Direct Measurements of Daily Milk Intake in Suckling Mink (Mustela vison) Kits

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EXPANDED ABSTRACT

In studies of the lactational performance of small mammals, estimates of the daily milk yield have been based mainly on methods involving various forms of test-weighing of the animals. However, because these methods require separation of the mothers from their young for a considerable length of time, such methods are unphysiological and may therefore lead to grossly erroneous results (Coward et al. 1982).

In the mink, daily milk production during the 6-wk lactation period is uncertain, although a few estimates, made by factorial methods, are available (Wamberg and Tauson 1998). More recently, direct methods based on the water isotope dilution technique have been introduced and their usefulness for estimating milk production documented in a number of animal species (Coward et al. 1982, Wamberg and Tauson 1998). Direct measurements by the isotope dilution technique of the milk yield of female mink have been reported in only a single study with few animals at peak lactation (Oftedal 1981).

Because newborn mink kits lack mobilizable energy stores, they are totally dependent on mother's milk for nourishment during the first 24–26 d of life. The high energetic demands of lactation, on the other hand, often result in a negative energy balance of the dam (Tauson et al. 1998), which may lead to metabolic disorders such as the so-called nursing sickness (Clausen et al. 1992, Wamberg et al. 1992). Therefore, a detailed knowledge of the daily milk production during the first 4 wk of lactation constitutes an important basis for adequate feeding of the mink dams.

In this study, we measured the milk yield of six mink dams during wk 1–4 postpartum using the tritiated water dilution technique described by Coward et al. (1982), which is based on the relationship between milk water inflow and the rate of disappearance from the young of tritiated water (\(^{3}\)HHO) under circumstances in which steady states do not exist because of body growth and discontinuous milk intake.

Materials and methods. Animals. Six lactating mink dams (2 yr old, wild color mutant) raising litters with 6–8 kits were maintained from wk 1 before delivery in metabolism cages for mink, made of stainless steel and equipped with plywood nest-boxes, in a controlled environment (temperature 18–20°C, relative humidity 40–60% and a natural daylight cycle at the location 55°N, 12°E). The animals were fed a conventional wet mink diet, based on industrial fish and slaughterhouse offal, containing (per kg) —310 g dry matter (DM), 180 g crude protein, 40 g crude fat and 4.6 MJ metabolizable energy (ME) (Wamberg et al. 1996). Drinking water was available from a closed water bottle system throughout the study. Body weight (BW) of the dams and the weight gained individually by the kits were recorded at regular intervals throughout the 4-wk study (Table 1).

The daily milk intake of the mink kits was calculated from body water turnover determined by isotopic water dilution over a period of 46 h after equilibration of a single dose of tritiated water injected intraperitoneally. To minimize disturbances of the mother-young relationship, three lactating mink dams were studied with their litters during wk 1 (d 3–5 postpartum) and restudied 2 wk later (d 16–18 postpartum) and another three dams were studied during wk 2 (d 8–10 postpartum) and restudied in wk 4 (d 22–24 postpartum).

Tritium loading. At the beginning of each study period, the mink kits of each litter were ranked by weight and given an accurately weighed amount (0.2–0.5 mL) of sterile isotonic (0.154 mol/L) saline containing 370 kBq/mL of \(^{3}\)HHO (code TRS 3, 185MBq/mL; Amersham International, Buckinghamshire, UK) by intraperitoneal injection. Two kits in each litter were not injected and served as controls for the calculation of isotopic water recirculation resulting from the uptake of urinary and fecal water by the dam (Baverstock and Green 1975).

Table 1

<table>
<thead>
<tr>
<th>Week (d)</th>
<th>BW (g)</th>
<th>Milk Intake (g/d)</th>
<th>T1/2 (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>5</td>
<td>120</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>5</td>
<td>120</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>5</td>
<td>120</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>5</td>
<td>120</td>
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<td>2</td>
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<td>3</td>
<td>5</td>
<td>120</td>
</tr>
</tbody>
</table>

● Milk intake
● Carnivores
● Mink
● Water turnover
● Tritiated water

Key words:

milk intake • carnivores • mink • water turnover • tritiated water

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Abbreviations used: BW, body weight; DM, dry matter; \(^{3}\)HHO, tritiated water; ME, metabolizable energy; MI, milk intake; T1/2, biological half-life.

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After 2 and 48 h of equilibration, the mink kits were placed on a heating pad for about 10 min and 60 μL of venous blood was taken from the tail tip using a heparinized hematocrit capillary tube. The plasma was separated in a calibrated 25-μL micropipette (Vitrex, Hounisen, Risskov, Denmark) and transferred to a disposable minivial containing 3 mL of scintillation fluid (Ecoscint-A, National Diagnostics, Manville, NJ). The radioactivities were determined by liquid scintillation counting, using the Packard Liquid Scintillation Analyzer, model Tri-carb 2100TR (Packard Instrument, Meriden, CT) as described by Wamberg and Tauson (1998).

All experimental procedures followed the guidelines approved by the member States of the Council of Europe for the protection of vertebrate animals used for experimental and other scientific purposes.

Calculation of milk intake. For each injected kit in a litter, the rates of total body water turnover and milk intake (MI) were calculated by the equation given by Coward et al. (1982),

\[
\text{T.W.T.} = \frac{\Delta \text{H}_{2}\text{O}}{\Delta \text{T}}
\]

where \( \Delta \text{H}_{2}\text{O} \) is the change in milk intake and \( \Delta \text{T} \) is the change in body water turnover.

\[
\text{MI} = \frac{\text{T.W.T.}}{\text{body weight}}
\]

TABLE 1

<table>
<thead>
<tr>
<th>Lactation week</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mink dams, N</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Kits/litter, N</td>
<td>7–9</td>
<td>7–8</td>
<td>7–9</td>
<td>7–8</td>
</tr>
<tr>
<td>Dam weight, g</td>
<td>1095 ± 17</td>
<td>1154 ± 22</td>
<td>1077 ± 25</td>
<td>1131 ± 18</td>
</tr>
<tr>
<td>Litter weight, g</td>
<td>151 ± 8</td>
<td>274 ± 34</td>
<td>595 ± 33</td>
<td>807 ± 109</td>
</tr>
<tr>
<td>Litter weight gain, g/d</td>
<td>21.7 ± 2.1</td>
<td>31.4 ± 4.1</td>
<td>48.1 ± 2.1</td>
<td>36.0 ± 3.4</td>
</tr>
<tr>
<td>Kit weight gain, g/d</td>
<td>2.7 ± 0.4</td>
<td>4.3 ± 0.3</td>
<td>5.6 ± 0.3</td>
<td>4.9 ± 0.2</td>
</tr>
<tr>
<td>3H2O half-life, d</td>
<td>1.05 ± 0.03</td>
<td>1.17 ± 0.05</td>
<td>1.75 ± 0.03</td>
<td>2.33 ± 0.12</td>
</tr>
<tr>
<td>Daily milk intake, g/kit</td>
<td>11.1 ± 0.7</td>
<td>18.0 ± 0.8</td>
<td>27.0 ± 1.4</td>
<td>27.7 ± 1.2</td>
</tr>
</tbody>
</table>

1 Values are means ± SEM.
2 Three dams were studied in wk 1 and wk 3; three different dams were studied in wk 2 and 4.
3 Measured individually.

FIGURE 1  Total daily milk production [g/(dam · d)] of three mink dams studied in wk 1 and 3 and another three dams studied in wk 2 and 4 postpartum (upper panel), calculated as the mean (±SEM) daily milk intake (g/d) per kit in the litter (lower panel) multiplied by the total number of kits per litter. For details, see text.

FIGURE 2  Mean (±SEM) daily energy output [ME; kJ/(dam · d)] in mink milk (●) compared with the estimated daily energy requirements for body growth (hatched columns) and maintenance (open columns) of the kits during the first 4 wk of lactation. For details, see text.
assuming that milk was the only source of water intake of the kits during the experimental periods. Furthermore, in calculations of the MI from tritiated water turnover, a factor of 0.92, accounting for preformed plus metabolic water, was used, which was based on data of the average chemical composition of mink milk obtained by Olesen et al. (1992) during wk 1–4 postpartum. The total milk yield (g/d) of each dam, shown in Figure 1 (upper panel), was calculated from the mean daily MI (g/g BW) of the tritium-loaded kits (Fig. 1, lower panel) multiplied by the mean total biomass of the litter during the corresponding experimental period. Calculations of the daily output of ME in mink milk (Fig. 2) were based on the data published by Olesen et al. (1992).

**Results and discussion.** The mean live weights of the two groups of lactating mink dams and their litters are given in Table 1. As expected, there was a considerable increase in total litter weight during wk 1–4 postpartum, whereas the weight changes of the dams in this period were moderate.

The mean biological half-lives (T½) of tritiated water in the mink kits during postnatal wk 1–4, given in Table 1, showed that the half-life of body water turnover increased markedly and in a linear fashion from 1.05 to 2.33 d.

The mean daily MI of kits and the calculated daily milk yield of the dams, shown in Figure 1, are considerably higher than the majority of values, based on factorial methods, that are reported in the literature (Wamberg and Tauson 1998). However, as demonstrated in Figure 2, the total daily energy output in the milk yielded by the dam was in close agreement with the estimated daily energy requirements for the suckling young.

Furthermore, the mean rate of body growth in the mink kits studied ranged from 2.7 to 5.6 g/d, and the calculated mean intake of milk per unit of BW gain remained relatively constant at ~4.1 g/g during wk 1 and 2 postpartum, after which it increased markedly to 4.8 and 5.6 g/g in wk 3 and 4 postpartum, as a result of the increasing demands of the kits for maintenance energy supplied by the milk (see Fig. 2). These values are in accordance with factorial data derived for mink by Tauson et al. (1998), but somewhat higher than the value (3.5 ± 0.3 g/g) obtained in mice by Knight et al. (1986).

**Conclusions.** In this study, the tritiated water dilution technique was found to be a useful and reproducible method for measurement of daily water turnover and milk intake in mink kits with a minimum of interference in the mother-young relationship. During postnatal wk 1–4, the calculated energy output of the daily milk yield of each dam corresponded well with the estimated value for daily energy requirements for growth and maintenance of the kits.

**LITERATURE CITED**


