Effects of feed energy and protein level on growth and pelt parameters in blue foxes (*Vulpes lagopus*) in the late growing-furring period

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The aim of the present study was to determine whether a decrease in feed energy content would prevent extreme body weight (BW) gain and fatness in blue foxes in the late growing-furring period, without compromising pelt quality or pelt size. BW gain, body mass index (BMI), body condition score (BCS), and pelt characteristics were studied in 60 blue foxes divided into four equal-sized groups from mid-October until pelting (50 days). Experimental diets in were "high energy – high protein", "high energy – low protein", "low energy – high protein", and "low energy – low protein". High-energy diets contained 19.3 MJ metabolisable energy (ME) in kg dry matter (DM) and high-protein diets contained digestible crude protein (DCP) 20% of ME. Low-energy diets contained 16.3 MJ ME in kg DM and low-protein diets DCP 17% of ME. Feeding was gradually increased towards *ad libitum*. Reduced ME intake had no effect on pelt size or pelt quality. High-energy feeds resulted in heavier animals with higher BMI. However, the final BW exceeded 20 kg and BCS was "fat" or "extremely fat" in all groups.

Key words: fur animal, fatness, pelt size, pelt quality

Introduction

Finland is the largest producer of blue fox pelt in Europe and one of the largest in the world, with blue fox pelt being the main product of the Finnish fur industry (FiFur 2018). Pelts are traded in auctions where pelt prices are affected by pelt size and pelt quality (Peura 2013). Pelt size is measured as the skin length from tip of the nose to base of the tail, while pelt quality is subjectively evaluated by experienced graders. Longer pelts obtain higher prices, and as a result pelt size has been increasing in recent decades (Peura et al. 2007). At the same time, body weight (BW) of blue foxes has increased over 100%, and most blue foxes are large and fat at pelting time (Kempe et al. 2009). The causes of these increases in size are multifactorial and involve genetic, other biological, and management-related variables. Pelt size is genetically and phenotypically correlated with BW, body condition score (BCS), and body length, and selection towards larger pelt size has been effective (Kempe et al. 2009, Kempe et al. 2013). As higher BW is a precondition for longer skins and higher prices, breeding programs have worked towards genotypes of larger blue foxes with high appetite. Furthermore, there is a genetic correlation between pelt size and fur density (a pelt quality parameter), which may further increase selection pressure towards larger animals (Kempe et al. 2013). Regarding management, blue foxes are often fed *ad libitum* with high-energy feed in the growing-furring period. Feed energy and fat content have also increased due to changes in supply and especially prices of ingredients (Dahlman 2003, Peura et al. 2007). High dietary fat content is an economic way of feeding blue foxes that are bred to grow rapidly.

Ad libitum feeding with high-energy diets for animals with high appetite and limited physical activity tends to result in a positive energy balance and obesity. Furthermore, the biological background of blue foxes supports burgeoning fatness. Originating from the arctic fox, the farmed blue fox has high fat-deposition ability and high feed intake in the autumn, which are essential mechanisms for survival in the arctic (Korhonen 1988, Prestrud and Nilssen 1992, Fuglei and Øritsland 1999). Together, these factors strongly support the increasing BW gain of blue foxes and are involved in increasing pelt sizes, which is the most important trait that affects pelt prices.

However, extreme fatness is an alarming welfare problem among Finnish blue foxes that can have detrimental effects on health and fertility. In blue foxes, obesity increases the incidence of leg weakness and eye infections, barrenness in breeding females, and early neonatal pup mortality (Korhonen et al. 2005, Koskinen et al. 2008, Kempe et al. 2010, Korhonen et al. 2014, Kempe and Strandén 2015). Obesity-induced disorders have also been demonstrated in other carnivores. In mink, higher BW gain is associated with a higher incidence of fatty liver

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disease (Rouvinen-Watt et al. 2010, Dick et al. 2014). In dogs, obesity is associated with a range of orthopaedic, metabolic, cardiorespiratory, and urinary diseases and other disorders (Zoran 2010). In addition to impaired welfare, problems in reproduction and health also decrease the profitability of blue fox pelt production. Successful breeding is one of the main factors in profitable production, and the breeding result has even higher economic importance than pelt characteristics (Peura et al. 2013). Animals culled due to eye infections or other health problems directly decrease profitability. Furthermore, feed intake is high among fast-growing fat animals, thus the elevated feeding costs will reduce the profits gained from larger pelts (Peura et al. 2007, Peura 2013).

The aim of the present study was to determine whether a decrease in feed-energy content in the late growing-furring period would prevent extreme BW gain and fatness in blue foxes, without compromising pelt quality or pelt size. In addition, we studied the effect of low-protein content together with low-energy content, as previous studies have shown that low-protein diets containing digestible crude protein at 15% of ME with supplemented methionine are sufficient for blue foxes in the late growing period (Dahlman et al. 2002, Dahlman et al. 2003, Ylinen et al. 2018). However, no previous studies have evaluated the effects of different energy and protein levels in the late growing-furring period. Growth, fatness, and obesity were assessed with measures of BW (average daily gain [ADG] and final BW), BCS, and body mass index (BMI). BMI is an objective indicator of BW relative to body length, which has been implemented only very recently for blue foxes. BCS is based on a subjective evaluation method, which has been developed for blue foxes by Kempe et al. (2009) and has been used to assesses the thickness of subcutaneous fat.

Our hypothesis was that reduced dietary energy content in the late growing-furring period, when the skeletal and muscular development is completed and BW gain consists of deposited fat, would prevent extreme BW gain without reducing pelt size or pelt quality.

Materials and methods

Two dietary energy levels (19 and 16 MJ metabolisable energy [ME]) in kg DM and two protein levels digestible crude protein [DCP] 20% and 17% of ME) were assessed at the research farm Luova Ltd, Kannus, Finland with 60 blue fox male cubs in four experimental groups (15 animals per group). The animals were kept single in semi-outdoor wire mesh cages. The experiment started on 18th October 2017 and lasted for 50 days until pelting. The initial BW of the animals was 15.4 (standard error of mean ±0·1) kg and BCS 3.6 (±0.5) and age 21 weeks. The four groups were "high energy – high protein" (HE – HP) containing 19.3 MJ ME in kg DM and DCP 20% of ME; "high energy – low protein" (HE – LP) containing 19.3 MJ ME in kg DM and DCP 17% of ME; "low energy – high protein" (LE – HP) containing 16.3 MJ ME in kg DM and DCP 20% of ME; and "low energy – low protein" (LE – LP) containing 16.3 MJ ME in kg DM and DCP 17% of ME. Wheat bran was added and rapeseed oil content was reduced to decrease the energy content of the low-energy diets (Table 1). Protein sources (fish, processed animal protein, and slaughter offal) were reduced to decrease protein content. Animals were fed once a day. Feed consumption was measured daily, and any feed residuals were collected and registered. The daily feed portion started from 800 g (as-fed basis) and was raised individually if no feed residual feeds were observed. Feed portion was maximum 1500 g during the trial. Drinking water was freely available. Watery faeces were assessed throughout the experiment using the Welfur assessment protocol definition of diarrhoea (Welfur 2014). BW was measured by weighing the animals at 2-week intervals. Body length from nose tip to tail root was measured at pelting immediately after electrocution of the animals. Pelt quality was evaluated as overall quality by a skilled grader at Fox Craft Ab on a scale of 1 (poorest) to 4 (best), with variables of woolliness, silkiness, and heaviness being evaluated. In addition, variables of guard hair length (in millimetres [mm]), under hair length (mm), texture (ratio between guard hair and under hair length), fur density, and fur colour were determined using an automatic grading machine. Pelt size was measured in centimetres (cm). BCS was determined according to Kempe et al. (2009) by an experienced assessor at the Kannus Research Farm Luova Oy. BMI was determined as described in Peura et al. (2017).

All institutional and national guidelines for the care and use of experimental animals were followed. All experimental procedures were approved by the National Animal Experiment Board in Finland with the guidelines established by the European Union Directive 2010/63/EU and current Finnish legislation on animal experimentation (Act on the Protection of Animals Used for Scientific or Educational Purposes 497/2013).

Table 1. Ingredients (g kg^{-1}) and calculated composition of the experimental diets.

	HE-HP	LE-HP	HE-LP	LE-LP
Fish (sprat)	196	98	96	124
Slaughter by-products (pork)	400	400	360	296
Processed animal protein	35	35	35	0
Precooked barley	147	197	169	216
Wheat bran	6	50	5	50
Rapeseed oil	74	57	82	52
DL-Methionine	1.2	2	1.6	1.7
Arbocel		10		10
Vitamin mixture	0.8	0.8	0.8	0.8
Water	140	150	250	250
DM %	41.4	46.8	40.7	42.4
In DM				
Crude protein %	26.1	22.9	22.8	18.9
Crude fat %	31.6	23.4	31.5	22.1
Nitrogen-free extract %	34.5	46.6	38.5	52.9
Ash %	7.9	7.1	7.3	6.1
ME MJ kg^{-1} DM	19.3	16.3	19.3	16.3
% of ME				
Crude protein	20.0	20.0	17.0	17.0
Crude fat	62.0	52.9	62.0	50.5
Nitrogen-free extract	18.0	27.1	21.0	32.5

HE-HP=high energy—high protein; LE-HP=low energy—high protein; HE-LP=high energy—low protein; LE-LP=low energy—low protein; DM=Dry matter; ME=metabolisable energy

Chemical analysis

The samples were pooled by diet (feeds). Pooled samples of the feeds were kept frozen until analysed at the Laboratory of Agricultural Sciences, University of Helsinki, Finland, except the analyses for crude fat (CF), which was analysed in the Laboratory of Fin Furlab Oy/Ab, Vaasa, Finland. The chemical composition of the feed was analysed by standard methods according to AOAC International (1995). DM was determined by oven drying at 103 °C and ash by ashing the samples at 600 °C for 24 h. The feed samples were dried using lyophilisation to prevent protein breakdown. CP was determined by the Kjeldahl method (AOAC International, 1995) with a Tecator Auto Digestion unit and a Kjeltec Auto 2300 Analyser (Foss A/S, Hillerød, Denmark). CF was determined by solvent extraction according to the Weibull-Stoldt technique (BÜCHI Hydrolysis Unit B-411 and BÜCHI Extraction Unit B-811; BÜCHI Labortechnik AG, Flawil, Switzerland). Nitrogen-free extract (NFE) was calculated as the difference obtained by subtracting the ash, CP, and CF from the DM content.

Calculations and statistical analysis

BMI was calculated using the following formula (Peura 2018).

$$BMI = 25 + 5 \times (BMI^{pre} - XBMIpre / \sigma BMIpre)$$

Where: $BMI^{pre} = (W / L^{P}) \times (L0^{P} / W0)$
Where: W = measured weight; L = measured length; WO = 13.8; LO = 72.7; P = 1.79; $XBMI^{pre}$ = 1.285381; σBMI^{pre} = 0.197083

Statistical analysis of BW, ADG, BMI, and pelt size data were performed with the general linear model (GLM) procedure of SAS 9.4 (SAS Institute, Cary, NC, USA). These data were observed to be normally distributed using the Shapiro-Wilk test. The model used in the analysis of BW, ADG, BMI, and pelt size was:

$$Yij=\mu + d_i + d(p_i * e_i) + \varepsilon_{ij}$$

where Y_{ij} = the outcome, μ = the general mean, d_i = the effect of diet (I = 1, …, 4), p_j = protein level group, e_i = energy level group, and ε_{ij} = the residual. The effect of diet was tested using two orthogonal contrasts. "Energy" tested the effect of the high vs low energy level, and "Protein" tested the effect of high vs low protein level. Statistical analysis of feed intake, DM, ME intake, BSC, and pelt quality was performed with the nonparametric Kruskal-Wallis test with pairwise comparisons, as these data were not normally distributed. In addition, we categorized BCS into a binary variable with animals being "extremely fat" or not. Binary variables were tested using logistic regression analysis. Incidence of woolliness, silkiness, and heaviness among groups were tested by chi-square analysis. Statistical analysis was performed using IBM SPSS version 24.

Results

Feeds

Both the energy and protein levels were higher than planned for all diets (Table 2). The low-energy feeds contained on average 17.1 MJ ME in kg DM and the high-energy feeds on average 19.9 MJ ME in kg DM. Feed composition as % of ME was determined using digestibility coefficients obtained in the present study (data on the digestibility study will be published elsewhere). The low-protein feeds contained DCP at 16% of ME and the high-protein feeds DCP at 19% of ME and thus followed the design. However, total protein content (as g kg^{-1} DM) between low and high protein diets was similar, especially between groups HE – LP and LE – HP (266 and 261 g kg^{-1} DM, respectively). Crude fat and nitrogen-free extract (carbohydrates) followed the design. Nitrogen-free extract (both as g kg^{-1} DM and as % of ME) was lowest in the HE – HP group. The fat:carbohydrate (F:C) ratio was over 2.3 in high-energy diets and less than 1.6 in low-energy diets.

Table 2. Analysed chemical composition

	HE-HP	LE-HP	HE-LP	LE-LP
DM %	38.7	41.4	39.5	37.6
In DM (g kg^{-1})				
Crude protein	317	261	266	236
Crude fat	334	234	311	261
NFE	274	445	347	429
Ash	75	60	75	74
ME MJ kg^{-1} DM	20.3	16.8	19.4	17.3
% of ME				
DCP	19.1	18.9	16.4	15.6
DCF	58.8	49.5	58.5	48.0
NFE	22.0	31.6	25.1	36.4
F:C	2.7	1.6	2.3	1.3

HE-HP=high energy—high protein; LE-HP=low energy—high protein; HE-LP=high energy—low protein; LE-LP=low energy—low protein; DM=dry matter; ME=metabolisable energy; DCP=digestible crude protein; DCF=digestible crude fat; NFE=nitrogen free extract; F:C=fat:carbohydrate ratio

Feed intake and faecal consistency

Feed intake did not differ between groups (Table 3). In all groups, feeds were consumed eagerly and no reduced feed intake was observed. Residual feeds were found only in a few sporadic cases. Thus, the average daily feed portion amounted to over 1000 g (as-fed basis) in all groups. Because the DM content of the feeds varied, daily DM intake differed between groups (p<0.0001). ME intake was lowest in low-energy groups (p<0.0001). CP intake was highest in high-energy and high-protein groups (p<0.0001 and p<0.0001). No residual feeds were detected. Consistency of faeces was normal in all groups in both trials.

Table 3. Dry matter (DM), crude protein (CP), and metabolisable energy (ME) intake from 18 October–7 December (50 days)

	HE – HP	LE – HP	HE – LP	LE – LP	SEM	Energy	Protein	Energy*Protein	K-W
DM g day^{-1}	457 ac	485 b	464 ab	448 ac	4.200				<0.0001
ME MJ day^{-1}	9.27 a	8.15 b	9.00 a	7.75 b	0.077				<0.0001
CP g day^{-1}	143.3	126.7	123.3	105.7		<0.0001	<0.0001	ns	
Initial BW (kg)	15.3	15.2	15.4	15.4	0.366	ns	ns	ns	
Final BW (kg)	21.6	20.6	21.4	19.9	0.371	0.0002	ns	ns	
ADG (g)	127.3	108.2	120.6	88.9	4.115	<0.0001	0.003	ns	
Final body length (cm)	73.4	73.3	73.5	73.6	0.540	ns	ns	ns	
Final BMI	31.1	29.5	30.6	28.1	0.632	0.002	ns	ns	
Final BCS	4.79	4.80	4.73	4.73	0.117				ns
Pelt size (cm)	147.7	147.7	148.1	147.5	1.283	ns	ns	ns	
Pelt quality (1–4)	3.0	2.7	3.0	3.1	0.175				ns

HE – HP=high energy – high protein; LE – HP=low energy – high protein; HE – LP=high energy – low protein; LE – LP=low energy – low protein. Contrasts: Energy =HE – HP and HE – LP vs LE – HP and LE – LP and Protein=HE – HP and LE – HP vs HE – LP and LE – LP. Interaction =HE – HP and LE – LP vs LE – HP and HE – LP, K-W=Kruskal-Wallis test; BW=body weight, ADG=average daily gain, BMI=body mass index, BCS=body condition score, ns=non-significant

Growth and pelt parameters

Blue foxes fed with high-energy feeds had higher ADG (p<0.0001), final BW (p=0.0002), and BMI (p=0.002) at pelting (Table 3). BCS at pelting was heavy (4) or extremely fat (5) in all animals and BCS did not differ between groups. For groups HE–HP, HE–LP, and LE–LP, the proportion of BCS 5 was 73% and in group LE–HP 80%. High-protein diets increased ADG (p=0.003) but did not influence any other parameters. Pelt size (cm) was not affected by the treatments (Table 3). Neither overall quality nor any other quality variables (woolliness, silkiness, heaviness, guard hair length, under hair length, ratio between guard hair and under hair length, fur density, and colour) were affected by the treatments.

Discussion

Feeds and feed intake

Fresh ingredients were pre-analysed and the table values were used for dry ingredients when formulating the diets for the study. Digestible protein, fat, and carbohydrate contents were calculated as percentage of ME (Lassén et al. 2012). As the energy content of the feeds varied, the total protein level of the diets HE – LP and LE – HP were rather similar. Furthermore, the CP intake was similar in these groups. Due to this similarity of CP intake, it was not possible to interpret the results of dietary protein level.

While feeding was gradually increased towards *ad libitum*, the maximum daily feed portion was kept at 1500 g. This corresponds with usual farm practice, where animals intended for pelting are fed intensively during the growing-furring period. We planned to assess whether blue foxes would vary their VFI depending on energy level of the feed. However, no reduced VFI occurred. Together with high fat deposition, intensive feed intake in the autumn has been observed in both wild arctic foxes and farmed blue foxes. This deposition of body fat reserve is seasonal, driven at least in part by photoperiod. In the wild, arctic animals prepare for periods of extreme cold and food scarcity by increasing feed intake and deposition of body fat reserves for both insulation of the body and energy reserve (Tauson et al. 2002). Correspondingly, seasonal species such as sheep, Siberian hamsters, and raccoon dogs exhibit seasonal regulation of VFI (Korhonen 1988, Boss-Williams and Bartness 1996, Iason et al. 2000). Although the factors that affect seasonal VFI may differ due to forage quality (Iason et al. 2000) or neuromodulator activity (Boss-Williams and Bartness 1996), VFI is still an effective regulator of BW changes in seasonal species (Loudon 1994, Mercer 1998). In farmed blue foxes, these biological survival mechanisms occur even though the farmed environment differs from wild nature, with almost unlimited feed available without physical exercise (Korhonen 1988, Mustonen et al. 2006). Farming conditions and management practices together with biological characteristics enable intensive feeding that results in obese animals.

Body weight

The initial body condition of the animals was moderate, with an average BCS of 3.6 (±0.5). Compared to the initial phase, the BCS increased from ideal to extremely fat. Intensive, almost *ad libitum* feed intake affected the fatness in all treatment groups, as in previous studies, where unrestricted feeding resulted in heavier animals when compared to restricted feeding in blue foxes (Korhonen et al. 2005, Korhonen et al. 2014, Sepponen et al. 2014). However, *ad libitum* feeding, high-energy feeds, and excessive BW gain is an infeasible combination. Just recently, a maximum BMI limitation has been implemented into the certification system in Finland, which creates even more pressure to prevent excessive fatness. Therefore, restricted feed allowance or low-energy feeds should be a matter of future research as there is an acute demand to control the progress of BW and size in blue foxes.

In our study, blue foxes that were fed with high-energy feeds had higher BW and BMI at pelting, but BCS did not differ between the diet groups. The percentage of extremely fat foxes with BCS 5 was 73% to 80% in all groups. BCS was introduced for the blue fox by Kempe et al. (2009) and is considered a practical tool to complement BW. In that study, the proportion of extremely fat foxes with BCS 5 was 24% and the proportion of heavy (BCS 4) and extremely fat (BCS 5) foxes together was 73%. In our study, the proportion of foxes with BCS 4 or 5 was 100%. However, in our study all blue foxes were males, which tend to have higher BCS than females. Nevertheless, the difference in BCS between these two studies is notable. The BCS method has been used by well-trained assessors for observing the degree of fatness in blue foxes (Kempe et al. 2009). Although this method is a practical tool (being correlated with higher BW of the animal), the massive winter fur of the animals makes the assessment difficult, and the correlation with the subcutaneous body fat content of the carcass is only moderate (Kempe et al. 2009). In addition, the use of BCS on farms has not decreased fatness of blue foxes (Peura et al. 2017). Recent studies have sought new evaluation methods for a more precise determination of fatness in blue foxes (Peura et al. 2017, Viksten 2018). The formula for BMI, which considers the relative BW together with body length, has been successfully developed for blue foxes and has been implemented since 2019 (Peura et al. 2017, 2018, Viksten 2018).

BMI is an objective measurement with a continuous scale, whereas BCS is a subjective ordinal variable (5-point scale). Therefore, for research purposes, BMI should be a more reliable variable, and statistical analysis of BMI should be more accurate compared to BCS. In addition, BMI as an independent measurement of body length could make it possible to use it as a tool for selective breeding without compromising pelt size when selection could be directed towards longer and leaner blue foxes. This might help prevent health problems related to fatness, especially leg weakness (Kempe et al. 2010). However, as observed in some dog breeds, excessive body length may increase the risk of intervertebral disc abnormalities (Packer et al. 2013, Kempe 2018).

In dogs, BMI has not yet been successful for estimating body fat (Mawby et al. 2004, Jeusette et al. 2010). According to these studies, BMI correlates with other body fat measurements (dual-X-ray absorptiometry) but the agreements of correlations are poor (Mawby et al. 2004, Jeusette et al. 2010).

Pelt size

Pelt size has both genetic and phenotypic correlation with grading size, body length, final BW, and BCS (Kempe et al. 2008). Greater grading size, BW, or BCS all indicate fatness and even obesity. Of these traits, body length is the only trait unrelated to extreme fatness. In the late growing-furring season, blue foxes have matured and skeletal and muscular development is complete (Dahlman et al. 2002). Therefore, excessive feeding during this time is not likely to influence body length but only fat deposition, which was the case especially in our high-energy treatments. Our treatments did not influence body length, which supports the conclusion of Dahlman et al. (2002).

In our study, high-energy diets contained a higher F:C ratio than the low-energy diets and did not affect pelt size or quality. Ahlstrøm and Skrede (1995a, 1995b) studied F:C ratio and skin length and found that a higher F:C ratio was related to higher BW in blue foxes but did not affect pelt size or pelt quality. However, in contrast to our study, the ME intake was similar between treatments (Ahlstrøm and Skrede 1995a). In their F:C ratio study with divergent ME content, skin length was positively affected by increasing ME content. Again, pelt quality was not affected (Ahlstrøm and Skrede 1995b). Both of these studies were conducted from July/August until pelting (consisting of the period of maturation, skeletal, and muscular growth) and the period of late autumn (when accumulation of fat occurs). In addition, the daily energy supply in their study was half of that in our study as was the BW of the animals. Our study, conducted when fat accumulation is the most intense, indicates that heavy fattening compared to the more moderate fattening in the late growing-furring period does not increase pelt size.

Pelt quality

Pelt quality is a multifactorial and complex trait. Professional graders evaluate overall pelt quality by considering several factors. Traits that affect pelt quality include the length of the guard hair and under hair, texture, and hair density. In addition, colour and colour clarity are determined. While nutrition may have multiple effects on pelt quality, research on its effects is scarce. In blue foxes, Dahlman et al. (2003) found that a dietary protein level 30% of ME had positive effect on guard hair quality, and that MET supplementation had a positive effect on overall pelt quality when dietary protein levels were low (22.5% of ME and 15% of ME). In mink, inadequate protein supply was associated with lower hair fibre length and diameter (Rasmussen and Børsting 2000). Rasmussen and Børsting (2000) observed that lower protein during pregnancy did not reduce the development of hair follicles of the mink kits, but lower protein supply during the growing-furring season reduced the activity of the follicles. They also showed that these histological variables were related to follicle activity, hair density, length and diameter, and that the sensory variables were associated with overall pelt quality.

Studies on inadequate energy supply and its effects on pelt or hair fibre quality are even scarcer, and to our knowledge such estimations have not been conducted in fur animals. However, inadequate energy supply may dullen the fur (NRC 1982). In the present study, overall quality was used as a variable defining pelt quality, which was not affected by the treatments. Other quality-related parameters were also unaffected. However, overall quality is rated only on a 4-point scale, and the number of animals may be insufficient to reveal small differences between groups.

Feeding economy is a significant factor when considering industrial feed formulation, feed preferences, and farm management in practice. The current study focused only on the effects of low-energy diets on growth and pelt characteristics, without considering financial costs. Barley and other low-energy ingredients used in this study might not be the most economical or easily obtained ingredients in practice. It is a question for future studies to determine whether, for example, a restricted daily feed allowance with ingredients containing more fat and therefore more energy would be a more economical alternative. However, daily energy intake should still be restricted to prevent extreme obesity in blue fox.

Conclusions

The results of our study show that voluntary energy intake and final BWs are reduced if dietary energy concentration is reduced from 19.4–20.3 to 16.8–17.3 MJ by decreasing the dietary F:C ratio in blue foxes during the late growing-furring period. Pelt size and fur quality was not affected by the lower BW. Although all animals were obese, there were fewer extreme obese animals with the low energy feed. These results are promising. To reduce the obesity problems in blue fox production further, studies with restricted feeding and with different dietary energy content should be performed.

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