Application of formulated diets and their effects on nutrient digestibility and reproductive performance of female mink (Neovison vison) during gestation

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ABSTRACT
This study was designed to investigate the possibility of total replacement of conventional diet by formulated experimental feed in farmed mink during gestation. Ninety female mink (Neovison vison) were randomly assigned to three groups: control group was fed conventional diet with normal (36%, C) protein level composed of fresh or frozen animal by-products and extruded corn. Formulated experimental diets contained animal meals, vegetable ingredients and fat, with normal (36%, E1) or high (44%, E2) protein level, and were mixed with water prior to administration. Nutrient digestibility, nitrogen (N)-balance and reproductive performance were determined to compare the effect of diets fed to female mink during gestation. Mink fed both experimental diets had lower nutrient digestibility than the control. Higher barren females, decreased birth survival rate and birth weight were noted for the two experimental groups, especially diet E1 with normal dietary protein, indicating impaired reproduction performance, but signs of improvement were seen in the experimental group with high protein level (44%, E2).

1. Introduction
Mink are important semi-domesticated animals raised for fur. Economical and efficient production is contingent upon the breeding result. Feed quality is one of the primary factors to influence reproductive performance (Shackelford 1980). An interesting challenge for scientists in the field of mink nutrition is the introduction of alternative feedstuffs that could overcome the problems of environmental harshness and production costs. At the same time, as with the preservation of animal health, production performance is also essential. Several investigations have been carried out to explore the alternative feed resource in mink (Ebner 1957; Skrede et al. 1998; Ljakjel et al. 2000; Demina et al. 2011). Attempts have been repeatedly made to formulate dry diets (Kifer and Schaible 1955; Ebner 1957; Travis and Schaible 1961; Aulerich 1965), some of which played a positive role in the development of mink farming. However, given the change in feed resources and advances in feed technology in the past decades, it was necessary to re-examine and refine them. This is especially important during gestation when nutrients are highly needed. However, investigations on the acceptance and feeding effects of formulated diets during gestation are limited.

The objective of the present study was to determine, based on the results of digestibility/balance trials and reproductive performances, whether female mink can be fed formulated dry diets as alternative feed in the gestation period.

2. Materials and methods
The experiment was carried out at the Fur Animal Breeding Base of Institute of Economic Animal and Plant Science, Chinese Academy of Agricultural Sciences (44.02°N, 126.15°E) in the northeast of China. The animals used in this work were managed according to the requirements of the national Experimental Animals Protection Law, and with bioethics and biosecurity committee approval.

2.1. Animals, diets and management
Ninety 2-year-old female mink (Neovison vison) of the standard black genotype were used and housed in roofed standard sheds with open sides. The experimental period extended from 14 d before mating until parturition. Thirty males were selected for mating. Due to management issue, the final number of females in each group was 27, 24 and 27 in groups C, E1 and E2, respectively. Therefore, the final ratio of female: male was 2.6:1. We adopted the regular 1 + 1 + 8 mating system, meaning to mate on the first, second and tenth days. Mating was started on various fixed dates between 5 March and 28 March.

All females were weighed at the experimental start and distributed randomly into three experimental groups. Control group (C) animals were exposed to standard mixed feed containing typical ingredients. Formulated experimental diets (E) were composed of animal meals, plant-origin ingredients, oil...
and essential supplements (vitamins and minerals), and were mixed with water prior to administration. The mink were mated starting 5 March. Throughout the experimental period, the mink were fed twice a day ad libitum at 8:00 am and 16:00 pm (Beijing time) with the experimental diets and had free access to drinking water. The ingredients of the three diets are listed in Table 1, chemical composition in Table 2 and amino acid content in Table 3.

2.2. Balance experiments, sample collection procedures

After about 25 days in pregnancy, 8 mink were randomly selected from each feeding group and housed in individual metabolism cages for digestibility measurements and N-balance experiments. Feed residues, faeces and urine were quantitatively collected, weighed and recorded daily and stored at −20°C until the end of the balance period. To avoid ammonia evaporation from the urine, 20 mL sulphuric acid (5% solution) was added to the urine collection bottles, and the urine collection trays were sprayed with citric acid (20% solution) once per day. In the N-balance calculations, retained N was determined as ingested N- (faecal N + urinary N) equipped for separate quantitative collection of faeces and urine. The experiments consisted of a three-day collection and recording period.

2.3. Chemical analysis

Wet samples of diets and faeces were analysed for dry matter (DM) and N (AOAC and Helrich 1990). The freeze-dried samples of diets and faeces were analysed for crude protein (CP) and ether extract (EE). Urine and citric acid rinses were analysed for N content. DM, ash, CP (Kjeldahl-N × 6.25) and EE after acid hydrolysis were determined according to standard procedures (AOAC and Helrich 1990). Crude carbohydrate (CC) was calculated as the difference by subtracting ash, CP and EE from the DM content. Amino acids in diets were analysed by using an amino acid analyser (L-8900, HITACHI, Japan), as described by Ma et al. (2010). The apparent digestibility (AD) coefficient of nutrients was calculated as follows: AD = (a-b)/a × 100, in which ‘a’ is the nutrient intake from feed and ‘b’ is the nutrient excretion in faeces. The calculation of metabolizable energy (ME) content and the proportional composition of ME were based on the digestibility coefficients achieved and the following values of ME: protein 18.8 MJ/kg, EE 39.8 MJ/kg and carbohydrate 17.6 MJ/kg (Clauss et al. 2010).

2.4. Reproductive performance evaluation

Mated female mink, barren female mink, kits per litter and live born kits per mated female were recorded or calculated. Mink kits were weighted at birth. All data were used as indexes to determine the reproductive performance of dams (Tauson & Aldén 1984; Shaw et al. 1997; Korhonen et al. 2002; Vesterdorf et al. 2012).

2.5. Statistical analysis

Statistical analyses of mated females (%) and barren females (%) were carried out using the Chi-square statistics and the rest were analysed by one-way analysis of variance procedure of SAS (version 8.2, SAS Institute, Inc., Cary, NC, USA). Duncan’s multiple range test was employed for multiple comparison. Data were represented as mean ± standard error. Values of p less than .05 were considered statistically significant and those of p less than .01 were considered statistically highly significant.

3. Results

Table 4 presents the results of digestibility trials. This experiment showed that diet C was characterized by better nutrient digestibility than diets E1 and E2. Diet E2 exhibited considerably higher DM input and DM output than diet C (p < .05), with lower DM digestibility consequently. Significantly decreased CP and EE digestibility was also observed in diets E1 and E2 (p < .05). It seems interesting that no differences were reported between diets E1 and E2.

Differences in nitrogen metabolism among diets are evident in Table 5. Nitrogen intake, faecal nitrogen and urine nitrogen...
were considerably higher in diet E2 ($p < .05$), but N retention showed non-significant difference between diets C and E2. Diet E1 remained constant with diet C except for the increased faecal nitrogen ($p > .05$).

Table 6 shows the data on reproductive performance. Decreased reproductive capacity of diet E1 was noted compared to diets C and E2. Highly significant differences were observed in respect of mated females, barren females and birth weight ($p < .05$). Differences were between diets E2 and C were smaller.

4. Discussions

4.1. Feed intake, DM and nutrient digestibility

An animal’s food intake is directly related to the palatability of its diet (Corbit & Stellar 1964). The high DM intake in diet E is likely due to the increased palatability of the formulated diets (Cheeke & Dierenfeld 2010). Another interpretation is that the high DM intake was the reflection of less CP and EE digestibility. Gugolek et al. (2013) revealed that farmed mink exhibit higher nutrient digestibility in order to achieve higher productivity. Previous studies have demonstrated that, metabolic flexibility in a few strict carnivores as well as cats and mink are able to adapt to varied protein provision by regulating the protein oxidation rate (Russell et al. 2002; Fink et al. 2004, 2006; Green et al. 2008; Matthiesen et al. 2010). When supplied with low-quality feedstuff, mink have to increase intake to meet the nutrient requirements of early lactation, for the development of the mammary gland and for a likely increase in protein requirement for the hypertrophy of visceral tissues, including gut and liver, in late pregnancy (Fell et al. 1972; Robinson et al. 1978). For the hypertrophy of visceral tissues, including gut and liver, in late pregnancy (Fell et al. 1972; Robinson et al. 1978) in maternal mink have to increase intake to meet the nutrient requirements of early lactation, for the development of the mammary gland and for a likely increase in protein requirement for the hypertrophy of visceral tissues, including gut and liver, in late pregnancy (Fell et al. 1972; Robinson et al. 1978).

Our results indicate that diet E2 had increased N intake, faecal nitrogen and urine nitrogen. This could result from high DM ingestion and protein level in these groups, especially diet E2. Of particular note, the content of valine, methionine, phenylalanine and lysine was higher in diet E2; but no significant difference was observed in N retention compared to the control diet. This indicates poorly digestibility of amino acids in diet E2. Diets E adopted corn and soybean meal as the main protein sources; therefore, it was rich in amino acids, which are absorbed at much slower rates (Gupta et al. 1958; Hara and Kiriyama 1991). This shows good agreement with the findings by Skrede (1979) who concluded that nutritionally important amino acids in meat and bone meal were less digestible than those in cod fillet.

In diet E2, higher protein level might compensate the relatively low digestibility of amino acids, but ways to minimize nitrogen excretion and reduce pollution from diet E2 should be paid more attention to.

4.3. Reproductive performance

Mink are seasonal breeders with one annual breeding season which begins in early March and lasts for approximately 20–
25 days in the northern hemisphere. Ovulation is induced by mating, and is followed by an embryonic diapause ranging from a few days to 12 weeks in length, which delays the implantation (Hansson 1947), so it is crucial to meet mink nutrient requirements so that females show oestrus and mate in good time. Results of the present study indicate that diets E produced reproductive failure, but differing in degree. More severe reproductive complications occurred in mink fed diet E1 with low protein level. Significantly higher percentage of barren E1 females with significantly reduced birth weight corresponds to findings in protein-restricted rats (Galler & Tonkiss 1991). In our present research, feeding diet E1 during gestation altered the number of litter size and born alive only numerically, in line with several findings in mink (Matthiesen, Blache, Thomsen, Hansen & Tauson 2010) and rats (Bellinger et al. 2006; Pinheiro et al. 2008). In our case, non-significance is probably due to high variance within group. Nevertheless, the decrease in the number of litter size and born alive in groups of diets E should be noted. Moreover, there is a trend that higher dietary protein achieved relatively better reproductive performance in diet E2 compared to E1. Another observation of the present study was the significantly reduced birth weight among diet E1-fed mink kits. This could be explained by the well-known effect of in utero protein malnutrition, which was also found in mink (Matthiesen et al. 2010) and rats (Kwong et al. 2007; Pinheiro et al. 2008). Decreased birth weight of the mink kits resulted from an imbalance between demand of foetal growth and supply of maternal nutrient, reflecting the limited amount of N available for foetal growth. This is confirmed by the fact that mink fed diet E2, composed of same ingredients as diet E1 but with higher protein level, showed improved reproductive performances. Hence, our results suggest that high dietary protein level can compensate the affected amino acid utilization in formulated dry feed.

5. Conclusion
In summarizing the results obtained, it is concluded that conventional diet is characterized by better nutrient digestibility, more efficient N utilization and higher reproductive performance, compared to formulated diets. Although diets E1 and C had similar nutritional value, significant differences in CP and EE digestibility, and impaired reproductive performance were observed. Formulated diet E2 with high protein concentration indicated improved N retention and reproductive capacity, but considering nitrogen excretion, farmed mink in gestation should be still fed conventional diet. More research is recommended to apply dry protein sources (fish meal, meat and bone meal, plant protein, etc.) to conventional diet to reach the optimum reproductive performance.

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Disclosure statement
No potential conflict of interest was reported by the authors.

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