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Research Article

Growth and Blood Parameters of Weaned Crossbred Beef Calves Fed Forage Kale (*Brassica oleracea* spp. *acephala*)

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Forty lightweight calves (206.4 ± 3.2 kg) were randomly distributed to four treatments: (Control) low nutritive value pasture and hay plus 1 kg d^{-1} of rolled barley; (Pasture) management intensive pasture; (Haylage) timothy haylage; and (Kale) 50% timothy haylage –50% kale pasture. Blood samples were analysed for thyroid hormones, liver enzymes, glucose, cholesterol, total proteins (TP), albumin, globulins, and urea-N. At the end of the trial, the Pasture group was the heaviest with 323.6 ± 4.2 kg BW and 1.54 kg ADG. Final BW and ADG were similar for the Kale and Haylage groups. Blood T_3 was higher for Kale than for the other groups. The T_3/T_4 ratio was greater for Control at the end of the experiment. There were no treatment differences for T_4, aspartate aminotransferase (AST), gamma glutamyl transferase (GGT), glutamate dehydrogenase (GLDH), cholesterol, and glucose. Blood urea-N was lower for Kale and higher for Pasture; however albumin concentrations were greater for Pasture and similar for other treatments. Except for the Control group, calves had a lower concentration of circulating globulins at the end than at the beginning of the experiment. This study showed that Kale could be fed to backgrounding calves without detrimental effects on performance.

1. Introduction

To optimize profit, cow-calf producers need to sell heavy calves to feedlots. In 2011, according to the Fédération des Producteurs de Bovins du Québec, producers received higher prices for beef calves weighing 340 kg live weight (LW). Hence, many cow-calf producers do feed lightweight calves, with low quality hay or pasture, plus grain such as barley or corn after weaning. However, with the recent increase in grain costs, forage alternatives need to be explored. Management intensive grazing is an option for lightweight growing beef cattle [1, 2], as well as high quality grass haylage [3]. Forage kale (*Brassica oleracea* spp. *acephala*), an annual forage crop, is another possible alternative when dealing with a shortage of perennial forage [4]. This annual crop can be seeded as late as mid-June in eastern Canada without detrimental effects on yield and *in vitro* digestibility [5]. Dairy cattle readily eat forage rape when fed around 40% of their daily DMI [6] and feeding sheep up to 40% forage rape in their diet DM had no detrimental effects on rumen and whole tract DM digestibility [7]. However, the forage rape family also contains antinutritive factors such as glucosinolates, which may have goitrogenic effects [8], S-methylcysteine sulfoxide [5] that induces hemolytic anemia [9] or may accumulate nitrates leading to nitrate poisoning [10]. Hence, cattle kale intoxication has been suspected [11], whereas growing cattle fed only kale performed poorly (mean ADG: 0.28 kg, Barry et al. [12]).

Our preliminary studies with growing steers suggested that forage kale could be fed up to 50% of the daily DMI without detrimental effects on health status and gain. However, effects of such diets on growth performance and blood

parameters related to health of growing beef calves have not been documented. Therefore, this study compares the gains and health status of growing calves fed forage kale, intensively managed pasture, grass haylage, or low nutritive value forage with barley supplementation.

2. Materials and Methods

Forty Angus-Simmental crossbred weaned bull calves 6 to 7 months of age, weighing 206.4 ± 3.2 kg LW, were randomly assigned to 4 treatments. The control diet (Control) consisted of *ad libitum* access to an extensively managed low nutritive value timothy (*Phleum pratense L.*) pasture and hay (50 g kg^{-1} CP; 421 g kg^{-1} ADF; 663 g kg^{-1} NDF; 668 g kg^{-1} *in vitro* true digestibility of dry matter (IVTD); 500 g kg^{-1} *in vitro* NDF digestibility (NDFD)) supplemented with 1 kg d^{-1} of rolled barley grain. The control diet was compared to the 3 other treatments. For the management intensive grazing diet (Pasture), calves were offered a new strip of timothy pasture daily (151 g kg^{-1} CP; 256 g kg^{-1} ADF; 417 g kg^{-1} NDF; 919 g kg^{-1} IVTD; 876 g kg^{-1} NDFD). A third group of calves were housed indoors and had free access to timothy haylage (Haylage) (109 g kg^{-1} CP; 385 g kg^{-1} ADF; 642 g kg^{-1} NDF; 883 g kg^{-1} IVTD; 726 g kg^{-1} NDFD). The forage kale group (Kale) had free access to the same haylage and were strip grazed with *Brassica oleracea* spp. acephala (114 g kg^{-1} CP; 212 g kg^{-1} ADF; 258 g kg^{-1} NDF; 926 g kg^{-1} IVTD; 721 g kg^{-1} NDFD) to allow approximately 50% of total daily DMI. All calves had free access to water and commercial vitamin-mineral licking blocks (Sup-R-bloc #3197, Purina, Portneuf, Qc, Canada) and received no antibiotics, antiparasitics, growth promoters, or vaccines. During the study, animals were daily monitored to detect any health changes.

Calves were weighed at the beginning of the experiment (initial BW) on September 15, 2010, and every 28 d until December 8, 2010 (final BW). Blood samples were drawn, at 09:00 h, from coccygeal vessels at the beginning and at the end of the experiment. They were left at room temperature for 20 min to allow clotting and then centrifuged at 1500 ×g for 15 min at 4°C. Sera were then collected and analysed on a Beckman-Synchron DX auto analyzer (Beckman instruments, Fullerton, CA, USA) using Beckman reagents. Glucose, cholesterol, albumin, and total proteins were measured by colorimetric endpoint methods [13–16]. Globulins were calculated by subtracting albumin from total proteins. Enzymatic activity of aspartate aminotransferase (AST), gamma glutamyl transferase (GGT), glutamate dehydrogenase (GLDH), and urea concentration were measured by kinetic-enzymatic methods [17–19]. Thyroid hormones (T_3 and T_4) were measured by a solid-phase competitive chemiluminescent enzyme immunoassay (IMMULITE 1000 sytems, Siemens, Gwynedd, UK) [20]. Protocol was approved by the animal care committee of the Centre de Recherche en Sciences Animales de Deschambault located in Deschambault, Quebec, Canada, where the experiment was performed.

Data were analyzed using the GLIMMIXED procedure of SAS with the repeated statement (SAS institute Inc., 2008) according to a completely randomised design. When treatment differences were observed, the Tukey test was used. The treatment, time, and time × treatment effects were considered as fixed and sampling periods as repeated measurements on each animal, the experimental unit. For weight gain, eight different covariance structures (SP(POW), SP(GAU), SP(EXP), SP(LIN), SP(LINL), SP(SPH), ANTE(1), and SP(POW)) were tested using repeated measures and SP(POW) was chosen because fit statistics were the smallest. For blood parameters, five different covariance structures (AR(1), CS, ARH(1), CSH, and TOEPH) were tested and ARH(1) was chosen for the same reason. Significance was declared at 0.05 level.

3. Results and Discussion

3.1. Animal Performance. During this study, no animal died or presented any clinical signs. At the end of the experiment, pasture-fed calves were the heaviest with an average LW of 323.6 kg ($P < 0.05$, Table 1) and a final ADG of 1.74 kg. The overall ADG was higher (1.54 kg; $P < 0.05$) for pasture-fed calves compared to the other treatments. The pasture ADG reported in the present study was greater than that reported elsewhere for heifers [1, 2]. It is however similar to the ADG reported by Ominski et al. [3] for steers and Mach et al. [21] for Holstein bulls calves. High rates of gain have also been reported [22] with calves grazing high quality Kentucky bluegrass (*Poa pratensis* L.) and quackgrass (*Elytrigia repens* L.). Kale-, haylage-, and control-fed calves had similar overall ADG, which were, respectively, of 0.87 and 0.85 and 0.81 kg. Marley et al. [23] reported greater ADG for lambs fed 100% kale silage compared to lambs fed ryegrass silage but lower gains for lambs fed alfalfa or red clover silage. Reid et al. [24] reported generally higher gains for lambs on brassica pasture than those on tall fescue, orchardgrass, or red clover pasture. Vipond et al. [25] did not find significant differences between lambs fed kale silage served alone or in combination with grass silage.

Control calves final weights were lower than kale and pasture fed calves (Table 1). Control fed calves had similar ADG to kale fed calves in periods 1 and 2 with ADG, respectively, of 1.13 and 1.10 kg for control compared to 0.87 and 0.80 kg for kale fed calves. During the last 28 days of the trial, the ADG of control calves dropped to 0.24 kg, whereas kale fed calves gained 0.97 kgd^{-1} ($P < 0.0001$). It is possible that colder weather associated with the presence of mud on lower body, chilly wind, rain, increased the maintenance energy [26]. The lower critical temperature is a function of hair depth; hide thickness and cleanness of the body [26]. Pasture and Haylage groups had dry and clean hair with no apparent mud on the body. Kale fed calves had mud on lower body, similar to control animals. However, the kale did not suffer from lower gains during the third period. This might be explained by the better nutritive value of the diet they were fed. The DMI of this group was around 7 kg d^{-1}, which is similar to those reported by Pordomingo et al. [1].

Haylage fed calves showed lower ADG in period 2 compared to other periods and lower than calves that were

Table 1: Live weight and average daily gain of calves fed kale/haylage (Kale) ration compared to intensively managed pasture (Pasture), haylage (Haylage), or a control hay ration with 1 kg d^{-1} of barley (Control).

Treatments	Start	Period 1	Period 2	Period 3
Live weight (kg)				
Control	206.4	236.9	267.6	274.2^{a}
Pasture	206.4	240.0	288.7	323.6^{c}
Kale	206.4	230.0	252.3	279.6^{b}
Haylage	206.2	237.8	250.5	277.4^{ab}
SEM	3.2	3.7	3.9	4.1
Average daily gain (kg d^{-1})				
Control	—	1.13^{ae}	1.10^{ae}	0.24^{ad}
Pasture	—	1.24^{bd}	1.74^{be}	1.74^{ce}
Kale	—	0.87^{a}	0.80^{a}	0.97^{b}
Haylage	—	1.17^{ae}	0.46^{ad}	0.96^{be}
SEM	—	0.05	0.05	0.05

[a,b,c]Values within the same column with different superscripts differ ($P < 0.05$).
[d,e]Values within the same row with different superscripts differ ($P \leq 0.01$).

Table 2: Blood thyroid hormones (T_3, triiodothyronine, and T_4, thyroxine) and hepatic enzymes (AST, aspartate aminotransferase; GGT, gamma-glutamyl transferase, and GLDH, glutamate dehydrogenase) at the beginning and the end of the experiment for calves fed a control hay diet with 1 kg of barley daily (Control), a 50% kale/50% haylage based diet (Kale), a management intensive grazing (Pasture), or a grass haylage based diet (Haylage).

Period of the experiment	Treatment	T_3	T_4	T_3/T_4	AST	GGT	GLDH
		nmol L^{-1}				UI L^{-1}	
Beginning	Control	1.63	72.19	0.0218	78.0	17.1	21.3
	Kale	1.41	66.35	0.0208	71.0	16.2	18.3
	Pasture	1.55	75.88	0.0228	66.0	16.9	16.7
	Haylage	1.79	72.57	0.0252	79.3	20.8	36.3
End	Control	1.58^{b}	80.11	0.0198^{b}	83.9^{a}	17.1	28.1
	Kale	2.33^{a*}	78.45	0.0309^{a*}	74.9^{ab}	15.8	15.7
	Pasture	1.49^{b}	65.33	0.0230^{ab}	67.3^{ab}	18.4	23.3
	Haylage	1.72^{b}	71.94	0.0247^{ab}	55.9^{b}	18.4	18.4
SEM		0.10	5.43	0.002	5.5	1.3	5.9
Source of variation				*P* value			
Treatment		0.008	0.8	0.02	0.05	0.3	0.3
Period		0.003	0.3	0.04	0.4	0.8	0.6
Treatment × Period		<0.001	0.007	<0.001	0.04	0.8	0.02

[ab]Values within the same column with different superscripts differ ($P < 0.05$).
[*]Significantly different from calves at the beginning of the experiment ($P < 0.05$).

on control or pasture treatment for this period. There was no health issue in this trial for any calf, in any treatment, as there was no sick calf observed, no health treatment, or medication given at any time in the project. It is unlikely but possible that unseen subclinical health problems affected ADG of this group for period 2.

3.2. Blood Parameters. Antinutritional substances such as S-methylcysteine sulfoxide [27] and glucosinolates [8] were reported in *Brassicas*. These substances are goitrogenic and should affect the thyroid hormones T_3 and T_4. Blood concentrations of thyroid hormones observed in the current experiment (Table 2) were within the acceptable range for healthy animals [28]. The treatment × period interaction was significant for all measured blood constituents, except for GGT (Table 2) and cholesterol (Table 3). Blood T_3, T_4, and T_3/T_4 ratio did not differ among treatments at the beginning of the experiment. Blood T_3 concentration in kale fed calves increased during the experimental period; at the end of the experiment, it was significantly higher for these calves than for the others. For Control and Haylage groups, blood T_4 concentration increased at the end of the experiment, while, for the other groups, it decreased or remained stable. Therefore experimental treatments had different effects on thyroid hormones over the course of the experiment. Vipond et al. [25] did not observe significant differences between kale silage and grass silage fed lambs although both hormones significantly increased with time.

Table 3: Blood parameters at the beginning and the end of the experiment for calves fed a control hay diet with 1 kg of barley daily (Control), a 50% kale/50% haylage based diet (Kale), management intensive grazing (Pasture), or a grass haylage based diet (Haylage).

Period of the experiment	Treatment	Glucose	Cholesterol	BUN	Total proteins	Albumin	Globulins
		mmol L^{-1}				g L^{-1}	
Beginning	Control	4.57	2.59	3.66*	61.8	32.7	29.10
	Kale	4.40	2.66	3.79*	59.3*	32.5	26.76*
	Pasture	4.63	5.66	3.22	60.0*	32.9	27.16*
	Haylage	4.69	2.62	2.94	63.2*	33.8*	29.32*
End	Control	4.20	2.37	2.39[b]	61.8[a]	31.7[b]	30.26[a]
	Kale	4.77	2.65	1.28[c]	54.0[b]	32.2[b]	21.78[b]
	Pasture	4.68	3.48	5.01[a]*	56.0[b]	35.0[a]*	20.87[b]
	Haylage	4.45	3.43	2.68[b]	54.2[b]	30.2[b]	23.95[b]
SEM		0.14	0.7	0.22	1.3	0.6	1.29
Source of variation				*P* value			
Treatment		0.3	0.2	<0.001	0.002	0.07	<0.001
Period		0.6	0.6	<0.001	<0.001	0.01	<0.001
Treatment × Period		0.05	0.5	<0.001	<0.001	<0.001	<0.001

[ab]Values within the same column with different superscripts differ ($P < 0.05$).
*Significantly higher from calves at the other period of the experiment ($P < 0.05$).
BUN, blood urea nitrogen.

Cox-Ganser et al. [29] reported increase in T_3 with time in sheep given *ad libitum* access to brassica pasture and no increase with time in sheep that grazed on stockpiled tall fescue. They also reported a significant difference in blood T_4 concentration for brassica-pastured lambs compared to lambs on stockpiled fescue. In the present study, blood T_3 concentration increased with time for kale fed calves, which differed, from other treatment calves at the end of the study. However, all values remained in the normal range reported by Doornenbal et al. [28]. Calves had limiting kale intake to 50% of their total DMI. This likely explains why kale did not adversely affect the thyroid gland.

At the end of the trial, the blood T_3/T_4 ratio was higher for kale compared to control fed animals but similar to the ratio of calves on other treatments. The elevated ratio for the Kale group is likely attributable to a significant increase in the blood T_3 concentration at the end of the experiment. Christopherson et al. [30] found higher thyroid hormones in blood of steers exposed to cold, and they also reported higher blood T_4 concentration during the colder month of February (average temperature −15.8°C) compared to March (average temperature +0.5°C). In the present study, cold stress during the last month of the trial probably had a subtle effect, if any, on thyroid hormones since Kale, Control, and Pasture calves were submitted to the same environment.

All measured hepatic enzymes (Table 2) were within the normal acceptable range for the bovine species [31]. The AST, GGT, and GLDH are indications of liver reaction to either poor quality feed and presence of toxins or antinutritional factors. Glucosinolates and S-methylcysteine sulfoxide present in kale were reported to affect liver and increase hepatic enzymes [9]. In the present study, AST of Kale and Pasture groups were intermediate between Control, the highest, and Haylage, the lowest. There was an interaction between dietary treatments and period on two of the three measured hepatic enzymes, AST and GLDH. The liver enzyme AST decreased over time in Haylage group while it increased in the other groups. This enzyme is produced in the cell cytosol and mitochondria and increases during hepatocyte damage. This result confirms that the haylage fed to this group was of a good quality. Cox-Ganser et al. [29] reported higher AST concentration in blood of lambs fed a grass-clover diet as compared to brassica. At the end of the current experiment, Control calves had higher AST blood concentration than those fed haylage. It is possible that the poor forage quality of the Control group contributed to increased blood AST concentrations. Values of GLDH in Pasture and Control groups increased with time while decreasing in Kale and Haylage groups. This confirms again that good haylage quality and kale had no impact on these hepatic enzyme concentrations.

Blood cholesterol was not affected by treatments ($P > 0.05$), neither at the beginning nor at the end of the experiment (Table 3). In the study of Cox-Ganser et al. [29] with sheep grazing brassica, blood thyroid hormones increased and cholesterol decreased. They reported an immediate inverse relationship between thyroid hormones and blood cholesterol. In the present study, such effect was not observed. Therefore, it is likely that antinutritional factors of forage kale did not play a significant role at the current incorporation level in the diet.

Blood glucose was not affected by treatments and was in the normal range for growing calves [28]. All calves were in positive energy balance as they gained weight consistently. There was a significant interaction (Treatment × Period) for this parameter. Blood glucose tended to decrease for Control and Haylage calves with time, while it tended to increase or remain stable for the other two treatments. Lower body weight has been associated with lower blood glucose [32]. Control calves had the lowest final LW (Table 1) followed

by the Haylage group. Lower blood glucose has also been associated with thermal stress [33]. It is possible that Control calves had a lower critical temperature, since they had the smallest ADG.

Blood urea nitrogen (BUN) generally decreased during the experimental period (Table 3) except for pasture calves; in these calves, BUN increased during the experiment and, at the end of the experiment, it was significantly higher in Pasture calves compared to the other groups. Blood urea nitrogen is correlated with forage CP content [22]. Crude protein concentration in the pasture offered to calves was 151 g kg^{-1} DM compared to 114 g kg^{-1} DM for kale, 108 g kg^{-1} DM for haylage, and 50 g kg^{-1} DM for control. Dietary CP requirements of growing calves on pasture treatment of this weight with ADG of 1.54 kg is around 145 g kg^{-1} DM [26]. For Kale and Haylage groups, CP requirements were around 100 g kg^{-1} DM and were met for calves with an overall average LW of 242 kg with an ADG of 0.87 kg. In the present study, despite a slightly higher CP supply than requirements, BUN at the end of the experiment was significantly lower for kale fed calves than for the other groups of calves. Water-soluble carbohydrates of kale were not evaluated in the present study but have been reported to be in the range of 200 to 250 g kg^{-1} DM [34]. It is possible that rumen microbes from this group of calves could utilize more of the degradable protein [25] due to its high carbohydrate contents. Cox-Ganser et al. [29] also reported decreased BUN in sheep fed kale.

Blood TP (Table 3) were within the acceptable ranges for growing calves but, according to Doornenbal et al. [28], this blood parameter has low correlation with the actual animal protein status. Conversely, blood albumin (Table 3) is generally considered with BUN as an indicator of the animal protein status. At the end of the experiment, blood albumin levels were similar ($P > 0.05$) in Control, Kale, and Haylage calves, and greater for Pasture calves, meaning that although BUN was lower in the Kale group, protein status was not impaired. The higher BUN in Pasture calves at the end of the experiment suggests that protein supply was higher than requirements for this group. Furthermore, higher blood albumin concentration for the Pasture group than the others suggests that there were more circulating proteins and these calves may possibly have benefited from a higher CP diet than suggested by the NRC [26]. It also suggests that pasture CP can be efficiently used by young growing animals. On a high quality pasture, the protein availability and the dietary profile of amino acids available for absorption do not appear to be limiting despite the highly degradable nature of pasture protein [35].

High circulating globulins are found generally when an animal immune system is challenged. In the present study (Table 3), this blood parameter was in greater concentrations at the beginning of the experiment and generally decreased during the experimental period for the majority of calves. Transportation may have an impact on animal health [36]. Before the start of the experiment, calves of the present study were transported from a distant farm and acclimated to a new environment. Therefore, it is possible that the immune system reacted to that and produced more antibodies as suggested by the higher initial globulin level. At the end of the experiment, calves from all treatments, except control, had a lower blood concentration of circulating globulins suggesting that the immune system was not overly solicited. Control calves were fed low nutritive value forage plus 1 kg d^{-1} of barley and, during the last month of the experiment, their ADG was low. It is possible that a combination of a low nutritive value diet, a low growth rate due to more rigorous climate, and possible parasite load caused an increase in antibody production in response to an adaptation to the environment. Kelley et al. [37] concluded that heat and cold stress can mediate either antibody or cell mediated immunity in dairy calves. Carr et al. [38] reported more antibodies production in cold stressed mice. Hicks et al. [39] reported elevated natural killer cytotoxicity in cold stressed pigs. Hangalapura et al. [40] found an enhancing effect of cold stress in chickens on lymphocytes proliferation. Miller and McConnell [41] reported higher antibody production in chronically malnourished infants suggesting an adaptive protective complex against infectious disease and mortality.

In conclusion, Kale pasture can be fed at around 50% of DMI to growing lightweight calves, in combination with a high quality haylage, without detrimental effects on growth performance and health. More research is needed to evaluate the effects of greater proportions of kale in growing cattle rations.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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