Effect of intensive fattening of bulls based on a high-grain diet on growth intensity and biochemical and acid-base parameters of blood

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ABSTRACT: The present study deals with the use of high-grain diets with a low proportion of fodder for fattened cattle, and with the evaluation of their effect on the growth intensity and metabolic profile of the animals. Thirty Holstein × Czech Pied bulls were given diets containing from 86.69 to 88.54% concentrates based on crushed cereals in the period from 216th to 327th day of age. The growth intensity of bulls was high, with the average daily weight gain of 1.64 kg in the course of the whole experiment. When the average body weight of animals reached 343.67 kg and 450.93 kg, blood samples were taken from the *vena jugularis* of 10 randomly selected animals for the assessment of acid-base balance and selected biochemical parameters. Slightly decreased pH values and increased pCO_2 were detected by the assessment of acid-base balance. The calculated values of base excess and standard bicarbonate were in the reference range; however in samples of the second collection a highly significant decrease was found ($P \leq 0.01$). By a biochemical analysis of blood increased levels of plasma phosphorus were detected in samples of both collections in comparison with the accepted reference range. A statistically highly significant increase ($P \leq 0.01$) in plasma urea concentrations was detected in samples of the second collection. Other investigated parameters ranged within the accepted reference values. The results of the experiments show that high-grain diets produced intensive growth with high daily weight gains, without adverse effects on the health status of the investigated bulls. Although some depletion of compensatory mechanisms maintaining the acid-base balance was recorded, no serious disturbance of metabolic profile was registered in the animals.

Keywords: bulls; fattening; high-grain diet; weight gain; acid-base balance

Fattening of cattle based on high-grain diets is the most intensive form of beef production. Although cattle are ruminants specialised in fodder utilisation, such effective systems of young cattle nutrition exist that resemble – by a high grain proportion – the fattening of non-ruminant animals. They are used most frequently for the fattening of lower slaughter weight categories of cattle (250 to 450 kg), i.e. for the production of so called baby beef. Many authors dealt with cattle fattening by the baby beef method, with 80% grain proportion of dry matter in the diet (Krása et al., 1995; Chládek et al., 1998; Pinďák and Vrchlabský, 2000).

High-grain diets may also be used for the fattening of animals up to higher slaughter weights about 600 kg, particularly for intensive fattening during the finishing period of cattle reared in pasture. Most authors who used concentrated diets for fattened cattle registered markedly increased daily weight gain during grain feeding in comparison with fodder-based fattening (Keane and Fallon, 2001; Makarechian et al., 1995; Fluharty et al., 2000; Schoonmaker et al., 2003). However, many authors pointed out the risk of acidogenic effect of highly concentrated diets produced by a high content of starch and a low content of structural fibre. High doses of grain may seriously influence ruminal fermentation in cattle and cause general health status disturbances (Owens et al., 1998; Sauvant et al., 1999; Galyean and Rivera, 2002). A number of authors investigated changes in acid-base balance and some biochemical parameters of blood plasma caused by feeding high-grain diets to fattened cattle (Harmon et al., 1985; Burrin and Britton, 1986; Leedle et al., 1995; Goad et al., 1998; Brown et al., 2000; Hersom et al., 2003; Schoonmaker et al., 2003). Some of the authors recorded decreased concentrations of standard bicarbonate and base excess, accompanied by slightly decreased blood pH in the later phase of subacute acidosis; however, the investigated parameters were in the physiological range (Harmon et al., 1985; Goad et al., 1998; Brown et al. 2000). Leedle et al. (1995) recorded quite a marked reduction in blood pH to 7.3 during the feeding of a highly concentrated diet, whereas Hersom et al. (2003) did not find any marked effect of a concentrated diet on acid-base balance in blood. Some authors reported that the level of plasma phosphorus might also be increased (Patra et al., 1993; Brown et al., 1999).

The aim of the present study was to test a possible use of high-grain diets during the standard fattening of Holstein × Czech Pied bulls. Based on the bibliographic data, we assumed that the growth of bulls would be highly intensive in this system of fattening. Further, our study was aimed at the evaluation of the effect of concentrated diets on the metabolic profile of animals; special attention was focused on acid-base balance. The study brings further information on the advantages and risks of the use of diets based on grain for the intensive fattening of cattle.

MATERIAL AND METHODS

Thirty Holstein × Czech Pied crossbred bulls were used in the experiment. The study was carried out under field conditions. The bulls were kept in stables with grated concrete floor without bedding, in two boxes with 15 animals in each.

When the phase of plant nutrition of calves terminated, the bulls were determined for fattening. During the following transitional period of one month, the bulls were adapting themselves to a high-grain diet. The experiment began after this period of adaptation on the 216th day of fattening, with the initial average body weight of animals 269.07 kg.

Since then the bulls were given a highly concentrated diet consisting of 71.35 to 77.37% crushed grain (barley and oats), 11.46 to 13.31% meadow hay and 9.32 to 16.30% protein concentrate (soybean meal, dried yeast, wheat bran and feed additives) twice a day. The total proportion of concentrates was 86.69 to 88.54% of dietary dry matter. Three variants of cereal diets were formulated for animals of the following weight categories/daily weight gains: 200 kg/1.35 kg (No. 1), 350 kg/1.4 kg (No. 2) and 500 kg/1.5kg (No. 3). The time parameters of the experiment are presented in Table 1. The contents of nutrients and components of the diets are shown in Table 2. Group feeding was used during the whole experiment and the animal/feeder-trough space ratio was 1 : 1. Diet formulation was based on Nutrient Requirements and Tables of Nutritive Values of Feeds for Ruminants (Sommer et al., 1994). The nutritive values of used feeds were determined in a department laboratory by methods laid down by Decree No. 124/2001 of the Ministry of Agriculture of the CR. The weight of bulls was taken at the beginning of the experiment and then twice during the fattening period. Based on these weights, average daily weight gains were calculated during the periods between the weight determinations and during the whole fattening period.

The health status was evaluated daily by observation of clinical signs of diseases and by evaluation of acid-base balance and selected biochemical parameters of blood. Blood from the *vena jugularis* was taken twice from the same 10 randomly selected bulls during the fattening period for the assessment of biochemical and acid-base parameters. Blood was always collected at the same time 4 hours after morning feeding. The average body weight of bulls was 343.67 kg and 450.93 kg. Acid-base balance of blood was evaluated by the Astrup equilibration

Table 1. Time parameters of the experiment

Diet	No. 1	No. 2	No. 3
Age of bulls (days)	216–232	232–295	295–327
Number of forage days	16	63	32
Bull weighing	1	2	3
Average age (days)	216	258	327
Blood sample collection		collection 1	collection 2

Table 2. Composition of the diets (CP – crude protein)

Feed (kg of dry matter)	Diet		
	No. 1	No. 2	No. 3
Meadow hay 9% CP	0.688	0.860	1.290
Crushed oat grain	1.349	1.799	2.249
Crushed barley grain	2.625	3.937	5.250
Wheat bran	0.087	0.087	0.156
Soybean meal	0.265	0.265	0.354
Sulphite yeast	0.180	0.180	0.135
Megapro	0.279	0.279	0.093
NaHCO3	0.020	0.020	0.020
Ground calcite	0.020	0.020	0.050
MIKROS M11	0.057	0.057	0.095
Proportion of concentrates in % of dry matter	87.65	88.54	86.69
Nutrient composition of the diets (g/kg of dry matter)			
Dry matter (g)	5 570.50	7 504.70	9 691.90
Crude protein (g/kg)	150.36	141.65	134.47
PDI-E (g/kg)	110.72	107.06	103.36
PDI-N (g/kg)	104.07	97.22	91.51
Fibre (g/kg)	92.96	89.04	92,81
Ca (g/kg)	7.23	5.72	6.19
P (g/kg)	5.18	4.91	4.87
Mg (g/kg)	2.18	1.95	2.02
NEV (MJ/kg)	7.08	7.31	7.44

method; current blood pH, partial pressure of CO_2 (pCO_2), base excess (BE) and standard bicarbonate (SB) were assessed. Among biochemical parameters, the concentrations of total protein (CP), glucose (Glu), urea (Urea), transaminases AST and ALT and calcium (Ca), phosphorus (P) and magnesium (Mg) in blood plasma were analysed. All the evaluated parameters were determined photometrically using commercial Bio-La-Test kits (Pliva Lachema, Ltd.).

All the detected values of total protein (CP), glucose (Glu), urea (Urea), transaminases AST and ALT and calcium (Ca), phosphorus (P) and magnesium (Mg) concentrations were statistically evaluated. Arithmetic means ($\bar{x}$) and standard deviations (sd) of respective mathematical-statistical values are shown in the present study. Student's *t*-test with the probabilities $P \leq 0.05$ (*) and $P \leq 0.01$ (**) was used to evaluate the significance of variance.

RESULTS

The aim of the study was to test a possibility of using high-grain diets for the fattening of bulls and to assess their impact on the growth intensity and metabolic profile of the animals. Their average body weight at the beginning of the experiment at the age of 216 days and on the day of the second weighing at the age of 258 days was 269.07 kg and 343.67 kg, respectively. The average daily weight gain during that period was 1.78 kg. On the day of the third weighing at the age of 327 days, the average body weight of the bulls was 450.93 kg; the average daily weight gain between the second and third weighing was 1.55 kg. A statistically highly significant decrease in the average daily weight gain was detected in that period compared with the previous one ($P \leq 0.01$). The average daily weight gain during the whole investigated period from the 216^{th} to the 327^{th} day of age was 1.64 kg. Table 3 shows average body weights of bulls and average

Table 3. Body weight and average daily weight gains in the respective periods and throughout the experimental period

Bull weighing	Average age (days)	Body weight (kg)		Forage days	Average daily weight gain (kg)		*P*
		$\bar{x}$	sd		$\bar{x}$	sd	
1	216	269.07	16.78	–	–	–	–
2	258	343.67	18.60	42	1.78	0.19	≤ 0.01
3	327	450.93	22.94	69	1.55	0.24	≤ 0.01
Average daily weight gain (kg) throughout whole experiment				111	1.64	0.17	–

daily weight gains during the respective periods and during the whole experiment.

At the beginning of the experiment from 216th to 258th day of age, concentrate consumption was 3.79 kg per kg of weight gain (3.35 kg of dry matter) and average daily consumption was 6.74 kg (5.57 kg of dry matter). In the following period from 259th to 327th day of age concentrate consumption was 5.83 kg per kg of weight gain (5.15 kg of dry matter) and average daily consumption was 9.04 kg (7.99 kg of dry matter).

During the experiment, the health status of the bulls and their metabolic profile were monitored, based on the examination of blood collected from the *vena jugularis*. The bulls did not show any clinical signs of diseases during the whole period of fattening.

Acid-base balance results shown in Table 4 indicate that the average values of blood pH were found to be below the lower limit of the reference range, and at the second blood collection they decreased from the average value of 7.362 to 7.334; however, the decrease was not statistically significant. Partial CO_2 pressure was increased at both collections (average values 7.474 kPa and 7.064 kPa) in comparison with the reference range; no statistically significant differences were detected between the average values from both blood collections. Average values of base excess and standard bicarbonate were in the reference range at both collections and the initial value of base excess was slightly increased. However, at the second collection, the average values of both base excess and standard bicarbonate levels decreased statistically highly significantly ($P \leq 0.01$), from 4.313 mmol/l to 1.560 mmol/l and from 26.738 mmol/l to 24.880 mmol/l, respectively.

In Table 5 the results of biochemical analyses of blood are shown. The average values of total plasma

Table 4. Results of acid-base balance assessment

Parameter	Collection	$\bar{x}$	sd	*P*
pH	1	7.362	0.030	> 0.05
	2	7.334	0.032	
pCO_2 (kPa)	1	7.474	0.742	> 0.05
	2	7.064	0.615	
BE (mmol/l)	1	4.313	1.390	≤ 0.01
	2	1.560	1.221	
SB (mmol/l)	1	26.738	1.136	≤ 0.01
	2	24.880	0.963	

pH – current blood pH, pCO_2 – partial pressure of CO_2, BE – base excess, SB – standard bicarbonate

Table 5. Biochemical parameters of blood

Parameter	Collection	$\bar{x}$	sd	*P*
CP (g/l)	1	68.277	2.320	≤ 0.05
	2	75.500	7.152	
Urea (mmol/l)	1	3.967	0.520	≤ 0.01
	2	6.988	1.088	
AST (µkat/l)	1	0.352	0.094	> 0.05
	2	0.358	0.053	
ALT (µkat/l)	1	0.150	0.020	> 0.05
	2	0.160	0.018	
Ca (mmol/l)	1	2.529	0.117	≤ 0.05
	2	2.776	0.224	
P (mmol/l)	1	2.934	0.251	≤ 0.01
	2	2.540	0.090	
Mg (mmol/l)	1	0.859	0.070	> 0.05
	2	0.913	0.051	

CP – total plasma protein, Glu – plasma glucose, Urea – plasma urea, AST and ALT – plasma transaminases, Ca – plasma calcium, P – plasma phosphorus, Mg – plasma magnesium protein were in the reference range in samples of both collections; however, at the second collection, its value significantly ($P \leq 0.05$) increased from 68.277 g/l to 75.500 g/l. The average value of plasma urea in samples of the first collection was 3.967 mmol/l being in the reference range; however, its value highly significantly ($P \leq 0.01$) increased in samples of the second collection to 6.988 mmol/l, and thus exceeded the upper limit of the reference range. Detected plasma calcium concentrations were in the reference range in samples of both collections; however, in blood samples of the second collection, its average value statistically significantly ($P \leq 0.05$) increased from 2.529 mmol/l to 2.776 mmol/l. Plasma phosphorus concentration was increased in samples of both collections, exceeding the upper reference range, particularly in samples of the first collection. Its average value decreased statistically highly significantly ($P \leq 0.01$) from 2.934 mmol/l to 2.540 mmol/l. Average values of plasma magnesium and both transaminases AST and ALT were in the reference range and no statistically significant differences were detected between samples of the two collections.

DISCUSSION

The results show that feeding grain-based diets containing 86.69 to 88.54% concentrates of dietary dry matter led to the intensive growth of bulls. Growth intensity was particularly high in the initial period of fattening from 216th to 258th day of age when the average daily weight gain of bulls reached 1.78 kg. In the following period from 259th to 327th, average daily weight gain decreased statistically highly significantly ($P \leq 0.01$) to 1.55 kg. Average daily weight gain during the whole experiment was 1.64 kg. Growth intensity in the investigated animals of Holstein × Czech Pied breed was practically consistent with the authors who studied the use of high-grain diets in crossbred beef bulls. For instance Makarechian et al. (1995) detected the daily weight gain of 1.8 kg in bulls fed concentrates *ad libitum* up to the weight of 600 kg, whereas bulls fed the same type of diet with a higher proportion of hay had the daily weight gain of 1.3 kg. In the study by Fluharty et al. (2000), Angus crossbred steers reared in the pasture which was followed by intensive feeding a concentrated diet produced a high average daily weight gain of about 1.7 kg provided the feed was available *ad libitum*. However, the average daily weight gain decreased to 1.17 kg in the final phase of fattening. Despite that, the average daily weight gain remained higher than in steers fed limited amounts of concentrates. On the contrary, Schoonmaker et al. (2003) reported a high average daily weight gain in a group of crossbred Angus × Simmental steers, fed *ad libitum* a concentrated diet (93% concentrates, high proportion of maize grain) during the whole period of fattening; it amounted to 1.85 kg in the final phase.

Evaluating the metabolic profile of the investigated bulls fed cereal diets, our attention was focused particularly on the assessment of acid-base balance of blood. Average pH of blood was below the lower limit of the reference range, 7.38 (Jagoš et al., 1981), at both collections. However, according to Kraft and Dürr (2001), the lower limit of blood pH in cattle is 7.36, which is the value detected in our study in samples of the first collection. At the second collection, pH value decreased to 7.334; the difference was not statistically significant compared with samples of the first collection. The value of pCO_2 was increased and exceeded the accepted upper limit of the reference range; however, the differences between samples of the two collections were not significant. We can suppose that the increased value of pCO_2 was not probably related to the given concentrated diet, but it was evidently caused by animal handling during the blood collection, and consequently it also caused a slight pH decrease. Similar conclusions were drawn by Doubek et al. (1994). The average values of concentrations of bases, i.e. base excess and standard bicarbonate, which are the primary parameters of acid-base balance, were in the reference range in samples of both collections. However, in samples of the second collection, the base levels, both base excess and standard bicarbonate, decreased statistically highly significantly ($P \leq 0.01$). The results give evidence that a certain depletion of compensatory mechanisms maintaining the acid-base balance occurred in the second phase of fattening. In that period, the acid-base status was already somewhat affected by feeding high-grain diets although metabolic acidosis with concurrent reduction in base levels was not below the physiological range. Goad et al. (1998) observed similar changes in bicarbonate and base excess concentrations. In their study, a significant reduction in blood bases occurred, however, the onset of the change was earlier because they experimentally induced subacute acidosis. Consistently with the present study, the decrease in bases was accompanied by a concurrent slight decrease in blood pH. The above-mentioned authors regarded the decrease in bicarbonate and base excess concentrations as indicators of physiological compensation of increased absorption of volatile fatty acids from the digestive tract. Burrin and Britton (1986), who obtained similar results, suggested that a decrease in blood pH and bicarbonate concentrations during the later phase of subacute acidosis indicated depletion of compensatory mechanisms. Less marked changes in bicarbonate and base excess concentrations were recorded during experimentally induced subacute acidosis by intraruminal administration of processed grain (Brown et al., 2000). Harmon et al. (1985) found out more marked changes in bicarbonate concentrations after a switch to a diet containing 70% of concentrates, whereas pH decrease was insignificant. In contrast, Leedle et al. (1995) recorded a decrease in pH of venous blood from the value 7.38 to 7.3 during adaptation to a cereal diet that gradually contained 25 to 90% concentrates. Hersom et al. (2003), who investigated changes in the parameters of acid-base balance during adaptation to a highly concentrated diet containing up to 90% concentrates at the final stage, reported that neither blood pH nor pCO_2 nor bicarbonate concentrations were affected by the diet.

The biochemical examination of blood samples showed that the average concentration of total plasma protein increased statistically significantly ($P \leq 0.05$) in sample of the second collection while the average concentration of plasma urea increased highly significantly ($P \leq 0.01$). Only very scarce data on the effect of high-grain diets on the nitrogen metabolism parameters can be found in literature. Particularly the increased urea levels were likely associated with high contents of dietary nitrogenous compounds. Brown et al. (1999) reported that blood serum urea levels in sheep fed a diet containing 90% of concentrates were not affected by such diet and did not change even after a direct ruminal glucose infusion. The concentrations of plasma calcium were in the reference range in samples of both collections; however, a statistically significant ($P \leq 0.05$) increase in samples of the second collection compared with those of the first collection was observed. Plasma phosphorus concentration was increased in samples of both collections and exceeded the upper limit of the reference range although its average value decreased statistically highly significantly ($P \leq 0.01$) in samples of the second collection. That is consistent with the results of other authors who recorded increased concentrations of plasma phosphorus in association with experimentally induced acidosis in sheep (Patra et al., 1993; Brown et al., 1999). In contrast, Brown et al. (2000) detected decreased levels of serum phosphorus after experimentally induced acidosis in fattened cattle. Average values of plasma magnesium and both transaminases AST and ALT were in the reference range in samples of both collections, and no statistically significant differences between the compared parameters of samples of the two collections were detected. These conclusions correspond to the results obtained by Brown et al. (1999), who did not find any changes in AST and ALT blood serum concentrations in sheep fed a high-grain diet.

CONCLUSIONS

In the present study intensive growth with high daily weight gains was achieved in fattened bulls fed high-grain diets. During the whole experiment from the 216^{th} to 327^{th} day of age the average daily weight gain was 1.64 kg. The time span of fattening is markedly shortened by such intensive growth and the animals reach the required slaughter weight much earlier than cattle predominantly fattened with voluminous feeds. The results of the experiment show that the feeding of highly concentrated diets (concentrate percentage higher than 80% of dietary dry matter) did not seriously disturb the metabolic profile of the animals. However, a certain depletion of compensatory mechanisms that maintain the acid-base balance occurred in the second phase of fattening; it was indicated by a significant decrease in the levels of bases. In spite of that, the metabolic component of the acid-base balance was maintained in the physiological range, and the change in the respiratory component (pCO_2) which also influenced blood pH was not likely related to the diet fed to the animals. Thus, metabolic acidosis did not occur in the examined bulls in the course of the experiment.

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