</th>
<th>Ponies, 6.5 yr</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter</td>
<td>64.8</td>
<td>63.3</td>
<td>66.2</td>
<td>60.0</td>
<td>62.7</td>
<td>63.8</td>
<td>56.9</td>
<td>57.9</td>
<td>61.7</td>
<td>.50</td>
</tr>
<tr>
<td>Gross energy</td>
<td>64.1</td>
<td>61.7</td>
<td>65.3</td>
<td>58.2</td>
<td>61.2</td>
<td>63.1</td>
<td>56.9</td>
<td>57.4</td>
<td>61.3</td>
<td>.50</td>
</tr>
<tr>
<td>Crude protein</td>
<td>77.7</td>
<td>77.8</td>
<td>80.7</td>
<td>75.9</td>
<td>76.6</td>
<td>78.3</td>
<td>74.0</td>
<td>73.0</td>
<td>79.0</td>
<td>.40</td>
</tr>
<tr>
<td>ADF</td>
<td>25.3</td>
<td>23.5</td>
<td>28.6</td>
<td>20.0</td>
<td>29.6</td>
<td>32.1</td>
<td>12.8</td>
<td>18.8</td>
<td>29.7</td>
<td>.79</td>
</tr>
<tr>
<td>NDF</td>
<td>48.3</td>
<td>45.2</td>
<td>50.1</td>
<td>40.1</td>
<td>45.5</td>
<td>49.4</td>
<td>36.0</td>
<td>39.5</td>
<td>45.3</td>
<td>1.07</td>
</tr>
<tr>
<td>Ca</td>
<td>67.8</td>
<td>68.7</td>
<td>74.2</td>
<td>72.9</td>
<td>73.4</td>
<td>74.7</td>
<td>69.5</td>
<td>68.0</td>
<td>76.3</td>
<td>.80</td>
</tr>
<tr>
<td>P</td>
<td>52.2</td>
<td>46.9</td>
<td>23.5</td>
<td>42.8</td>
<td>39.2</td>
<td>32.1</td>
<td>34.8</td>
<td>27.1</td>
<td>28.8</td>
<td>1.50</td>
</tr>
<tr>
<td>Retention time</td>
<td>40.5</td>
<td>40.2</td>
<td>47.4</td>
<td>38.9</td>
<td>37.2</td>
<td>45.7</td>
<td>36.9</td>
<td>34.1</td>
<td>46.3</td>
<td>.93</td>
</tr>
</tbody>
</table>

*Represents true Ca or P digestibility based on correction for endogenous fecal Ca excretion of 20 mg per kilogram of BW (Schryver et al., 1970) and for P of 10 mg/kg BW (Schryver et al., 1971).  
Within row or comparison, values for warm- and cold-housed horses differ (P < .05).  
Within row or comparison, values for cold-housed horses differ (P < .05).  
Within row or comparison, values for periods 1 and 2 differ (P < .05).  
Within row or comparison, values for periods 1 and 2 differ (P < .05).  
Treatment × period interaction (P < .05).
fed diets at similar intake rates (Slade and Hintz, 1969). In the present study, the mean DE content of the diet was determined to be 2.69 and 2.83 Mcal/kg DM for the colts and ponies, respectively.

The lower DM and GE digestibilities by horses over time were associated with reductions in dietary fiber digestion. Ponies digested a higher percentage of dietary ADF and NDF (P < .05) than horses did. A significant treatment × period interaction (P < .05) was related to the decline in ADF and NDF digestibility for warm-housed colts with an absence of change in ponies and cold-housed colts until the final period. At 10 and 12 mo of age, cold-housed horses digested 13.7 and 9.7% more NDF (P < .05) than warm-housed horses.

Cold exposure resulted in a higher digestion of cell wall components by horses. This contrasts with data from cattle and sheep (Young and Christopherson, 1974; Christopherson, 1976) but would be a thermodynamically prudent response to cold stress. Digestion of fibrous feeds by horses has been hypothesized to yield a higher heat increment from 8 to 12 mo of age, cold-housed horses digested 13.7 and 9.7% more NDF (P < .05) than warm-housed ponies.

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TABLE 6. EFFECTS OF HOUSING TEMPERATURE ON DAILY WATER INTAKE AND URINE PRODUCTION OF COLTS AND PONIES

<table>
<thead>
<tr>
<th>Item</th>
<th>Period 1</th>
<th>Period 2</th>
<th>Period 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Warm, Cold, 8 mo old Ponies</td>
<td>Warm, Cold, 10 mo old Ponies</td>
<td>Warm, Cold, 12 mo old Ponies</td>
</tr>
<tr>
<td></td>
<td>8 mo old</td>
<td>6 yr old</td>
<td>6.5 yr old</td>
</tr>
<tr>
<td>Temperature, °C</td>
<td>9.4 -8.4 8.3</td>
<td>8.2 -16.9 8.5</td>
<td>15.5 6.2 15.4</td>
</tr>
<tr>
<td>DM intake, kg</td>
<td>5.00 5.19 4.30</td>
<td>5.73 5.72 4.47</td>
<td>6.02 5.89 4.34</td>
</tr>
<tr>
<td>Water intake, liters/kg DM</td>
<td>2.49 2.30 2.33</td>
<td>2.40 2.08 2.29</td>
<td>2.70 2.60 2.65</td>
</tr>
<tr>
<td>intake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urine produced, liters</td>
<td>4.14 4.00 3.44</td>
<td>6.27 5.17 3.53</td>
<td>7.36 5.77 3.49</td>
</tr>
<tr>
<td>Fecal water, liters</td>
<td>4.54 5.03 3.90</td>
<td>5.45 5.04 4.04</td>
<td>6.68 6.34 4.08</td>
</tr>
</tbody>
</table>

aValues for warm-housed colts differ (P < .05) from values for cold-housed colts.

bValues for ponies differ (P < .05) from those of colts.

Period effect (P < .05).

Water intake includes free water plus feed water.

dWolter

digestion also may have arisen from using a constant rather than a changing value for endogenous fecal P excretion.

Housing temperature effects on P digestion by the colts were confounded by age effects. Cold-housed horses digested less (P < .05) P than warm-housed horses at all ages. Because no individual animal discrepancies were found, this implies that housing temperature contributed to decreased P utilization. Although within normal limits, cold-housed horses also had lower mean blood P concentrations (2.26 mM) than warm-housed colts (2.36 mM). Reduced P digestion would be disadvantageous to cold-housed animals because this would impair intracellular energy utilization.

Retention Time. The 80% feed retention time differed (P < .05) with treatment group and also showed a tendency (P = .14) to decrease with period (age) (Table 5). The treatment effect was ascribed to the longer retention time for the ponies. Retention time did not differ between cold- or warm-housed colts. Digestion of DM, ADF and P was related directly (P < .05) to retention time. Retention times obtained for horses depend on the marker used. All of the Cr2O3 administered to horses fed hay or hay-grain diets was recovered within 96 h (Vander Noot et al., 1967). Retention times of 45 h (Hintz and Loy, 1966) and 23 h (Uden et al., 1982) were obtained for horses fed various diets using polystyrene particles or mordanted Cr2O3 as markers, respectively. Horses fed complete pelleted and pelleted forage diets had retention times of 28 to 37 h (Wolter, 1982), similar to the values found here (34 to 40 h). Pelleting of the diet increased the rate of passage in horses (Hintz and Loy, 1966). Thus, the feed retention time obtained for these colts may be shorter than would be obtained if more conventional horse diets had been fed.

Water Intake and Urine Production. Water intake, computed as free water plus feed water, was directly related to DM intake (r = .80, P < .01; Table 6). Urine production was related directly (r = .81, P < .01) to water intake. Horses fed the type of diet used in this study and housed at 15 to 20°C would be expected to drink 2.0 to 2.5 liters/kg DM intake (Cymbaluk, 1989). Thus, water intakes by these colts were consistent with the diet used. Free water intake per unit DM intake (Y, liters/kg DM) was related (P < .01) to ambient temperature (T, °C) according to the equation, Y = 2.25 + .016 T (R2 = .50; SEY = .004). Water intake in cold-exposed cattle decreased 1.75% per kilogram of DM intake for each degree Celsius below 0°C (Thiessen, 1977).

Maintenance Requirement. The maintenance energy requirement of horses (Y) as predicted by the equation Y (Mcal DE/d) = 1.4 + .03 BW (Pagan and Hintz, 1986) has been adopted by NRC (1989) to determine maintenance energy requirement for all classes of horses. The data used to derive this equation were collected on idle, mature horses kept in standing stalls in a thermoneutral environment. In western Canada, mature and growing horses often are overwintered outdoors at variable, often extreme, ambient temperatures (< -15°C). These cold extremes may elevate the
TABLE 7. AVERAGE WEIGHTS, INTAKES AND EFFICIENCIES OVER 22 WK FOR COLTS REARED IN A WARM OR COLD BARN DURING WINTER IN A PRAIRIE CLIMATE

<table>
<thead>
<tr>
<th>Item</th>
<th>Warm</th>
<th>Cold</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean barn temperature, °C</td>
<td>10.9</td>
<td>-5.2</td>
<td>1.55</td>
</tr>
<tr>
<td>ADG, kg/d(^a)</td>
<td>.67</td>
<td>.52</td>
<td>.03</td>
</tr>
<tr>
<td>DMI, kg/d</td>
<td>5.88</td>
<td>5.85</td>
<td>.03</td>
</tr>
<tr>
<td>DE intake, Mcal/d</td>
<td>15.83</td>
<td>15.76</td>
<td>.06</td>
</tr>
<tr>
<td>Gain to feed, g/kg DM(^a)</td>
<td>113.3</td>
<td>90.5</td>
<td>4.71</td>
</tr>
<tr>
<td>Gain to DE, g/Mcal DE(^a)</td>
<td>42.2</td>
<td>33.5</td>
<td>1.73</td>
</tr>
<tr>
<td>Maintenance requirement, kcal/kg BW(^b)</td>
<td>26.3</td>
<td>34.6</td>
<td>.18</td>
</tr>
</tbody>
</table>

\(^a\)Within row or comparison, treatments differ (P < .05).

\(^b\)Assumes efficiency of gain was unaffected by ambient temperature.

...energy demand for maintenance substantially. The 20% reductions in gain:feed and gain:DE intake ratios of cold-exposed horses support this suggestion (Table 7). Cold-exposed, adult horses have been shown to use .408 Mcal DE/500 kg BW or about 2.5% more DE for maintenance per 1°C drop below lower critical temperature (McBride et al., 1985). Similarly, cold-reared weanling horses may need 3 to 6% more DE for growth and maintenance per Celsius degree below -10°C (Cymbaluk and Christison, 1989; Cymbaluk et al., 1989a).

Ambient temperature has profound effects on ME needed for maintenance but does not affect the efficiency of use of ME above maintenance in productivity (Reid et al., 1980). Assuming that the energetic costs for gain given by NRC (1989) are correct, the daily maintenance energy expenditure by each group could be derived by subtracting energy used for gain from daily DE intake. By regression of this residual or maintenance DE intake against BW, the maintenance cost of rearing growing horses under naturally occurring cold housing (-5°C) was determined to be 34.6 kcal/kg BW. For growing horses kept principally in a thermoneutral environment (10°C), maintenance energy need was 26.3 kcal/kg BW (Table 7).

The original equation derived by Pagan and Hintz (1986) indicated that the maintenance energy need was 21.3 kcal/kg BW for mature horses confined in standing stalls. Horses in the present study also were confined, but they could move freely within their stalls and could exercise voluntarily outdoors for 4 h daily. Hence, the 29% correction factor used by Pagan and Hintz (1986) to correct maintenance energy for "normal activity" would be an overcorrection based on our data.

The maintenance energy requirements derived for our warm-housed colts was 14% below NRC (1989) values. If our values are increased by 14%, the maintenance energy needed by colts in warm housing would be 30 kcal/kg BW, and for cold-housed horses the value would be 39.4 kcal/kg BW. This estimated maintenance energy needed by colts kept in the cold barn agrees with the 37.8 kcal/kg BW derived for growing Quarter horses overwintered in an unheated barn (Cymbaluk et al., 1989a) and the 45.7 kcal/kg BW needed by weanlings kept outdoors in a severely cold winter (Cymbaluk and Christison, 1989). Maintenance DE estimated on a weekly basis (scaled to 100 kg BW) regressed on mean ambient temperature (°C) resulted in the equation, Y (DE Mcal/100 kg BW) = 3.2 -.042 T (R\(^2\) = .12; P < .04; SE .022). This implies that growing horses may need a 1.3% increase in maintenance energy per Celsius degree below 0°C. This value is comparable to requirements of cold-adapted, adult horses, which required 2.5% more maintenance energy per Celsius degree below their lower critical temperature of -15°C (McBride et al., 1985).

The present data emphasize the importance of environmental conditions in studies of equine energetics. In a prairie climate, growing Standardbred colts overwintered in an unheated barn at a mean ambient temperature of -5°C had 29% lower weight gains than related horses kept in a thermoneutral environment. The reduced weight gains by cold-housed colts were attributed to a higher maintenance energy requirement (39 kcal/kg BW) versus the NRC (1989) maintenance energy value of 30 kcal/kg BW.

The cold-exposed young horses herein gained weight, but their productivity, as
measured by ADG, was impaired by cold housing despite a nutrient intake that met NRC (1989) recommendations. Based on the data from this and previous studies (Cymbaluk and Christopherson, 1989; Cymbaluk et al., 1989a), the maintenance energy required by growing horses may need to be increased 1.3% per Celsius degree decrease in ambient temperature below 0°C. On this basis, the daily DE intake needed by horses of this age to sustain moderate growth in addition to maintenance may increase by about .7% per Celsius degree decrease in ambient temperature below 0°C.

Implications

Cold temperatures exacerbated the energy status of growing horses by increasing maintenance energy needs; cold also retarded phosphorus utilization. To meet energy needs at cold temperatures, more feed or feed with a greater energy density must be fed to young horses. Alternatively, heated housing could be provided. Although additional phosphorus might benefit horses during cold weather, no advantage likely would accrue from increasing dietary crude protein and calcium content above current guidelines. The present data dispute the universal use of a constant nutrient: energy ratio in formulation of equine diets.

Literature Cited


