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Dietary Modified Cassava Chip and Corn Seed: Effect on Growth Performance, Rumen Production, and Blood glucose and Insulin in Early Fattening Beef Bulls

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Abstract

Effects of feeding modified cassava chip and corn seed as energy source inclusion in diet were investigated on growth performance, rumen fermentation, and blood metabolites in early fattening bulls. Thirty-six 1-year-old Charolais crossbred bulls with initial weight 270 ± 50 kg were randomly assigned into 6 groups with different experimental rations as cassava-based concentrates including non-modified cassava chip (Cass-Con), with 15 % of alkaline-treated cassava chip (Cass-Alkaline), with 15 % of steam-treated cassava chip (Cass-Steam) and corn-based concentrates including non-modified corn seed (Corn-Con), with 15 % of alkaline-treated corn seed (Corn-Alkaline), and with 15 % of steam-treated corn seed (Corn-Steam), according to completely randomized design (CRD). Results showed that feed intake and digestibility were not significantly different among treatments, while digestible dry matter and organic matter intake of Cass-Steam and Corn-Alkaline were higher than those of the other diets ($P < 0.05$). Ruminal pH post-feeding was highest in Corn-Alkaline and lowest in Cass-Con ($P < 0.05$). Blood glucose was similar among treatments. However, blood insulin at 4 h post-feeding was higher in Cass-Steam, Corn-Alkaline, and Corn-Steam than in the others. Blood insulin in bulls fed corn-based concentrate was higher than in bulls fed cassava-based concentrate ($P < 0.01$). Body weight gain and average daily gain were significantly higher ($P < 0.05$), while feed conversion ratio was lower in Cass-Steam, Corn-Alkaline, and Corn-Steam as compared with in Cass-Con, Cass-Alkaline and Corn-Con. Results indicated that using a modified energy source can improve growth performance in early fattening beef bulls. An appropriate method to modify cassava chip was steam method, while alkaline method for corn seed was superior.

Keywords: Modification, Cassava chip, Corn seed, Growth performance, Blood glucose, Insulin, Fattening beef bulls

Introduction

Starch is the main energy component used in beef cattle feeds due to its availability [1]. In Thailand, starch sources including ground corn and cassava chip are typically used at high ratios in beef cattle diet [2]. Management systems typically encourage the inclusion of high amounts of both starch sources in the diet to support growth performance and fat accumulation. Starch from cassava and corn seed differs in terms of solubility and fermentability in the rumen. Cassava starch has solubility and is rapidly degradable in the rumen at over 90 %, while corn starch has low ruminal solubility at 40 - 60 % [3]. High cassava diets are rapidly fermented, with increasing short chain fatty acid (SCFA) and lactic acid production accumulation in the rumen causing low pH with predisposition to rumen acidosis [4,5]. By contrast, excess ground corn in the diet causes low starch digestibility, and cattle receive less energy than expectation. Kathrin *et al.* [6] found that an excess of ruminal non-degradable starch in the diet resulted in low efficiency of ruminal nitrogen utilization and microbial protein synthesis and also decreased starch utilization efficiency [7]. The optimal level of non-degradable starch showed a positive effect on maintaining pH in the rumen, with increased digestibility and starch flow from the rumen to the small intestine. The starch was subsequently digested by pancreatic enzymes, increasing net absorption of glucose and with a decreased minor loss of energy in the form of methane and heat produced in the rumen [6]. Throckmorton and Lengs [8] found that diet supplementation with optimal by-pass starch level increased live weight gain in cows and directed the energy of unfermented starch in the rumen directly toward live weight gain rather than milk production. Thus, many researchers have attempted to elucidate an appropriate method to modulate the degradability of starch sources in the rumen by enhancing feed efficiency through altering the nature and amount of starch available to rumen microbes and, hence, shifting some starch digestion to the small intestine [9]. Methods to optimize starch flow to the duodenum without reducing rumen fermentability and total tract digestibility are required. Several methods have been used to modify starch structure from grains and tubers, such as application of alkaline and steam approaches. Steam processing improved starch digestion in the rumen [10,11], while treatment with sodium hydroxide (NaOH) was reported to increase starch flow to the duodenum [9,12]. However, our previous *in vitro* study showed different results. We found that modifying cassava starches with steaming and NaOH treatment decreased ruminal degradability and increased by-pass starch, while non-processed corn resulted in decreased by-pass starch [13]. Different results may depend on grain kernel structure, pericarp of cereal grains, structure of starch (amylose: Amylopectin), and other nutrient contents in the grain (e.g., protein, fat, and fiber) which can bond with starch molecules [14]. We also found that modified cassava chip and corn seed treated with steam and NaOH had greater ability to modify starch solubility and degradability in the rumen by decreasing the degradability of starch from cassava and increasing the degradability of corn starch. Optimal level in diet at 15 - 25 % of concentrate did not affect rumen fermentation production and increased growth performance in beef cattle [13]. However, an *in vivo* study is required to further elucidate these results. Therefore, here, the effects of modified cassava chip and corn seed in diet were determined for rumen fermentation, blood metabolites, and growth performance in early fattening beef bulls.

Materials and methods

Animal ethics

The experimental procedure was approved by the Animal Ethics Committee of Khon Kaen University based on the Ethic of Animal Experimentation of the National Research Council of Thailand. Record No. ACUC-KKU-64/60.

Animal and experimental design

Thirty-six 1-year-old 50 % Charolais and 50 % Thai × Brahman crossbred bulls (270 ± 50 kg initial body weight; BW) were individually housed in 2×2.5 m^2 concrete-floor pens with ambient air ventilation. All animals were dewormed with IVERMECTIN$^{@}$ (2.5 mL/heads), injected with a multiple vitamin including A, D, and E with a commercial dosage (3 mL/heads), and received FMD vaccinations before being submitted to a 21-day adaptation period to experimental facilities, handling, and diets, in which animals received 3 step-up diets containing increasing levels of concentrate, and to a 90-day early fattening period. The animals were divided into 6 groups, with each group containing 6 bulls, and randomly assigned to 1 of 6 experimental rations according to completely randomized design (CRD). Animals were fed twice daily with drinking water ad libitum.

Feed preparation

All corn seed and cassava chip were delivered to the laboratory form animal feed factory of Khon Kaen University in the same lot. The steam method was modified from [15]. Whole corn seed and cassava chip were soaked in water for 12 h to increase moisture content before steaming in a 2 tiered steam pot (20 × 80 cm^2 of high × diameter of pot size) for 45 min at 150 °C, and then spread on a carpet in natural sun conditions until dry. The alkaline method was modified from De Campeneere *et al.* [16]. Both corn seed and cassava chip were treated with NaOH solution applied at 3.5 % (wt/vol) with water. The NaOH solution was then mixed with the ingredients at ratio 1:1 (vol/wt) in large buckets and left uncovered for 24 h. The mixed ingredients and residual NaOH were spread on a carpet in natural sun conditions until dry. Both modified corn seed and cassava chip were ground to the same particle size to pass through a 4 mm sieve screen before being mixed in the concentrate.

Experimental feed and feeding

All concentrates were formulated with similar crude protein (18 %CP) and metabolizable energy (2.70 Mcal ME/kg DM) (**Tables 1** and **2**). Animals were fed the diets as a separated feed twice daily (08.00 am and 05.00 pm), with concentrate offered at 1.5 % of body weight (BW) and rice straw as roughage source *ad libitum*. Experimental diets were categorized as T1; cassava-based concentrate without modified cassava chip (Cass-Con), T2; cassava-based concentrate with 15 % alkaline-treated cassava chip (Cass-Alkaline), T3; cassava-based concentrate with 15 % steam-treated cassava chip (Cass-Steam), T4; corn-based concentrate without modified corn seed (Corn-Con), T5; corn-based concentrate with 15 % alkaline-treated corn seed (Corn-Alkaline), and T6; corn-based concentrate with 15 % steam-treated corn seed (Corn-Steam).

Table 1 Percentage of feed ingredients of experimental diets.

Items	T1	T2	T3	T4	T5	T6
	kg/100 kg					
Cassava chip	57.0	42.0	42.0	26.0	26.0	26.0
Alkaline-treated cassava chip	-	15.0	-	-	-	-
Steam-treated cassava chip	-	-	15.0	-	-	-
Ground corn	-	-	-	40.0	25.0	25.0
Alkaline-treated corn seed	-	-	-	-	15.0	-
Steam-treated corn seed	-	-	-	-	-	15.0
Rice brand	8.50	8.50	8.50	8.50	8.50	8.50
Soybean meal	15.0	15.0	15.0	13.5	13.5	13.5
Palm kernel meal	14.0	14.0	14.0	7.00	7.00	7.00
Salt	0.40	0.40	0.40	0.40	0.40	0.40
Dicalcium phosphate	1.50	1.50	1.50	1.50	1.50	1.50
Premixed	0.50	0.50	0.50	0.50	0.50	0.50
Sulfur	0.30	0.30	0.30	0.30	0.30	0.30
Molasses	1.50	1.50	1.50	1.50	1.50	1.50
Urea	1.30	1.30	1.30	0.80	0.80	0.80
Total	100.0	100.0	100.0	100.0	100.0	100.0

T1 = cassava-based concentrate without modified cassava chip (Cass-Con), T2 = cassava-based concentrate with 15 % of alkaline-treated cassava chip (Cass-Alkaline), T3 = cassava-based concentrate with 15 % of steam-treated cassava chip (Cass-Steam), T4 = corn-based concentrate without modified corn seed (Corn-Con), T5 = corn-based concentrate with 15 % of alkaline-treated corn seed (Corn-Alkaline), and T6 = corn-based concentrate with 15 % of steam-treated corn seed (Corn-Steam).

Table 2 Chemical composition of experimental diets.

Items	T1[1]	T2	T3	T4	T5	T6	Rice straw
Dry matter, %	90.2	91.1	89.9	90.1	90.4	90.6	89.7
	------------------------------ % of dry matter ----------------------------------						
Organic matter	93.4	92.9	94.1	94.9	94.7	94.7	88.2
Crude protein	18.3	18.0	17.9	18.0	17.9	17.9	3.3
Ether extract	5.7	5.9	5.9	5.1	5.5	5.6	0.6
Crude fiber	11.6	10.3	6.5	5.7	7.56	7.21	47.1
NFE[2]	57.8	58.6	63.8	66.1	63.7	63.9	37.2
NDF[2]	40.1	44.2	37.3	45.3	39.0	38.8	81.1
ADF[2]	14.5	12.9	8.13	7.14	9.45	9.01	57.7
Ash	6.57	7.11	5.90	5.05	5.31	5.32	11.8
ME[3], Mcal/kgDM	2.65	2.68	2.78	2.78	2.73	2.76	1.46

[1]See **Table 1**
[2]NFE = nitrogen free extract, DF = Neutral Detergent Fiber, ADF = Acid Detergent Fiber
[3]Calculated according to Harris *et al.* [17]
ME in Mcal/kg = DE (Mcal/kg) × 0.82
DE is using the factor of 4.41 Mcal/kg TDN
for concentrate TDN (% of DM) = 40.2625 + 0.1969 (%CP) + 0.4228 (%NFE) + 1.1903(%EE) − 0.1379(%CF)
for rice straw TDN (% of DM) = −7.2649 + 1.2120(%CP) + 0.8352(%NFE) + 2.4637(%EE) + 0.4475(%CF)

Body weight gain and performance measurement

Animals were weighed in the early morning at the beginning of every month during the experimental period to determine BW gain and average daily gain (ADG). Feed intake was adjusted monthly to be used as a concentrate feeding guideline for the beef bulls. Feeding volume and feed refusal were recorded at 8:00 am daily to calculate individual feed intake and feed conversion ratio during the early fattening period.

Sample collection and analysis

Experimental concentrate and rice straw formulae were sampled every 30 days. Fecal samples were collected during the last 7 days of the finishing period by rectal sampling. Samples of diets and feces of each collection time were pooled before drying at 60 °C for 72 h and then analyzed for dry matter (DM), ether extract (EE), ash and CP contents [18], fiber fractions, such as neutral detergent fiber (NDF), and acid detergent fiber (ADF) [19]. Acid insoluble ash (AIA) was analyzed and used to calculate the apparent digestibility of nutrients [20].

At the end of the experiment, rumen fluid and jugular blood samples were collected at 0 and 4 h post-morning feeding. Ruminal fluid samples (approximately 500 mL) were collected by a stomach tube. The pH of the ruminal fluid was immediately measured using a portable pH meter. Samples of rumen fluid were filtered through four layers of cheesecloth and then 100 mL of filtrated rumen fluid was mixed with 10 mL of 50 % sulfuric acid (H_2SO_4) solution and used for ammonia-nitrogen (NH_3-N) and volatile fatty acid (VFA) analyses. The mixed sample was centrifuged at 16,000×g for 15 min and the supernatant was stored at −20 °C prior to NH_3-N measurement, according to the method of Bremner and Keeney [21], and VFA analysis using HPLC (model RF-10AXmugiL; Shimadzu; Japan) [22]. Samples of blood were drawn from the jugular vein into two tubes (about 10 mL/tube). The 1st tube was separated by centrifugation at 500×g for 10 min and stored at −20 °C until analysis of blood urea nitrogen (BUN), according to the method of Crocker [23]. The 2nd blood tube was used to measure blood metabolites such as glucose and insulin at Thonburi Lab Center Co., Ltd.

Statistical analysis

All obtained data were subjected to the Analysis of Variance (ANOVA) procedures of SAS [24] according to a CRD design. Data were analyzed using the model Yij = μ + Mi + εij, where Yij = observation from animal j, receiving diet i; μ = the overall of mean, Mi = the mean effect of treatment (i = 1, 2, 3, 4, 5, 6), εij = the residual effect. Means were statistically compared using Duncan's New Multiple Range Test (DMRT) [25].

Results and discussion

Feed intake and nutrient digestibility

No difference among dietary treatments was observed concerning intake of concentrate, rice straw, and total feed (P > 0.05) (**Table 3**). Total feed intake averaged 2.37 - 2.55 % BW and related to normal guidelines for feeding beef cattle weighing 250 - 350 kg as recommended average feed intake at 2.5 % BW [26]. Schmidt *et al.* [27] reported that steers with average initial weight of 320 ± 20 kg consumed diet at about 2.45 % BW. Apparent digestibility of DM, organic matter (OM), CP, EE, NDF, and ADF were not significantly different among treatments (P > 0.05). Digestibility of CP was influenced by starch sources which increased in dietary corn-based concentrate compared to dietary cassava-based concentrate (P < 0.05).

However, apparent OM digestibility (OMD) was influenced by adding modified starch. Diets containing modified starches showed higher OMD than the non-modified starch diets (P < 0.05). Starch caused gelatinization (intermolecular disruption of hydrogen bonds) during alkaline or steam treatment and enhanced the surface of the corn kernel, available for microbial attachment, resulting in greater ruminal digestion of starch related with high OMD [28]. Moreover, diets containing modified cassava and corn showed higher rumen pH at 4 h post-feeding, with more stable values than diets containing non-modified starch (**Table 4**). Observed pH was reported as optimal for microbial digestion of fiber [29] and also digestion of protein in the rumen [30].

Table 3 Effects of dietary modified cassava and corn on voluntary feed intake and digestibility.

Items	Treatments						SEM	Contrast			
	T1[1]	T2	T3	T4	T5	T6		T1,2,3: T4,5,6	T1,4: T2,3,5,6	T2:T3	T5:T6
Feed intake (kg, DM)											
Concentrate	5.02	5.08	5.23	5.07	5.17	4.93	0.13	0.84	0.74	0.63	0.15
Rice straw	3.25	3.09	3.31	3.15	3.28	3.16	0.07	0.95	0.93	0.06	0.16
Total	8.27	8.18	8.54	8.22	8.45	8.09	0.17	0.86	0.80	0.27	0.12
% of BW	2.49	2.37	2.45	2.53	2.55	2.47	0.07	0.17	0.55	0.43	0.42
Apparent digestibility (%)											
DM	64.0	66.0	67.9	67.6	67.6	67.6	1.85	0.35	0.30	0.57	0.99
OM	67.4	70.6	72.6	70.9	71.4	72.4	1.67	0.48	0.05	0.48	0.68
CP	73.8	74.1	75.8	76.2	76.2	77.4	1.33	0.05	0.36	0.41	0.49
EE	81.1	80.1	82.2	84.9	81.1	80.5	1.68	0.53	0.20	0.42	0.77
NDF	59.4	63.3	62.5	66.4	63.7	62.5	1.47	0.07	0.97	0.66	0.62
ADF	42.0	46.7	40.1	41.6	48.6	44.2	2.90	0.51	0.30	0.23	0.34
Digestible nutrient intake (kg/day)											
DM	5.29^{c}	5.40^{bc}	5.80^{a}	5.56^{b}	5.71^{ab}	5.47^{bc}	0.07	0.37	0.01	0.01	0.03
OM	5.09^{b}	5.26^{ab}	5.69^{a}	5.38^{ab}	5.55^{a}	5.39^{ab}	0.12	0.52	0.03	0.05	0.47

Items	Treatments						SEM	Contrast			
	T1[1]	T2	T3	T4	T5	T6		T1,2,3: T4,5,6	T1,4: T2,3,5,6	T2:T3	T5:T6
CP	0.76	0.75	0.79	0.77	0.79	0.77	0.04	0.11	0.28	0.24	0.31
EE	0.25	0.26	0.27	0.24	0.25	0.24	0.04	0.09	0.14	0.86	0.26
NDF	2.76	3.01	2.89	3.21	2.97	2.80	0.15	0.07	0.22	0.28	0.13
ADF	1.01	1.14	0.94	0.91	1.16	1.00	0.03	0.58	0.43	0.12	0.16
Metabolizable energy intake, Mcal/d											
	19.3^{b}	20.0^{ab}	21.6^{a}	20.4^{ab}	21.1^{a}	20.5^{ab}	0.40	0.53	0.04	0.06	0.46

^{abc}Values in the same row with different superscripts differ (p < 0.05).
[1] See **Table 1**

Nevertheless, digestible DM and OM intake (P < 0.05) were highest in Cass-Steam and Corn-Alkaline (**Table 3**), while digestible CP, EE, NDF, and ADF intake were not significantly different among dietary treatments (P > 0.05). Higher DMD and OMD intake in Cass-Steam and Corn-Alkaline (P < 0.05) were related to higher intake of energy, as shown in **Table 3**. Growth performance of fattening bulls observed here met energy requirements for gain, as reported by Br-Corte [31].

Rumen fermentation products

Ruminal pH values in all treatments before morning feeding were high and similar (P > 0.05), while values decreased at 4 h post-feeding (**Table 4**). Ruminal pH value remained high in Corn-Alkaline and slightly decreased in Corn-Steam, Corn-Con, Cass-Alkaline, and Cass-Steam, with lowest value in Cass-Con (P < 0.05) By comparison, bulls fed a diet including corn had higher ruminal pH value than those fed cassava diets (P < 0.05). The modified starch diet maintained high pH compared with non-modified diets (P < 0.05). Rumen pH ranged 6.58 - 7.08 and in the normal range of rumen ecology (pH 6.2 - 7.0), reported as optimal for microbial fermentation [32]. Reduction of ruminal pH found in Cass-Con treatment may be explained by higher degradation in the rumen of cassava chip than corn seed and all modified diets of corn seed and cassava chip. Similarly, Gulmez and Turkmen [33] observed a decrease of ruminal pH in lactating cows when corn was replaced by wheat. Generally, cassava is a fermentable energy source in ruminant feed, with a high rate and extent of ruminal degradation [34]. Sommart *et al.* [3] reported that rate of ruminal degradation of starch from cassava was higher than corn and broken rice, while Huntington [35] reported that percentage intakes of rumen degradable starch by the in situ method of corn, wheat, and cassava were 49.5, 88.3, and 94.0 %, respectively. Ruminal degradability of starch varied with different sources of grain [3]. Bulls fed diets with modified starch showed slightly higher rumen pH than normal diets, influenced by increasing the portion of rumen-undegradable starch in diets (P < 0.05). Kathrin *et al.* [6] reported that slow-fermented diet in the rumen results in low product of short-chain fatty acids (SCFA) and higher ruminal pH.

Rumen fermentation end-products, including total VFAs, acetate (C2), propionate (C3), and butyrate (C4) concentration, C2:C3 ratio, rumen NH_3-N, and BUN were not significantly different among dietary treatments (P > 0.05). Yang *et al.* [36] found that increasing the level of by-pass starch from 12.1 to 33 % in goat feed showed no effect on production of C2, C3, and C4, while McNiven *et al.* [37] showed that feeding dairy cows with NaOH treated barley diets did not affect VFA production. However, Ørskov and Reid [38] found that C2 to C3 ratio was greatest for cows fed NaOH-treated barley. According to our observed data, although C2:C3 ratio was not significant different among treatments, C2:C3 ratio at 4 h post feeding tended to be lower when beef bulls were fed modified starch diets (P = 0.09). The NH_3-N values in this experiment ranged in the optimal level (15 - 30 mg%) to support microbial protein synthesis and to optimize ruminal feed digestibility [30].

Table 4 Effects of dietary modified cassava and corn on ruminal production and blood metabolites.

Items	Treatments						SEM	Contrast			
	T1[1]	T2	T3	T4	T5	T6		T1,2,3: T4,5,6	T1,4: T2,3,5,6	T2:T3	T5:T6
Ruminal fermentation products and blood metabolites, 0 h post-feeding											
Rumen pH	7.07	7.04	7.06	7.04	7.08	7.05	0.04	0.84	0.98	0.77	0.63
Rumen NH_3, mg/dL	13.1	11.3	12.2	14.0	12.2	15.7	1.86	0.39	0.76	0.80	0.32
Ruminal VFA production, % of total											
C2	68.0	69.2	69.1	68.3	70.1	66.9	1.09	0.79	0.60	0.94	0.13
C3	20.4	20.8	20.9	21.5	18.8	21.8	0.87	0.99	0.70	0.96	0.08
C4	11.6	9.98	10.1	10.2	11.1	11.3	0.59	0.63	0.67	0.94	0.89
C2:C3 ratio	3.33	3.32	3.31	3.17	3.69	3.10	0.64	0.22	0.12	0.69	0.10
Total, mg/100 mL	117.9	123.0	122.6	122.2	121.0	116.1	3.98	0.83	0.76	0.95	0.58
BUN, mg/dL	9.00	13.0	12.3	10.6	9.60	9.00	1.23	0.22	0.41	0.77	0.77
Ruminal fermentation products and blood metabolite, 4 h post feeding											
Rumen pH	6.58^{b}	6.77^{ab}	6.75^{ab}	6.80^{ab}	6.92^{a}	6.82^{ab}	0.06	0.03	0.04	0.78	0.11
Rumen NH_3, mg/dL	20.1	17.5	22.6	18.3	17.4	17.5	1.64	0.21	0.80	0.11	0.99
Ruminal VFA production, % of total											
C2	69.7	68.1	66.7	69.2	67.8	68.0	1.14	0.88	0.17	0.51	0.93
C3	20.7	22.0	23.4	21.7	22.8	22.2	0.87	0.83	0.17	0.37	0.70
C4	9.51	9.84	9.77	8.90	9.29	9.74	0.54	0.56	0.53	0.95	0.68
C2:C3 ratio	3.36	3.09	2.85	3.18	2.97	3.06	0.36	0.47	0.09	0.31	0.12
Total, mg/100 mL	131.4	127.8	130.4	136.5	132.5	128.4	7.79	0.76	0.64	0.85	0.77
BUN, mg/dL	9.30	13.7	15.3	12.0	12.3	10.0	1.40	0.38	0.49	0.52	0.38

^{abc}Values in the same row with different superscripts differ ($p < 0.05$).
See **Table 1**

Blood glucose and insulin

Concentrations of blood glucose and insulin are shown in **Figure 1**. Blood glucose was not affected by dietary treatments ($P > 0.05$). Glucose level in the blood prior to feeding was slightly lower than in blood at 4 h post-feeding. According to Wasserman [39], glucose levels are usually lowest in the morning before the 1st feed of the day and, thereafter, rise every hour or two by a few millimoles. Glucose concentrate values in all dietary treatments were within the normal range of 45 to 75 mg/dL [40]. Glucose is stored in skeletal muscle and liver cells in the form of glycogen [41]. Cellular glucose uptake is primarily regulated by insulin, a hormone produced in the pancreas. Hormone regulation is most important. There are 2 types of mutually antagonistic metabolic hormones affecting blood glucose levels: catabolic hormones (such as glucagon, cortisol, and catecholamines) which increase blood glucose [42], and an anabolic hormone (insulin) which decreases blood glucose. Glucose levels in the blood are usually within the normal range. If glucose levels stray out of this range, amounts of insulin and glucagon produced by the pancreas adjust to bring glucose levels back into normal range [41]. In this study, blood insulin levels at 4 h after morning feeding increased in beef cattle fed Cass-Steam, Corn-Alkaline, and Corn-Steam ($P < 0.01$), and levels were influenced by starch sources and modified methods ($P < 0.01$). Beef bulls fed corn-based diets had higher insulin levels than those fed cassava-based diets, while modified starches showed increased insulin concentration in blood compared with non-modified starches. These results indicated that the concentration of glucose absorbed across gut epithelial cells to the blood may increase in treatments of high blood insulin, but levels of glucose in the blood were not significantly different, owing to homeostasis, which decreased blood glucose to bring glucose levels back into normal range by insulin [41]. Thus, increasing concentration of insulin in the blood may result in beef bulls fed modified corn seed or cassava chip having more bypass energy to the small intestine. This is then digested by pancreatic enzymes and directly absorbed as glucose [43].

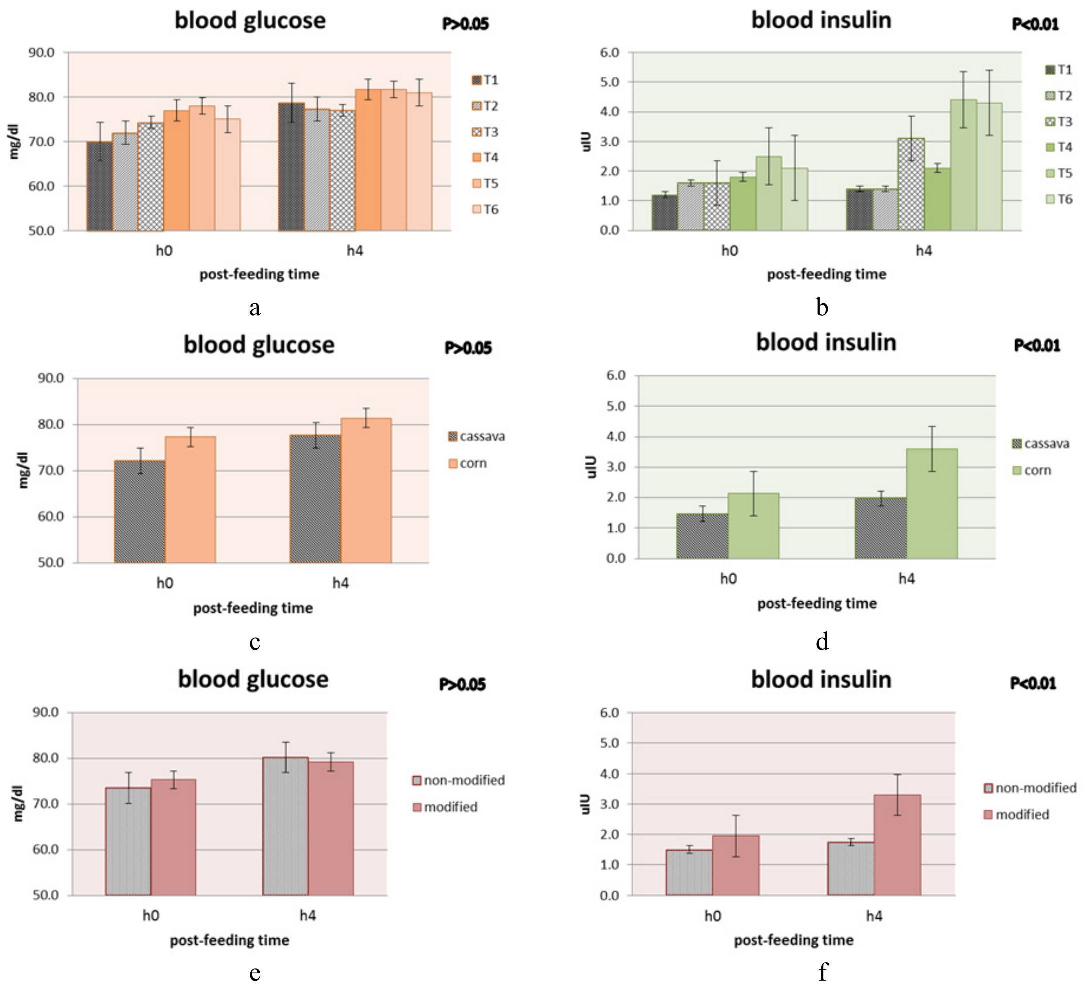

Figure 1 Effects of using modified cassava and corn in diets on blood glucose and insulin in beef bulls. **a)** blood glucose in all treatments, **b)** blood insulin in all treatments, **c)** blood glucose compared between cassava and corn diets, **d)** blood insulin compared between cassava and corn diets, **e)** blood glucose compared between modified and non-modified starch diets, **f)** blood insulin compared between modified and non-modified starch diets

Body weight changes and feed conversion ratio

Animal performances during the experimental period are shown in **Table 5**. Significant differences were shown among treatments ($P < 0.05$). BW gain and ADG were significantly higher in Corn-Alkaline and Corn-Steam diets, and slightly higher in Cass-Steam and Corn-Con diets, compared with Cass-Con and Cass-Alkaline ($P < 0.05$). Moreover, bulls fed diets containing corn-based concentrates had higher BW gain and ADG than those fed cassava-based concentrates ($P < 0.01$). Bulls fed Cass-Steam and Corn-Alkaline diets showed highest BW gain and ADG, with lowest feed concentration ratio (FCR) of cassava-based concentrate and corn-based concentrate, respectively ($P < 0.05$). The FCR exhibited a strong decrease when the bulls received Corn-Alkaline diet and slightly low in Cass Steam, Corn-Steam, and Corn-Con diets compared with Cass-Con and Cass-Alkaline diets ($P < 0.05$). However, there was no significant difference between the efficiency of feed-conversion for body weight gain of non-modified and modified diet animals ($P > 0.05$).

Several previous studies found similar growth performances when comparing corn and cassava as energy sources in diet [44]. Addition of modified cassava chip or corn seed to the diet may decrease the rate of starch fermentation, causing a stable high rumen pH value. Ground corn is a great source of energy due to its high carbohydrate and protein content compared with cassava chip. However, methods used for modifying corn can change ruminal starch availability [45]. When compared with intact corn seed, steam processed corn was more digestible due to changes in the structure of starch granules following exposure to a combination of moisture and heat. As a result, using steamed corn increased starch utilization and released higher energy available for production to the cow [45]. Cereal grain treated with NaOH inclusion in dairy cow diets increased milk production [16] but had no effect on milk yield or milk composition for cows fed NaOH treated barley [46]. Throckmorton and Lengs [8] found that diet supplementation with modified by-pass starch increased live weight gain and directed the energy of starch escaping rumen fermentation directed toward live weight gain rather than milk production.

Table 5 Effects of dietary modified cassava and corn on growth performance.

Items	Treatments						SEM	Contrast			
	T1[1]	T2	T3	T4	T5	T6		T1,2,3: T4,5,6	T1,4:T2, 3,5,6	T2:T3	T5:T6
Initial weight (kg)	278.6	278.8	286.3	274.8	269.6	287.3	-	-	-	-	-
Final weight (kg)	381.0	382.0	412.8	387.5	408.0	410.0	-	-	-	-	-
Weight gain (kg)	102.4^{c}	103.3^{c}	126.5^{ab}	112.8^{bc}	138.3^{a}	123.0^{ab}	6.92	0.01	0.05	0.09	0.02
ADG (kg/day)	1.09^{c}	1.10^{c}	1.35^{ab}	1.20^{bc}	1.47^{a}	1.31^{ab}	0.07	0.01	0.05	0.09	0.02
FCR	7.58^{c}	7.44^{c}	6.35^{ab}	6.85^{b}	5.97^{a}	6.17^{ab}	0.27	0.21	0.61	0.16	0.41

^{abc}Values in the same row with different superscripts differ ($p < 0.05$).
[1] See **Table 1**

Conclusions

The results from the present study are interpreted to suggest that using modified cassava chip and corn seed incorporated in concentrate at 15 % can be used to improve feed utilization, rumen fermentation, body weight gain, and average daily gain of Charolais × Brahman crossbred bulls in developing tropical countries. Furthermore, our results indicate that cassava chip modified by the steam method and corn seed modified by the alkaline method were suitable for increasing bypass energy in early fattening bull diets.

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