Energy Metabolism, Nutrient Oxidation and Water Turnover in the Lactating Mink (Mustela vison)\textsuperscript{1,2}

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EXPANDED ABSTRACT

KEY WORDS:  • fur animals  • heat production  • milk yield  • substrate oxidation  • water balance

Mink kits are born very immature physiologically; they are blind, nearly hairless, devoid of their own thermoregulatory capacity and have very limited locomotor ability. Moreover, they have almost no mobilizable energy reserves because the fat content in the body at birth is only 1% (Tauson 1994). On the other hand, they have the capacity for rapid growth during the suckling period, with an average relative growth rate of 12%/24 h during the first 3 wk of life (Tauson 1994), a period in which the kits are totally dependent on mother’s milk for nourishment. For these reasons, and because litters usually are large (commonly averaging>6 kits), the lactation period is very demanding on the energy resources of the dam. Despite a substantial increase in food intake, dams with large litters are unable to sustain their energy needs by food consumption and have to mobilize body fat reserves; weight losses of 20% frequently occur during the lactation period (Hansen 1997). Furthermore, female mink have been shown to be in negative energy balance during late gestation (Tauson and Elnf 1994); therefore, a profound additional weight loss during lactation may lead to nursing sickness (Wamberg et al. 1992). It is of utmost importance, therefore, to stimulate energy and water intake to improve lactation performance and animal health. This study aimed to increase knowledge regarding the specific features of energy metabolism and water turnover in lactating mink and to estimate the milk yield by the use of a factorial approach.

Materials and methods. Mated female mink of the standard brown color type (n = 10) were used; three females that were not mated served as reference material. The animals were kept in the laboratory in metabolism cages equipped with devices for quantitative collection of feed residues, feces and urine; individual drinking water bottles, jars for water spill, and nesting boxes (only for mated females) were provided. Natural daylight conditions (increasing from 13 to 18 h of daylight) at the location (55°N, 12°E) prevailed from immediately after mating (20 March) until the end of May, corresponding to 3–4 wk after parturition. Two conventional mink diets, one suitable for gestation and one modified for lactation, were used (Stårup Fodercentral A/S, Sjælland, Denmark). The diets, to which the animals had free access, were based mainly on fish products; their chemical composition (pregnancy/lactation) was as follows: 305/287 kg/dry matter (DM),\textsuperscript{4} 108/123 g ash, 517/458 g crude protein, 133/138 g fat and 242/281 g carbohydrate. The gross energy (GE) content was 22.0 and 21.2 MJ/kg, respectively. Energy balance and quantitative water input/output measurements were carried out in consecutive periods of 1 wk, each including a 22-h respiration experiment by means of indirect calorimetry in an open-air circulation system. Gas exchange measurements and nitrogen excretion in urine (UN) were used for the calculation of heat production (HE) according to the formula of Brouwer (1965) as follows: HE = 16.18 × O\textsubscript{2}(L) + 5.02 × CO\textsubscript{2}(L) − 5.99 × UN (g), quantitative oxidation of protein (OXP), fat (O XF) and carbohydrate (OXCHO) according to Chwalibog et al. (1992):

\begin{align*}
\text{OXF}, \text{kJ} &= \text{UN} \times 6.25 \times 18.42 \\
\text{OXP}, \text{kJ} &= (1.719 \times \text{CO}_2(L) - 1.719) \\
&\quad \times \text{CO}_2(L) - 1.963 \times \text{UN}(\text{g}) \times 39.76 \\
\text{OXCHO}, \text{kJ} &= (-2.968 \times \text{CO}_2(L) + 4.174 \times \text{CO}_2(L) - 2.446) \\
&\quad \times \text{UN}(\text{g}) \times 17.58,
\end{align*}

4 Abbreviations used: DM, dry matter; GE, gross energy; HE, heat production; \(k_p\), efficiency of utilization of metabolizable energy for fat retention; \(k_p\), efficiency of utilization of metabolizable energy for protein retention; ME, metabolizable energy; ME\textsubscript{carb}, metabolizable energy for maintenance; OXF, quantitative oxidation of carbohydrates; OXP, quantitative oxidation of fat; OXCHO, quantitative oxidation of protein; UN, urinary nitrogen; \(W_{bala}\), water balance; \(W_{drink}\), water intake by drinking; \(W_{feed}\), water output in feces; \(W_{milk}\), water intake by feed; \(W_{milk}\), water output in milk; \(W_{urine}\), water output in urine.
and metabolic water (Wmet) was calculated according to Mclean and Tobin (1987) as:

\[ W_{\text{met}}(g) = 0.181 \times O_2(L) + 0.490 \times CO_2(L) - 0.826 \times UN(g). \]

Water turnover (g) was calculated based on intake of water in feed (Wfeed) and by drinking (Wdrink), Wmet and output of water in feces (Wfeces), urine (Wurine) and milk (Wmilk), giving the following balance equation (Wbal):

\[ W_{\text{bal}} = W_{\text{feed}} + W_{\text{drink}} + W_{\text{met}} - W_{\text{feces}} - W_{\text{urine}} - W_{\text{milk}}. \]

Milk yield, and hence Wmilk, were calculated by a factorial approach, using the chemical composition of milk according to Olesen et al. (1992), chemical composition of mink kit bodies from 0 to 5 d of age (Tauson 1994) and at 24 d of age (Glem-Hansen, personal communication 1992). The efficiencies for utilization of metabolizable energy (ME) for protein (kP) and fat (kF) retention were set to 0.5 and 0.8, respectively, and the energy requirement for maintenance (ME0) was assumed to be 527 kJ/kg0.75 (Chwalibog et al. 1980). Metabolizability (ME/GE) in milk was set to 0.85. Protein and fat retentions in each 1-wk balance period were calculated as the weight gain in the period multiplied by the chemical composition of the gain; energy in retained protein (kJ) was calculated as retained protein (g) × 23.86, and energy in retained fat (kJ) as retained fat (g) × 39.76.

All experimental procedures followed the guidelines approved by the member states of the Council of Europe.

Statistical analyses were conducted according to the General Linear Models procedure in SAS (SAS Institute, version 5, Cary, NC). The effect of physiologic stage (not mated, last trimester of true pregnancy, wk 1, 2, 3 and 4 of lactation) was evaluated for the dependent variables using a model comprising the fixed effect of physiologic stage and the effect of random dam within stage, which was used as the error term when evaluating effect of stage. Values were considered to be significantly different when P < 0.05. Results are presented as least-squared means.

Results and discussion. Animal performance. All of the mated females became pregnant; the average litter size at birth was 5.6 kits. Kit survival rate and weight gain were normal, with average litter sizes of 5.1 kits and individual kit body weights of 140 g in wk 4 of lactation. The females that were not mated exhibited lower live weights than those of pregnant and lactating females (Table 1).

Energy metabolism. ME intake was lowest in the females that were not mated; however, in the last trimester of true gestation, ME intakes were low and clearly exceeded by HE, which, in agreement with Tauson and Elnif (1994), showed that mink are likely to be in negative energy balance in late gestation. During lactation, ME intake increased profoundly; except in lactation wk 2. HE, measured for dam and offspring together, was above ME, indicating that the females were unable to sustain their energy requirement by feed intake (Table 1), a result in accordance with Hansen (1997). There was a tendency for the deficit in ME intake to increase in lactation wk 4, a result that concurs with the finding that the major weight loss in lactating mink occurs during the last part of lactation (wk 4–6) (Hansen 1997).

Nutrient oxidation. Data on nutrient oxidation (Table 1) confirmed earlier findings (Tauson and Elnif 1994), showing the immense importance of protein as an energy source and in situations in which the demand for dietary protein is high. When the mink were in strongly negative energy balance, high values for fat oxidation, together with decreasing live weights, demonstrated that fat was mobilized from the body (Table 1).

Milk yield. The factorial calculations on milk yield indicated that the daily milk production for the females in this study increased from 48 g per female (8.6 g per kit) in wk 1 of lactation to 151 g per female (29.7 g per kit) in wk 4 of lactation, values in close agreement with results from direct measurements with the use of the water isotope dilution technique (Wamberg and Tauson 1998).

Water turnover. Compared with females that were not mated, females in the last trimester of gestation had a slightly higher water intake and a lower output, resulting in higher water turnover and metabolic water (Wmet) was calculated according to Mclean and Tobin (1987) as:

\[ W_{\text{met}}(g) = 0.181 \times O_2(L) + 0.490 \times CO_2(L) - 0.826 \times UN(g). \]

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**TABLE 1**

<table>
<thead>
<tr>
<th>Live weight, g</th>
<th>Not mated</th>
<th>3rd trimester of gestation</th>
<th>Lactation, week</th>
<th>P-value; stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>953</td>
<td>1063</td>
<td>1015</td>
<td>0.07</td>
<td></td>
</tr>
<tr>
<td>ME, kJ/d</td>
<td>573a</td>
<td>612a</td>
<td>762b</td>
<td></td>
</tr>
<tr>
<td>HE, kJ/d</td>
<td>663a</td>
<td>764a</td>
<td>986c</td>
<td></td>
</tr>
<tr>
<td>OXP, % of HE</td>
<td>34</td>
<td>35</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>OXF, % of HE</td>
<td>33</td>
<td>18</td>
<td>799bc</td>
<td></td>
</tr>
<tr>
<td>OXCHO, % of HE</td>
<td>33</td>
<td>18</td>
<td>1104c</td>
<td></td>
</tr>
<tr>
<td>Milk yield, g/d</td>
<td></td>
<td>18</td>
<td>1294d</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>18</td>
<td>1352c</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>19</td>
<td>1&lt;0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>18</td>
<td>1&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>

* Based on three measurements of HE.

a–d Values within a row that share no common superscript differ significantly (P < 0.05).
W_{net}), with the highest value recorded during wk 4 of lactation, possibly reflecting an increased oxidation of body fat.

**Conclusions.** This study has clearly demonstrated that lactating mink are not able to sustain their energy requirements by feed intake after wk 2 of lactation, but have to mobilize fat reserves from the body. The milk yield can be considered very high in relation to body size; our data indicate that a female of 1100 g with a litter size of 5 kits produces 3000 g milk during the first 4 wk of lactation. Water to sustain milk production is provided mainly by the feed, provided that conventional wet diets are fed, but metabolic water contributes 10% of the total water input. Water output in urine increases substantially in lactating animals, reflecting the need for excretion of excess nitrogen from deaminated protein via urine. To sustain the metabolic needs of high yielding female mink, palatable diets with a high energy concentration must be provided, as well as an ample water supply.

**LITERATURE CITED**


