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Blood Metabolites, Feed Utilization and Performance in Thai Native X Lowline Angus Crossbred Cattle Fed Cassava Byproducts

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Abstract: The purpose of this study was to assess the effect of dried Cassava top Fermented Cassava pulp (CtFCp) on growth performance, digestibility, ruminal parameters, and blood metabolites in Thai native x low-line Angus crossbred cattle. Twelve females of Thai native x lowline angus crossbred cattle were assigned an Initial Body Weight of 99.50±9.83 kg IBW. Dietary treatments were assigned in a Completely Randomized Design (CRD), with three treatments of four replications, each containing four calves and a 90-day feeding trial. Feeding treatments were (1) 100% concentrate (Control), (2) 100% Concentrate +50% dried Cassava top Fermented Cassava pulp (CtFCp-50), and (3) 100% concentrate + dried Cassava top Fermented Cassava pulp fed freely (CtFCp-*ad libitum*). The variance analysis was used to assess the data and the treatment mean was compared using the Ducan Multiple Ranging Test (DMRT). The results demonstrated that Average Daily Gain (ADG) was significantly increased by groups fed CtFCp-50 and CtFCp-*ad libitum* compared to control ($p<0.05$). The total feed intake between groups was unchanged ($p>0.05$) but %BW ($p<0.001$). In addition, the average feed intake of %BW ($p<0.001$). Feed Conversion Ratio (FCR) revealed that groups CtFCp-50 and CtFCp-*ad libitum* were greater than control ($p<0.01$). Acetic acid (C_2) and propionic acid (C_3) were not affected during the 90-d of each group ($p>0.05$). Meanwhile, the proportion of C_2/C_3 in the groups Control and CtFCp-*ad libitum* was greater than CtFCp-50 at 45 days ($p<0.05$), but at 90 days was not different ($p>0.05$). In conclusion, CtFCp-50 and CtFCp-*ad libitum* are suitable roughage direct supplies for cattle that could improve feed effectiveness, growth performance, and digestibility.

Keywords: Cassava Top, Cassava Pulp, Rumen Fermentation, Growth Performance

Introduction

Ruminant feed production accounts for roughly 70% of the total cost and many animal feed developers have attempted to reduce the minimum concentration used in tropical countries (Gunun *et al*., 2023). By-products such as crop residue, rice straw, cassava tops, and cassava pulp being used as animal feedstuffs could derive plentiful benefits and be cheaper alternatives, making ruminant production sustainable. The yield of cassava roots compared to cassava leaves is 10 tons/ha of Dry Matter (DM) (Morgan and Choct, 2016) and 10.2 tons/ha according to Li *et al*. (2019b). Whereas Crude Protein (CP) contained 16.7-44% in dried cassava leaves (Wanapat, 2003; Oni *et al*., 2014; Oresegun *et al*., 2016; Li *et al*., 2019a; Hawashi *et al*., 2019). According to Oni *et al*. (2014); Li *et al*. (2019a), fermented cassava leaves contained 20.76-21.55% of CP. Cassava roots contained 2.02-2.19% of CP (Fanelli *et al*., 2023). In addition, using cassava tops would improve an energy-dense diet (Thang *et al*., 2010) and enhance the nutritional value of the animal feedstuffs (Morm *et al*., 2023). Faccio-Demarco *et al*. (2019) revealed that various feed additives are being used to increase cattle productivity. Furthermore, yeast-derived products contain 28 g/day of yeast culture plus enzymatically hydrolyzed *Saccharomyces cerevisiae*, suitable for rumen health and animal health maintenance (Faccio-Demarco *et al*., 2019). The cassava leaves contained a high cyanide content and were unsafe for animal consumption without appropriate processing methods (Ayele *et al*., 2022; Boukhers *et al*., 2022). Meanwhile, sun-dried or fermented cassava leaves can reduce toxic contents and improve nutrients (Morgan and Choct, 2016).

Cassava pulp is a by-product that contains approximately 30% cassava root on a dry matter basis (Ghimire *et al*., 2015). Furthermore, it was 15.8-23.4% dry matter basis, 2.2-2.5% CP, 55-74.4% NEF, 17.9-24% CF, and 74.4% total digestible nutrients (Fathima *et al*., 2023). It has an alternative to high starch gain that is an energy source (Lounglawan *et al*., 2011; Norrapoke *et al*., 2018). To promote feedstuff quality, fermented cassava pulp with additives increased nutritive value (Pilajun and Wanapat, 2018). The current study was supported (Morm *et al*., 2023; Inngarm *et al*., 2023), who revealed that cassava pulp-fermented dried cassava top and live yeast increase CP efficiency, increase animal feed production, and reduce feed costs. Moreover, feed intake, reproduction, methane production, and digestibility of nutrients were not affected (Norrapoke *et al*., 2018; Morm *et al*., 2023). Yeasts are a potential part of dissolving oxygen in the rumen; pH was managed, lactic acid bacteria were controlled and the danger of acidosis was reduced (Chaucheyras-Durand *et al*., 2016). Moreover, using cassava pulp was not affected by the heat production of Thai native beef cattle, and it can digest up to 74.4% of nutrients and 12.9 MJ/kg DM of energy digestion while containing 11.3 MJ/kg DM (Keaokliang *et al*., 2018). The lamp was supplied with cassava foliage at 650 g and cassava tubers at 450 g daily, as an individual was a tremendous digestible crude protein intake (Marie-Magdeleine *et al.*, 2010). Moreover, supplied cassava foliage can enhance feed intake and weight gain; meanwhile, 2% of BW is provided in diets without effect on the lambs' health (Hue *et al*., 2012). According to Norrapoke *et al*. (2018) showed that using molasses and urea to treat 4% of the cassava pulp can enhance the feed's nutritional value, increase gas production and improve the dominant cellulolytic bacterial population, (Hawashi *et al*., 2019), whereas using *Saccharomyces cerevisiae* fermented cassava foliage can reduce poison content and can be obtained with an enzyme activity of 0.53 units per gram of dry-based substrate (U/gds). On the other hand, OM and CP of digestibility were increased when yeast-fermented cassava pulp replaced soybean meal in diets (Sommai *et al*., 2020). Cassava pulp-fermented Total Mixed Rations (TMR) increased the nutrient digestibility in lambs (Khejornsart *et al*., 2022), while this has been confirmed previously (Morm *et al*., 2023) and by this current study. In addition, using concentration assists in boosting nutrient digestibility and intake in cattle (Jiang *et al*., 2022). Providing a high-concentrate diet for dairy cows could reduce ruminal ammonia concentration and boost ammonia utilization to synthesize protein in milk (Agle *et al*., 2010). Moreover, concentrate is a potential element for ruminal fermentation and microbial growth, an additional ruminant nutrient (Phesatcha *et al*., 2021a-b), while cassava residue affects production when proportioned in concentrate for Holstein cows (Zheng *et al*., 2021). Nevertheless, 75% of soybean meal replaced yeast waste fermented cassava pulp did not affect gas kinetics or ruminal parameters *in vitro* digestibility (Dagaew *et al*., 2021).

Based on our knowledge, previous studies have yet to extensively demonstrate the directly used CtFCp to understand growth performance, nutrient intake, and digestibility in Thai native x low-line angus crossbreed cattle. Therefore, the main objective was to investigate the effect of dried Cassava top Fermented Cassava pulp (CtFCp) on growth performance, digestibility, ruminal parameters, and blood metabolites in Thai native x low-line angus crossbred cattle.

Materials and Methods

Preparation of Cassava Top Fermented Cassava Pulp

The study was conducted at the experimental field and central laboratory (15°07'55.8"N 104°55'48.2" E) of the faculty of agriculture, Ubon Ratchathani University, Thailand. The fresh cassava top or cassava top combines leaf, petiole, and greening stem approximately 20-30 cm in length from the leaf bud. Cassava tops) *Manihot esculenta* Kasetsart 50 (were collected from local a farmer in ban hare, Tumbon Khamkwang, Warin Chamrap district, Ubon Ratchathani province, Thailand. A magnum electronic monitor in the GS150 model, type mL-90S2-2, with 3HP, matched power, 2800 rpm rotation speed, and production efficiency greater than 1,000 kg/hr, was used to chop fresh cassava top into 2cm-long pieces. The chopped cassava leaves were sun-dried for three days at ambient temperature. Dried cassava tops at 15% were proportioned to 85% of dried cassava pulp on a dry matter basis (CtFCp), fermented for 21 days, and used with a 100 mL plastic tank. The active dried yeast (*Saccharomyces cerevisiae*), CNCM-1077 strain, levucell SC20 (r) SC, 1010 CFU/g, was purchased from local markets in Ubon Ratchathani province, Thailand. Before fermentation, 20 g of *Saccharomyces cerevisiae* was stimulated with an oxygen flush. Solution A added 40 g of sugar with tap water in 660 mL for 30 min. Solution B used 830 mL of tap water mixed well with 50 mL of molasses and 3 g of urea. Mixed A and B for 1 h of flushed air at a 1:1 ratio (v/v) (solution C) (Morm *et al*., 2023). This product is provided to individual cows without mixing feed at 1% BW.

Table 1: Chemical composition of concentrate, CtFCp, and RS (DM basis)

Items	Concentrate	CtFCp	RS
Ingredients (%)			
Cassava pulp	-	76.40	-
Dry cassava top	-	15.00	-
Cassava chip	41.00	-	-
Soybean meal	14.00	-	-
Palm kernel meal	9.00	-	-
Corn meal	13.50	-	-
S. cerevisiae	-	0.20	-
Rice brand	13.00	-	-
Urea	2.00	3.00	-
Molasses	5.00	5.00	-
Sugar	-	0.40	-
Salt	0.50	-	-
Sulfur	1.00	-	-
Monocalcium phosphate	0.50	-	-
Mineral premix	0.50	-	-
Chemical composition (%)			
DM	89.92	38.11	85.42
Ash	5.97	7.20	10.43
OM	94.03	92.79	89.57
CP	15.09	15.01	3.92
NDF	29.50	49.26	72.33
ADF	18.47	37.20	57.77
EE	4.57	1.15	1.40
AIA	2.29	5.50	5.31

Note: CtFCp = Dried Cassava top Fermented Cassava pulp, RS = Rice Straw

Dietary Treatment and Experimental Design

The animal care approved all animal procedures and use for scientific purpose committee, Ubon Ratchathani University, Thailand (34190). Twelve females of Thai native × lowline angus crossbred cattle were assigned a 99.50±9.83 kg Initial Body Weight)IBW(at an average of 12 months of age .Dietary treatments were given in a Completely Randomized Design)CRD .(To receive three feeding treatments were (1) 100% concentrate (control), (2) 100% concentrate +50% dried Cassava top Fermented Cassava pulp (CtFCp-50) and (3) 100% concentrate + dried Cassava top Fermented Cassava pulp fed freely (CtFCp-*ad libitum*) 0.5% of concentrate was given to their treatments. Rice straw was fed *ad libitum* and used as a roughage. The current study was similarly designed for several researchers who used limited ruminants to conduct experiments by fed concentrate-to-forage or by-product ratios, replacement, or supplementation. Jiang *et al*. (2022) conducted an experimental design with eight male cattle yaks, four heads for each treatment to compare different concentrate-to-forage ratios. According to Gunun *et al*. (2023), feeding concentrate was replaced by yeast-fermented cassava peels for 12 goats by designing three groups with four heads in each group. In addition, Thai crossbred Holstein Friesian cows with twelve and three heads represented each group (Polyorach *et al*., 2023). Moreover, eight Thai native steers were fed sugarcane bagasse-treated lactobacillus casei TH14, with four heads in each group (So *et al*., 2022). Table 1 shows ingredients, concentrate, and CtFCp of chemical composition. The CtFCp was mixed well by an SM-3.0CR, 3HP, Hz 50, VOLTS 220, AMP'S 20.0, r/min 1450, and JIS C 4004 JP 22 JC machine, mixed monthly and kept in plastic tanks in 100 L dimensions and placed in the dry zone to use in this study. The concentrate was fed at 0.5% Dry Matter (DM) of Body Weight (BW), CtFCp-50 DM basis, and CtFCp-*ad libitum* DM basis of BW twice daily at 7:00 a.m. and 4:00 p.m. Rice Straw (RS) was fed freely daily, with a 100 g/kg refusal of the total RS offered. RS and feeds were supplied simultaneously, although they were divided into two halves using buckets measuring 40×60 cm, RS feeding stock and 30×40 cm for feeding .The individual pens were assigned for each cow (2.5×4 m) equipped with concrete floor and iron walls. *Ad libitum* of the mineral salt block and clean water were provided to all calves. During the animal adaptation period, cows were given Ivermectin at 1% w/v, 1 mL/50 kg BW, and vitamin AD3E at 1 mL/50 kg BW.

Growth Performance, Feed Intake, Feces, Blood Collection and Measurement

Before the experiment, the cows were pre-adapted in their pens for five days to familiarize them with their living, environmental conditions, feed provider, flavor, and palatability. The experiment lasted 90 days, with the test feeding regimen for 85 days and sample collection in the last five days. At the beginning of the investigation, calves were weighed to adjust feeding diets in Dry Matter Intake (DMI) and were weighed every 14 days. Before supplying new feed, daily notes were collected to track the amount of feed consumed and refusal of feed. The Average Daily Gain (ADG) was calculated using the IBW and Final Weight (FW). The Feed Conversion Ratio (FCR) was computed as total DMI proportioned by total WB gain through the trial.

Sample Collection and Measurement

Feed offered and refused, including RS, concentrate and CtFCp were recorded daily, while each sample was taken weekly and used in a hot air oven at 70°C to dry the collected samples. The dried form was kept for chemical analysis. During the last five days, 7:00 a.m. feces were collected from the individual rectum before being supplied feed .The feces were mixed and kept at -20°C until they were analyzed for chemical composition. The frozen feces samples were defrosted and dried in a hot air oven for 72 h at 60°C to ascertain their chemical composition. A 0.5 mm screen Tecator, Hoganas, Sweden (was used to ground all samples and analyzed DM, ash, and Crude Protein (CP) (AOAC, 1990).

According to Van Soest *et al*. (1991), Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF). Acid-Insoluble Ash (AIA) is an indicator used to estimate digestibility (Van Keulen and Young, 1977). During day 45 and 90 of the collection period, at 4 h post-feeding, rumen fluid and blood samples were collected. A stomach tube inserted through the esophagus was used to collect approximately 200 mL of rumen fluid from each calf. The tube (inside diameter 0.8 cm, outside diameter 1-400 cm length) was connected to a vacuum pump from different sites of the rumen. A large quantity of rumen fluid can be collected when the tube is employed. The Omron flextime digital clinical thermometer measured rumen temperature, Blue/White (101302), Netherlands, and pH (Hanna Instruments HI 8424 microcomputer, Singapore).

A four-layer cheesecloth was used to filter rumen fluid; 1 M of sulfuric acid) H_2SO_4 (was used at a 1:9 ratio and kept at 20°C until chemically analyzed .The rumen fluid was centrifuged at 3,500× rpm for 15 min; the supernatant was used to analyze Volatile Fatty Acid (VFA 0.45 μm millipore filter was used to filter the supernatant before injecting it into the chromatographic apparatus. H_2SO_4) 0.005 mol/L (was used as the mobile phase in VFA analyses using a Dionex UHPLC Thermo scientific UltiMate 3000 linked to a C18) 4.6×250 mm (column) Choromeleon Dionex Corp) with UV-Vis detection at 210 nm according to (Coutinho *et al*., 2011) Moss *et al*. (2000) used VFA as an indicator to estimate Methane (CH_4). 10% of formalin was used in 9 and 1 mL of rumen fluid (1:9 v/v ratio) and stored in a refrigerator to count the protozoal and fungal zoospore numbers using a hemocytometer under a microscope (Galyean, 1989).

The blood was taken from the jugular vein for 10 mL of total; 4 mL was placed in a test tube containing sodium fluoride or EDTA for glucose analysis and each 4 mL was stored in a test tube containing a serum clot activator tube for Blood Urea Nitrogen (BUN), creatinine, total protein and triglyceride analysis and sent to the U wellness center co. Ltd., Thailand. BUN uses the urase method, creatinine uses the IDMS traceable method, glucose (plasma) uses the glucose oxidase method, total protein (serum) uses the biuret lithium method and triglyceride uses the glycerophosphate O method (Ruiz-Gutiérrez and Barron 1995; Küme *et al*., 2018; Zhang *et al*., 2022). According to Robinson *et al*. (2004), the metabolizable energy was calculated using an equation. Li *et al*. (2019a-b) described the Digestibility of Organic Matter in Rumen (DOMR) using an equation for calculation as follows: DOMR (kg/d) = Intake of Digestible Organic Matter (IDOM), (kg/d) ×0.65, where IDOM = [digestibility of organic matter (kg/kg DM) × intake of organic matter (kg/d)]/100, 1 kg IDOM = 15.9 MJ, ME/kg. Microbial crude protein (MCP), (kg/d = 0.00825× ME intake) MJ/d (Galyean, 1989).

Statical Analysis

All results were analyzed using a one-way ANOVA in a Completely Randomized Design (CRD) in the Statistical Package for the Social Science (SPSS, version 21, Chicago, USA). The UNIVRUATE was tested for normal distribution. Trends or tendencies were considered significant at $0.05<p<0.10$, while the effects were considered significant at $p<0.05$. The Ducan Multiple Ranging Test (DMRT) was compared to the dietary mean. The standard error of the mean (mean ± SEM) was described.

Results

Animal Growth Performance Characteristics, Energy Estimated, and the Microbial Protein of Thai Native X Lowline Angus Crossbred Cattle

The growth performance characteristics of Thai native x lowline Angus crossbred cattle fed on dietary treatments with Control, CtFCp-50, and CtFCp-*ad libitum* are elucidated in Table 2. The Initial Body Weight (IBW) and Final Body Weight (FBW) showed no difference between groups ($p>0.05$). Meanwhile, Average Daily Gain (ADG) was affected in the groups ($p<0.05$); control was 288.24 g, CtFCp-50 and CtFCp-*ad libitum* 368.83 and 370.59 g and representative superscripts were in the same row. Control had a higher intake compared to CtFCp-50 and CtFCp-*ad libitum*.

In contrast, Microbial Protein (MCP) was not affected while supplementing CtFCp with limited and *ad libitum* Control ($p>0.05$).

Intake of Dry Matter, Nutrients, and Digestibility in Thai Native X Lowline Angus Crossbred Cattle

Table 2 displays the total intake in kg between the groups' Control, CtFCp-50 and CtFCp-*ad libitum* were not different ($p>0.05$). Whereas total intake in g/kg BW was greater ($p<0.001$), group CtFCp-*ad libitum* used a more considerable feed amount than group Control and CtFCp-50. So far, the Feed Conversion Ratio (FCR) has been noted ($p<0.01$). The group control consumed an 8.68 ratio, but CtFCp-*ad libitum* and CtFCp-50 were non-different ratios, 6.09 and 7.07, and representative superscripts were in the same row. Table 3, The nutrient intake of CP was greatly affected between groups ($p<0.05$); groups CtFCp-50 and CtFCp-*ad libitum* were non-significant but had a larger intake than Control, while DM, NDF, ADF, and EE were negatively affected between groups. Nutrient digestibility revealed that CP in the group control was better digested ($p<0.01$) and there was a non-significant difference between the groups CtFCp-50 and CtFCp-*ad libitum*. NDF in the group's Control was better digested than CtFCp-50 and CtFCp-*ad libitum* ($p<0.001$). The percentage of ADF digestibility ($p>0.05$), Table 3, respectively.

Table 2: Growth performance and feed utilization in Thai native × low-line Angus crossbred cattle supplemented cassava pulp

Variable	Treatments			Standards	p-value
	Control	CtFCp-50	CtFCp-*ad libitum*		
Initial weight, kg	103.00	99.00	99.75	2.800	0.850
Final weight, kg	127.50	130.33	131.25	3.390	0.900
Average daily gain, g	288.24[b]	368.83[a]	370.59[a]	15.900	0.020
Feed conversion ratio					
FCR	8.68[a]	6.09[b]	7.07[b]	0.380	0.003
Total intake					
kg/d	2.49	2.24	2.60	0.070	0.150
%BW	2.16[a]	1.96[b]	2.26[a]	0.040	0.001
g/kg $BW^{0.75}$	76.89[b]	71.56[c]	82.44[a]	1.480	<0.001
Dry matter intake					
Concentrate					
kg/d	0.61	0.60	0.60	0.020	0.970
%BW	0.53	0.52	0.52	0.002	0.140
g/kg $BW^{0.75}$	18.78	19.07	19.01	0.150	0.760
Dry cassava top fermented cassava pulp					
kg/d	-	0.57[b]	0.78[a]	0.200	0.010
%BW	-	0.31[b]	0.45[a]	0.150	0.004
g/kg $BW^{0.75}$	-	9.73[b]	14.32[a]	4.590	0.006
Rice straw					
kg/d	1.88[a]	1.07[b]	1.19[b]	0.120	<0.001
%BW	1.63[a]	0.94[b]	1.03[b]	0.100	<0.001
g/kg $BW^{0.75}$	58.10[a]	34.27[c]	37.63[b]	3.390	<0.001
Average intake					
kg/d	2.45	2.11	2.56	0.070	0.150
%BW	2.12[a]	1.93[b]	2.22[a]	0.040	0.001
g/kg $BW^{0.75}$	75.68[b]	68.84[c]	81.25[a]	1.480	<0.001
Estimate energy intake					
Mcal g/d)	1.62	1.65	1.69	0.010	0.080
Estimate microbe					
MCP, kg/d	0.55	0.57	0.59	0.010	0.060

Note: 100% concentrate (Control); 100% concentrate +50% dried cassava top fermented cassava pulp (CtFCp-50); 100% concentrate + dried cassava top fermented cassava pulp fed *ad libitum* (CtFCp-*ad libitum*); [a-c]Values with different superscripts on the same row (p<0.05)

Table 3: The effect of concentrates replacing dried cassava tops and fermented cassava pulp on intake of nutrients and digestibility Thai native × low-line angus crossbred cattle

Variable	Treatments			Standards	p-value
	Control	CtFCp-33	CtFCp-67		
Nutrient intake, kg/h/d					
Dry matter	4.82[a]	3.60[ab]	2.73[b]	0.33	0.020
Organic matter	4.96	4.48	3.63	0.27	0.110
Crude protein	0.46[a]	0.40[ab]	0.30[b]	0.07	0.040
Ether extract	0.15[a]	0.10[ab]	0.08[b]	0.01	0.004
Neutral detergent fiber	3.71[a]	2.92[ab]	2.34[b]	0.23	0.030
Acid detergent fiber	2.34[a]	1.89[ab]	1.59[b]	0.13	0.040
Nutrient digestibility, %					
Dry matter	59.64[a]	49.54[b]	49.43[b]	1.59	<0.001
Organic matter	65.63	65.15	65.18	0.37	0.570
Crude protein	75.08[a]	58.91[b]	56.49[b]	2.60	<0.001
Ether extract	86.58[a]	76.50[b]	73.04[c]	1.78	<0.001
Neutral detergent fiber	62.88[a]	61.43[a]	58.70[b]	0.66	0.010
Acid detergent fiber	39.63	37.79	38.01	0.80	0.640
Total digestible nutrients	69.17[a]	66.14[ab]	66.01[b]	0.48	<0.001

Note: 100% concentrate (control); 100% concentrate +50% dried cassava top fermented cassava pulp (CtFCp-50); 100% concentrate + dried Cassava top Fermented Cassava pulp fed *ad libitum* (CtFCp-*ad libitum*); [a-c]values with different superscripts on the same row (p<0.05)

Table 4: Effect of dried cassava top fermented cassava pulp on rectum temperature and blood metabolites in Thai native × low-line angus crossbred cattle

	Treatments				
Variable	Control	CtFCp-50	CtFCp-*ad libitum*	Standards	p-value
Rectum temperature, °C					
45-d: 4 h post-feeding	39.07[b]	39.32[a]	39.25[a]	0.05	0.030
90-d: 4 h post-feeding	38.80[b]	39.15[a]	39.02[ab]	0.06	0.040
Protozoa, log cell/mL					
45-d: 4 h post-feeding	4.03	4.05	4.14	0.08	0.860
90-d: 4 h post-feeding	4.75	4.6	4.73	0.04	0.210
Fungi, log cell/mL					
45-d: 4 h post-feeding	3.71	3.63	3.74	0.05	0.730
90-d: 4 h post-feeding	4.70	4.48	4.78	0.06	0.100
Rumen, pH					
45-d: 4 h post-feeding	6.59	6.66	6.70	0.04	0.510
90-d: 4 h post-feeding	6.64[a]	6.17[b]	6.55[a]	6.28	0.010
Glucose, mg/dL					
45-d: 4 h post-feeding	68.75	68.50	75.50	2.14	0.350
90-d: 4 h post-feeding	75.00	77.25	82.00	2.04	0.400
BUN, mg/dL					
45-d: 4 h post-feeding	14.50	15.75	13.50	0.63	0.380
90-d: 4 h post-feeding	13.25	14.50	13.75	0.46	0.600
Creatinine, mg/dL					
45-d: 4h post-feeding	1.27	1.34	1.17	0.04	0.230
90-d: 4h post-feeding	1.40	1.24	1.30	0.04	0.250
Triglyceride, mg/dL					
45-d: 4 h post-feeding	42.50	39.50	40.75	4.08	0.140
90-d: 4 h post-feeding	56.25	38.75	30.00	4.97	0.070
Total protein-serum, g/dL					
45-d: 4 h post-feeding	6.57	6.17	6.05	0.12	0.210
90-d: 4 h post-feeding	6.20	5.82	5.70	0.10	0.090

Note: 100% concentrate (Control); 100% concentrate +50% dried Cassava top Fermented Cassava pulp (CtFCp-50); 100% concentrate + dried Cassava top Fermented Cassava pulp fed *ad libitum* (CtFCp-*ad libitum*); [a-c]values with different superscripts on the same row ($p<0.05$), mg/dL, milligram/deciliter, g/dL, gram/deciliter, BUN, blood urea nitrogen

Table 5: Effects of dried cassava tops fermented cassava pulp in ruminal fermentation and volatile fatty acid in Thai native × low line angus crossbred cattle

	Treatments				
Variable	Control	CtFCp-50	CtFCp-*ad libitum*	Standards	p-value
Total volatile fatty acid (TVFA), mmol/L					
45-d: 4 h post-feeding	91.45	90.25	91.37	1.10	0.900
90-d: 4 h post-feeding	111.94	116.37	113.85	1.50	0.550
Volatile fatty acid profiles, mmol/100 moL					
Acetic acid (C_2)					
45-d: 4 h post-feeding	76.18[a]	73.00[b]	76.49[a]	0.56	0.003
90-d: 4 h post-feeding	81.12	80.49	81.01	0.21	0.490
Propionic acid (C_3)					
45-d: 4 h post-feeding	23.82	25.18	24.76	0.28	0.110
90-d: 4 h post-feeding	18.88	19.5	18.99	0.21	0.490
Butyric acid (C_4)					
45-d: 4 h post-feeding	7.47	7.47	6.80	0.32	0.660
90-d: 4 h post-feeding	4.56	4.46	4.36	0.31	0.100
Acetic: Propionic acid ratio (C_2: C_3)					
45-d: 4 h post-feeding	3.20[a]	2.90[b]	3.09[ab]	0.05	0.049
90-d: 4 h post-feeding	4.31	4.13	4.27	0.06	0.500
Estimated methane (CH_4), g/d					
45-d: 4 h post-feeding	30.72[a]	28.91[b]	30.33[a]	0.05	0.010
90-d: 4 h post-feeding	33.14	32.64	32.98	0.07	0.510

Note: 100% concentrate (Control); 100% concentrate +50% dried Cassava top Fermented Cassava pulp (CtFCp-50); 100% concentrate + dried Cassava top Fermented Cassava pulp fed *ad libitum* (CtFCp-*ad libitum*); [a-c]values with different superscripts on the same row ($p<0.05$)

The Blood Metabolites Temperature Variable and Rumen pH

Table 4 demonstrates rectum temperatures at both 45-d and 90-d and found that the CtFCp-50 and CtFCp-*ad libitum*, superscript was in the same row and was higher than the group Control at 4 h post-feeding ($p<0.05$). Separately, rumen pH, glucose, BUN, creatinine, triglyceride, and total protein were not affected in groups administered Control, CtFCp-50, and CtFCp-*ad libitum*, both collected 45-d and 90-d at 4 h post-feeding ($p>0.05$). The blood metabolism, such as glucose (plasma) and triglyceride, are in the standard administered 74-110 mg/dL, lower than 150 mg/dL.

Volatile Fatty Acid (VFA), Supplemented with CtFCp-50 and CtFCp-Ad Libitum to Concentrate

As revealed in Table 5, the compounds specified are propionic acid (C_3), acetic acid (C_2), and Total Volatile Fatty Acids (TVFA). At 45-d and 90-d at 4 h post-feeding fluid collection, the average TVFA, varied from 91.45- 90.25 and 91.37 mmol/L between the groups ($p>0.90$) at 4 h post-feeding on 45 d of fluid collection. So far, there was no difference between administered groups, while fluid collection at 90-d at 4 h post-feeding varied from 111.94, 116.37, and 113.85 mmol/L of TVFA ($p>0.55$). In addition, C_2 and C_3 were not affected at 90-d at 4 h post-feeding between groups administered Control, CtFCp-50 and CtFCp-*ad libitum* ($p>0.05$) but C_2 at 45 d ($p<0.01$). However, the 45-d fluid collection was affected; Control and CtFCp- *ad libitum* were higher than CtFCp-50. Nevertheless, the C_2:C_3 ratio significantly differed in the 45-d fluid collection ($p<0.05$). The group using Control and CtFCp-*ad libitum* was the best, but CtFCp-50 and CtFCp-*ad libitum* had the same outputs and the superscript was in the same row, while the 90-d measurement was not strongly effected ($p>0.50$).

Discussion

Chemical Composition and Feed Ingredients

Due to its factor sources, such as carbohydrate, Non-Protein Nitrate (NPN), urea supplementation and their amounts, incubation times, technical procedures, climatic circumstances and the type of yeast, the CtFCp produced by live yeast might vary (Sommai *et al*., 2020). In contrast to (Sommai *et al*., 2020), this study found that the CP in fermented cassava pulp was similar (Gunun *et al*., 2018). Prior studies support each other concerning CP in concentrated and fermented cassava pulp (Sommai *et al*., 2020). Separately, the current study of Rice Straw (RS) containing CP was varied and found it was better than the previous study (Khejornsart *et al*., 2022; Gunun *et al*., 2018; Dagaew *et al*., 2023), but it was similar to (Sommai *et al*., 2020).

Animal Growth Performance Characteristics, Energy Estimation, and Microbial Protein of Thai Native X Lowline Angus Crossbred Cattle

This current study revealed that CtFCp-50 and CtFCp-*ad libitum* of ADG agreed with (Brown *et al*., 2006) and was greater than (So *et al*., 2022) but unsupported by Gunun *et al*. (2018). The current study results were greater than some previous studies, which could be due to different growing stages of calves, environmental conditions being more suitable, or probably only one feeder feeding experimental calves, which had no fear of calves during feeding. In addition, according to (Desnoyers *et al*., 2008; Jiang *et al*., 2022), dry matter intake was greater than the current study, which found between 2.24-2.60 kg/day. Furthermore, CtFCp-50 and CtFCp-*ad libitum* in the ruminant diet effectively consumed energy intake and growth performance. According to (Gunun *et al*., 2023), 50% of the concentrate was substituted for yeast-fermented cassava peel without affecting ADG. Furthermore, Dagaew *et al*. (2023) feed cassava pulp with yeast waste in a concentrated ratio of (50:50 w/w), which enhances the digestibility of Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) and positive feed intake. However, this was unsupported by Keaokliang *et al*. (2018), with a high concentration and low cassava pulp supply in the diet. According to Khejornsart *et al*. (2022), the utilization of nutrients, rumen ecology, and protein synthesis of micro were increased in tropical sheep while cassava pulp was added to fermented mixed ratios in the diet. Meanwhile, to enable the fibrinolytic enzymes that yeast may release to break down the fiber content of cassava pulp, the CtFCp comprised yeast cells and urea. Utilizing CtFCp with a high urea concentration is also an additional way to enhance feed digestion. The hemicellulose-lignin complex in cassava pulp expands because of the alkaline agents produced by urea during the fermentation stage of CtFCp (Jing *et al*., 2022). The current study estimated energy and found that Metabolizable Energy (ME) in the diet groups was 1.62 Mcal g/d in Control, 1.69 Mcal g/d in CtFCp-50, and 1.69 Mcal g/d in CtFCp-*ad libitum*. These findings were fewer than those of the NRC (2000), which recommended 7.06 Mcal g/d for the maintenance animal with 240 kg of live weight.

Intake of Dry Matter, Nutrients, and Digestibility of Nutrients

The current study, supported by Jiang *et al*. (2022), used concentrate-to-forage ratios in cattle yaks and found that 70% of concentrate-to-forage ratios increased intake of dry matter and digestibility of nutrients. In contrast, Dagaew *et al*. (2023) treated fermented cassava pulp with yeast waste in concentrate ratios, 50:50 increased appearance digestibility of neutral detergent fiber and acid detergent fiber. The different levels of dry matter and nutrient intake, probably the amount of feed provided to individual calves, were at different rates, or the calves' physical growth stages were different. According to Gunun *et al*. (2023), feeding concentrate was replaced by yeast-fermented cassava peels replace more than 50% of concentrate with cassava peel fermented by yeast, and cassava peel fermented by effective microorganisms was not affected by feed intake, feed digestibility, or rumen fermentation. Still, feedstuff costs can decrease by up to 32% per gain. Results found by Hue *et al.* (2012); Sommai *et al*., (2020); Norrapoke *et al*. (2022); Gunun *et al*. (2023), which used fermented cassava pulp additives with different levels of substitutes or supplements in concentrate were greater in dry matter feed intake and nutrient intake than in the current study. Moreover, cassava pulp fermentation has not revealed any reduction in the feed intake of beef cattle (Norrapoke *et al*., 2022) and was supported by the current outcomes. CtFCp-50 and CtFCp-*ad libitum* products have a high nutritional content intake, especially Crude Protein (CP), animal hosts, and rumen microscopes may be needed. The increasing nutrient intake could be influenced by the yeast (*Saccharomyces cerevisiae)* and urea level of 3.0 kg used, which indicated a greater concentration of nitrogen in the CtFCp. Thus, yeast *(Saccharomyces cerevisiae)* may replicate during fermentation as single-cell Proteins that improve CP (Gunun *et al*., 2018). Activating polysaccharides and glycosidase hydrolase enzymes in yeast can improve ruminal fermentation efficiency, and average daily gain, increase the population of bacteria, and fungi zoospores, and decrease the protozoal population in native crossbred cattle (Chuelong *et al*., 2011) .Therefore, urea in the solution might cause a breakdown of the fiber structure in cassava pulp and acts as an alkaline substance of ammonium hydroxide (Suriyapha *et al*., 2021) .The fraction of NDF and ADF were less digestible, maybe due to the tendency of a minimal ruminal pH to greater qualities of soluble carbohydrates. The recent results on the nutrient digestibility of Dry Matter (DM), Crude Protein (CP), Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF) are much more digested than previous findings (Khejornsart *et al*., 2022; Dagaew *et al*., 2022; Norrapoke *et al*., 2022), but less than (Sommai *et al*., 2020), which substituted soybean meal with yeast-fermented cassava pulp and (Keaokliang *et al*., 2018), which used a cassava diet in cattle. Fibrolytic enzymes that yeast may release break down the fiber content of cassava pulp, which comprises yeast cells and urea. Utilizing CtFCp with a high urea concentration is also an additional way to enhance feed digestion. According to Khejornsart *et al*. (2022), the nutrient digestibility of DM, OM, CP, NDAF, and ADF increased while a mixed ratio of cassava pulp fermented, as supported by Morm *et al*. (2023).

The Blood Metabolism, Temperature Variables, Rumen pH and Microbial Population

Currently, the results of rectum temperature in 45-d and 90-d post-feeding were confirmed by Morm *et al.* (2023), by substituting dry Cassava pulp Fermented (CtFCp) into concentrate. On the other hand, protozoal population, fungus, and Blood Urea Nitrogen (BUN) were unaffected and confirmed by Sommai *et al*. (2020); Jiang *et al*. (2022); Dagaew *et al*. (2022), which used fermented cassava pulp substituted or supplemented in concentrate but (Morm *et al*., 2023), dissented and replaced fermented cassava pulp in concentrate. Additionally, Blood Urea Nitrogen (BUN) represents the amount of CP consumed through the diet, the ratio of CP to rumen fermentable OM, and the amount of protein present in the rumen; a higher dietary protein consumption results in a higher BUN concentration (Hammond, 1997). Thus, higher BUN in the CtFCp-50 and control groups was related to more CP intake from this diet in Table 3. The rumen pH was not influenced by using CtFCp in animal diets and was reported to rank 6.17-6.70 (Hung *et al*., 2013). Rumen pH was not affected and it could be that since the CtFCp production process uses yeast (*Saccharomyces cerevisiae*), it produces high live yeast content. Used CtFCp-50 and CtFCp-*ad libitum* may also have no bearing on rumen pH. The correlation between lactate-Using bacteria (LUB) and yeast is crucial to maintaining a rumen-healthy environment. Nevertheless, a high level of LUB can prevent a lactate-producing bacterium from functioning, regulate the rumen's pH, and prevent lactic acid from accumulating (Amin and Mao, 2021). Moreover, using 100% cassava pulp fermented yeast waste in concentrate can sustain the rumen pH in Thai native cattle (Dagaew *et al*., 2022).

The TVFA profile did not change when used CtFCp supplemented concentrate at any level and this has been confirmed (Cherdthong *et al*., 2018; Khejornsart *et al*., 2022; Dagaew *et al*., 2023). The recent results revealed that the VFA rumen concentration in control, CtFCp-50 and CtFCp-*ad libitum* were 111.94, 116.37 and 113.85 mmol/L and were closed results (Sommai *et al*., 2020; Khejornsart *et al*., 2022; Gunun *et al*., 2023), but some disagreed (Gunun *et al*., 2018; Dagaew *et al*., 2022) and reported between 64.36-68.00 mmol/L and (Norrapoke *et al*., 2022) found 123.6-127.7 mmol/L. The current studies have shown that C_2 and C_3 were unaffected by use at all levels of CtFCp; it has high fiber content levels and a low fermentation fraction that leads to low substrate supply to generate C_2 and C_3 in the rumen. Meanwhile, C_3 is an activity of rumen microorganism fermentation; a small amount of rumen microorganism can impact C_3 (Gunun *et al*., 2018). In addition, the current outcomes found that the protozoal population had not changed; protozoa are typically absent from the rumen due to the large quantity of grain in the diet. Moreover, the methane estimated (CH_4) in the current study was not effected and was supported by Cherdthong *et al*. (2018);

Khejornsart *et al*. (2022). Protozoa effectively compete with bacteria and make up a significant component of the rumen's microbial biomass because the pH of the rumen is high and there is a readily available glucose source in the meal (Gunun *et al*., 2018). The ruminal pH usually causes a marked reduction while providing concentration up to 60% in the ruminant diet (Abe *et al*., 1973; Wedekind *et al*., 1986). Protozoal concentrations generally decrease due to a decrease in ruminal pH (Abe *et al*., 1973). This possible cause would be the effect of high-concentrate diets' passage rate. Meanwhile, the protozoal population in the current study among diet groups were 4.75, 4.60, and 4.74 log cells/mL. In addition, triglycerides are stored in the lipids in the blood, and calories from any feed move into the triglycerides and are stored as energy. Afterward, hormones release triglycerides for energy between meals. Whereas creatinine in Control, CtFCp-50, and CtFCp-*ad libitum* were 1.27, 1.34, and 1.17 mg/dL higher than standard (1.04 mg/dL for females), so all animals faced kidney disease, but glucose was normal (Stringer *et al*., 2015).

Conclusion

The diet groups of the CtFCp-50 or CtFCp-*ad libitum* were unaffected in blood metabolites, rumen fermentation, digestibility, protozoal population, and improved growth performance. In conclusion, CtFCp-50 and CtFCp-*ad libitum* are suitable roughage direct supplies for cattle that could improve feed effectiveness, growth performance, and digestibility in Thai native × Lowline Angus crossbred cattle. Thus, CtFCp-50 or CtFCp-*ad libitum* are recommended for cattle feedstuffs.

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Author’s Contributions

Sophany Morm: Participated in all experiments, conducted, sampled, statical analysis, and drafted manuscript.

Areerat Lunpha: Experimental designed and coordinated the data-analysis and contributed to the wrote of the manuscript.

Ruangyote Pillajun and Anusorn Cherdthong: Manuscript edited and finalized.

Ethics

This article is unique and hasn't been released anywhere else. All authors have read and approved the work, according to the corresponding author. Ubon Ratchathani University's animal care committee, Thailand (34190), has approved all animal treatments.

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