EFFECTS OF CASSAVA TOP FERMENTED CASSAVA PULP ON NUTRIENT UTILIZATION AND GROWTH PERFORMANCE OF THAI NATIVE CATTLE

SOPHANY MORM

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY MAJOR IN AGRICULTURE FACULTY OF AGRICULTURE UBON RATCHATHANI UNIVERSITY

ACADEMIC YEAR 2023

UBON RATCHATHANI UNIVERSITY

THESIS APPROVAL

DOCTOR OF PHILOSOPHY

IN AGRICULTURE FACULTY OF AGRICULTURE

TITLE EFFECTS OF CASSAVA TOP FERMENTED CASSAVA PULP ON NUTRIENT UTILIZATION AND GROWTH PERFORMANCE OF THAI NATIVE CATTLE

AUTHOR MR. SOPHANY MORM

EXAMINATION COMMITTEE

ASSOC. PROF. DR. PRAMOTE PAENGKOUM	CHAIRPERSON
ASST. PROF. DR. AREERAT LUNPHA	MEMBER
ASSOC. PROF. DR. RUANGYOTE PILAJUN	MEMBER
ASSOC. PROF. DR. ANUSORN CHERDTHONG	MEMBER
ASST. PROF. DR. SURACHAI SUWANLEE	MEMBER
DR. CHAWALIT SIRIBOON	MEMBER
DR. CHITTRAPORN YEANPET	MEMBER

ADVISORS

..... ADVISOR

(ASST. PROF. DR. AREERAT LUNPHA)

..... CO-ADVISOR

(ASSOC. PROF. DR. RUANGYOTE PILAJUN)

..... CO-ADVISOR

(ASSOC. PROF. DR. ANUSORN CHERDTHONG)

.....

(DR. NARINTORN BOONBRAHM)

DEAN, FACULTY OF AGRICULTURE

.....

(ASST. PROF. DR. CHARUWAN THANAWIROON)

VICE PRESIDENT FOR ACADEMIC AFFAIRS

ACADEMIC YEAR 2023

ACKNOWLEDGMENT

First and foremost, I would like to express my special appreciation, gratitude, and thanks to my advisor, Assist. Prof. Dr. Areerat Lunpha has tremendously mentored me with her patience and knowledge. I attribute the level of my Ph.D. degree to her encouragement and effort; with her, this thesis was completed and written. I would like to thank you for encouraging my research and for allowing me to grow as a research scientist.

I would like to thank all my committee members for serving as my committee members even in hardship. I appreciate them for making my defense be enjoyable and for their brilliant comments and suggestions. Special heartfelt thanks to Assoc. Prof. Dr. Ruangyote Pilajun and Assoc. Prof. Dr. Anusorn Cherdthong, my co-advisor, for their advice, encouragement, and friendship during my study. They acknowledged me for their words of wisdom and encouragement for this important step of my life. I thanks His Excellency Sok Khorn, a rector at the National University of Battambang (NUBB), who appreciates support during my PhD study. I also sincerely thank Dr. Srean Pao, dean of the Faculty of Agriculture and Food Processing, NUBB, Cambodia, for his encouragement to keep progressing to the PhD life. I thank the Higher Education Improvement Project (HEIP) of the Ministry of Education, Youth, and Sport, Cambodia for the financial support of this research. Also, thanks to the Office of Experimental Field and Nutrition Lab, Faculty of Agriculture, Ubon Ratchathani University, for providing the best facilitation.

I gratitude to the Cambodian team; M.Sc. and Ph.D. students under the HEIP, and Thai friends who have readily contributed their helpful hands and support throughout my study. The support and inspiration of my parents (parents and parents-in-law), sister, brothers, and other relatives have been essential in reaching this and other life goals. My deepest appreciation and gratitude are extended to my beloved wife, Mrs. Sokuntheavy Song, who is strongly supported. My study was only completed with her patience, understanding, and encouragement.

Sophany Morm

Researcher

บทคัดย่อ

ชื่อเรื่อง	:	ผลของยอดมันสำปะหลังในกากมันสำปะหลังหมักต่อการใช้ประโยชน์ได้ของโภชนะ และสมรรถนะการเจริญเติบโตของโคพื้นเมืองไทย
ผู้แต่ง	:	SOPHANY MORM
ชื่อปริญญา	:	ปรัชญาดุษฎีบัณฑิต
สาขาวิชา	:	เกษตรศาสตร์
ที่ปรึกษาหลัก	:	ผู้ช่วยศาสตราจารย์ ดร.อารีรัตน์ ลุนผา
ที่ปรึกษาร่วม	:	รองศาสตราจารย์ ดร.เรืองยศ พิลาจันทร์
	:	รองศาสตราจารย์ ดร.อนุสรณ์ เชิดทอง
คำสำคัญ	:	ยอดมันสำปะหลัง, กากมันสำปะหลัง, การย่อยได้, กระบวนการหมักในกระเพาะรูเมน, สมรรถนะการเจริญเติบโต

งานวิจัยครั้งนี้ประกอบด้วย 3 การทดลอง เพื่อประเมินประสิทธิภาพการใช้ประโยชน์ของโภชนะในยอดและกากมันสำปะหลังในหลอดทดลองและในตัวสัตว์ การทดลองที่ 1 เป็นการศึกษาผลของระดับยอดมันสำประหลังแห้งและยอดมันสำปะหลังสดในการหมักร่วมกับกากมันสำปะหลังที่ระดับต่างๆ ต่อคุณค่าทางโภชนะ จลนพลศาสตร์ของแก๊ส ลักษณะในกระเพาะรูเมน และความสามารถในการย่อยสลายในหลอดทดลอง วางแผนการทดลองแบบสุ่มอย่างสมบูรณ์ (CRD) ประกอบด้วยอาหารทดลองจำนวน 8 สูตร และมีจำนวน 3 ซ้ำ อาหารทดลอง ได้แก่ 1) กากมันสำปะหลังหมักโดยไม่มีการเติมสารเสริม (nA) 2) กากมันสำปะหลังหมักร่วมกับสารเสริม (CSA) 3) CSA 95% หมักร่วมกับยอดมันสำปะหลังแห้ง 5% (5DCT) 4) CSA 90% หมักร่วมกับยอดมันสำปะหลังแห้ง 10% (10DCT) 5) CSA 85% หมักร่วมกับยอดมันสำปะหลังแห้ง 15% (15DCT) 6) CSA 95% หมักร่วมกับยอดมันสำปะหลังสด 5% (5FCT) 7) CSA 90% หมักร่วมกับยอดมันสำปะหลังสด 10% (10FCT) 8) CSA 85% หมักร่วมกับยอดมันสำปะหลังสด 15% (15FCT) ผลการทดลองพบว่ากากมันสำปะหลังหมักร่วมกับยอดมันสำปะหลังแห้งที่ระดับ 5-10 % มีปริมาณโปรตีนหยาบสูงที่สุดเมื่อเปรียบเทียบกับกากมันสำปะหลังหมักที่ไม่มีการเติมสารเสริม (กลุ่มควบคุม) ($P<0.05$) การย่อยสลายได้ของวัตถุแห้งในหลอดทดลองของกากมันสำปะหลังหมักร่วมกับยอดมันสำปะหลังแห้งที่ 5-10% มีการย่อยสลายได้สูงกว่ากลุ่มควบคุม ($P<0.01$) ในขณะที่กากมันสำปะหลังหมักร่วมกับยอดมันสำปะหลังสดมีการย่อยสลายได้ของวัตถุแห้งต่ำกว่ากลุ่มควบคุม ($P<0.01$) ศักยภาพของการผลิตแก๊ส (p) และผลผลิตแก๊สจากส่วนที่หมักย่อยได้จากเศษส่วนที่ไม่ละลายน้ำ (b) ไม่มีความแตกต่างกันในอาหารทดลองทุกสูตร ($P>0.05$) อย่างไรก็ตาม ปริมาณผลผลิตแก๊สจากส่วนที่ละลายได้ทันที (a) มีค่าสูงสุดในกากมันสำปะหลังหมักร่วมกับยอดมันสำปะหลังแห้งที่ระดับ 15% ($P<0.05$) การทดลองที่ 2 เป็นการศึกษาผลของการใช้กากมันสำปะหลังหมักร่วมกับยอดมันสำปะหลังแห้งทดแทนอาหารข้นต่อประสิทธิภาพการใช้อาหาร การกินได้ของโภชนะ กระบวนการหมักในกระเพาะรูเมน และจำนวนของจุลินทรีย์ วางแผนการทดลองแบบ CRD อาหารทดลอง 3 สูตรประกอบไปด้วย อาหารข้น 100% (กลุ่มควบคุม), อาหารข้น 67% + กากมันสำปะหลังหมักร่วมกับยอดมันสำปะหลังแห้ง 33% (CtFCp-33) และอาหาร

ข้น 33% + กากมันสำปะหลังหมักร่วมกับยอดมันสำปะหลังแห้ง 67% (CtFCp-67) ของน้ำหนักแห้ง ผลการทดลองพบว่าปริมาณการกินได้ของวัตถุแห้งทั้งหมดมีความแตกต่างกัน (P <0.05) กล่าวคือ อาหารทดลอง CtFCp-67 และ CtFCp-33 มีค่าน้อยเมื่อเทียบกับกลุ่มควบคุม การย่อยได้ของวัตถุแห้, โปรตีนหยาบ และไขมันรวม ของอาหารทดลอง CtFCp-67 มีค่าต่ำกว่ากลุ่มควบคุม หลังการให้อาหารทดลองในกลุ่ม CtFCp-67 พบว่าว่าปริมาณกรดไขมันระเหยง่ายทั้งหมด และปริมาณ C4 เพิ่มขึ้น (P <0.05) ในขณะที่ปริมาณ C2 และ C3 กลับลดลง (P <0.05) หลังการให้อาหารทดลอง CtFCp-67 และการทดลองที่ 3 เป็นการศึกษาผลของ CtFCp ต่อสมรรถนะการเจริญเติบโต ประสิทธิภาพการใช้อาหาร ปริมาณการกินได้ของโภชนะ กระบวนการหมักในกระเพาะรูเมน และจำนวนจุลินทรีย์ในกระเพาะรูเมน วางแผนการทดลองแบบ CRD อาหารทดลอง 3 สูตร ประกอบด้วย: อาหารข้น 100% (กลุ่มควบคุม), อาหารข้น 100% + CtFCp 50% (CtFCp-50) และอาหารข้น 100% + CtFCp ให้กินแบบเต็มที่ (CtFCp-ad libitum) ของน้ำหนักแห้ง ผลการทดลองพบว่าอัตราการเจริญเติบโตเฉลี่ยต่อวันมีความแตกต่างกันอย่างมีนัยสำคัญ (P<0.05) โดยกลุ่มควบคุมมีค่าเท่ากับ 288.24 กรัมต่อตัวต่อวัน กลุ่มที่ได้รับอาหารทดลอง CtFCp-50 และ CtFCp-ad libitum เท่ากับ 368.83 กรัมต่อตัวต่อวัน และ 370.59 กรัมต่อตัวต่อวัน ตามลำดับ ส่วนปริมาณการกินได้ทั้งหมดของทุกกลุ่มทดลองไม่มีความแตกต่างกัน (P>0.05) ส่วนอัตราการเปลี่ยนอาหารเป็นน้ำหนักตัวในกลุ่มอาหารทดลอง CtFCp-50 และ CtFCp-ad libitum มีค่า 6.09 และ 7.07 ส่วนการย่อยได้ของโปรตีนหยาบในกลุ่มควบคุมมีค่าสูงกว่ากลุ่มที่ได้รับอาหารทดลอง CtFCp-50 และ CtFCp-ad libitum ส่วนปริมาณ C2 และ C3 ไม่ได้รับผลกระทบในช่วง 90 วันหลังให้อาหาร อย่างไรก็ตาม สัดส่วนของ C2: C3 ในของเหลวจากกระเพาะรูเมนที่เก็บในช่วง 45 วันหลังให้อาหารมีความแตกต่างกัน (P <0.05) เมื่อพิจารณาโดยรวมแล้ว ในงานทดลองที่ 1 กากมันสำปะหลังหมักร่วมกับยอดมันสำปะหลังแห้งที่ระดับ 5% ถึง 10% สามารถเพิ่มปริมาณโปรตีนหยาบ การย่อยได้ของวัตถุแห้งในหลอดทดลอง และปริมาณผลผลิตแก๊สจากส่วนที่ละลายได้ทันที ในงานทดลองที่ 2 และ 3 แสดงให้เห็นว่าสามารถใช้กากมันสำปะหลังหมักร่วมกับยอดมันสำปะหลังเพื่อทดแทนอาหารข้นได้โดยไม่ส่งผลเสียต่อการการกินได้ การย่อยได้ สารเมตาบอไลต์ในเลือด กระบวนการหมักในกระเพาะรูเมน และช่วยเพิ่มสมารถนะการเจริญเติบโต

ABSTRACT

TITLE : EFFECTS OF CASSAVA TOP FERMENTED CASSAVA PULP ON NUTRIENT UTILIZATION AND GROWTH PERFORMANCE OF THAI NATIVE CATTLE
AUTHOR: : SOPHANY MORM
DEGREE : DOCTOR OF PHILOSOPHY
MAJOR : AGRICULTURE
ADVISOR : ASST. PROF. AREERAT LUNPHA, Ph.D.
CO-ADVISORS : ASSOC. PROF. RUANGYOTE PILLAJUN, Ph.D.
: ASSOC. PROF. ANUSORN CHERDTHONG, Ph.D.
KEYWORDS : CASSAVA TOP, CASSAVA PULP, DIGESTIBILITY, RUMEN FERMENTATION, GROWTH PERFORMANCE

We designed three experiments to evaluate the nutrient efficiency of the cassava top and pulp *in vitro* and *in vivo*. Trial **(I)** sought to investigate the impact of different levels of dried cassava top (DCT) and fresh cassava top (FCT) fermented cassava pulp (CS) on its nutritional value, gas kinetics, rumen characteristics, and *in vitro* degradability. Dietary treatments used a completely randomized design (CRD) with eight treatments and three replications. 1) CS fermented with no additive (nA), 2) CS fermented with additives (CSA), 3) 95% CSA fermented with 5% DCT (5DCT), 4) 90% CSA fermented with 10% DCT (10DCT), 5) 85% CSA fermented with 15% DCT (15DCT), 6) 95% CSA fermented with 5% FCT (5FCT), 7) 90% CSA fermented with 10% FCT (10FCT), 8) 85% CSA fermented with 15% FCT (15FCT). The results show that fermented CS with DCT at 5% to 10% DM had the highest increase in CP when compared to nA or CSA ($P<0.05$). *In vitro* dry matter disappearance (IVDMD) was significantly higher in CS fermented with 5% to 10% DCT ($P<0.01$), whereas CS fermented with FCT levels demonstrated lower IVDMD than the control group ($P<0.01$). The gas potential extent of gas production *(p)* and gas production from the insoluble fraction *(b)* did not differ significantly across treatments ($P>0.05$). However, the gas production from the immediately soluble fraction *(a)* was maximum when CS was fermented at 15DCT ($P<0.05$). Trial **(II)** sought to investigate the effect

of dried cassava top fermented cassava pulp (CtFCp) on substituted concentrates for feed efficiency, nutrient intake, rumen fermentation, and rumen microbial populations. Dietary treatments were assigned in a CRD, and assigned to receive three feeding treatments. The feeding treatments were as follows: 100% concentrate (control; CON), 67% concentrate + 33% CtFCp (CtFCp-33), and 33% concentrate + 67% CtFCp (CtFCp-67) on a dry matter basis (DM). The extrapolated results of total DM feed intake was significant ($P<0.05$), while CtFCp-67 and CtFCp-33 were minimal compared to CON. The digestibility of DM, crude protein, and ether extracts were significantly lower for CtFCp-67 than CON. TVFA and C4 significantly increased ($P<0.05$) while C2 and C3 significantly decreased ($P<0.05$) after post-feeding for the CtFCp-67 group, and trial **(III)** sought to investigate the effect of CtFCp on growth performance, feed efficiency, nutrient intake, rumen fermentation, and the rumen microbial population. Dietary treatments were assigned in a CRD to receive three feeding treatments. The feeding treatments were as follows: 100% concentrate (control; CON), 100% concentrate + 50% CtFCp (CtFCp-50), and 100% concentrate + CtFCp-*ad libitum* (CtFCp-*ad libitum*) on a dry matter basis (DM). That average daily gain (ADG) was a significant difference ($P<0.05$); CON was 288.24 g/h/d, CtFCp-50, and CtFCp-*ad libitum were* 368.83 g/h/d and 370.59 g/h/d. The total intake between groups were non-significant ($P>0.05$). Feed conversion ratio (FCR), groups CtFCp-50 and CtFCp-*ad libitum* were potentially used at 6.09 and 7.07. CP in the group CON was better digested than CtFCp-50 and CtFCp-*ad libitum.* C2 and C3 were not affected during the 90-d. Nevertheless, the C2:C3 ratio significantly differed in the 45-d fluid collection ($P<0.05$). Overall, (**I)** CS fermented with DCT at 5% to 10% concentration can increase crude protein, *in vitro* dry matter disappearance (IVDMD), and gas production from the immediately soluble fraction. Therefore, **(II)** and **(III)** show that CtFCp could substitute/supplement concentrate without negatively impacting feed intake, digestibility, blood metabolites, ruminal fermentation, and enhanced growth performance.

CONTENTS

CONTENTS (CONTINUED)

LIST OF TABLES

LIST OF TABLES (CONTINUED)

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADG	Average daily gain
ADF	Acid detergent fiber
AIA	Acid-Insoluble ash
ANOVA	Analysis of variance
BUN	Blood urea nitrogen
BW	Body weight
C2	Acetic acid
C3	Propionic acid
C4	Butyric acid
CH4	Methane
CP	Crude protein
CRD	Completely randomized design
CT	Condensed tannins
CS	Cassava pulp
CtFCp	Dried cassava top fermented cassava pulp
DM	Dry matter
DMI	Dry matter intake
DMRT	Duncan’s Multiple Range Test
DOMI	Digestible organic matter intake
DOMR	Digestible organic matter fermented in rumen
DCT	Dry cassava top
EDTA	Ethylenediaminetetraacetic acid
EE	Ether extract
FCT	Fresh cassava top
FCR	Feed conversion ratios
FinW	Final weight
g	Gram
g/dL	Gram/deciliter
g/ kg BW0.75	Gram per kilogram metabolic weight
g/kg DM	Gram per kilogram dry matter

LIST OF ABBREVIATIONS (CONTINUED)

g/kg/d	Gram per kilogram per day
HPLC	High performance liquid chromatography
H2	Hydrogen
in vitro	In glass
inW	Initial weight
kg	Kilogram
L	Liter
ME	Metabolisable energy
MPC	Microbial crude protein
mg	Milligram
mg/dL	Milligram per deciliter
mL	Millititer
NaHCO3	Sodium bicarbonate
NDF	Neutral detergent fiber
NH3-N	Ammonia nitrogen
OM	Organic matter
OMD	Organic matter digestibility
P	Probability
pH	Hydrogen potential
SPSS	Statistical Package for the Social Sciences
SEM	Standard error mean
TDN	Total digestible nutrient
VFA	Volatile fatty acid
^{0}C	Degree centigrade

CHAPTER 1
INTRODUCTION

1.1 Importance and justifications

Livestock in Cambodia increased during the pandemic (MAFF, 2020), with 53.9 million heads of livestock, up 17.6% compared to the same period in 2019. Small scale-farming was found that beef cattle increased by up to 4.1% and large scale-farming 10.8 % by comparing between 2020-2021, as reported by MAFF (2022). Cambodian farmers' incomes were referred from livestock (MP, 2015; Katherine et al., 2018), and food security is increasingly recognized as a global problem (IRDC, 1999). Cambodian people prefer beef over other meat: in 2020 alone, Cambodians consumed about 301,010 million tons, and 301,081 tons in 2021, an increase of 0.24%, and beef is in high market demand (MAFF, 2022). However, cattle production needs several issues, including limited practical management, advice, high labor, space-intensive, disease, shortage of water, financing, and feed sources (Mob et al., 2014). Farmer in Cambodia has many encounters in their cattle management during wet and drought seasons; farmers need more feeds with restricted nutrients, usually weeds and paddy rice, in the rainy season (ACIAR, 2019). Furthermore, nutrient deficiency was provided to animals tethered to grazing rice paddies and provided rice straw at night time, which had much fiber with low protein that making weight gain inhibited (ACIAR, 2019). In addition, small-scale or household farming always uses the cut-carry method to collect the native grass to grazing areas to supply to their ruminants, but only a few farmers feed crop residue as feed (Miranda et al., 2010; Mob et al., 2014). Traditional practices management with large ruminants for survival, resulting in low body condition scores (BCS), which are vulnerable to diseases increasing, poor reproduction, and typically it is addressed with poor productivity, which obtains less cost attaching during the sale to the market (ACIAR, 2019; USAID, 2012). Research indicates that feed availability is the major constraint on animal herd size. Low feed quantity and quality are critical for animal health and performance, as cattle require adequate nutrition to support growth and resilience to environmental impacts (Keo et al., 2008; Mob et al., 2014). Sustainable livestock husbandry requires quantity and

quality of feed but much investment. Small scale-farming is fed to livestock such as rice stalk, rice straw, maize, sugarcane bagasse, cassava residual, and natural grasses with insufficient nutrients (Arun, 2012). In contrast, roughages need more ensiling sources to improve levels of digestibility and nutrient contents.

The yield of cassava roots compared to cassava leaves is 10 tons/ha of dry matter (DM) (Morgan et al., 2006) and 10.2 tons/ha, according to (Li et al., 2019). The crude protein (CP) contained in dry cassava leaves is between 16.7-44% (Wanapat, 2003; Oni et al., 2014; Li et al., 2019; Hawashi et al., 2019). It contained 20.76-21.55% of CP in fermented cassava leaves as fermented (Oni et al., 2014; Li et al., 2019). 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., 2022). Additionally, cassava leaves can reduce methane emissions from ruminants (Inthapanya et al., 2015). Various feed additives increase cattle productivity (Morm et al., 2021; Faccio-Demarco et al., 2019), including yeast-derived products such as *Saccharomyces cerevisiae,* which stand out because they suit rumen health and animal health maintenance (Faccio-Demarco et al., 2019). The cassava leaves contained a high cyanide content and were unsafe for human and animal consumption without appropriate processing methods (Ayele et al., 2022; Boukhers et al., 2022).

Cassava pulp (CS) is a by-product that contains approximately 30% of cassava roots (CR) (Ghimire et al., 2015). It contains 15.8%-23.4% dry matter (DM), 2.2-2.5% CP, 55-74.4% nitrogen-free extract, 17.9-24 % crude fiber, and 74.4% total digestible nutrients (Fathima et al., 2015). 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 CS with additives increased nutritive value (Pilajun and Wanapat, 2018). CS-fermented dry cassava tops and live yeast increase CP efficiency, increase animal feed production and reduce feed costs (Morm et al., 2023). Moreover, CS was unaffected by feed intake, reproduction performance, methane production, and nutrient digestibility (Narapoke et al., 2018; Morm et al., 2023). In the gastrointestinal systems of ruminants, yeast is frequently utilized as a probiotic and prebiotic (Phesatcha et al., 2021). Yeasts are a potential part of dissolving oxygen in the rumen, and they can manage the pH by competing with lactic acid bacteria and minimizing the danger of acidosis (Chaucheyras-Durand et al., 2021). Moreover, using the CS was not affected

by the heat production of Thai native 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 (Hue et al., 2012). Moreover, supplied cassava foliage can improve feed intake (FI) and live weight gain (LWG) with no effect on the lambs' health (Hue et al., 2012). Jiang (2022) reported that using urea and molasses to treat CS can enhance the feed's nutritional value, increase gas production, and improve the dominant cellulolytic bacterial population. Hawashi (2019), whereas *Saccharomyces cerevisiae*-fermented cassava foliage can decline poisoning content, it can be obtained with an enzyme activity of 0.53 units per gram of dry-based substrate (U/gds). CS-fermented total mixed rations (TMR) increased lambs' nutrient digestibility and nutrient intake (Khejornsart et al., 2022). Nevertheless, CS fermented with yeast waste (CSYW) replaced soybean meal (SBM) can improve nutrient digestibility (Dagaew et al., 2021).

Based on our knowledge, cassava top, cassava pulp is a potential quality and sustainable feedstuff for ruminants. While using cassava by-products in the diet, ensiled yeast (*Saccharomyces cerevisiae)* enhances ruminant feed efficiency and rumen ecology. The previous studies have yet to extensively demonstrate the direct use of cassava top fermented cassava pulp in Thai native cattle on growth performance; thus, cassava top fermented cassava pulp as substitutes or supplementation in concentrate for ruminant ecology, blood metabolites, nutrient digestibility, and growth performance in Thai native cattle are required.

1.2 Objectives

1.2.1 To study the improvement of the nutritive value of fresh and dried cassava top fermented cassava pulp rumen fermentation, gas kinetics, and *in vitro* digestibility.

1.2.2 To study the effects of dried cassava top fermented cassava pulp substitute on feed intake, nutrient digestibility, rumen fermentation, and rumen microbial population in Thai native x Lowline Angus crossbred cattle.

1.2.3 To study the dried cassava top fermented cassava pulp to supplementation in concentrate on growth performance, feed intake, nutrient efficiency, rumen fermentation, and rumen microbial population in Thai native x Lowline Angus crossbred cattle.

1.3 Scope of research

The study was conducted at the Faculty of Agriculture, Ubon Ratchathani University, Thailand's Experimental Field and Central Laboratory (15°07'55.8"N 104°55'48.2" E). The fresh cassava top or cassava top combines the leaf, petiole, and greening stem approximately 20-30 cm or reaches the greening part of stem in length from the leaf bud. The cassava tops (*Manihot esculenta* Kasetsart 50) were purchased from a local producer in Ban Hare, Tambon Kham Kwang, Warin Chamrap District, Ubon Ratchathani Province, Thailand. The active dry yeast (*Saccharomyces cerevisiae*), strain CNCM-1077, Levucell SC20 (r) SC, and its ingredient, 10^{10} CFU/g, and cassava pulp (CS) were purchased from a local market in Ubon Ratchathani Province. Two species of cattle were selected: 1) Five female 75% Holstein-Friesian crossbred dairy steers with 150±20 kg body weight (BW) and an age of 12 months were used for donor fluid collection to use on an *in vitro* method to scan the suitable levels of fresh and dried cassava top fermented cassava pulp, 2) Twelve Thai native x Lowline Angus crossbreeds were designated at 97±18.10 kg of initial body weight (IBW) and an average of 14 months of age to study the effects of using dried cassava top fermented cassava pulp substitute concentrate to evaluate feed intake, nutrient efficiency, rumen fermentation, and microbial population, and 3) Cassava top and cassava pulp were provided to the animal to measure their growth performance, feed intake, and blood metabolites in Thai native x Lowline Angus crossbreed cattle by using twelve females of Thai native x Lowline Angus crossbred cattle were assigned 99.50±9.83 kg initial body weight (IBW) and an average of 12 months of age.

1.4 Expected outcomes

After conducted three experimental steps, will be obtained several anticipations as below:

1.4.1 Gas kinetics, rumen characteristics, and *in vitro* degradability of varied levels of dried and fresh cassava top-fermented with cassava pulp.

1.4.2 Thai native x Lowline Angus crossbred cattle on feed intake, feed digestibility, rumen microorganisms, and fermentation: Effects of using cassava products to replace concentrate.

1.4.3 Effects of feeding dried cassava top fermented cassava pulp on ruminal parameters, blood metabolites, digestibility, and growth performance of Thai native x Lowline Angus crossbred cattle

CHAPTER 2
LITERATURE REVIEWS

2.1 Indigenous beef cattle

The origin of indigenous beef cattle is obscure in the mists of antiquity. To some, however, integrating current archaeological, anthropological, historical, linguistic, and genetic evidence can disperse animal breeds (WTSR, 2009). Three related cattle types emerge: Bos *taurus, Bos indicus* and *Bos (bibos) banteng* (Payne and Hodges, 1997). Three major types of domestic cattle are involved either with three regions or at centers immediately adjacent, suggested in archaeological evidence not only the Western or Asia a primary for the first indigenous wild cattle (*Bos primigenius*; an extinct). These types, humpless long-shorthorn (*Bos taurus)* and humpless Zebu (*Bos-indicus*), were accurate in different locations and times (Payne, 1970; Payne & Hodges, 1997). The sub-family Bovinae of the relationship between the wild and indigenous species are shown in Figure 2.1. In addition, the nutrient requirement of Thai native beef cattle is shown in Table 2.2. Whereas, brahman crossbred nutrient requirements are represented in Table 2.3. Hence, the Angus breed is shown in Table 2.4.

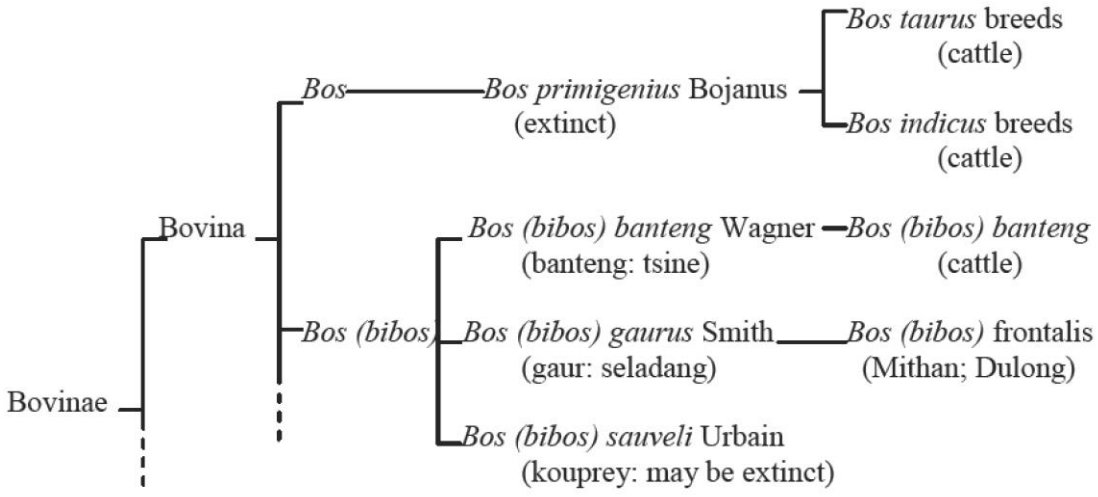


Figure 2.1 Bovine of the sub-family, wild and domestic species relationship

Source: WTSR (2009)

2.1.1 Cattle breed provelances

The seven provenances of the group cattle based on their geographic lineage with well genetic characteristics and regional described. Continental (European B. taurus), Criollo (American B. taurus), Hybrid (B. taurus × B. indicus), B. indicus (Indian sub-continent), Mediterranean (Any country bordering the Mediterranean; B. Taurus; with exceptions in France and Italy, where breeds were classified as ‘Continental’ and ‘Mediterranean’), Sanga (southeastern African; stabilized B. indicus × B. Taurus [sometimes taurindicus]), and British Isles (“British”; consti-tuting Ireland and the United Kingdom of Great Britain and Northern Ireland B. taurus). Crossbreds of cattle from British and Continental backgrounds (e.g., Simmental × Hereford) were lumped into the ‘British Isles’ group because this pairing is typically aimed at maintaining marbling and carcass traits of British breeds and increasing offspring size and weight gains due to hybrid vigor and larger body frames of continental breeds. In instances where Criollo was crossbred with Hybrid or indicus cattle, they were considered Hybrids because of the resulting B. taurus × B. indicus cross. Continental French and Italian breeds were deemed such because of their derivation from non-Mediterranean biomes; for instance, Charolais cattle are from Charolais, France, which is in the eastern central region of the country within the continental temperate biome. Likewise, Piedmontese cattle are from northwest Italy's Piedmont region, Charolais has a similar continental temperate habitat (Ginja et al., 2019; Pitt et al., 2019) in Figure 2.2, respectively. Meanwhile, for most beef cattle, whether native or hybrid, their living and eating behaviours are different in different regions. Thus, most of the cattle were represented in Table 2.1.

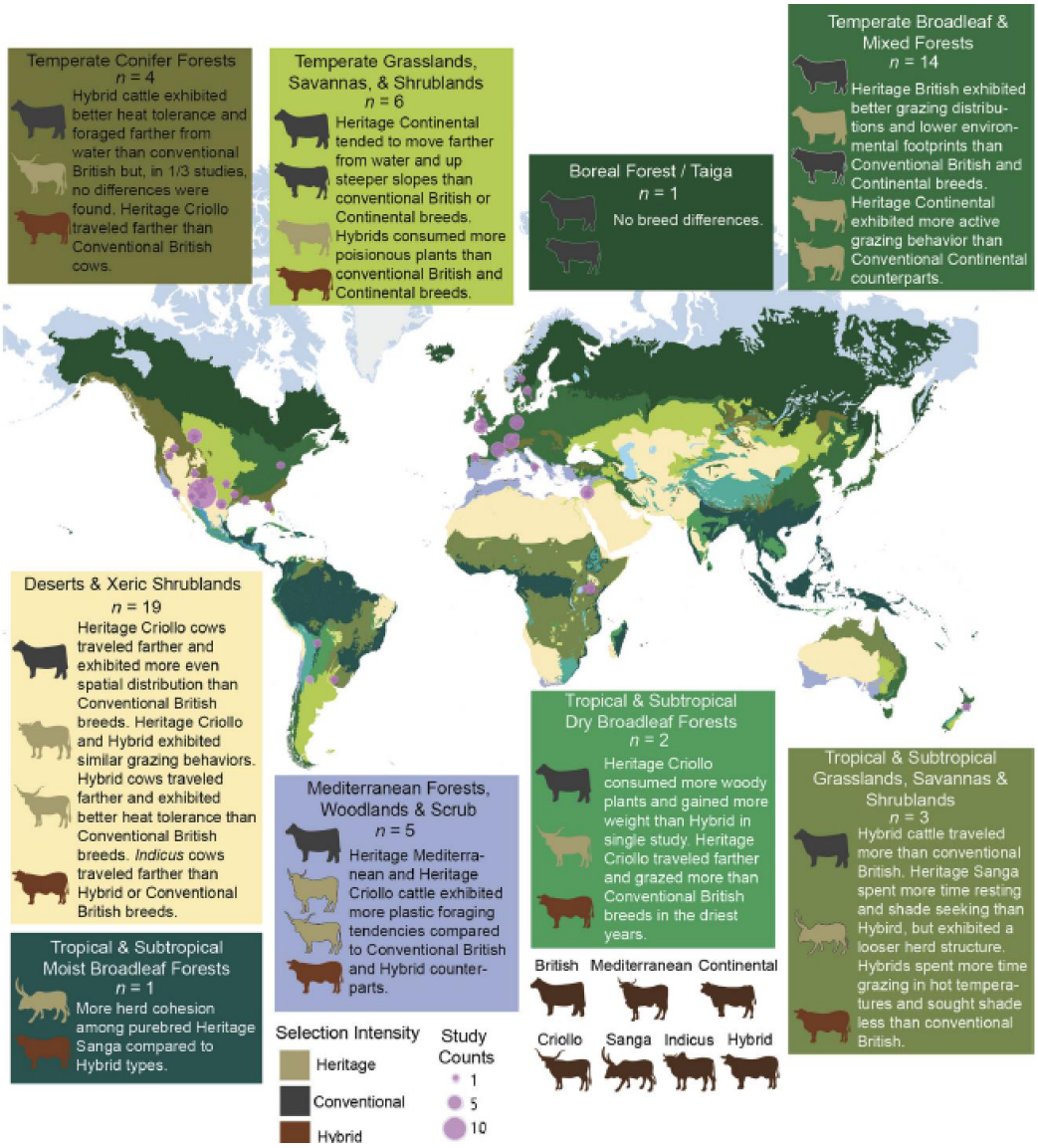


Figure 2.2 The cattle breed provenance, selection intensity, and major cattle world biomes

Source: Morgavi et al. (2023)

Table 2.1 Location, cattle sex, breed, breed provenance, intensity selection, and primary behavior findings

Cattle	Location	Biome	Cattle sex	Breeds	Breed provenance	Selection intensity	Primary grazing findings	Authors
Bite rate	UK, Germany, France	Temperate Broadleaf & Mixed Forests	steers	Devon Charolais × Friesian	British Continental	Heritage Conventional	Heritage breeds at the UK site selected forbs more often than conventional; Heritage breeds at others. sites were less selective than conventional types	Dumont et al. (2007)
	North Wyke, Devon, UK	Temperate Broadleaf & Mixed Forests	steers and heifers	North Devon Hereford × Friesian × Simmental	British	Heritage Conventional	Heritage breed yearlings had greater total jaw movements but spent less time ruminating than conventional types.	Orr et al. (2014)
	Palmerston North, New Zealand	Temperate Broadleaf & Mixed Forests	Bulls	Piedmontese × Friesian	Continental	Conventional	The bite rate and grazing time of Blue Belgian x Friesian were less than Friesian; Blue Belgian × Friesian daytime idling time was greater than Piedmontese × Friesian or Friesian counterparts. Few differences between provenance groups.	Morris et al. (1993)
Diet	Swiss Alps, Switzerland	Temperate Broadleaf & Mixed Forests	Cows	Highland Brown Swiss	British Continental	Heritage Conventional	Heritage breed was more productive on Alpine pastures than conventional cows and better-utilized pastures with poor nutrient quality.	Berry et al. (2002)
	Las Cruces, NM, USA	Deserts & Xeric Shrublands	Cows	Beefmaster Brangus Barzona	Hybrid Hybrid Hybrid	Hybrid Hybrid Hybrid	No diet difference is determined.	De Alba Becerra et al. (1998)
	Las Cruces, NM	Deserts & Xeric Shrublands	Cows	Raramuri Criollo Angus	Criollo British	Heritage Conventional	Heritage breed consumed less black grama (critical forage resource) than conventional.	Estell et al. (2022)
	Southeast Texas, USA	Temperate Conifer Forests	Cows	Angus × Brahman Angus	Hybrid British	Hybrid Conventional	A conventional sought shade more than a hybrid, but no grazing time or diet differences were detected.	Forbes (2005)
	West Texas, USA	Deserts & Xeric Shrublands	Cows	Tuli × Brahman Angus	Hybrid British	Hybrid Conventional	Conventional grazed for the least time, but exhibited longer residence times and slower passage rates than Indicus hybrid counterparts.	Forbes (2005); Forbes et al. (1998)
	West Texas, USA	Deserts & Xeric Shrublands	Cows	Tuli × Brahman Angus	Hybrid British	Hybrid Conventional	Conventional grazed for the least time, but exhibited longer residence times and slower passage rates than Indicus hybrid counterparts.	Forbes (2005); Forbes et al. (1998)

Table 2.1 Location, cattle sex, breed, breed provenance, intensity selection, and primary behavior findings (Continued)

Cattle	Location	Biome	Cattle sex	Breeds	Breed provenance	Selection intensity	Primary grazing findings	Authors
Diet	West Texas, USA	Deserts & Xeric Shrublands	Cows	Tuli × Brahman Angus	Hybrid British	Hybrid Conventional	Conventional grazed for the least time, but exhibited longer residence times and slower passage rates than Indicus hybrid counterparts.	Forbes (2005); Forbes et al. (1998)
	Gran Chaco, Argentina	Tropical & Subtropical Dry	Cows	Angus × Brahman Criollo Chaque˜no Brahman × Criollo Chaque˜no	Indicus Hybrid Criollo	Heritage Hybrid Heritage	Heritage breed tended to eat more woody plants and gained weight in the intermediate dry-rainy season compared to hybrids.	Marquardt et al. (2018)
	Las Cruces, NM, USA	Deserts & Xeric Shrublands	Cows	Barzona Brangus	Hybrid Hybrid	Hybrid Hybrid	No diet composition differences were determined.	Winder et al. (2000)
	Las Cruces, NM, USA	Deserts & Xeric Shrublands	Cows	Brangus Hereford	Hybrid Hybrid	Hybrid Hybrid	Compared with conventional, hybrid preferred dropseed sand and consumed more Yucca and total shrubs.	Winder et al. (1996)
	Montana, USA	Temperate Grasslands, Savannas & Shrublands	Cows	Tarentaise Hereford Hereford × Tarentaise	Continental Hybrid Hybrid	Heritage Conventional Conventional	Hereford and Herford × Tarentaise decreased faecal output as body condition increased during lactation, whereas Tarentaise faecal output did not change.	Sprinkle (1992)
	Las Cruces, NM, USA	Deserts & Xeric Shrublands	Cows	Barzona Beefmaster Brangus	Hybrid Hybrid Hybrid	Hybrid Hybrid Hybrid	Barzona selected the least NDF and greatest digestibility diet compared to (indicus × taurus) counterparts.	Quezada (1998)
Foraging behaviour	Galilee, Israel	Mediterranean Forests, Woodlands & Scrub	Cows	Baladi Beefmaster × Simford	Mediterranean Hybrid	Heritage Hybrid	Heritage was more active in all seasons, walked farther distances, spent more time grazing, and was more metabolically efficient in low-quality herbage conditions than hybrids.	Aharoni et al. (2014)
	Galilee, Israel	Mediterranean Forests, Woodlands & Scrub	Cows	Baladi Beefmaster × Simford	Mediterranean Hybrid	Heritage Hybrid	Heritage cows grazed more, walked more, had more feed intake per unit metabolic body weight, and had lower locomotion costs than their hybrid counterparts.	Aharoni et al. (2009)
	Basilicata, Italy	Mediterranean Forests, Woodlands & Scrub	Cows	Podolian Chianina Romagnola	Mediterranean Mediterranean Mediterranean	Heritage Heritage Heritage	No differences in activity budgets were detected, but Chianina selected more forbs than breed counterparts, and Podolian cows selected more ferns than breed counterparts.	Braghieri et al. (2011)

Table 2.1 Location, cattle sex, breed, breed provenance, intensity selection, and primary behavior findings (Continued)

Cattle	Location	Biome	Cattle sex	Breeds	Breed provenance	Selection intensity	Primary grazing findings	Authors
Foraging behaviour	Santa Rita, AZ, USA	Deserts & Xeric	Cows	Barzona Hereford	Hybrid British	Hybrid Conventional	No differences in diet composition or behavior were detected.	De Souza Gomes (1983)
	Massif Central, France	Shrublands Temperate Broadleaf & Mixed Forests	Heifers	Salers Limousin	Continental Continental	Heritage Continental	Conventional heifers grazed longer than Salers (conventional, but more rustic) counterparts, but Salers had greater bite rates. Salers were less affected by a decrease in available herbage vs Limousin counterparts.	D'Hour et al. (1994)
	Galilee, Israel	Mediterranean Forests, Woodlands & Scrub	Cows	Baladi Beefmaster × Simford	Mediterranean Hybrid	Heritage Hybrid	Heritage cows were more active across all seasons, walked farther, and grazed for longer periods than hybrids.	Dolev et al. (2014)
	Brecon, Powys, UK	Temperate Broadleaf & Mixed	Steers	Welsh Black Charolais crossbreds	British Continental	Conventional Heritage	No behavioural differences were detected.	Fraser et al. (2009)
	Montana, USA	Temperate Grasslands, Savannas & Shrublands	Cows	Hereford Simmental × Hereford Angus × Hereford Simmental × Hereford (75/25) Tarentaise × Hereford Tarentaise × Simmental × Hereford Charolais × Simmental × Hereford	British British British Continental British Continental Continental	British British British Continental British Continental Continental	Angus × Hereford grazed longer than Angus and Simmental × Hereford. Simmental × Hereford travelled greater distances than other breeds. Tarentaise × Simmental × Hereford exhibited more bite rates than Hereford, but no differences were determined among other breeds.	Funston et al. (1991)
	Central Florida, USA	Temperate Conifer Forests	Heifers	Senepol Hereford	Hybrid British	Hybrid Conventional	Hybrid grazed longer and exhibited lower internal body temperatures compared to conventional.	Hammond (1993)
	Las Cruces, NM, USA	Forests, Deserts & Xeric	Cows	Santa Gertrudis Hereford	Hybrid British	Hybrid British	Hybrid cows walked farther and more often than conventional. Conventional grazed for more time than a hybrid.	Herbel and Nelson (1966)
	Las Cruces, NM, USA	Forests, Deserts & Xeric	Cows	Santa Gertrudis Hereford	Hybrid British	Hybrid British	Hybrid cows walked farther than conventional. Grazing distribution was overall similar among breeds.	Herbel et al. (1967)
	Skara, Sweden	Temperate Broadleaf & Mixed Forests	Heifers	V¨aneko Charolais	Continental Continental	Heritage Conventional	Few breed differences were determined, but heritage heifers exhibited increased activity.	Hessle et al. (2008)

Table 2.1 Location, cattle sex, breed, breed provenance, intensity selection, and primary behavior findings (Continued)

Cattle	Location	Biome	Cattle sex	Breeds	Breed provenance	Selection intensity	Primary grazing findings	Authors
Foraging behaviour	Gran Chaco, Argentina	Subtropical Dry Broadleaf Forests	Cows	Argentine Criollo Angus	Criollo British	Heritage Conventional	Heritage travelled and explored larger areas during dry winter months than conventional.	Herrera Conegliano et al. 2022
	Mbarara district, SW Kenya	Tropical & Subtropical Moist Broadleaf Forests	Heifers	Ankole Ankole × Holstein	Sanga Hybrid	Heritage Hybrid	No behavioural differences were detected. Authors note Ankole (heritage) heifers exhibited greater herd cohesion than crossbred counterparts.	Huber et al. (2008)
	Kabete, Kenya	Tropical & Subtropical Grasslands, Savannas & Shrublands	Cows	Boran Hereford	Sanga British	HeritageConventional	Heritage cows spend more time walking than conventional cows. Conventional cows spend more time grazing in the wet season, while heritage grazing during the dry season.	Kanyenda (1979)
	El Reno, OK, USA	Temperate Grasslands, Savannas & Shrublands	Heifers	Hereford Hereford × Holstein Holstein	British British Continental	Continenal Continental Continental	Conventional grazed and idled for longer periods than other conventional breeds.	Kropp et al. (1973)
	Las Cruces, NM, USA	Deserts & Xeric Shrublands	Steers	Raramuri Criollo Criollo crossbreds	Criollo Hybrid	Heritage hybrid	No behaviour differences were detected.	McIntosh et al. (2021)
	Las Cruces, NM, USA	Deserts & Xeric Shrublands	Cows	Raramuri Criollo Angus	Criollo British	Heritage Conventional	Heritage cows had lower internal temperatures than conventional cows. Heritage also travelled farther, faster and spent more time grazing and resting less than conventional.	Nyamuryekung'e et al. (2021)
	Las Cruces, NM, USA	Deserts & Xeric Shrublands	Cows/Calves	Angus	British	Conventional	Calves spatially unconstrained heritage cows via exhibiting a 'follower' mothering style. Conventional cows were constrained by the 'hider' mother style.	Nyamuryekung'e et al. (2020)
	Las Cruces, NM, USA	Deserts & Xeric Shrublands	Cows	Raramuri Criollo Angus	Criollo British	Heritage Conventional	Heritage cows exhibited less herd cohesion and greater selection for the greenest patches on the landscape than	Nyamuryekung'e et al. (2022)

Table 2.1 Location, cattle sex, breed, breed provenance, intensity selection, and primary behavior findings (Continued)

Cattle	Location	Biome	Cattle sex	Breeds	Breed provenance	Selection intensity	Primary grazing findings	Authors
Foraging behaviour	Swiss Alps	Temperate Broadleaf & Mixed Forests	Cows	Braunvieh Highland Angus x Holstein	Conventional British British	Conventional Heritage Conventional	Heritage cows exerted less static pressure on the landscape, exhibited a more even grazing distribution, and moved farther from water and up steep slopes than conventional Angus x Holstein and conventional but rustic Braunvieh.	Pauler et al. (2020a)
	Las Cruces, NM, USA	Deserts & Xeric Shrublands	Cows	Raramuri Criollo Angus Charolais × Friesian Simmental	Criollo British	Heritage Conventional	Heritage cows foraged at greater spatial extents during dry fall periods than conventional cows	Peinetti et al. (2011)
	Spain	Temperate Broadleaf & Mixed Forests	Steers	Asturian Mountain Asturian Valley	Mediterranean Mediterranean	Heritage Heritage	Asturian Mountain (heritage breed) steers tended to graze on shrubby heathlands more often than Asturian Valley (heritage breed, but more conventionally used) steers, but both exhibited similar grazing durations.	Rom´an-Trufero et al. (2019)
	Las Cruces, NM, USA	Deserts & Xeric Shrublands	Cows	Brahman Brangus Angus	Indicus Hybrid British	Heritage Hybrid Conventional	Heritage cows travelled farther and in more sinuous pathways than hybrid or conventional, but no breed differences in distance to water were detected.	Russell et al. (2012)
	Zumwalt Prairie Oregon, USA	Temperate Grasslands, Savannas & Shrublands	Cows	Angus Hereford Corriente × Longhorn	British British Criollo	Conventional Conventional Heritage	Heritage cattle travelled and rested farther from watering sources and accessed water less often than two conventional breeds in the dormant fall season.	Sheehy (2007)
	Burns, Oregon, USA	Deserts & Xeric Shrublands	Steers	Brahman × Hereford Hereford	Hybrid British	Hybrid Conventional	Hybrid steers tended to walk farther, travel more, and grazing less than conventional steers.	Sneva (1970)
	Las Cruces, NM	Deserts & Xeric Shrublands	Cows	Raramuri Criollo Angus	CriolloBritish	HeritageConventional	Heritage cows expressed larger home ranges and half as many hotspots (areas of reuse) in dry seasons compared to conventional cows.	Spiegal et al. (2019)
	Uvalde, TX, USA	Temperate Grasslands, Savannas & Shrublands	Steers	Brahman × Angus Tuli × Angus Angus	Hybrid Hybrid British	Hybrid Hybrid Conventional	Conventional steers had greater gastrointestinal tract load and accumulated more metabolic heat than hybrid steers. In early summer, Hybrid Tuli × Angus steers sought shade more than other steer types.	Sprinkle et al. (2000)

Table 2.1 Location, cattle sex, breed, breed provenance, intensity selection, and primary behavior findings (Continued)

Cattle	Location	Biome	Cattle sex	Breeds	Breed provenance	Selection intensity	Primary grazing findings	Authors
Foraging behaviour	Pennsylvania, USA	Temperate Broadleaf & Mixed Forests	Cows	Angus Angus × Charolais	British British	Conventional Conventional	Conventional Angus × Charolais spent more time grazing than conventional Angus, but few other differences were detected.	Stricklin et al. (1976)
	Paysandú, Uruguay	Tropical & Subtropical Grasslands, Savannas & Shrublands	Cows	Bonsmara × Hereford Hereford	Hybrid British	Hybrid Conventional	Conventional cows spent more time resting and more time seeking shade than hybrid cows; Hybrid cows showed lower internal temperatures in hot summer seasons and grazed under hotter conditions.	Taborda et al. (2018)
	Norway	Boreal Forests/Taiga	Cows	Hereford Charolais Limousin	British Continental Conventional	Conventional Conventional Conventional	No differences in time spent grazing detected	Tofastrud et al.(2020)
Impacts on vegetation	Baton Rouge, Louisiana, USA	Temperate Conifer Forests	Steers	Hereford Hereford × Brahman	British Hybrid	Conventional Hybrid	No behavioural differences detected	White Pas and Saxton (1998)
	UK, Germany, France	Temperate Broadleaf & Mixed Forests	Steers and Heifers	Devon Angus Salers Charolais × Friesian Simmental Charolais	British British Conventional Continental Continental Continental	Heritage Hybrid Heritage Continental Continental Continental	No behavioral differences detected	Isselstein et al. (2007)
	Switzerland, Germany	Temperate Broadleaf & Mixed Forests	Cows	Highland Limousin Simmentaler Braunvieh Angus Charolais	Continental British Continental Continental British Continental	Heritage Continental Continental Continental Continental Continental	Heritage cows positively responded to vegetation diversity (reduced woody species cover, increased epizoochoric species) compared to pastures grazed by conventional cows.	Pauler et al. (2019)
	UK, Germany, France	Temperate Broadleaf & Mixed Forests	Steers and Heifers	Devon Angus Salers Charolais × Friesian Simmental Charolais	British British Continental Continental Continental Continental	Heritage Conventional Heritage Conventional Conventional Conventional	No breed effects on vegetation were detected.	Scimone et al. (2007)

Table 2.1 Location, cattle sex, breed, breed provenance, intensity selection, and primary behavior findings (Continued)

Cattle	Location	Biome	Cattle sex	Breeds	Breed provenance	Selection intensity	Primary grazing findings	Authors
Slope/dist	Havre, Montana, USA	Temperate Grasslands, Savannas & Shrublands	Cows	Tarentaise Hereford Tarentaise × Hereford and crossbreds thereof	Continental British British	Heritage Conventional Conventional	Heritage cows and ¾ conventional Tarentaise × Hereford cows used steeper slopes in one study year and travelled farther from water than conventional Hereford and crossbreds.	Bailey et al. (2001)
	Havre, Montana, USA	Temperate Grasslands, Savannas & Shrublands	Cows	Piedmontese Salers Angus Charolais	ContinentalContinentalBritishContinental	HeritageHeritage ConventionalConventional	Heritage Piedmontese-sired cows travelled farther from water and tended to utilize steeper slopes more than Conventional Angus-sired cows.	VanWagoner et al. (2006)
Vegetation impacts on animals	Swiss Alps	Temperate Grasslands, Savannas & Shrublands	Cows	Braunvieh Highland Angus x Holstein	Continental British British	Conventional Hybrid Conventional	Plants of better forage quality were preferred among conventional cows, but less often selected by heritage cows. Hybrid cows expressed less selective grazing preferences than conventional cows, resulting in more diverse pasture-level species composition.	Pauler et al. (2020b)
	Des Moines, NM, USA	Temperate Grasslands, Savannas & Shrublands	Steers	Brangus Charolais Hereford	Hybrid Continental British	Hybrid Conventional Conventional	Hybrid consumed more toxic locoweed in the study year 1, week 1, and year 2, week 1, 2, and 3 than either conventional steer type. Alkaline phosphatase levels did not differ among breeds, however.	Duff et al. (2002)

Table 2.2 Nutrient requirement for Thai native beef cattle

Weight range	**100-400 kg**						
ADG range	**0-1.00 kg**						
Body weight, kg	100	150	200	250	300	350	400
Dry matter intake, kg	2.31	3.75	5.2	6.64	8.08	9.53	10.97
Maintenance and growth requirements			ME required for gain (g/day)				
ADG(kg/d)							
0.00	15.29	20.73	25.72	30.4	34.86	39.13	43.25
0.25	23.13	28.57	33.56	38.25	42.7	46.97	51.1
0.50	30.98	36.41	41.4	46.09	50.54	54.82	58.94
0.75	38.82	44.25	49.24	53.93	58.39	62.66	66.78
1.00	46.66	52.09	57.09	61.77	66.23	70.5	74.62
ADG(kg/d)			Crude protein required for gain (g/d)				
0.00	159	215	267	316	362	407	450
0.25	254	311	363	411	458	502	545
0.50	349	406	458	506	553	597	640
0.75	445	501	553	602	648	692	735
1.00	540	596	648	697	743	788	830

Source: WTSR (2009)

Table 2.3 Nutrient requirement for Brahman crossbred

Weight range	**100-400kg**						
ADG range	**0-1.00 kg**						
Body weight, kg	100	150	200	250	300	350	400
Dry matter intake, kg	2.31	3.75	5.2	6.64	8.08	9.53	10.97
Maintenance and growth requirements				ME required for gain (g/day)			
ADG (kg/d)							
0.00	-	-	-	-	-	-	-
0.25	-	-	-	-	-	-	-
0.50	-	-	-	-	-	-	-
0.75	-	-	-	-	-	-	-
1.00	-	-	-	-	-	-	-
ADG (kg/d)				Crude protein required for gain (g/d)			
0.00	173		234	291	344	394	443
0.25	320		382	438	491	542	590
0.50	468		529	586	639	689	737
0.75	615		677	733	786	837	885
1.00	763		824	881	934	984	1032

Source: WTRS (2009)

Table 2.4 Nutrient requirement for growing Angus beef cattle

Weigh of maturity		**890 kg**					
Weigh range		**300-800 kg**					
ADG range		**0.50-2.50 kg**					
Body weight, kg		300	400	500	600	700	800
Maintenance requirements							
NEm	Mcal/day	6.38	7.92	9.36	10.73	12.05	13.32
MP	g/d	274	340	402	461	517	572
Ca	g/d	9	12	15	19	22	25
P	g/d	7	10	12	14	17	19
Growth requirements							
ADG (kg/d)	NEg required for gain, Mcal/d						
0.50	kg/d	1.72	2.13	2.52	2.89	3.25	3.59
1.00	kg/d	3.68	4.56	5.39	6.18	6.94	7.67
1.50	kg/d	5.74	7.12	8.42	9.65	10.83	11.97
2.00	kg/d	7.87	9.76	11.54	13.23	14.85	16.41
2.50	kg/d	10.05	12.47	14.74	16.9	18.97	20.97
required for gain, g/d							
0.50	kg/d	158	145	122	100	78	58
1.00	kg/d	303	272	222	175	130	86
1.50	kg/d	442	392	314	241	170	102
2.00	kg/d	577	506	400	299	202	109
2.50	kg/d	710	617	481	352	228	109
Calcium required for gain, g/d							
0.50	kg/d	12	10	9	7	6	4
1.00	kg/d	23	19	16	12	9	6
1.50	kg/d	33	27	22	17	12	7
2.00	kg/d	43	35	28	21	14	8

Table 2.4 Nutrient requirement for growing Angus beef cattle (Continued)

Weigh of maturity			**890 kg**				
Weigh range			**300-800 kg**				
ADG range			**0.50-2.50 kg**				
Body weight, kg			300	400	500	600	700
2.50	kg/d	53	43	34	25	16	8
Phosphorus required for gain, g/d							
0.50	kg/d	5	4	3	3	2	2
1.00	kg/d	9	8	6	5	4	2
1.50	kg/d	13	11	9	7	5	3
2.00	kg/d	18	14	11	8	6	3
2.50	kg/d	22	17	14	10	6	3

Source: NRC (2000)

2.1.2 Enteric methane energy and methane metabolism

Enteric methane production in livestock is considered an energy loss in the equation for estimating energy metabolism in feeding systems. To some extent, the gross energy derived from feeds, as specified by adiabatic calorimetry, is progressively lost as feeds are fermented and digested. Nutrients are metabolized before being assimilated into animal products. The diet's structural carbohydrates, proteins, and other feed components break down into fewer unit components, fermented by rumen microorganisms into volatile fatty acids (VFAs), CO2, and H2 (Morgavi et al., 2022). Methanogenic archaea employ H2, CO2, and, to some extent, various fermentation byproducts as substrates for generating methane, which is their only mode of energy intake. Microbes use the energy from feed to create biomass and heat fermentation, with fermentation intermediates and end products becoming less complicated and providing less energy value with each fermentation reaction. Methanogens, which can grow by using reduced molecules (H2) and other electron carriers) generated by other rumen microorganisms, are situated at the bottom of this microbial gastrointestinal trophic chain and move metabolites from producers to users (Morgavi et al., 2010; Mizrahi et al., 2021). Energy losses from feed to animal

products are an average diet, total heat production, faeces, methane, and urine (Morgavi et al., 2022). Figure 2.2 shown energy flows in ruminants and the rumen, respectively. The energy loss is defined in red, Sankey flows depict medium values of the average percentage of gross energy intake, and (k) is the coefficient of energy in Figure 2.3, respectively.

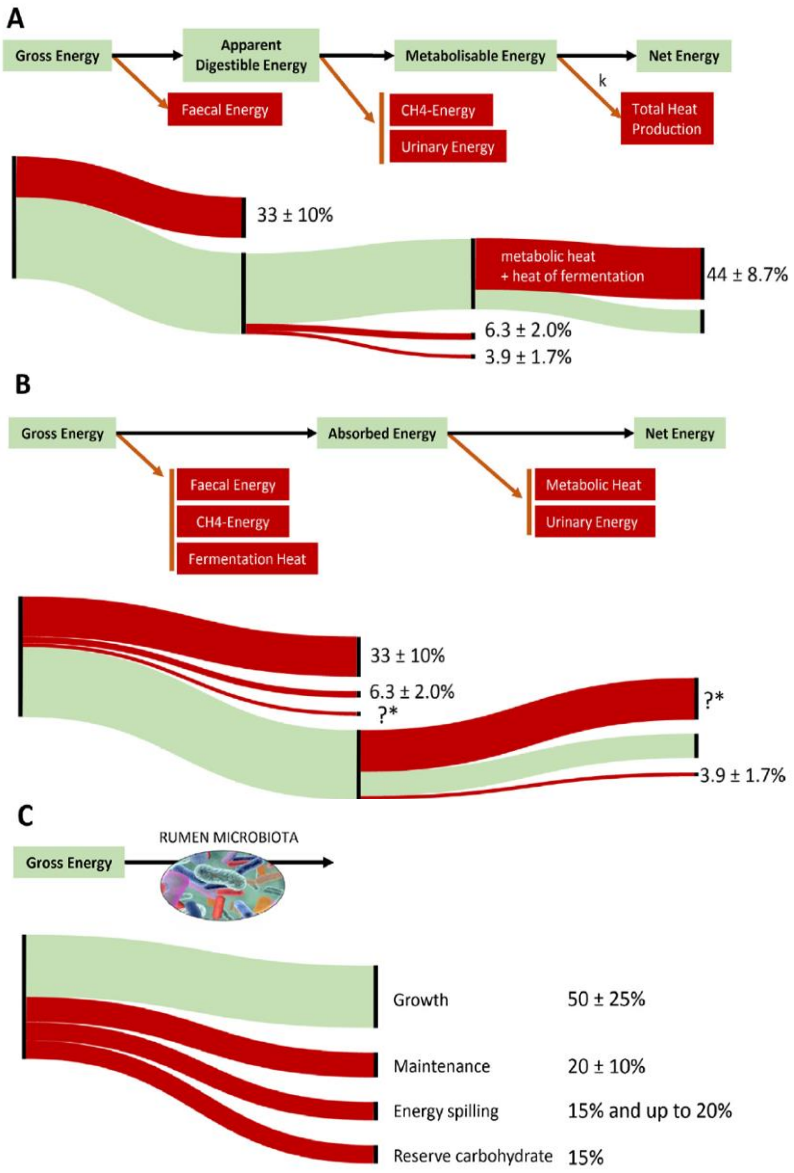


Figure 2.3 Energy flows in ruminants and in the rumen
Source: (A) Traditional approach (INRAE, 2018)
(B) Physiological approach (Ortigues-Marty et al., 2019)
(C) Microbial in the rumen (Hackmann & Firkins, 2015)

2.2 The world cassava production

In 2020 alone, the world's annual production of cassava roots was estimated at approximately 303 million metric tons (MT), of which 64% were produced in Africa, Asia contributed 27%, the United States of America 8.9%, and Oceania 0.1%. Nigeria alone is the world's biggest cassava investor, with 19.8% of all worldwide output, followed by the Democratic Republic of the Congo at 13.6%, Thailand at 9.6%, Ghana at 7.2%, Indonesia at 6.1%, Brazil at 6%, and Indonesia at 4.8%. China and Thailand invested in cassava production. Thus, Cambodia and Vietnam have been forced to increase propagation rapidly in the last decade, as shown in Figure 2.4 (Sowcharoensuk, 2023).

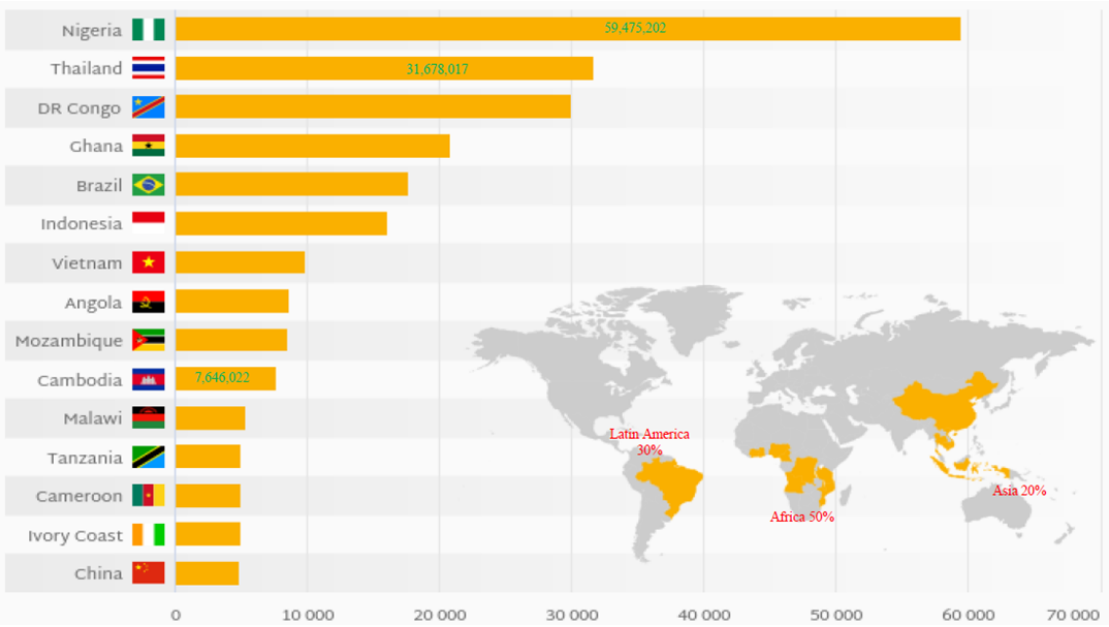


Figure 2.4 World cassava production (MT)

Source: Modified from Faostate (2020)

2.2.1 Characteristics of cassava root

Cassava is used mainly as a source of carbohydrates for human food and animal feed, and the most popular ruminant feed is made from cassava roots. Cassava chips are dried, shredded roots, usually produced from fresh, sun-dried roots for 2 to 3 days until the moisture content is reduced to 14% (Wanapat and Kang, 2015). Alternative feed sources for ruminant feeding are in constant demand because of the

high cost of cassava chips and competition with the human food and biofuel industries. Fresh cassava root (CR), which costs less than cassava chips, appeals to ruminant diets as a key energy source. Additionally, better soils can yield higher crop returns because cassava can be cultivated on subpar soils with high phosphorus fixation erosion, low exchangeable base content, and high aluminium content. (Morgan and Choct, 2016). Cassava root has a high hydrocyanic acid (HCN) level, responsible for chronic toxicity. Wanapat and Kang (2015) shown that fresh CR contains about 85–114 mg/kg HCN.

2.2.2 The utilization of cassava root and supply chain

Cassava roots have many benefits and are used for daily human and animal needs. Cassava root can produce cassava chips, cassava pellets, cassava dried, cassava powder or starch, and cassava end-user industries. In the end-user industries, cassava starch can produce amino acids and derivatives (monosodium glutamate, lysine for animal feed). Furthermore, cassava starch is a sweetener (glucose or dextrose: candies, beverages, etc.). Besides, modified cassava starch can be acetylated, crosslinked, oxidized, cationic, and alpha. In addition, end-user industries received cassava roots in the form of peel, pulp, and residue. That byproduct can be used as animal feed, compost, mushrooms, biogas, and electronics in the Figure 2.5. Also, cassava pulp and cassava wastewater can produce bioethanol by fermenting under the investigated conditions (Srimuang and Polprasert, 2019).

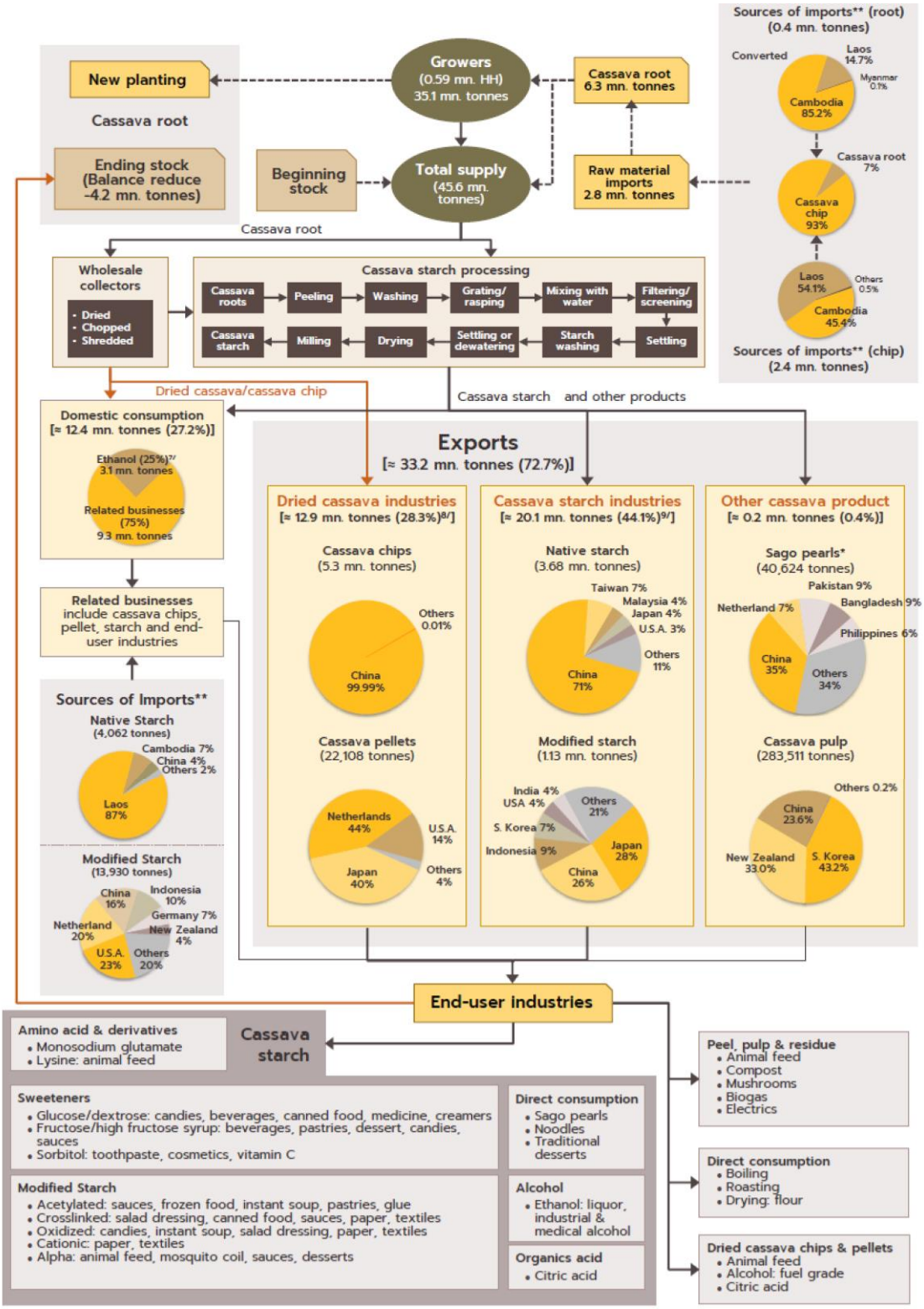


Figure 2.5 The utilization of cassava roots and supply chain

Source: Sowcharoensuk (2023)

2.2.3 Characteristics of cassava pulp

Cassava pulp contains approximately 68% starch (Dry basis) and 27% fiber (dry basis) (Sriroth et al., 2000). According to the Srinorakutara et al. (2004) report, cassava pulp's starch and fiber content ranged from 61.84 to 69.90%. Typically, cassava pulp contains high starch content (79.45%) and 21.36% amylose, which is produced by small-scale tapioca industries (Hermiati et al., 2012); in addition to starch, cassava pulp contains other carbohydrates (cellulose, galactan, xylan, shaman, arabinan, and mannan) (Kosugi et al., 2009; Hermiati et al., 2012) and starch particles trapped in the fibrous cell wall structure of the material, which consists of these carbohydrates in cassava pulp. Fresh cassava pulp contains 72–85% moisture (Pandey et al., 2000; Sriroth et al., 2000). Microorganisms work hard to degrade some materials within wet cassava pulp. High fiber and less protein are unsuitable in feedstuffs treated or mixed with increasing protein from other raw substrates. Nevertheless, it would be provided by the hydrolysis of starch, followed by sugar fermentation with less ash and fat content in cassava pulp. The sugars could be further used for different kinds of chemicals, such as citric acid (Prado et al., 2005), lactic acid (Thongchul et al., 2010), fumaric acid (Carta et al., 1999), glutamic acid (Jyothi et al., 2005), or xanthan gum (Wojciechowski et al., 2004), by fermentation processes using microorganisms. Panichnumsin et al. (2010), cassava pulp could be produced from cassava starch, which is very good for livestock feed at low prices in Tables 2.5 and 2.6. In addition, 1 ton of cassava root can produce about 12% of tapioca starch, processing flow is shown in Figure 2.6.

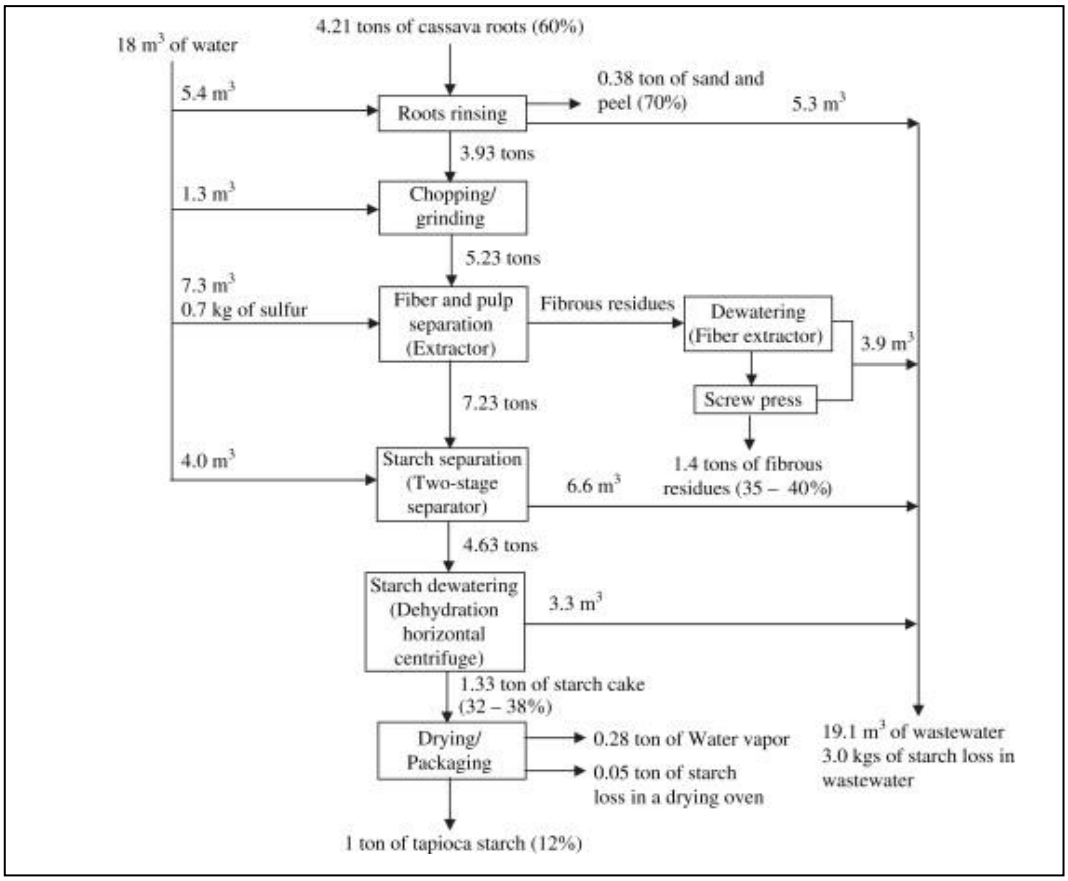


Figure 2.6 Diagram of cassava root processing for starch production

Source: Chavalparit and Ongwandee (2009)

Table 2.5 Cassava pulp composition in the percentage of dry matter

Components	Authors											
	[1]	**[2]**	**[3]**	**[4]**	**[5]**	**[6]**	**[7]**	**[8]**	**[9]**	**[10]**	**[11]**	**[12]**
Starch content	50.2	18.4	88.1	75.1	24.8	75.1	60.1	65.6	60.6	80.6	74.8	55.9
Total fiber	-	-	-	-	12.3	-	23	20.1	28.1	10.7	19.2	6.6
Cellulose	21.76	20.6	-	4.11	46.7	4.1	15.6	8.1	-	-	-	5.9
Hemicellulose	14.79	-	-	4.2	9.5	4.2	4.6	2.8	-	-	23.3	27.8
Lignin	1.44	4.08	-	1.15	5.2	1.2	2.8	2.2	2.2	-	-	3.9
Crude protein	-	2.17	1.95	-	2	-	-	3.1	2.5	2.5	1.12	2.6
Ether extract	-	0.43	-	-	0.1	-	-	0.2	-	0.5	2	0.2
Crude ash	1.87	2.3	-	11.9	7.4	11.9	-	5.7	-	1.7	2.7	3.8
Neutral detergent fiber	-	36	-	-	-	-	-	-	-	-	-	-
Acid detergent fiber	-	23.5	-	-	-	-	-	-	-	-	-	-
Gross energy	-	-	1.67	-	-	-	-	-	-	-	-	-
Fat	-	-	0.48	-	-	-	-	-	-	-	-	-
Crude fiber	-	-	10.4	-	-	-	-	-	-	-	-	-

[1] Tawida (2019); [2] Ornvimol et al. (2018); [3] Chauynarong et al. (2015); [4] Chompunuch et al. (2013); [5] Virunanon et al. (2013); [6] Lounglawan et al. (2011); [7] Rattanachomsri et al. (2009); [8] Djuma'ali et al. (2011); [9] Kosugi et al. (2009); [10] Chumpawadee and Soychuta (2009); [11] Aro et al. (2008); [12] Suksombat et al. (2007)

The chemical composition of cassava pulp computed by percentage found that starch contents were ranked between 18.4 and 88.1%, cellulose was 5.9 to 46.7%, and crude protein was 1.12 to 3.1%. (Suksombat et al., 2007; Aro et al., 2008 Kosugi et al., 2009; Chumpawadee and Soychuta, 2009; Rattanachomsri et al., 2009; Lounglawan et al., 2011; Djuma'ali et al., 2011; Virunanon et al., 2013; Chompunuch et al., 2013; Chauynarong et al., 2015; Ornvimol et al., 2018; Tawida and Supawadee, 2019).The compositional accumulation content of cassava depends on the specific tissue of roots

or leaves, and it also depends on several factors, including geographic location, variety, age of plant harvesting, and environmental conditions (Julie et al., 2009). Furthermore, the extracted methods from various industries are the main factor in maintaining the different starch contents. Less crude protein in cassava pulp should be more effective in providing it to ruminants. Protein content in cassava pulp was increased from 1.2-2.8% of DM to 12.1% DM by ensiled *Saccharomyces cerevisiae* (Khampa et al., 2009). Furthermore, ensiled *Aspergillus oryzae* and *Saccharomyces cerevisiae* in cassava pulp with 4% urea increased by 22.78 CP and were safe for ruminal animals (Wisitiporn et al., 2018). Cassava residue increased CP between 1.55 and 18.50% after ensiling with *A. niger* (Kompiang et al., 1995). Typically, Aro et al. (2008) found that 7% crude protein was increased by microbial fermentation (combination of fungi and bacteria) with additional biodegradation of anti-nutritional components of cassava residual, and some of the substance additives would increase a nutrient component of fermented cassava residual. Supplementation of molasses and Urea can improve ruminal fermentation efficiency and the average daily gain of crossbred native cattle (Khampa et al., 2011), and cassava pulp can be used in silage up to 40% DM (Lounglawan et al., 2011), but it should not be the main feeding diet for the ruminants. Separately, *Saccharomyces cerevisiae*, 2% Molasses, and 3% Urea in the crossbred native cattle fed with 2% body weight of fermented cassava pulp gained 0.5 kg of daily weight gain (Chuelong et al., 2011). *Saccharomyces cerevisiae* fermented cassava pulp and palm oil at 2% increased 633.10 g of average daily gain in crossbred native cattle (Sarunyu et al., 2011).

Table 2.6 Nutritional composition of dried cassava pulp and ensiled cassava pulp

Component	Dried cassava pulp	Fermented cassava pulp
Dry matter, %	93.22	95
True protein, %	1.98	13.25
Crude fiber, %	0.98	12.37
Ash, %	2.83	1.59
TME, kcal/kg	2763	2228
Cyanide, mg/kg	3.26	1
Amino acid, mg/100 g feedstuffs		
Alanine	24.91	84.32
Arginine	<5.00	<5.00
Aspartic acid	15.76	56.86
Cystine	<5.00	<5.00
Glutamic acid	98.09	234.3
Glycine	42.48	81.83
Histidine	58.99	178.53
Isoleucine	84.61	178.77
Leucine	106.32	227.56
Lysine	226.22	501.28
Methionine	<5.00	<5.00
Phenylalanine	118.19	239.6
Proline	25.4	53.39
Serine	<5.00	32.28
Threonine	<5.00	30.5
Tryptophan	6.76	19.54
Tyrosine	71.12	134.96
Valine	87.11	150.3

Source: Okrathok et al. (2018)

2.2.4 The utilization of cassava peels, characteristics and processing

The cassava peel contains 5–15% of cassava roots after tubers have been water-cleaned and peeled by machinery (Nwokoro et al., 2005a; Aro et al., 2010). This peel contains high levels of cyanide glycosides but more protein than any part of cassava tube plants (Tewe, 2004). The toxins in cassava peels can be removed by proper processing methods such as sun-drying, ensiling, fermentation, and soaking with sun-drying (Salami et al., 2003). The cyanide glycosides contained 0.86 g of cyanide equivalent/kg of dry matter, and they can be reduced to 0.1 g of cyanide equivalent/kg of dry matter at 48, 72, and 96 hours by drying or fermentation (Robert and Ignatious, 2002). Fresh cassava peels have three main deficiencies being spoiled, containing phytates, and containing large amounts of cyanogenic glycosides. Under-processed, cyanide glycosides declined and preserved nutritive quality (Salami et al., 2003; Oboh, 2006). Chopping peels to about 2cm for easy compaction and wilting for two days can reduce moisture content by 70–75%. Cassava peel silage can be light brown in color, firm in texture, and have a good smell. The pH was 4.4, and no fungal growth was observed under the beginning conditions (Asaolu, 1988). Roots are normally peeled to rid them of two outer coverings: a thin brown outer covering and a thicker leathery parenchymatous inner covering. So these are regarded as waste and are generally discarded and allowed to rot. Usually, hand peeling can constitute 20–30% of the total weight of the tuber (Ekundayo, 1980). Cassava peel fermentation from such heaps included foul odours and sometimes toxic and polluted air. Humans and animals inhaled polluted air from cassava products, which can cause infection and illness and can take a long time to manifest. Peels are potential crucial sources if properly harnessed (Obadina et al., 2006).

2.2.4.1 Utilization of cassava peels for animal

The quantity of cassava peels generated by processing is 351.60kg/T, which implies that 23% of the processed tubers constitute peels and, in turn, waste (Odediran et al., 2015), but as reported (Nwekeet al., 2002), peels contain 20–35% of the total weight of cassava tubers. So the peels are high among the waste generated from agricultural production. Fresh cassava peels were unaffected by milk yield production but contained a high level of hydrogen cyanide (HCN), which decreased dry matter intake (DMI) and diet digestibility due to disturbance in ruminant function

but was significant for growth rate performance in dairy cattle (Supreena et al., 2018). In addition, cassava peels are crucial indicators used in biogas and mushroom culture (Kortei, 2014; Agwu and Anyaeche, 2007). The dry matter of cassava peels resembled Ganiyu (2006) and Idugboe et al. (2018) with 92.1–94.3%, but Supreena et al. (2018), Aro et al. (2010), and Dongmeza et al. (2009) were similar with 24.71–28.2% of DM. The compositional accumulation content of cassava depends on the specific tissue of roots or leaves, and it also has several factors impacted, including geographic location, variety, age of plant harvesting, and environmental conditions (Julie et al., 2009). Furthermore, the extraction methods from various industries are the main factor in retaining the different starch contents. Thus, fresh cassava peels dried in a hot oven were 24.71%–28.2% of DM (Supreena et al., 2018; Aro et al., 2010), and moisture accumulated less than when already dried in a hot air oven, between 92.1%–94.4% of DM (Ganiyu, 2006; Idugboe et al., 2018).

2.2.5 Utilization of cassava pulps

2.2.5.1 Cassava pulp for animal consumptions

Cassava pulp is a by-product that constitutes approximately 30% of the original weight of roots (Chauynarong et al., 2009b). Cassava pulp, sun-dried, contains 10–13% of DM and is used for animal feed. The difference in nutrient quality of cassava pulps according to the number of indicators on the starch extraction method and cultivars (Bede, 2010). Cassava pulp contains approximately 68% starch (DM basis) and 27% fiber (DM basis) (Sriroth et al., 2000). Srinorakutara et al. (2004) found that cassava pulp's starch and fibre content ranged from 61.84 to 69.90%. Typically, cassava pulp contains a high starch content of 79.45% and 21.36% amylose produced by the small-scale tapioca industry (Hermiati et al., 2012). Cassava pulp contains cellulose, galactan, xylan, shaman, arabinan, and mannan, which are carbohydrates (Kosugi et al., 2009; Hermiati et al., 2012), and starch particles trapped in the fibrous cell wall structure of the material that consists of these carbohydrates in cassava pulp. Besides, fresh cassava pulp contained 72–85% moisture (Pandey et al., 2000; Sriroth et al., 2000). Microorganisms work hard to degrade some materials within wet cassava pulp. High fibre and fewer proteins are unsuitable in feedstuffs or mixed with increasing protein with other raw substrates. However it would be

provided by the hydrolysis of starch, followed by sugar fermentation with less ash and fat content in cassava pulp.

2.2.5.2 Advantages of cassava pulp to produce ethanol products

A dried cassava pulp weight of 870 kg can produce 437 litres of ethanol (Euis et al., 2012). Several kinds of cassava pulp can produce ethanol through physical, chemical, biological, or combinations of those processes. Sulphuric acid was most effective for hydrolysis, with maximum sugar reduction produced at 69.96% (Yoonan et al., 2004) and the yield of ethanol from sugar reduced by 47% (51% of the theoretical yields), or 0.23 g ethanol/g cassava pulp. Modig et al. (2002) reported that periods of acid hydrolysis did not support the growth of the fungus *R. oryzae* to ferment hydrolysate. Therefore, a concentration of furfural over 1.5g/L can inhibit the growth of S. cerevisiae, so it is affected by producing ethanol. Inhibitors can be removed by carbon activation after hydrolysis is completed or activated carbon during the hydrolysis of cassava pulp under microwave operation. The activated carbon added to a 1 g/20 mL suspension of cassava pulp in water and heated by microwave at 210 °C for 15 minutes revealed a result of 52.27% glucose yield with only 46.25 mg/100g hydroxymethyl furfural (Hermiati et al., 2012).

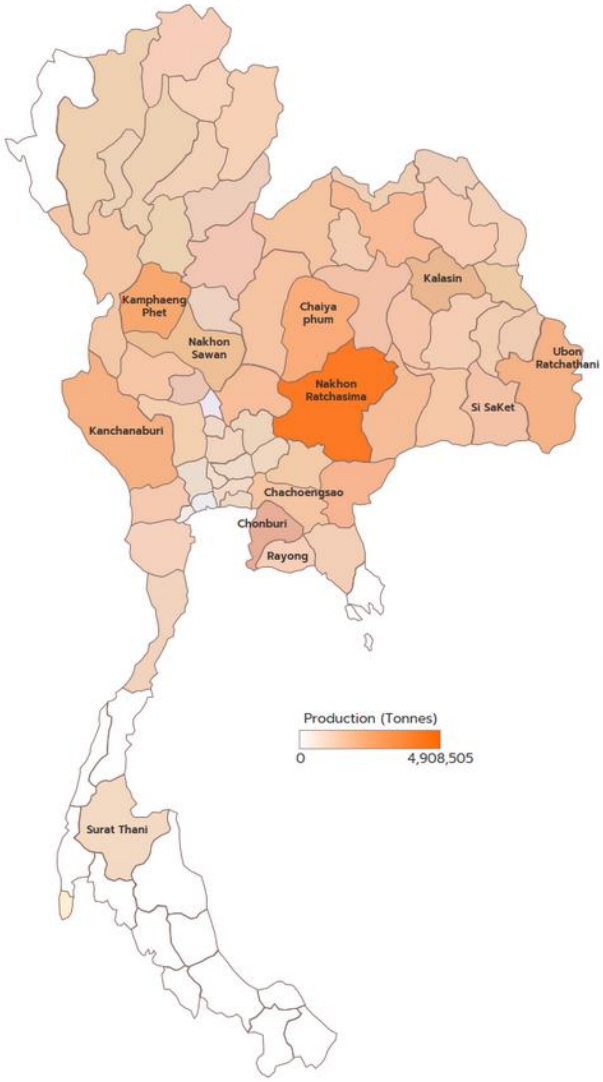
2.2.5.3 Chemical characteristics of cassava waste and processing

Cassava starch wastes (wastewater and solid waste) contain 9.6-37.5 g/L of total carbohydrates and 2.3% CP. In addition, it is a weakly acidic liquid, nitrogen, and phosphorus. Also, cassava bagasse, a typical solid residue of cassava processing, contains between 40.1% and 75.1% starch by dry weight and between 14.9% and 50.6% fibre (Zhang et al., 2016). Cassava waste making for bio-energy processing has been categorized into two majors 1) Thermochemical reactions, including pyrolysis, gasification, and combustion, and 2) biochemical procedures, including fermentation of bioethanol and anaerobic digestion. The transformation concept, typically cassava waste**,** would follow green processing to contribute to technological innovation development. Thermal processes convert the wastes directly into heat energy while thermo-chemical and biochemical processes first convert the wastes into secondary energy such as syngas, torrefied pellets, biogas, bio-ethanol and bio-oil that it can subsequently be burnt to produce energy in the form of heat and electricity (Gumisiriza et al., 2017). For every million tons of fresh cassava root

processed, there is an increase in liquid waste of 8.85 to 10.62 million tons, or around 1% of the total solids: 150–200 kg of cassava flour, 550–200 kg of peel, fibrous material, 180–200 kg of starch, and 680 kg of waste (Zhang et al., 2016).

2.2.6 Cassava top production

Cassava foliage produced approximately 10 tons of dry matter annually per hectare with high protein, ranging between 16.6-34.8% reported (Ayodeji, 2005), 34.3–36.3% elucidated by Castellanos et al. (1994), and reported by Wanapat (2009). Cassava tops collected at 3–4 months intervals contain 3.6–12.6 t/ha of cassava leaves. According to Vicharn (1979), harvested cassava leaves without petioles at eight months old obtained between 1.92 and 5.78 tons of DM, but Kittivorawate (1996) also reported that the dry leaf yield at the same period was approximately 2 t/ha. Separately, harvested in 12 months, we get between 2.9 and 7.7 t/ha of DM (Wanapat, 1997). According to Sowcharoensuk (2023), over the past two decades, the total area was planted with cassava: 1.66 million hectares of Thai farm and was harvested with cassava, yielding roughly 35.1 million tones of raw product. Cassava cultivation is clustered most heavily in Nakhon Ratchasima at 14.1% of all Thai cassava harvested area), followed by Kamphaeng Phet at7.3%, Kanchanaburi at 5.8%, and Chaiyaphum at 5.5%. As of 2022, Thailand was also home to 1,205 cassava processing facilities, but these are generally located close to cassava-producing areas for convenience and to save on transportation costs. So with 162 plants, Nakhon Ratchasima has the highest concentration of all of Thailand’s provinces, followed by Kamphaeng Phet (151), Nakhon Sawan (88), and Chaiyaphum (59). Thai players have also cited facilities in positions that allow them easy access to imports from neighboring countries, especially Lao PDR, Cambodia, and Myanmar. However, to ensure secure supplies of inputs, they have established basic processing facilities in these countries. Thus, there are 76 cassava plants in Ubon Ratchathani, 62 in Kanchanaburi, and 33 in Sri Saket, while to make exports more convenient, there are a further 26 facilities in Chonburi, 14 in Rayong, and 14 in Chachoengsao, these locations having the advantage of ready access to major ports Figure 2.7.



5 provinces with the largest cassava production

	Province	Production (Tonnes)	Cassava Pellet, Cassava Chip	Starch Factory
1.	Nakhon Ratchasima	4,908,505	131	31
2.	Kamphaeng Phet	2,536,527	141	10
3.	Kanchanaburi	2,011,705	59	3
4.	Chaiyaphum	1,920,715	54	5
5.	Ubon Ratchathani	1,818,897	73	3

5 provinces with the largest number of cassava processors

	Province	Starch Factory	Cassava Pellet, Cassava Chip	Production (Tonnes)
1.	Nakhon Ratchasima	31	131	4,908,505
2.	Chonburi	11	15	606,153
3.	Kamphaeng Phet	10	141	2,536,527
4.	Kalasin	10	20	1,039,972
5.	Rayong	8	6	149,952

Figure 2.7 The cassava production and processing facilities of Thailand

Source: Sowcharoensuk (2023)

2.2.6.1 Toxicity contents accumulation and distribution in cassava leaves

Cassava leaves cause hydrogen cyanide formation. Cassava contains double cyanogenic glucosides, linamarin, and lotaustralin in Figure 2.8. It is synthesized with the amino acids valine and isoleucine as their respective predecessors (Bokanga, 1994). Cyanogenic glucosides in cassava are biosynthesized in leaves, translocate, and accumulate in plant tissues in varying amounts (Koch et al., 1992). The cells are intact; cyanogenic glucosides cannot be broken down. Therefore, either by animal chewing or technical processing, enzymes and cyanogenic glucosides

initiate contact, resulting in the formation of HCN. At pH above 5, hydroxy nitrile spontaneously breaks down into a ketone compound and HCN (Bokanga, 1994). Therefore, at pH values lower than 5, an α-hydroxy nitrile lyase directly catalyzes the dissociated reaction into a ketone compound and HCN. The hydrolysis of linamarin and lotaustralin leads to sugar and α-hydroxy nitrile formation. Cassava leaves, including petioles, generally contain a premium concentration of cyanogenic glucosides, which is probably 5 to 20 times higher than the concentration of cyanogenic glucosides in the root, and they are mostly stored inside the vacuole cells (Bokanga, 1994). All cassava tissue accumulates cyanogenic glucosides (linamarin 95% and lotaustralin 5%) (Nartey, 1968). Leave, stem, and root cortex contain linamarin (>400 mg/kg HCN eq.) more than parenchyma root (<100 mg/kg). Cyanide in cassava leaves decreases; it contains 50% compared to 70% in young leaves (Nambisan & Sundaresan, 1994). Bitter cassava had a cyanogenic glucoside content ranging from 320–1,100 μg/g (Sinha & Nair, 1968).

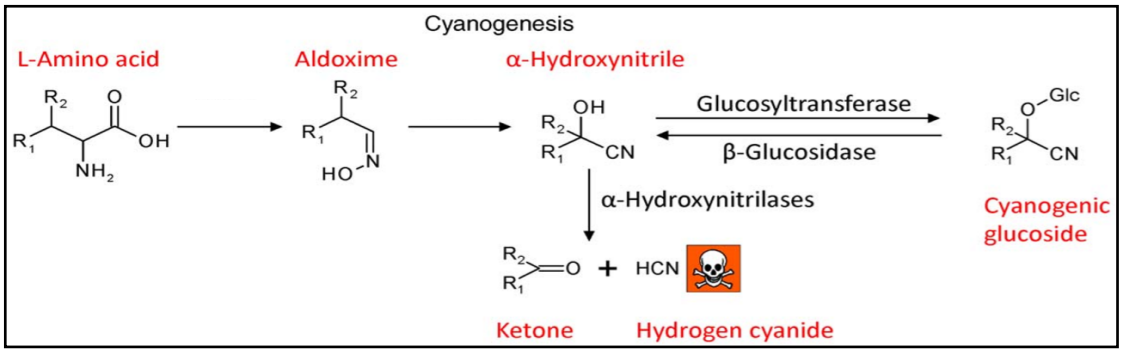


Figure 2.8 Linamarin cyanogenesis

Source: Birger (2020)

2.2.6.2 Metabolism of cyanoglucosides in cassava plant

The primary amino acids for the biosynthesis of linamarin and lotaustralin are valine and isoleucine, and the basic pathway involves the sequential changing of the amino acids to the N-hydroxy amino acid, oxime, and hydroxy nitrile by a multienzyme complex in the microsomes. The following biochemical and physiological processes would affect the accumulation of cyanoglucosides in cassava: 1) biosynthesis of linamarin, 2) catabolism and turnover, and 3) transport of linamarin from leaves to roots shown in Figure 2.9. The cultivar variation reflects the

effectiveness of these processes' linamarin levels (Nartey, 1969). All plants contain β-Cyanoalanine synthase activity. When cyanide metabolism in cassava has not been broadly analyzed, it has been shown that all tissues can metabolize cyanide. Generally, this is based on the observation that all tissues have high levels of β-cyanoaline synthase activity, incorporate free cyanide into C4 compounds (assumably by β-cyanoaline synthase), and have rhodanese activity that catalyzes the formation of thiocyanate from CN- and S2O32- (Blumenthal et al., 1968). As noted, linamarin is synthesized and accumulates in the vacuole. Following a cell break, the linamarin is converted to cyanide by the linamarase and hydroxynitrile lyase (HNL) in the cell wall. Cyanide translocates and tissue-specific differences in cyanide metabolism are not sufficiently characterized to model cyanogen metabolism at whole plant levels. In addition, using HCN over 5–35 mg for 10kg of live body weight poisons animals and makes them seriously vulnerable or die in Table 2.7.

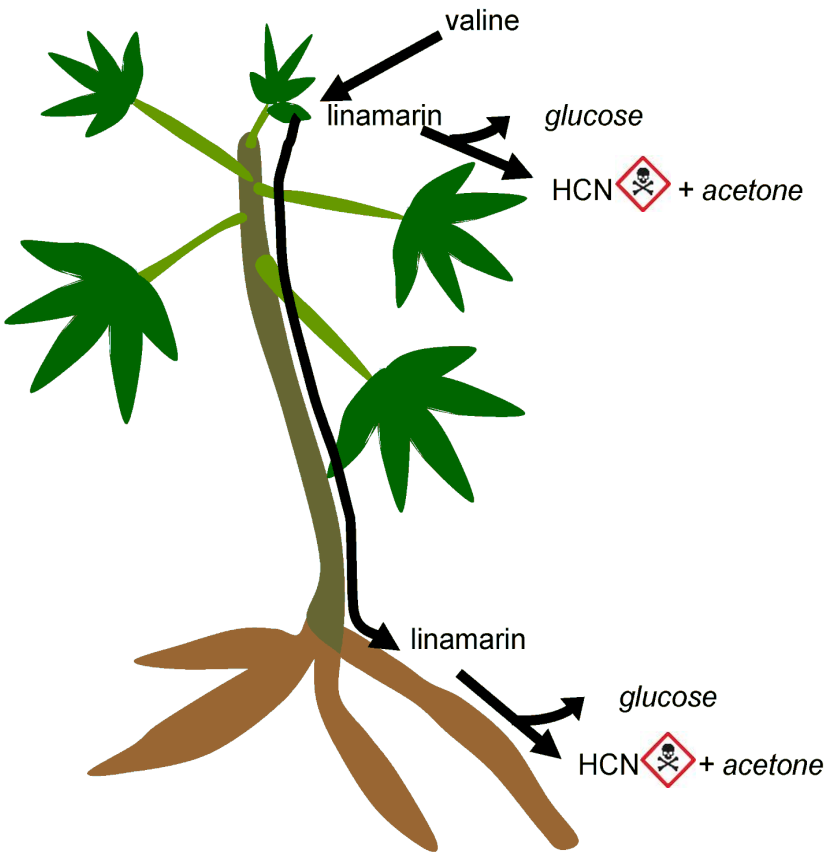


Figure 2.9 Cyanogenesis in cassava

Table 2.7 The CHN range of doses impacts animal life

Body weight (kg)	Lethal dose ranging	Lethal amount of cassava product (kg)	
	HCH (mg)	10 ppm HCN	40 ppm HCH
10	5-35	0.5-3.5	0.13-0.88
20	10-70	1-7	0.25-1.75
40	20-140	2-14	0.50-3.50
60	30-210	3-21	0.75-5.25
80	40-280	4-28	1.00-7.00
100	50-350	5-35	1.25-8.75

Source: Anna et al. (2012)

2.2.6.3 Utilization of cassava leaves

Cassava tops collected at 3–4 month intervals contain 12.6 T in the hay of cassava leaves. It would be produced as a by-product at root harvest (Ravindran & Rajangru, 1988); moreover, it can be used as animal feed in tropical areas. Cassava leaves are a valuable source of vitamins B1, B2, C, and carotenes. Moreover, the amino acid concentration almost resembles that of alfalfa (Ravindran, 1991) and ME, about 1,590 kcal/kg (Khajarern & Khajarern, 2007) to 1,800 kcal/kg (Ravindran, 1991). Cassava leaves contain the antinutrient hydrocyanic acid (HCN), low digestible energy, and high tannin and phytic content (Ravindran et al., 1986). Furthermore, in monogastric animals, leaves could be processed as a meal. Generally, cassava leaves contain a lot of HCN, which is toxic to animals, but this toxicity would be reduced by using conventional techniques such as sun-drying, oven, fermentation, etc. After wilting or another mechanical process, cassava leaves provide huge animal benefits.

2.2.6.4 Fresh cassava leaves and fermentation

The nutritional cassava residual has different level contents, crude protein in fresh cassava foliage 221.0-226.7 g/kg and leaves fermentation 207.6-215.5 g/kg (Oni et al., 2014; Mao et al., 2019) in Table 2.8. The crude protein in fermented cassava leaves was less than in fresh cassava leaves, but fermented cassava leaves can reduce the maximum amount of cyanide glucoside.

Table 2.8 Chemical composition between fresh and fermented cassava leaf

Parameters	Mao et al. (2019)		Oni et al. (2014)	
	Fresh cassava foliage (g/kg)	Cassava foliage silage (g/kg)	Fresh cassava foliage(g/kg)	Cassava leaf fermentation (g/kg)
DM	248	325.2	218.7	252.4
CP	226.7	215.5	221	207.6
OM	920	913.9	937.5	921.2
EE	57.3	68.8	98.8	118.7
Ash	-	-	62.5	78.8
NFE	-	-	472	411
NDF	411.9	413.9	622.5	561.4
ADF	338.8	304.8	414	413.7
ADL	-	-	25.1	26.1
Cellulose	-	-	387.9	388.6
Hemicellulose	-	-	208.5	147.7
Tannin	-	-	32	12.8
HCN(mg/kg)	-	-	112.3	95.8
ME (MJkg DM)	-	-	12.73	12.76
pH	-	-	3.66	-
NH3-N, %	-	-	8.81	-
TVFA, %	-	-	7.54	-
C2, %	-	-	4.16	-
C3, %	-	-	0.46	-
C4, %	-	-	0.18	-

CHAPTER 3
EXPERIMENTAL

The study was conducted at the Experimental Field and Central Laboratory (15°07'55.8"N, 104°55'48.2" E), Faculty of Agriculture, Ubon Ratchathani University, Thailand. The main investigation in the study was focused on the growth performance of Thai native x Lowline Angus crossbred cattle fed fresh and dried cassava top and fermented cassava pulp for ruminant feed. Three experiments were done to ensure the specific outcome of feedstuff: 1) The *in vitro* method was conducted to understand the effect of altered fresh and dried cassava top fermented cassava pulp levels; 2) To screen the specific levels of experiment 1 to apply *in vivo* to investigate the effect on feed efficiency, nutrient intake, rumen fermentation, and rumen microbial population; and 3) The last experiment screened from experiment 2 to ensure the effects on growth performance, feed efficiency, nutrient intake, rumen fermentation, and rumen microbial population.

3.1 Experiment I Gas kinetics, rumen characteristics, and *in vitro* degradability of varied levels of dried and fresh cassava top fermented cassava pulp

3.1.1 Materials and methods

3.1.1.1 Preparation of cassava top (CT)

The fresh cassava top or cassava top combines the leaf, petiole, and greening stem approximately 20-30 cm or reaches the greening part of stem in length from the leaf bud. The cassava top (*Manihot esculenta* Kasetsart 50) was purchased from a local producer in Ban Hare, Tambon Kham Kwang, Warin Chamrap District, Ubon Ratchathani Province, Thailand. The cassava top was collected at six months at most. The FCT was chopped into 2 cm long pieces using a magnum electric motor (type mL-90S2-2, model: gs150, matched power of 3hp, rotation speed: 2800 rpm, production efficiency ≥1000kg/hr). The copped FCT was divided into two parts. The first part was fresh to fermented CS, and the second part was dried to fermented CS at different levels. Dried cassava top (DCT) were sun-dried within three days at ambient temperature in the dry season.

3.1.1.2 Experimental design and treatments

Dietary treatments were administered using a completely randomized design (CRD) with eight treatments and three replicate runs. Each treatment was balanced with 12% crude protein (CP). The ingredients of concentrate to provide the donor cattle for fluid collection was shown in Table 3.1. In addition the dietary treaments were administered with eight treatments as follows: Therefore, eight treatments were as follows: 1) CS fermented with no additive (nA), 2) CS fermented with additives (*S. cerevisiae*, urea, molasses, and sugar) (CSA), 3) 95% CSA fermented with 5% DCT (5DCT), 4) 90% CSA fermented with 10% DCT (10DCT), 5) 85% CSA fermented with 15% DCT (15DCT), 6) 95% CSA fermented with 5% FCT (5FCT), 7) 90% CSA fermented with 10% FCT (10FCT), 8) 85% CSA fermented with 15% FCT (15FCT).

Table 3.1 The ingredients of concentrate for donor cattle

Items	Concentrate
Ingredients, g/kg DM	
Cassava chip	410
Soybean meal	138
Palm kernel meal	90
Corn meal	135
Rice brand	132
Urea	20
Molasses	50
Salt	5
Sulfur	10
Monodicalcium phosphate (P ≥ 21%, Ca ≥ 14%)	5
Mineral premix	5

3.1.1.3 Additives sources and CS fermentation

The active dry yeast (*Saccharomyces cerevisiae*), strain CNCM-1077, Levucell SC20 (r) SC, and its ingredient, 10^{10} CFU/g, urea, molasses, and sugar were purchased from a local market in Ubon Ratchathani Province, Thailand. At the same time, CS was bought at Aiemsiri Cassava Starch Powder in the Kantralak district of the province of Sisaket, Thailand. Different treatments added yeast, urea, and molasses to the CS fermentation. Before adding yeast, urea, and sugar, 20 g of yeast was stimulated aerobically with oxygen flushed and 40 g of sugar in 660 mL of tap water for 30 minutes (Solution A). As much as 50 mL of molasses and 4.11 g of urea were used for additive treatments, and 3.76 g, 3.41 g, and 3.07 g of urea were used in 5%, 10%, and 15% DCT. As much as 3.76 g, 3.41 g, and 3.07 g of urea were used in 5%, 10%, and 15% FCT in 830 mL of tap water and mixed well (Solution B). Urea was mixed into solutions A and B one by one. Solution C was a mix of A+B at a 1:1 ratio (v/v) and flushed with air for 1 h (Adopted from Polyrach et al., 2014). After incubation, the yeast solution was applied to CS containing FCT and DCT. The FCT and DCT fermented CS and the product were allowed to ferment for 21 days and then sampled for chemical composition analysis, followed by oven-drying at 60 ^{o}C for 72 hours to less than 10% moisture. All substrates were used for an *in vitro* test on the gas production kinetics.

3.1.1.4 Sampling and chemical composition analysis

All samples were dried in a hot air oven at 60 ^{o}C for 72 hours for chemical composition analysis, ground using a Cyclotec 1093 sample mill, and passed through a 1-mm screen (Tecator, Hoganas, Sweden). The ground samples were divided into two parts: one for analyzing DM, ash, and CP, and one for ether extract (EE), according to AOAC (1997). The method of Van Soest et al. (1991) was used for analyzing neutral detergent fiber (NDF) and acid detergent fiber (ADF).

3.1.1.5 Donors of ruminal fluid and substrates of inoculum

Using a stomach tube with a vacuum pump, 2,600 mL of ruminant fluid was taken from five of 75% Holstein-Friesian crossbred dairy steers with 150±20 kg body weight (BW) and an age of 1 year before morning feeding. Homemade feed containing 12% CP was fed to the animals at 1% BW twice daily at 7:30 am and 4:00 pm. Rice straw and water were provided *ad libitum*, and the cattle were separately

housed. According to the Menke & Steingass (1988) method, artificial saliva was introduced after rumen fluid was filtered through four cheesecloth layers and placed in pre-warmed thermos flasks. Feedstuff samples were milled and passed through a 1.0 mm sieve, and an amount of about 200 mg was placed into 60 mL serum bottles. The bottles contained artificial saliva and rumen fluid at a 2:1 ratio. They were pre-warmed in a water bath at 39 °C and flushed with CO2 to make them strictly anaerobic. Rumen liquor (35 mL) was added to the serum bottles using 18 a gauge, 1.5-inch needle. The bottles were then sealed with butyl rubber and metal caps and incubated at 39 °C for further measurement. The gas production kinetics were evaluated using 3 serum bottles per group (8 groups + 3 serum bottles of blanks). All serum bottles for the experiments were shaken every 3 hours during incubation. Rumen liquor was added to the blank bottles without any substrates, and accumulated gas production was calculated by subtracting the gas yield from the average value in the experimental bottles. A 50 mL precision hypodemic glass syringe (U4520, Becton, Dickinson and Company, Franklin Lakes, NJ, USA) and an 18-gauge injection needle were used to measure gas yield production.

3.1.1.6 Fermentation parameters and degradability

As much as 12 mL fluid inoculum samples were collected after 12 and 24 hours of incubation and kept in plastic bottles containing 2 mL of 1 M sulfuric acid at -20 °C. The fluid inoculum was thawed and centrifuged at 16,000x g for 15 min to obtain the supernatant and to measure the pH using a pH meter (HI 8424 microcomputer; Hanna Instruments; Singapore) according to the AOAC (1997). To count the protozoal population, 1 mL inoculum fluid samples were taken, placed in 9 mL of 10% formalin, and stored in a refrigerator. The protozoal population was counted on a hemocytometer under a microscope, according to Galyean (1989). After all samples were taken, they were removed from a hot air oven and frozen at -20 ^{o}C to analyze DM, ash, organic matter (OM), and degradability. Before analysis, a sample from each bottle was filtered through a pre-weighed Gooch crucible and oven-dried at 105 ^{o}C for 24 hours. After drying, the Gooch crucibles were weighed and used to calculate the DM degradability by adjusting to the blank. After measuring DM degradability, the same Gooch crucibles were ashed at 550 ^{o}C for 5 hours, weighed, and used to calculate the OM degradability, according to Tilley & Terry (1963).

3.1.1.7 Fermentation characteristics and *in vitro* gas production

According to Menke & Steingass (1988), the amount of gas produced was measured at 1 h, 2 h, 3 h, 4 h, 6 h, 8 h, 12 h, 18 h, 24 h, 48 h, 60 h, and 84 h of incubation. Cumulative gas production data were fitted to the model of Ørskov & McDonald (1979): $y = a + b\ (1 - e^{-ct})$. Where *a* was the gas production from the immediately soluble fraction, *b* was the gas production from the insoluble fraction, *c* was the gas production rate constant for the insoluble fraction *(b), t* was the incubation time, *p(a+b)* was the potential extent of gas production, and *y* was the gas produced at a time *"t"*. At 12 h, 24 h, and 84 h post-inoculation, samples were taken to determine the *in vitro* digestibility, referring to Van Soest & Robertson (1985). True digestibility (TD) = ((DM feed taken of incubation- residues of NDF) x 100))/DM feed taken of incubation.

3.1.1.8 Statistical analysis

All data were analyzed using a one-way ANOVA in a completely randomized design (CRD) in the Statistical Package for the Social Sciences (SPSS, version 21.0 Chicago, USA). Treatment means were compared using the Duncan's Multiple Range Test (DMRT). For the *in vitro* data, Pearson correlation coefficients (r) were used in two sets of observations (12 h vs 24 h) tested in two runs with rumen liquid to evaluate DM disappearance, ruminant fermentation, and microbial population in eight different groups with and without additives. The effects were considered significant at $p<0.05$, and trends/tendencies at $0.05<P<0.10$.

3.2 Experiment II Thai native x Lowline Angus crossbred cattle on feed intake, feed digestibility, rumen microorganisms, and fermentation: Effects of using cassava products to replace concentrate

3.2.1 Materials and methods

3.2.1.1 Animal feedstuffs preparation

The fresh cassava top or cassava top combines the leaf, petiole, and greening stem approximately 20-30 cm or reaches the greening part of stem in length from the leaf bud. The cassava tops (*Manihot esculenta* Kasetsart 50) were purchased from a local producer in Ban Hare, Tambon Kham Kwang, Warin Chamrap District, Ubon Ratchathani Province, Thailand. The fresh cassava tops were chopped into 2 cm long pieces using a Magnum Electric Motor (Type ml-90S2-2, Model: GS150, matched power of 3 HP, rotation speed: 2800 rpm, production efficiency ≥1000 kg/hr). Fresh cassava tops were sun-dried within three days at an ambient temperature in the dry season. Dried cassava top (DCT) was replaced with dried cassava pulp (DCS) at a ratio of 15:85 (g/g) on a dry matter basis, fermented for 21 days, and used with a 100 mL volume plastic tank. The active dry yeast (*Saccharomyces cerevisiae*), strain CNCM-1077, Levucell SC20 (r) SC, and its ingredient, 10^{10} CFU/g, were purchased from a local market in Ubon Ratchathani Province. Before the fermentation procedure, 20 g of *saccharomyces cerevisiae* was stimulated aerobically with an oxygen flush and 40 g of sugar in 660 ml of tap water for 30 minutes (Solution A). 50 mL of molasses and 3 g of urea were used in 830 mL of tap water, mixed well (Solution B). Solution C was a mixture of A and B at a 1:1 ratio (v/v) and flushed with air for 1 h. In addition, solution C was treated with dried cassava top fermented cassava pulp at a 1:1 ratio (v/w) (Polyorach et al., 2014; Morm et al., 2023).

Table 3.2 The ingredients of concentrate and dried cassava top fermented cassava pulp (CtFCp)

Items	Concentrate	CtFCp
Ingredients, g/kg DM		
Cassava pulp	-	764
Dry cassava leaves	-	150
Cassava chip	410	-
Soybean meal	140	-
Palm kernel meal	90	-
Corn meal	135	-
S. cervisiae	-	2
Rice brand	130	-
Urea	20	30
Molasses	50	50
Sugar	-	4
Salt	5	-
Sulfur	10	-
Monodicalcium phosphate (P ≥ 21%, Ca ≥ 14%)	5	-
Mineral premix	5	-

3.2.1.2 Animal experimental design

The study was conducted at the Experimental Field and Central Laboratory (15°07'55.8"N 104°55'48.2" E), Faculty of Agriculture, Ubon Ratchathani University, Thailand. All the experimental animals have been carefully maintained to minimize errors originating from humans, animals, or environmental conditions. Twelve females of Thai native x Lowline Angus crossbred cattle were designated at 97±18.10 kg of initial body weight (IBW) and an average at 14 months of age. The experiment was conducted in a completely randomized design with three treatments and four replications, and one head represented each replication. The treatments consisted of dried cassava top fermented cassava pulp (CtFCp) as a

replacement in 67% and 33% concentrations. The dietary treatments were as follows: 100% concentrate (Control; CON), 67% concentrate + 33% dried cassava top fermented cassava pulp (CtFCp-33), and 33% concentrate + 67% dried cassava top fermented cassava pulp (CtFCp-67) as a dry matter basis (DM). The concentrate or CtFCp are presented in Table 3.2.

3.2.1.3 Animal experimental dietary arrangement

The concentrate and CtFCp mixture were thoroughly mixed by an SM-3.0CR, 3HP, Hz 50, VOLTS 220, AMPS 20.0, r/min 1450, and JIS C 4004 JP 22 JC machine, mixed monthly, and kept in plastic tanks in 100-liter dimensions and placed in the dry zone for use in this study. The mixture had 1% dry matter (DM) of body weight (BW) added twice daily at 7:00 a.m. and 4:00 p.m. The mineral salt block and clean water were offered *ad libitum* to all cows. The cows were fed rice straw (RS) *ad libitum* daily, with 100g kg^{-1} refusal of the total RS offered. RS and feeds were supplied simultaneously, although they were divided into two halves using buckets measuring 40 cm x 60 cm, RS feeding stock and 30 cm x 40 cm for feeding. The cows were placed in individual pens (2.5 x 4 m) equipped with iron walls and a concrete floor. One week before the trial, the cows were given Ivermectin at 1% w/v, 1 mL/50 kg BW, and Vitamin AD3E at 1 mL/50 kg BW.

3.2.1.4 Feed intake

The cows were pre-adapted in their pens for ten days to make them familiar with their environment, feed provider, flavor, and palatability before the experiment started. The experiment lasted for 21 days, with 14 days assigned to treatment adaption and feed intake assessment and the last 7 days for sample collection. Cows were weighed at the beginning of the experiment to adjust dry matter feed intake (DMI). Before morning feeding, daily notes were collected to track the amount of feed consumed and feed refused.

3.2.1.5 Sample collection procedures

The animal diets were separately provided by RS, concentrate, and concentrate with CtFCp. During the last 7 days of the 21-day experiment, feed offered and refused, including RS, concentrate, and concentrate with CtFCp mixed, was recorded daily, while each sample was taken weekly and dried in a hot air oven at 70 °C and kept in dried form prior to chemical analysis. During the last 7 days, feces were

collected from individual rectums daily at 7:00 a.m. before being supplied feed. The feces were mixed and stored at -20 °C prior to their chemical composition analysis. On the last day of the experiment, rumen fluid and blood samples were collected at 0 and 4 h post-feeding. The rumen fluid was collected in amounts of approximately 100 mL using a stomach tube attached to a vacuum pump. The pH of a rumen fluid sample was measured immediately by using a glass electrode pH meter (HANNA instrument (HI) 8424 microcomputer, Singapore). A four-layer cheesecloth was used to filter rumen fluid; 1 M of sulfuric acid (H2SO4) was used at a 1:9 ratio, and it was kept at -200C until it was chemically analyzed. Another 1 mL of rumen fluid was taken, placed in 9 mL of 10% formalin, and stored in a refrigerator to count the protozoal and fungal zoospore numbers by using a hemocytometer under a microscope (Galyean, 2010).

3.2.1.6 Chemical composition analysis

The frozen feces samples were defrosted and oven-dried at 60 °C for 72 hours to ascertain their chemical composition. Those samples were ground through a 0.5 mm screen (Tecator, Hoganas, Sweden) and analyzed on DM, ash, and crude protein (CP) (AOAC, 1990) with a neutral detergent fiber (NDF) and acid detergent fiber (ADF) (Van Soest et al., 1991). To estimate the apparent digestibility, acid insoluble ash (AIA) was used as an indicator (Keulen and Young, 1997). The rumen fluid was centrifuged at 3,500 x rpm for 15 minutes; the supernatant was used to analyze volatile fatty acid (VFA). A 0.22-μm millipore filter was used to filter the supernatant before injecting it into the chromatographic apparatus. H2SO4 (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 x 250 mm) column (Choromeleon Dionex Corp), with UV-Vis detection at 210 nm (De Sá et al., 2011). The methane (CH4) was estimated by using VFA as an indicator according to (Moss et al., 2000). The CH4 predicted was CH4 = (0.45 x acetic acid) - (0.275 x propionic acid) + (0.40 x butyric acid). Another 1 mL of rumen fluid was taken, placed in 9 mL of 10% formalin, and stored in a refrigerator to count the protozoal and fungal zoospore numbers by using a hemocytometer under a microscope (Galyean, 2010). A total of 10 mL of blood samples were collected from the jugular vein; 4 mL were kept in a test tube containing a sodium fluoride/ EDTA tube for glucose analysis, and each 4 mL was kept in a test tube containing a serum clot activator tube for blood urea

nitrogen (BUN), creatinine, total protein, and triglyceride analysis and were sent to the U Wellness Center Co. Ltd.,Thailand. BUN uses the urease 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-Gutierrez et al., 1995; Küme et al., 2018; Zhang et al., 2022). Metabolizable energy (ME) was calculated according to an equation described by earlier research (Robinson et al., 2004). Digestible organic matter fermented in the rumen (DOMR) was calculated according to the equation earlier (Li, Esser, et al., 2019) as follows: DOMR (kg/d)=digestible organic matter intake (DOMI), kg/d) x 0.65, where DOMI=[digestibility of organic matter (kg/kg DM) x organic matter intake (kg/d)]/100, 1kg DOMI=15.9 MJ, ME/kg. MCP (Microbial crude protein), kg/d=0.00825 x ME intake(MJ/d) (Galyean, 2010).

3.2.1.7 Statical analysis

The results were analyzed using a one-way ANOVA in a completely randomized design (CRD) in the Statistical Package for the Social Sciences (SPSS, version 21.0, Chicago, USA) concerned with the management and feeding of animals. A single collection of samples for the chemical composition analysis of the diet precluded statistical comparison. The effects were considered significant at $P<0.05$, and trends or tendencies at $0.05<P<0.10$. Repeated-measure analysis was employed for assessing a couple of weeks of feed intake and the last seven days for nutrient intake, digestibility of nutrients, and rumen fermentation of the Thai native x Lowline Angus crossbred cattle in different groups. The dietary treatment means of CON, CtFCp-33, and CtFCp-67 were compared using the Duncan’s Multiple Range Test (DMRT). All the means were described by the standard error of the mean (means±s.e.m). The general linear model procedure was tested for normal distribution using the UNIVARIATE to all data.

3.3 Experiment III Effects of using dried cassava top fermented cassava pulp on ruminal parameters, blood metabolites, and growth performance of Thai native x Lowline Angus crossbred cattle

3.3.1 Materials and methods

3.3.1.1 Animal feedstuffs preparation

The fresh cassava top or cassava top combines the leaf, petiole, and greening stem approximately 20-30 cm or reaches the greening part of stem in length from the leaf bud. The cassava tops (*Manihot esculenta* Kasetsart 50) were purchased from a local producer in Ban Hare, Tambon Kham Kwang, Warin Chamrap District, Ubon Ratchathani Province, Thailand. The fresh cassava tops were chopped into 2 cm long pieces using a Magnum Electric Motor (Type ml-90S2-2, Model: GS150, matched power of 3 HP, rotation speed: 2800 rpm, production efficiency ≥1000 kg/hr). Fresh cassava tops were sun-dried within three days at an ambient temperature in the dry season. Dried cassava top (DCT) was replaced with dried cassava pulp (DCS) at a ratio of 15:85 (g/g) on a dry matter basis, fermented for 21 days, and used with a 100 mL volume plastic tank. The active dry yeast (*Saccharomyces cerevisiae*), strain CNCM-1077, Levucell SC20 (r) SC, and its ingredient, 10^{10} CFU/g, were purchased from a local market in Ubon Ratchathani Province. Before the fermentation procedure, 20 g of *saccharomyces cerevisiae* was stimulated aerobically with an oxygen flush and 40 g of sugar in 660 ml of tap water for 30 minutes (Solution A). 50 mL of molasses and 3 g of urea were used in 830 mL of tap water, mixed well (Solution B). Solution C was a mixture of A and B at a 1:1 ratio (v/v) and flushed with air for 1 h. In addition, solution C was treated with dried cassava top fermented cassava pulp at a 1:1 ratio (v/w) (Polyorach et al. 2014; Morm et al., 2023).

Table 3.3 The ingredients of concentrate and dried cassava top fermented cassava pulp (CtFCp)

Items	Concentrate	CtFCp
Ingredients, g/kg DM		
Cassava pulp	-	764
Dry cassava leaves	-	150
Cassava chip	410	-
Soybean meal	140	-
Palm kernel meal	90	-
Corn meal	135	-
S. cervisiae	-	2
Rice brand	130	-
Urea	20	30
Molasses	50	50
Sugar	-	4
Salt	5	-
Sulfur	10	-
Monodicalcium phosphate ($P \geq 21\%$, $Ca \geq 14\%$)	5	-
Mineral premix	5	-

3.3.1.2 Animal experimental design

The study was done at the Faculty of Agriculture, Ubon Ratchathani University, Thailand's Experimental Field and Central Laboratory (15°07'55.8"N 104°55'48.2" E). All test cattle were meticulously cared for to minimize mistakes made by people, animals, or their surroundings. Twelve females of Thai native x Lowline Angus crossbred cattle were assigned 99.50±9.83 kg initial body weight (IBW) and 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*) on a dry matter basis (DM). The concentrate or CtFCp were shown in Table 3.3.

3.3.1.3 Animal experimental dietary arrangement

The CtFCp was well mixed by 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-liter dimensions and placed in the dry zone to use in this study. The CON and CtFCp were fed at 0.5% dry matter (DM) of body weight (BW) twice daily at 7:00 a.m. and 4:00 p.m. The mineral salt block and clean water were offered *ad libitum* to all cows. The cows were fed rice straw (RS) *ad libitum* daily, with 100g kg^{-1} refusal of total RS offered. RS and feeds were supplied simultaneously, although they were divided into two halves using buckets measuring 40 cm x 60 cm, RS feeding stock and 30 cm x 40 cm for feeding. The cows were placed in individual pens (2.5 x 4 m) equipped with iron walls and a concrete floor. 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.

3.3.1.4 Sample collection on feed intake and growth performance

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 the last five days were used for sample collection. Cows were weighed at the beginning of the experiment to adjust feeding dietary in dry matter intake (DMI) and weighed every 14 days. Before supplying new feed, daily notes were collected to track the amount of feed consumed and refused feeds. The average daily gain (ADG) was determined using the IBW and final weight (FW). According to the Kleiber (1947), the BW gain for the study was estimated from the ratio of BW gain to mid-point kg $BW^{0.75}$ (Kelly et al., 2011). The feed conversion ratio (FCR) was computed as total DMI proportioned by total WB gain through the trial. Feed offered and refusal, including RS, concentrate, and CtFCp, were recorded daily, while each sample was taken weekly and dried in a hot air oven at 70 ˚C and kept in the dried form before chemical analysis. During the last five days, feces were collected from the individual rectum daily at 7:00 a.m. before being supplied feed. The feces were mixed and stored at -20 ˚C until their chemical composition analysis. The rumen

fluid, temperature, and blood samples were collected twice: 45 days and 90 days after the last day of the experiment. The sample was collected 4h post-feeding. The rumen fluid was collected in amounts of approximately 100 mL using a stomach tube attached to a vacuum pump. A rumen fluid sample's pH was immediately measured using a glass electrode pH meter (HANNA instrument (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^{0}C until chemically analyzed. Another 1 mL of rumen fluid was taken, placed in 9 mL of 10% formalin, and stored in a refrigerator to count the protozoal and fungal zoospore numbers using a hemocytometer under a microscope (Galyean, 2010).

3.3.1.5 Chemical composition analysis

The frozen feces sample was defrosted and oven-dried at 60 ˚C for 72 hours to ascertain their chemical compositions. All the samples were ground through a 0.5 mm screen (Tecator, Hoganas, Sweden) and analyzed on DM, ash, and crude protein (CP) referring to (AOAC, 1990). The neutral detergent fiber (NDF) and acid detergent fiber (ADF), according to (Van Soest et al., 1991). To estimate the apparent digestibility, acid insoluble ash (AIA) was used as an indicator (Keulen and Young, 1997). The rumen fluid was centrifuged at 3,500 x rpm for 15 minutes; the supernatant was used to analyze volatile fatty acid (VFA). A 0.22-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 x 250 mm) column (Choromeleon Dionex Corp), with UV-Vis detection at 210 nm according to (De Sá et al., 2011) The methane (CH4) was estimated using VFA as an indicator, according to (Moss et al., 2000). A total of 10 mL of blood samples were collected from the jugular vein; 4 mL were kept in a test tube containing Sodium Fluoride/ EDTA tube for glucose analysis, and each 4 mL was kept 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 Urease method, creatinine uses the IDMS Traceble method, glucose (plasma) uses the Glucose Oxidase method, total protein (serum) uses the Biuret Lithium method, and triglyceride uses the Glycerophosphate O method (Ruiz-Gutierrez et al., 1995;

Küme et al., 2018; Zhang et al., 2022). Metabolizable energy (ME) was calculated according to the equation described by (Robinson et al., 2004). Digestible organic matter fermented in the rum (DOMR) was calculated according to the equation described by (Li et al., 2019) as follows: DOMR (kg/d)=digestible organic matter intake (DOMI), kg/d) x 0.65, where DOMI=[digestibility of organic matter (kg/kg DM) x organic matter intake (kg/d)]/100, 1kg DOMI=15.9 MJ,ME/kg. MCP (microbial crude protein), kg/d=0.00825 x ME intake(MJ/d) (Galyean, 2010).

3.3.1.6 Statical analysis

The results were analyzed using a one-way ANOVA in a completely randomized design (CRD) in the Statistical Package for the Social Sciences (SPSS, version 21, Chicago, USA) based on the animal and feed as the experimental units. The general linear model procedure was tested for normal distribution using the UNIVARIATE to all data. Repeated-measure analysis was employed for assisting feed intake, growth performance, nutrient digestibility, ruminal parameters, blood metablolites, and rumen permentation. The dietary treatment means of CON, CtFCp-50, and CtFCp-*ad libitum* were compared using Ducan’s Multiple Range Test (DMRT). All the means were described by the standard error of the mean (means±s.e.m).

CHAPTER 4
RESULTS AND DISCUSSIONS

The experiment consisted of three objectives: To scan the suitable of fresh and dried cassava top fermented cassava pulp to simultaneously feed of Thai native x Lowline Angus crossbred cattle as following: 1) The effect of fresh and dried cassava varied top levels of fermented cassava pulp used *in vitro* method to scan the suitable level effect on gas kinetics, rumen characteristics, and *in vitro,* degradability was revealed to use in the ruminant sequencing simultaneously. 2) In contrast, cassava product substituted concentrate in the *in vivo* trial to evaluate the overview aspects on feed intake, feed digestibility, rumen microorganisms, and fermentation. 3) To supplement cassava pulp to derive tremendous conclusions about the effects of dried cassava top fermented cassava pulp on ruminal parameters, blood metabolites, nutrient intake, and growth performance.

4.1 Results I Gas kinetics, rumen characteristics, and *in vitro* degradability of varied levels of dried and fresh cassava top fermented cassava pulp

4.1.1 Chemical composition of DCS and FCT

Basic chemical make up of FCT and CS. The FCT and DCS were analyzed prior to the experimental processes. The FCT contained 198.80 g/kg CP, approximately 20 times higher than the CP in DCS in Table 4.1.

Table 4.1 Chemical composition in fresh cassava tops (FCT) and dried cassava pulp (DCS)

Chemical compositions(g/kg)	Fresh cassava top	Dried cassava pulp
DM	192.10	888.60
Ash	710.10	640.00
OM	928.90	936.00
CP	198.80	26.60
NDF	467.00	445.00
ADF	388.30	364.90
EE	36.80	3.00

4.1.2 Chemical composition of cassava top fermented cassava pulp

Table 4.2 displays the chemical composition of cassava top fermented cassava pulp. The NDF and ADF compositions of the dietary treatments were not significantly different (P>0.05) among groups. However, DM, ash, OM, EE, and CP differed significantly (P<0.05). The ash composition in 5FCT had the highest amount, OM was highest in nA and CSA, and EE was highest in 15FCT. Fermented CS with DCT at 5% to 10% DM had the highest increase in CP when compared to nA or CSA (P<0.05).

Table 4.2 Chemical composition of cassava top fermented cassava pulp

Variable (g/kg-DM)	nA	CSA	5DCT	10DCT	15DCT	5FCT	10FCT	15FCT	SEM	P-value
DM	292.80^{bc}	307.40^{abc}	279.90^{bc}	279.10^{bc}	302.60^{abc}	264.00^{c}	322.10^{ab}	351.50^{a}	7.08	0.020
Ash	71.70^{d}	72.90^{d}	91.10^{b}	89.80^{bc}	87.80^{bc}	98.90^{a}	85.70^{c}	91.60^{b}	1.90	0.010
OM	928.30^{a}	927.10^{a}	908.90^{c}	910.20^{bc}	912.10^{bc}	901.10^{d}	914.30^{b}	908.40^{c}	1.90	0.010
CP	29.90^{b}	86.50^{ab}	110.50^{a}	103.50^{a}	101.70^{a}	97.50^{ab}	94.50^{ab}	99.30^{a}	5.00	0.010
NDF	484.30	461.90	438.80	484.00	463.50	482.20	495.00	495.60	6.40	0.320
ADF	384.80	381.40	378.50	395.20	414.60	392.50	401.60	403.80	3.90	0.270
EE	2.50^{e}	2.60^{e}	5.70^{d}	8.40^{bc}	8.90^{bc}	7.90^{c}	9.50^{b}	10.90^{a}	0.60	0.010

Note: nA, cassava pulp fermented no additive; CSA, CS fermented with additives (*S.cerevisiae*, urea, molasses, and sugar); 5DCT, 95% CSA fermented with 5% DCT; 10DCT, 90% CSA fermented with 10% DCT; 15DCT, 85% CSA fermented with 15% DCT; 5FCT, 95% CSA fermented with 5% FCT; 10FCT, 90% CSA fermented with 10% FCT; 15FCT, 85% CSA fermented with 15% FCT, $^{a-d}$ Means in the same row with different superscripts differ significantly ($p<0.05$); SEM, standard error of the mean.

4.1.3 *In vitro* disappearance

Table 3.3 displays the *in vitro* dried matter disappearance (IVDMD) and *in vitro* organic matter disappearance (IVOMD) after 12 h and 24 h of incubation, respectively. The DM and OM disappearance were substantially different ($P<0.05$) according to the liquor fluid incubation serum bottles within substrates established for 12 hours. IVDMD was significantly higher in CS fermented with 5% to 10% DCT ($P<0.01$), whereas CS fermented with FCT levels demonstrated lower IVDMD than the control group ($P<0.01$).

Table 4.3 *In vitro* dried matter disappearance (IVDMD), and *in vitro* organic matter disappearance (IVOMD) at 12 h and 24 h of incubation

(g/kg-DM)	nA	CSA	5DCT	10DCT	15DCT	5FCT	10FCT	15FCT	SEM	P-value
Liquor fluid incubation in 12 h, disappearance (g/kg)										
DM	321.80^{ab}	325.40^{ab}	338.70^{a}	341.30^{a}	330.70^{a}	289.00^{b}	283.60^{b}	269.60^{b}	6.10	<0.010
OM	410.50^{a}	411.20^{a}	405.90^{a}	423.70^{a}	402.60^{a}	343.10^{b}	338.00^{b}	318.70^{b}	8.40	<0.010
Liquor fluid incubation in 24 h, disappearance (g/kg)										
DM	434.40^{ab}	476.30^{a}	452.40^{ab}	414.10^{b}	413.30^{b}	457.90^{ab}	447.40^{ab}	425.60^{b}	6.20	0.040
OM	561.40^{a}	543.80^{ab}	508.60^{bc}	486.20^{c}	490.90^{c}	530.10^{abc}	532.90^{c}	492.20^{abc}	6.90	0.030

Note: nA, CS fermented no additive; CSA, CS fermented with additives (*Saccharomyces cerevisiae*, urea, molasses, and sugar); 5DCT, 95% CSA fermented with 5% DCT; 10DCT, 90% CSA fermented with 10% DCT; 15DCT, 85% CSA fermented with 15% DCT; 5FCT, 95% CSA fermented with 5% FCT; 10FCT, 90% CSA fermented with 10% FCT; 15FCT, 85% CSA fermented with 15% FCT, DM, dry mater; OM, organic matter; NDF, neutral detergent fiber; ADF, acid detergent fiber;

EE, ether extract; CP, crude protein; [a-d] Means in the same row with different superscripts differ significantly (P<0.05); SEM, standard error of the mean.

4.1.4 *In vitro* kinetics of gas production

Table 4.4 shows *in vitro* dried matter disappearance (IVDMD) and *in vitro* organic matter disappearance (IVOMD) after 12 and 24 hours of incubation. The gas potential extent of gas production *(p)* and gas production from the insoluble fraction *(b)* did not differ significantly across treatments (P>0.05). However, the gas production from the immediately soluble fraction (*a)* was maximal when CS was fermented with 15DCT (P<0.05).

Table 4.4 Gas kinetics production (GKP) and disappearance at 84 h of incubation

Variable		nA	CSA	5DCT	10DCT	15DCT	5FCT	10FCT	15FCT	SEM	P-value
Gas kinetics (mL/g DM)	a	-1.43^{c}	-2.21^{c}	2.76^{ab}	-1.33^{c}	4.07^{a}	1.39^{b}	3.00^{ab}	-1.95^{c}	2.65	<0.010
	b	49.4	48.4	46.17	44.60	45.17	46.53	49.03	45.53	2.64	0.180
	c	0.05^{ab}	0.06^{ab}	0.03^{ab}	0.07^{b}	0.02^{ab}	0.03^{ab}	0.02^{ab}	0.05^{ab}	0.02	<0.010
	p	50.80	50.80	48.97	45.93	49.23	48.20	52.00	47.50	2.02	0.240
Disappearance (g/kg)	DM	744.20^{bc}	733.80^{c}	766.00^{a}	751.90^{b}	720.40^{d}	716.70^{d}	776.90^{a}	776.40^{a}	0.48	<0.010
	OM	842.10^{c}	846.30^{c}	862.00^{b}	843.00^{c}	835.40^{c}	816.10^{c}	876.10^{a}	841.40^{c}	0.37	<0.010

Note: *a*, the gas production from the immediately soluble fraction; *b*, the gas production from the insoluble fraction; *c*, the gas production rate constant for the insoluble fraction *(b); p(a+b)*, the gas potential extent of gas production; nA, CS fermented no additive; CSA, CS fermented with additives (*S. cerevisiae*, urea, molasses, and sugar); 5DCT, 95% CSA fermented with 5% DCT; 10DCT, 90% CSA fermented with 10% DCT; 15DCT, 85% CSA fermented with 15% DCT; 5FCT, 95% CSA fermented with 5% FCT; 10FCT, 90% CSA fermented with 10% FCT; 15FCT, 85% CSA fermented with 15% FCT; [a-d] Means in the same row with different superscripts differ significantly (P<0.05); SEM, standard error of the mean.

4.1.5 Protozoal population

Table 4.5 shows the ruminal pH and protozoal population at 12 h and 24 h. Different treatments significantly affected the pH of the fermentation solution, with the addition of 10DCT and 15DCT for 12 and 24 hours of incubation, respectively ($p<0.01$). After 12 hours of incubation, the protozoa population was lowest when 5DCT and 10DCT were evaluated ($P<0.01$).

Table 4.5 Ruminal pH and protozoal population at 12 h and 24 h

Variable	nA	CSA	5DCT	10DCT	15DCT	5FCT	10FCT	15FCT	SEM	P-value
Ruminal pH										
12 h	6.61^{d}	6.72^{d}	6.54^{e}	6.83^{a}	6.78^{b}	6.76^{bc}	6.65^{d}	6.71^{c}	0.02	<0.010
24 h	6.66^{c}	6.70^{bc}	6.66^{c}	6.72^{ab}	6.74^{a}	6.68^{c}	6.60^{d}	6.68^{c}	0.01	<0.010
Ruminal protozoa (log cells/mL)										
12 h	5.39^{c}	5.39^{c}	5.15^{e}	5.35^{d}	5.46^{b}	5.60^{a}	5.62^{a}	5.62^{a}	0.03	<0.010
24 h	5.64^{a}	5.65^{a}	5.68^{a}	5.66^{a}	5.68^{a}	5.44^{b}	5.46^{b}	5.22^{c}	0.03	<0.010

Note: nA, CS fermented no additive; CSA, CS fermented with additives (*Saccharomyces cerevisiae*, urea, molasses, and sugar); 5DCT, 95% CSA fermented with 5% DCT; 10DCT, 90% CSA fermented with 10% DCT; 15DCT, 85% CSA fermented with 15% DCT; 5FCT, 95% CSA fermented with 5% FCT; 10FCT, 90% CSA fermented with 10% FCT; 15FCT, 85% CSA fermented with 15% FCT; $^{a-d}$ Means in the same row with different superscripts differ significantly ($P<0.05$); SEM, standard error of the mean.

4.1.6 Pearson correlation coefficients (r)

Table 4.6 shows Pearson correlation coefficients (r) of dry matter degradability, pH, and gas generation after 12 h and 24 h of incubation. The results revealed that the dietary treatments for IVDMD were significant within 12 h ($P<0.01$) but not in 24 h or 12 h vs 24 h. On the other hand, it has a very low correlation in 24 h, with $R^2=0.25$. The pH exhibited a substantial difference between 12 and 24 h, as well as a strong correlation between 12 and 24 h, $R^2=0.75$. In contrast, there is no significant ($P<0.01$) correlation in gas production, and it was weakly correlated in 12 h

against 24 h by R^2=0.34. Separately, the microbial population was significant in three times (12 h, 24 h, and 12 h vs 24 h) (P<0.01), with the strongest correlation in 12 h, R^2=0.75.

Table 4.6 Pearson correlation coefficients (r) of dried matter degradability, pH, and gas production at 12 h and 24 h of incubation

Group								P-value				r		
nA	CSA	5DCT	10DCT	15DCT	5FCT	10FCT	15FCT	SEM	12h	24h	12hx24h	12h	24h	12hx24h
DM_d								0.48	<0.01	0.74	0.14	-0.68	0.25	-0.31
pH								0.02	0.33	0.35	<0.01	0.21	-0.2	0.75
GP								2.02	0.24	0.25	0.1	0.24	-0.24	0.34
Protozoa (log.cell/mL)								0.03	<0.01	<0.01	0.04	0.75	-0.80	-0.42

Note: Statistical significance of (r); DMd, dry matter degradability; CP, crude protein; GP, gas production; pH, hydrogen potential, nA, CS fermented no additive; CSA, CS fermented with additives (*Saccharomyces cerevisiae*, urea, molasses, and sugar); 5DCT, 95% CSA fermented with 5% DCT; 10DCT, 90% CSA fermented with 10% DCT; 15DCT, 85% CSA fermented with 15% DCT; 5FCT, 95% CSA fermented with 5% FCT; 10FCT, 90% CSA fermented with 10% FCT; 15FCT, 85% CSA fermented with 15% FCT; $^{a-d}$Means in the same row with different superscripts differ significantly (P<0.05); SEM, standard error of the mean.

4.2 Discussion

4.2.1 Chemical composition in FCT and DCS

The FCT composition analysis indicated that the OM, NDF, and ADF contents were low, and the CP content was 198.80 g/kg, which was consistent with earlier findings (Oni et al., 2014; Mao et al., 2019; Leguizamón et al., 2021). DCS had a CP content of 26.6 g/kg, which is similar to the values of 11.2-31 g/kg reported by previous studies (Polyorach et al., 2014; Chauynarong et al., 2015; Ornvimol et al., 2018; Tawida & Supawadee, 2019) and 20.2 g/kg reported by Chirinang & Oonsivilai (2018). The difference in these results could be due to cultivar, harvest time, or various climatic zones of crops (Burns et al., 2012; Ornvimol et al., 2018).

4.2.2 Chemical composition of cassava tops fermented cassava pulp

CS without additives had 484.30 g/kg of NDF and 29.90 g/kg of CP in DM. Previous studies found 360 g/kg of NDF and 23.0 g/kg of CP in DM (Ornvimol et al., 2018). Our findings were quite similar to those of Norrapoke et al. (2016), who discovered 452 g/kg of NDF and 18.0 g/kg of CP, and Napasirth et al. (2015), who noticed that 254.0 g/kg of NDF and 28.0 g/kg of CP when CS fermented without additives. Fermented CS with additives contained 461.90 g/kg of NDF and a CP content of 86.50 g/kg in DM, and there was decreased fiber and increased CP. These results are comparable to those of an earlier study using CS fermented yeast waste (CSYW) containing *S. cerevisiae,* which found 243 g/kg of NDF and a CP content of 537 g/kg DM (Dagaew et al., 2021). However, Norrapoke et al. (2017) reported that the CP concentration was high at 940 g/kg DM in silage when CS fermented urea at 4% and 2% molasses.

This result is unsupported by results from Pilajun & Wanapat (2018). CS fermented with yeast and molasses revealed minimized NDF and higher CP at 13.3 g/kg DM. This was similar to a study by Napasirth et al. (2015), who used FCT-fermented Chikuso-1 (CH, *L. plantarum* and Snow *Lact L* (SN, *L. rhamnosus*). They found 550.3 g/kg of NDF and 148.8 g/kg of CP in DM. Some nutrient parameters were different, which may be from various levels of additive source supplementation or the effects of some chemicals in CT and CS on the fermentation process. Nevertheless, those nutrient contents can be used for animal feedstuffs to improve animal productivity.

4.2.3 *In vitro* kinetics of gas production

DCT and FCT fermented CS additives were tested for gas production from an immediately soluble fraction *(a)* and for the gas rate constant for the insoluble fraction *(c)*, which were different among treatments ($P<0.05$). Gas production from the insoluble fraction *(b)* and the potential extent of gas production *p (a+b)* was not changed within 84 h of incubation ($P>0.05$). 5DCT, 10FCT, and 15FCT had DM digestibility of 76.6 g/kg, 776.90 g/kg, and 776.40 g/kg, which was higher than in other groups ($P<0.05$). Dagaew et al. (2021) had a different result when they used CSYW and found significant gas production from the insoluble fraction *(b)*, potential extent of gas production *p (a+b)*, and net gas production at 96 h compared to a control

group (P<0.05), and DM degradability was 576 g/kg. According to Pilajun & Wanapat (2018), the increases in the gas produced from the soluble fraction *(a),* rate of gas production *(c),* and potential of gas production *(p)* could result from molasses addition. Paengkoum & Bunnakit (2012) showed that average gas production was significantly higher in a mixture of CS and urea than in the control.

4.2.4 Protozoal population

The protozoa population was lowest after 12 h of incubation when 5DCT and 10DCT were examined. The protozoal concentration decline may have resulted from toxicity when we used DCT during incubation for 24 h. DCT contains cyanogenic glycoside, a toxic compound in cassava leaves, and anti-nutrients (*e.g.*, tannin, polyphenols, and phylic acid) (Latif & Müller, 2015). Tannin has a high molecular weight and is composed of phenolic hydroxyl groups that form strong interactions with proteins (Supapong et al., 2017). It inhibits digestion and nutrient absorption (Wobeto et al., 2007). Small *Entodinium* species respond to bacterial CP return and can contribute more than 50% of the biomass in the rumen (Newbold et al., 2015). In agreement with Wanapat et al. (2018), feeding cows 1.5 kg/day of cassava top silage reduced protozoal concentration by 62% compared to the control group. However, Sommai et al. (2020) reported that yeast-fermented CS did not affect the bacterial concentration in Thai native beef cattle. This was agreed by Cherdthong & Supapong (2019), who used yeast-fermented cassava bioethanol waste (YECAW) and found no significant effect on bacteria and protozoa concentrations in dairy calves.

After 12-24 h of rumen incubation, the pH was 6.54-6.74. These findings contradicted to those of Napasirth et al. (2015), who discovered that CS fermented with additives had a pH of less than 4.0. However, our results were comparable to those of Dagaew et al. (2021), who employed CSYW and discovered a pH of 6.91. The pH range of 6.5-7.0 has been proposed as the ideal level for rumen microbial degradability of fiber and protein (Souza et al., 2022). Thus, the research findings differ from earlier results, most likely attributable to differences in feedstuff chemical composition and incubation period.

4.3 Results II Thai native x Lowline Angus crossbred cattle on feed intake, feed digestibility, rumen microorganisms, and fermentation: Effects of using cassava products to replace concentrate

4.3.1 Chemical composition in concentrate, CtFCp, and RS

The chemical composition of the concentrate, dried cassava top fermented cassava pulp (CtFCp), and rice straw (RS) were presented in Table 4.7. In the current study, the crude protein (CP) of the concentrate product was 150.9 g/kg dry matter (DM), whereas in dried cassava top fermented cassava pulp (CtFCp) it was 150.0 g/kg dry matter (DM), which was less than the concentrate. In contrast to the concentrate diet, the fiber content of dried cassava top fermented cassava pulp (CtFCp) diets, including neutral detergent fiber (NDF) and acid detergent fiber (ADF), increased by 207.4 g/kg and 187.4 g/kg for dry matter, respectively. The fiber increased because dried cassava top fermented cassava pulp (CtFCp) has a higher fiber content than concentrate.

Table 4.7 Chemical composition in the concentrate, CtFCp, and RS

Items	Concentrate	CtFCp	RS
Chemical composition, g/kg DM			
DM	960.4	381.0	854.2
Ash	59.7	72.1	104.3
OM	940.3	927.8	895.7
CP	150.9	150.0	40.6
NDF	285.2	492.6	723.4
ADF	184.7	372.1	577.7
EE	45.7	11.3	14.0
AIA	22.9	55.3	53.1

Note: RS, rice straw; CtFCp, dried cassava top fermented cassava pulp

4.3.2 Feed intake characteristics, energy estimated, microbial protein of Thai native x Lowline Angus crossbred cattle

The DM intake in g/kg $BW^{0.75}$ demonstrated a significant difference ($P<0.05$), and group CON used a bigger feed amount compared to group CtFCp-33, and CtFCp-67 in Table 4.8. Whereas estimated energy intake ME, MJ/kgDM showed a significant difference ($P<0.05$), groups CON and CtFCp-33 had a higher energy intake than group CtFCp-67. In addition, microbial crude protein (MCP) was different in consistency compared to the group and was positive and statistically significant ($P<0.05$) in Table 4.9.

Table 4.8 Effect of concentrate replaced with dried cassava top fermented cassava pulp (CtFCp) on feed intake feed utilization in Thai native x Lowline Angus crossbred cattle

Variable	CON	CtFCp-33	CtFCp-67	SEM	P-value
Dry matter intake Concentrate and CtFCp					
kg/d	1.18	1.45	1.16	0.07	0.150
%BW	1.06^{c}	1.49^{a}	1.30^{b}	0.05	<0.001
g/kg $BW^{0.75}$	35.35^{c}	47.94^{a}	39.94^{b}	1.65	<0.001
Rice straw					
kg/d	2.01^{a}	0.80^{b}	0.79^{b}	0.18	<0.001
%BW	1.85^{a}	0.80^{b}	0.79^{b}	0.16	<0.001
g/kg $BW^{0.75}$	61.29^{a}	27.26^{b}	26.49^{b}	5.20	<0.001
Total intake					
kg/d	3.19^{a}	2.33^{b}	2.12^{b}	0.18	0.003
%BW	2.91^{a}	2.34^{b}	2.15^{b}	0.12	0.005
g/kg $BW^{0.75}$	93.27^{a}	75.19^{b}	68.31^{b}	5.60	0.001

Note: (control; CON), 100% concentrate + 0% CtFCp; (CtFCp-33), 67% concentrate + 33% CtFCp; and (CtFCp-67), 33% concentrate + 67% CtFCp; $^{a–c}$ Values on the same row with different superscripts differ ($P<0.05$); SEM, standard error of the mean

Table 4.9 Effects of concentrate replaced dried cassava top fermented cassava pulp on energy intake and microbial crude protein in Thai native x Lowline Angus crossbred cattle

Variable	CON	CtFCp-33	CtFCp-67	SEM	P-value
Estimated energy intake					
ME, MJ/kgDM	3.37[a]	2.63[a]	1.52[b]	0.29	0.005
ME, MJ/kgDM/d	53.59[a]	41.81[a]	24.28[b]	4.63	0.005
ME, MJ, g/kgBW$^{0.75}$	101.72[a]	92.13[a]	51.34[b]	8.94	0.010
Estimate microbe					
MCP, kg/d	0.43[a]	0.32[ab]	0.22[ab]	0.38	0.040

Note: (control; CON), 100% concentrate + 0% CtFCp; (CtFCp-33), 67% concentrate + 33% CtFCp; and (CtFCp-67), 33% concentrate + 67% CtFCp; [a–c] Values on the same row with different superscripts differ (P<0.05); SEM, standard error of the mean

4.3.3 Nutrient intake and digestibility in Thai native x Lowline Angus crossbred cattle

Table 4.10 nutrient digestibility demonstrates that the OM in the group CON, CtFCp-33, and CtFCp-67, were not statistically different (P>0.05). CP in the group CON was digested more thoroughly (P<0.001), and there was a non-significant difference between the groups CtFCp-33, and CtFCp-67. There was a significant difference (P<0.05) between NDF in the group's CON and CtFCp-67 being digested better than the group CtFCp-33. The percentage of ADF digestibility was not statistically significant (P>0.05). The nutrient intake of OM was not significantly different among groups (P>0.05). However, DM, CP, EE, NDF, and ADF were significantly different (P<0.05), and superscripts were in the same row between CON and CtFCp-33, except group CtFCp-67.

Table 4.10 The effect of concentrates replaced with dried cassava top and fermented cassava pulp (CtFCp) on nutrient intake and digestibility in Thai native x Lowline Angus crossbred cattle

Variable	CON	CtFCp-33	CtFCp-67	SEM	P-value
Nutrient intake, kg/h/d					
DM	4.82^{a}	3.60^{ab}	2.73^{b}	0.33	0.020
OM	4.96	4.48	3.63	0.27	0.110
CP	0.46^{a}	0.40^{ab}	0.30^{b}	0.07	0.040
EE	0.15^{a}	0.10^{ab}	0.08^{b}	0.01	0.004
NDF	3.71^{a}	2.92^{ab}	2.34^{b}	0.23	0.030
ADF	2.34^{a}	1.89^{ab}	1.59^{b}	0.13	0.040
Nutrient digestibility, %					
DM	59.64^{a}	49.54^{b}	49.43^{b}	1.59	<0.001
OM	65.63	65.15	65.18	0.37	0.570
CP	75.08^{a}	58.91^{b}	56.49^{b}	2.60	<0.001
EE	86.58^{a}	76.50^{b}	73.04^{c}	1.78	<0.001
NDF	62.88^{a}	61.43^{a}	58.70^{b}	0.66	0.010
ADF	39.63	37.79	38.01	0.80	0.640
TDN	69.17^{a}	66.14^{ab}	66.01^{b}	0.48	<0.001

Note: (control; CON), 100% concentrate + 0% CtFCp; (CtFCp-33), 67% concentrate + 33% CtFCp; and (CtFCp-67), 33% concentrate + 67% CtFCp; $^{a–c}$ Values on the same row with different superscripts differ (P<0.05); SEM, standard error of the mean

4.3.4 The blood metabolites, rectum temperature, and rumen pH

In Table 4.11 the rectal temperature, protozoal and fungus populations, rumen pH, and glucose, and demonstrated an insignificant difference between 0 h and 4 h post-feeding (P>0.05) between the groups' CON, CtFCp-33, and CtFCp-67. At 0 h post-feeding, there was a statistically significant difference in BUN (P<0.05). The group CON had more BUN than groups CtFCp-33 or CtFCp-67, but the difference was insignificant after 4 hours. Whereas creatinine, triglyceride, and total protein-

serum levels were insignificant at 0h and 4h post-feeding in the groups CON, CtFCp-33, and CtFCp-67 (P>0.05).

Table 4.11 The effects of concentrate replacing dried cassava top and fermented cassava pulp (CtFCp) on rectum temperature and blood metabolites in Thai native x Lowline Angus crossbred cattle

Variable	CON	CtFCp-33	CtFCp-67	SEM	P-value
Rectum temperature, °C					
0h post-feeding	38.60	38.55	38.78	0.09	0.590
4h post-feeding	39.52	39.70	39.12	0.13	0.170
Protozoa log cell/mL					
0h post-feeding	4.32	4.41	4.22	0.06	0.460
4h post-feeding	4.26	4.30	4.14	0.05	0.460
	Fungi log cell/mL				
0h post-feeding	3.91	3.93	3.77	0.03	0.460
4h post-feeding	3.81	3.71	3.61	0.17	0.250
		Rumen pH			
0h post-feeding	6.44	6.27	6.18	0.10	0.630
4h post-feeding	6.16	6.00	6.31	0.07	0.150
	Glucose, mg/dL				
0h post-feeding	77.25	71.50	61.00	3.64	0.190
4h post-feeding	70.75	67.75	64.00	1.26	0.070
	BUN, mg/dL				
0h post-feeding	12.25^{b}	13.75^{a}	12.75^{b}	2.84	0.020
4h post-feeding	15.50	15.02	15.00	0.38	0.600

Table 4.11 The effects of concentrate replacing dried cassava top and fermented cassava pulp (CtFCp) on rectum temperature and blood metabolites in Thai native x Lowline Angus crossbred cattle (Continued)

Variable	CON	CtFCp-33	CtFCp-67	SEM	P-value
Creatinine, mg/dL					
0h post-feeding	1.28	1.21	1.17	0.04	0.660
4h post-feeding	1.34	1.29	1.15	0.04	0.190
Triglyceride, mg/dL					
0h post-feeding	35.00	38.00	40.75	2.90	0.760
4h post-feeding	35.75	45.25	50.00	3.21	0.190
Total protein-serum, g/dL					
0h post-feeding	6.98	6.85	6.45	0.23	0.670
4h post-feeding	6.88	6.60	6.32	0.15	0.360

Note: (control; CON), 100% concentrate + 0% CtFCp; (CtFCp-33), 67% concentrate + 33% CtFCp; and (CtFCp-67), 33% concentrate + 67% CtFCp; $^{a–c}$ Values on the same row with different superscripts differ (P<0.05); SEM, standard error of the mean; TDN, total digestible nutrients; mg/dL, milligram/deciliter; g/dL, gram/deciliter

4.3.5 Volatile fatty acid (VFA) using concentrate and concentrate replacing CtFCp in Thai native x Lowline Angus crossbred cattle

Total volatile fatty acid (TVFA), acetic acid (C2), propionic acid (C3), and butyric acid (C4) are listed. From 0h and 4h, the average TVFA, which varied from 94.70 to 100.45 and 103.70 to 111.15 mmol/L, respectively, showed no significant difference between the groups (P>0.05). At 4h post-feeding, C2 altered differently between groups (P<0.05). The usage for CtFCp-33 was greater than the CON or CtFCp-67. C3 and it had no effect on any of the groups at 0h (P> 0.05) but did have an effect at 4h (P <0.05), with CON and group CtFCp-33 exhibiting the greatest effect

compared to group CtFCp-67. C4 did not alter differently between groups (P>0.05) at 0h, but changed at 4h (P<0.05). The group usage of CtFCp-67 was the lowest compared to any other groups; CON and CtFCp-33 were in the same row superscript. Nevertheless, the ratio of acetic acid and propionic acid (C2:C3) showed a significantly differed both at 0h and 4h (P<0.05). The group using CtFCp-33 had the most faverable outcome but the other two groups were similar. Separately, methane (CH4) estimated after using CtFCp-33 was higher than the CON and CtFCp-67 groups (P<0.05).

Table 4.12 The effects of concentrate replacing dried cassava top and fermented cassava pulp (CtFCp) in ruminal fermentation and volatile fatty acid concentration in Thai native x Lowline Angus crossbred cattle

Variable	CON	CtFCp-33	CtFCp-67	SEM	P-value
Total volatile fatty acid (TVFA), mmol/L					
0h post-feeding	111.15	100.45	109.95	3.94	0.520
4h post-feeding	94.70^{b}	103.70^{ab}	110.00^{a}	3.06	0.020
Volatile fatty acid profiles, mmol/100 mol					
Acetic acid (C2)					
0h post-feeding	56.74	63.89	61.59	1.37	0.080
4h post-feeding	63.20^{b}	68.44^{a}	61.98^{b}	1.02	0.005
Propionic acid (C3)					
0h post-feeding	35.92	28.64	31.60	1.27	0.050
4h post-feeding	32.33^{a}	26.23^{b}	30.77^{a}	0.93	0.003
Butyric acid (C4)					
0h post-feeding	7.47	7.47	6.80	0.32	0.660
4h post-feeding	4.36^{b}	5.33^{ab}	5.86^{a}	0.31	0.010
Acetic : Propionic acid ratio (C2: C3)					
0h post-feeding	1.60	2.27	1.98	0.12	0.060
4h post-feeding	1.97^{b}	2.61^{a}	2.02^{b}	0.10	0.002

Table 4.12 The effects of concentrate replacing dried cassava top and fermented cassava pulp (CtFCp) in ruminal fermentation and volatile fatty acid concentration in Thai native x Lowline Angus crossbred cattle (Continued)

Variable	CON	CtFCp-33	CtFCp-67	SEM	P-value
Estimated methane (CH4), g/d					
0h post-feeding	18.67[b]	23.86[a]	21.74[ab]	0.92	0.040
4h post-feeding	21.23[b]	25.72[a]	22.33[b]	0.67	0.003

Note: (control; CON), 100% concentrate + 0% CtFCp; (CtFCp-33), 67% concentrate + 33% CtFCp; and (CtFCp-67), 33% concentrate + 67% CtFCp; BUN, blood urea nitrogen; pH, hydrogen potential; kg, kilogram; d, day; [a–c] Values on the same column with different superscripts differ ($p < 0.05$); SEM, standard error of the mean

4.4 Discussions

4.4.1 Chemical composition and feed ingredients

The CtFCp fermented by live yeast can be varied due to its factor sources, including carbohydrate, non-protein nitrate (NPN), urea supplementation, and their concentrations, incubation times, technical practices, climatic conditions, and type of yeast (Boonnop et al., 2009; Sommai et al., 2020). This current study found that CP in concentrate was similar to So et al. (2020), but less than Goiri et al. (2021), and greater than in Sommai et al. (2020), but in fermented cassava, it was less than that (Sommai et al., 2020). Earlier research concurs concerning CP in ntrated and fermented cassava (Sommai et al., 2020).

4.4.2 Dry matter intake and nutrient digestibility

The nutrient digestibility of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), and ether extract (EE) were thoroughly digested in the CON. In contrast, increasing the concentration enhanced OM, CP, NDF, and ADF with a great intake among the CON, CtFCp-33, and CtFCp-67 groups. According to Sommai et al.(2020), replacing soybean meal with yeast-fermented CS (YFCP) increased the digestibility of nutrients in CP and OM. As reported by (Khejornsart et al., 2022), CS added to the fermented total mixed rations in lambs increased the digestibility of DM,

OM, CP, NDF, and NDF, and support for this was found in the current study and in earlier research (Morm et al., 2023). The high-concentrate diet elucidated the high digestibility of OM content and improved milk yield production in goats (Serment et al., 2011). Furthermore, the current study was supported by Jiang et al. (2022) using concentrate-to-forage ratios in cattle yaks and found that 70% of concentrate-to-forage ratios increased dry matter feed intake and nutrient digestibility. Whereas Dagaew et al. (2023) treated fermented cassava pulp with yeast waste in 50:50 concentrate ratios increasing the digestibility of neutral detergent fiber and acid detergent fiber. According to Gunun et al. (2023), more than 50% of feed concentrate was replaced by yeast-fermented cassava peels and cassava peel fermented by effective microorganisms which did not affect feed intake, feed digestibility, or rumen fermentation. Further, it can reduce feed costs by up to 32% per gain. The results have been confirmed (Cherdthong and Supapong, 2019; Sommai et al., 2020; Phesatcha et al., 2022), cows provided high concentrate diets demonstrated significantly increased nutrient digestibility and intake but it differed from some earlier studies (Dagaew et al., 2022). A roughage content of 30% and concentration of 70% can improve bacterial populations and nutrient digestibility because they contain more available energy. This could be due to the fact that the concentrate may provide additional nutrients through enhanced rumen fermentation and rumen microbial growth (Phesatcha et al., 2022). In addition, using high-concentrate feed, a reduced ruminal ammonia concentration, and expanded ammonia utilization proved to be good conditions for microorganisms to digest feed (Agle et al., 2010). Furthermore, the activation of polysaccharides and glycosidase hydrolase enzymes in yeast can improve the defecation of ruminants (Chuelong et al., 2011). Whereas the urea in the solution might cause a breakdown of the fiber structure in cassava pulp (CS), it acts as an alkaline substance (ammonium hydroxide)(Suriyapha et al., 2021). The fraction of NDF and ADF and a lower level of digestibility could be due to the tendency of a minimal ruminal pH to greater qualities of soluble carbohydrates. This current study has prior support (Khejornsart et al., 2022) through a 21-day experiment that found that CS added to fermented mixed total rations in sheep was digested well in NDF, but others (Keaokliang et al., 2018), who used the CS diet in cattle found that the CP digested was at a constantly low level.

4.4.3 The blood metabolism, temperature variables, rumen pH, and microbial population

Currently, results showed that rectum temperature, protozoal population, fungus, rectum pH, and blood urea nitrogen (BUN) were unaffected, but some (Sommai et al., 2020; Phesatcha et al., 2022 and Morm et al., 2023) disagree. Glucose, creatinine, triglyceride, and total protein levels in the serum did not alter at both 0h and 4 h post-feeding among the CON, CtFCp-33, and CtFCp-67 groups. TVFA, C2, C3, and C4 levels were unaffected at 0 h post-feeding, but C2 and C3 levels increased after 4 h, as reported by some (Zheng et al., 2021; Dagaew et al., 2022), but others (So et al., 2022) disagree. Some reports revealed that high concentrates supplied in diets enhanced C3, and a comparison of concentrate proportioned with a high-forage diet found that TVFA and molar proportions of C2 were a negative alteration (Bauman et al., 1971; Sutton et al., 2003). The current study results employed CtFCp-67 and CtFCp-33, and C2, and C4 increased while 4 h post-feeding found research support (Jiang et al., 2022), and cattle-yaks were fed a high concentrate with a high forage diet. Thus, rumen fermentation alters structural carbohydrate fermentation to a non-structural form. As a result, the high concentrations used may affect rumen microbes. Therefore, C4 production increased due to low ruminal pH, which increased some ruminal microbes such as *Succiniclasticum, Ruminococcus, Butyrivibrio, Mogibacterium,* and *Butyrivibrio* in the rumen epithelium (Liu et al., 2015).

4.5 Results III Effects of feeding dried cassava top fermented cassava pulp on ruminal parameters, blood metabolites, and growth performance of Thai native x Lowline Angus crossbred cattle

4.5.1 Nutrient composition in animal feed

In the current study, the crude protein (CP) of the concentrate product was 15.09 kg dry matter (DM), whereas in dried cassava top fermented cassava pulp (CtFCp), it was 15.01 kg dry matter (DM), which was less than the concentrate. In contrast to the concentrate diet, the fiber content of dried cassava top fermented cassava pulp (CtFCp) diets, including neutral detergent fiber (NDF) and acid detergent fiber (ADF), increased by 19.76 kg and 14.73 kg for dry matter, respectively. The fiber increased because dried cassava top fermented cassava pulp (CtFCp) has a higher fiber content than concentrate in Table 4.13.

Table 4.13 Chemical composition in concentrate, dried cassava top fermented cassava pulp, and rice straw

Items	Concentrate	CtFCp	RS
Chemical composition, kg DM			
DM	89.92	38.11	85.42
Ash	5.97	7.20	10.43
OM	94.03	92.79	89.57
CP	15.09	10.60	3.92
NDF	29.5	49.26	72.33
ADF	22.47	37.20	57.77
EE	4.57	1.15	1.40
AIA	2.29	5.50	5.31

Note: RS, Rice straw; CtFCp, dried fermented cassava pulp

4.5.2 Animal growth performance characteristics, energy estimated, and microbial protein of Thai native x Lowline Agus crossbred cattle

The growth performance characteristics of Thai native x Lowline Angus crossbred cattle fed on dietary treatments with the CON, CtFCp-50, and CtFCp-*ad libitum* are elucidated in Table 4.14. The results indeed showed that the initial body weight (IBW) and final body weight (FBW) were non-significantly different (P>0.05). That average daily gain (ADG) was a significant difference (P<0.05); the CON was 288.24 g/h/d, CtFCp-50, and CtFCp-*ad libitum* 368.83 g/h/d and 370.59 g/h/d, and representative superscripts were in the same row. The total intake differences between the groups' CON, CtFCp-50, and CtFCp-*ad libitum* were non-significant (P>0.05). The DM intake in g/kg $BW^{0.75}$ was a significant difference (P<0.05), and group CtFCp-*ad libitum* used a more considerable feed amount compared to groups the CON and CtFCp-50. So far, the feed conversion ratio (FCR) has been significant (P<0.05). The group the CON 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. In table 4.15 the estimated energy intake ME, MJ/kgDM, was a significant difference (P<0.05), and group CON 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* CON (P>0.05).

Table 4.14 Growth performance and feed utilization in Thai native x Lowline Angus crossbred cattle supplemented cassava top fermented cassava pulp

Variable	CON	CtFCp-50	CtFCp-*ad libitum*	SEM	P-value
Initial weight, kg	103.00	99.00	99.75	2.80	0.850
Final weight, kg	127.50	130.33	131.25	3.39	0.900
ADG, g/h/d	288.24[b]	368.83[a]	370.59[a]	15.90	0.020
Feed conversion ratio					
FCR	8.68[a]	6.09[b]	7.07[b]	0.38	0.003
Total intake					
kg/d	2.49	2.24	2.60	0.07	0.150
%BW	2.16[a]	1.96[b]	2.26[a]	0.04	0.001
g/kg $BW^{0.75}$	76.89[b]	71.56[c]	82.44[a]	1.48	<0.001
Dry matter intake Concentrate					
kg/d	0.61	0.60	0.60	0.02	0.970
%BW	0.53	0.52	0.52	0.002	0.140
g/kg $BW^{0.75}$	18.78	19.07	19.01	0.15	0.760
Dried cassava top fermented cassava pulp					
kg/d	-	0.57[b]	0.78[a]	0.20	0.010
%BW	-	0.31[b]	0.45[a]	0.15	0.004
g/kg $BW^{0.75}$	-	9.73[b]	14.32[a]	4.59	0.006
Rice straw					
kg/d	1.88[a]	1.07[b]	1.19[b]	0.12	<0.001
%BW	1.63[a]	0.94[b]	1.03[b]	0.10	<0.001
g/kg $BW^{0.75}$	58.10[a]	34.27[c]	37.63[b]	3.39	<0.001

Note: 100% concentrate + 0% CtFCp (control; CON); 100% concentrate + 50% CtFCp (CtFCp-50); 100% concentrate + CtFCp-*ad libitum* (CtFCp-*ad libitum*); [a-c] Values on the same row with different superscripts differ ($P<0.05$), SEM, standard error mean

Table 4.15 Estimated energy intake and microbial crude protein fed dried cassava top fermented cassava pulp in Thai native x Lowline Angus cross-bred cattle

Variable	CON	CtFCp-50	CtFCp-*ad libitum*	SEM	P-value
Estimated energy intake					
NEv(Mcal/KgDM)	1.62	1.65	1.69	0.01	0.080
NEv(Mcal/g DM)/d	115.97	117.96	120.94	0.90	0.060
ME,MJ kgDM	2.43^{a}	2.24^{b}	2.22^{b}	0.01	<0.001
Estimated microbe					
MCP, kg/d	0.55	0.57	0.59	0.01	0.060

Note: 100% concentrate + 0% CtFCp (control; CON); 100% concentrate + 50% CtFCp (CtFCp-50); 100% concentrate + CtFCp-*ad libitum* (CtFCp-*ad libitum*); $^{a-c}$ Values on the same row with different superscripts differ (P<0.05), SEM, standard error mean

4.5.3 Dry matter intake, nutrient intake, and digestibility in Thai native x Lowline Angus crossbred cattle

Table 4.14 displays the concentrate intake; total dry matter intake was unaffected (P>0.05). Additionally, %BW and g/kg $BW^{0.75}$ intake DM were improved by CtFCp-*ad libitum* (P<0.05). Table 4.16, The nutrient intake of CP was significantly different between groups (P<0.05); groups CtFCp-50 and CtFCp-*ad libitum* were non-significant, superscripts were in the same row and had a larger intake than CON. While DM, NDF, ADF, and EE were non-significant different statistics (P>0.05) between groups. Nutrient digestibility revealed that OM was not positively affected between the groups (P>0.05). CP in the group CON was better digested (P<0.01), and there was a non-significant difference between the groups CtFCp-50 and CtFCp-*ad libitum;* superscripts were in the same row. NDF in the group CON, which was better digested compared to CtFCp-50 and CtFCp-*ad libitum*, was significantly different statistics (P<0.05). The percentage of ADF digestibility was not statistically significant (P>0.05), table 4.16 respectively.

Table 4.16 Effect of dried cassava top fermented cassava pulp on voluntary nutrient intake and digestibility in Thai native x Lowline Angus crossbred cattle

Variable	CON	CtFCp-50	CtFCp-*ad libitum*	SEM	P-value
Nutrient intake, kg/d					
DM	2.45	2.20	2.60	0.08	0.150
CP	0.29[b]	0.34[a]	0.35[a]	0.03	0.020
EE	0.13	0.12	0.12	0.01	0.290
NDF	1.80	1.55	1.95	0.27	0.150
ADF	1.45	1.20	1.60	0.26	0.150
Nutrient digestibility,%					
DM	64.99	65.06	63.84	0.31	0.220
CP	65.67[a]	63.72[b]	63.71[b]	0.99	0.003
EE	79.68[a]	68.91[b]	68.95[b]	1.60	<0.001
NDF	62.53[a]	58.59[b]	57.75[b]	0.68	<0.001
ADF	53.23	51.73	51.36	0.54	0.340
CF	79.65[a]	61.99[b]	57.24[b]	3.54	0.002

Note: 100% concentrate + 0% CtFCp (control; CON); 100% concentrate + 50% CtFCp (CtFCp-50); 100% concentrate + CtFCp-*ad libitum* (CtFCp-*ad libitum*); [a-c] Values on the same row with different superscripts differ (P<0.05), SEM, standard error mean

4.5.4 The blood metabolites, rectum temperature variable, and rumen pH

Table 4.17 domentrates rectum temperature at both 45-d and 90-d and found that the CtFCp-50 and CtFCp-*ad libitum*, superscript was in the same row, and they were higher than the group CON at 4 h post-feeding (P<0.05). Separately, rumen pH, glucose, BUN, creatinine, triglyceride, and total protein were non-significantly different in groups administered CON, 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. However, creatinine in CON, CtFCp-50, and CtFCp-*ad libitum* were 1.27, 1.34, and 1.17 mg/dL.

Table 4.17 Effects of dried cassava top fermented cassava pulp on rectum temperature, rumen fermentation, and blood metabolites in Thai native x Lowline Angus crossbred cattle

Variable	CON	CtFCp-50	CtFCp-*ad libitum*	SEM	P-value
Rectum temperature, ˚C					
45-d: 4h post-feeding	39.07[b]	39.32[a]	39.25[a]	0.05	0.030
90-d: 4h post-feeding	38.80[b]	39.15[a]	39.02[ab]	0.06	0.040
Protozoa, log cell/mL					
45-d: 4h post-feeding	4.03	4.05	4.14	0.08	0.860
90-d: 4h post-feeding	4.75	4.60	4.73	0.04	0.210
Fungi, log cell/mL					
45-d: 4h post-feeding	3.71	3.63	3.74	0.05	0.730
90-d: 4h post-feeding	4.70	4.48	4.78	0.06	0.100
Rumen, pH					
45-d: 4h post-feeding	6.59	6.66	6.70	0.04	0.510
90-d: 4h post-feeding	6.64[a]	6.17[b]	6.55[a]	6.28	0.010
Glucose, mg/dL					
45-d: 4h post-feeding	68.75	68.50	75.50	2.14	0.350
90-d: 4h post-feeding	75.00	77.25	82.00	2.04	0.400
BUN, mg/dL					
45-d: 4h post-feeding	14.50	15.75	13.50	0.63	0.380
90-d: 4h 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	0250

Table 4.17 Effects of dried cassava top fermented cassava pulp on rectum temperature, rumen fermentation, and blood metabolites in Thai native x Lowline Angus crossbred cattle (Continued)

Variable	CON	CtFCp-50	CtFCp-*ad libitum*	SEM	P-value
Triglyceride, mg/dL					
45-d: 4h post-feeding	42.50	39.50	40.75	4.08	0.140
90-d: 4h post-feeding	56.25	38.75	30.00	4.97	0.070
Total protein-serum, g/dL					
45-d: 4h post-feeding	6.57	6.17	6.05	0.12	0.210
90-d: 4h post-feeding	6.20	5.82	5.70	0.10	0.090

Note: 100% concentrate + 0% CtFCp (control; CON); 100% concentrate + 50% CtFCp (CtFCp-50); 100% concentrate + CtFCp-*ad libitum* (CtFCp-*ad libitum*); [a-c] Values on the same row with different superscripts differ (P<0.05), SEM, standard error mean; 4h, 4 hours; mg/dL, milligram/deciliter; g/dL, gram/deciliter; BUN, blood urea nitrogen

4.5.5 Volatile fatty acid (VFA), supplemented CtFCp-50 and CtFCp-*ad libitum* to concentrate

As revealed in Table 4.18, total volatile fatty acids (TVFA), acetic acid (C2), and propionic acid (C3) are listed. At 45-d and 90-d at 4 h post-feeding fluid collection, the average TVFA, which varied from 91.45 to 90.25 and 91.37 mmol/L, respectively, revealed no significant difference between the groups (P>0.05) 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>0.05). Whereas C2 at 4 h post-feeding at 45-d was affected, the CON and CtFCp-*ad libitum* were greater than CtFCp-50 (P<0.01). Nevertheless, at 90-d was not changed (P>0.05). In addition, C3, and C4 were not affected in both periods of collection at 45-d and 90-d at 4 h post-feeding between groups administered CON, CtFCp-50, and CtFCp-*ad libitum* (P>0.05). Nevertheless, the C2:C3 ratio significantly differed in the 45-d fluid collection (P<0.05). The group using CON and CtFCp-*ad libitum* was the best, but

CtFCp-50 and CtFCp-*ad libitum* had the same outputs. While the 90-d measurement was not strongly affected (P>0.05). Whereas methane (CH4) estimated found at 45-d at 4 h post-feeding was increased between the CON and CtFCp-*ad libitum* groups but CtFCp-50 was not affected (P<0.05). However, at 90-d at 4 h post-feeding was not affected (P>0.05).

Table 4.18 Effects of dried cassava top fermented cassava pulp (CtFCp) in ruminal fermentation and volatile fatty acid in Thai native x Lowline Angus crossbred cattle

Variable	CON	CtFCp-50	CtFCp-*ad libitum*	SEM	P-value
Total volatile fatty acid (TVFA), mmol/L					
45-d:4h post-feeding	91.45	90.25	91.37	1.10	0.900
90-d:4h post-feeding	111.9	116.37	113.85	1.50	0.550
Volatile fatty acid profiles, mmol/100 mol					
Acetic acid (C2)					
45-d:4h post-feeding	76.18[a]	73.00[b]	76.49[a]	0.56	0.003
90-d:4h post-feeding	81.12	80.49	81.01	0.21	0.490
Propionic acid (C3)					
45-d:4h post-feeding	23.82	25.18	24.76	0.28	0.110
90-d:4h post-feeding	18.88	19.5	18.99	0.21	0.490
45-d:4h post-feeding	7.47	7.47	6.8	0.32	0.660
90-d:4h post-feeding	4.56	4.46	4.36	0.31	0.100
Butyric acid (C4)					
45-d:4h post-feeding	7.47	7.47	6.8	0.32	0.660
90-d:4h post-feeding	4.56	4.46	4.36	0.31	0.100
Acetic: Propionic acid ratio (C2: C3)					
45-d:4h post-feeding	3.20[a]	2.90[b]	3.09[ab]	0.05	0.049
90-d:4h post-feeding	4.31	4.13	4.27	0.06	0.500
Methane estimated (CH4), g/d					
45-d:4h post-feeding	30.72[a]	28.91[b]	30.33[a]	0.05	0.010
90-d:4h post-feeding	33.14	32.64	32.98	0.07	0.510

Note: 100% concentrate + 0% CtFCp (control; CON); 100% concentrate + 50% CtFCp (CtFCp-50); 100% concentrate + CtFCp-*ad libitum* (CtFCp-*ad libitum*); [a-c] Values on the same row with different superscripts differ (P<0.05), SEM, standard error mean

4.6 Discussion

4.6.1 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 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., 2022). Prior studies support each other concerning CP in concentrated and fermented cassava pulp (Sommai et al., 2020). Separately, the current study in rice straw (RS) containing CP was varied and found it was better than the previous study (Khejornsart et al., 2022; Gunun et al., 2022; Dagaew et al., 2023), but it was similar to Sommai et al.(2020).

4.6.2 Animal growth performance characteristics, energy estimated, and microbial protein of Thai native x Lowline Angus crossbred cattle

The current study revealed that the use of CON, CtFCp-50, and CtFCp-*ad libitum* resulted in DMI of 2.49, 2.24, and 2.60 kg/day were fewer intakes compared (Desnoyers et al., 2008; Jiang et al., 2022), which issued that increasing concentrate by 30 and 60% were double times increased DMI between 5.3-5.63 kg/day. High levels of concentrate in the diet of ruminants were affecting fermentation and could be related to the low rumen fill effect of concentrate. A high proportion of concentrates with roughage might contribute to increasing average daily gain (ADG) due to increased feed intake, which can improve ruminant production efficiency (Brown et al., 2006). This current study revealed that CtFCp-50 and CtFCp-*ad libitum* of ADG was agreed (Tavares et al., 2021), greater than those (So et al., 2022) but unsupported by Gunun et al. (2022). CtFCp-50 and CtFCp-*ad libitum* in ruminant diet were effective on energy intake and growth performance. However, there was unsupported by Keaokliang et al. (2018), supply at 70.2% concentrate and 29.8% CS in the diet. According to Khejornsart et al. (2022), CS added to fermented total mixed rations

increased tropical sheep's nutrient utilization, rumen ecology, and microbial protein synthesis. Regarding the NRC (2000), maintenance animal requirements for ME and CP with 240 kg live weight (LW) are 29.56 MJ/d and 303.6 g/d, but this current research found that ME is between 2.43 and 2.24, and 2.22 ME, MJ kgDM, respectively.

4.6.3 Dry matter intake, nutrient intake, and nutrient digestibility

Results found by Hue et al. (2012; Sommai et al. (2020); Norrapoke et al. (2022); Gunun et al. (2023) used fermented cassava pulp additives in different levels of substitutes or supplements in concentrate were greater in dry matter intake (DM) and nutrient intake than in the current study. Moreover, cassava pulp fermentation has not revealed any depression 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 (Gunnun et al., 2022). While activating polysaccharides and glycosidase hydrolase enzymes in yeast can improve the disappearance of ruminants (Chuelong et al., 2011). Therefore, urea in the solution might cause a breakdown of the fiber structure in CS; it acts as an alkaline substance of ammonium hydroxide (Suriyapha et al., 2021). The fraction of NDF and ADF were lower 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 the previous finding (Norrapoke et al., 2022; Khejornsart et al., 2022; Dagaew et al., 2023), but lesser than (Sommai at al., 2020), which substituted soybean meal with yeast-fermented cassava pulp and (Keaokliang et al., 2018), who used cassava diet in cattle. According to Khejornsart et al. (2022), CS added to fermented total mixed rations in lambs increased the digestibility of DM, OM, CP, NDF, and NDF, while this was also agreed upon in this current study (Morm et al., 2023).

4.6.4 The blood metabolism, temperature variable, rumen pH, rumen fermentation, and microbial population

Currently, the results of rectum temperature in 45-d and 90-d post-feeding were agreed upon by Morm et al. (2023), substituting dry cassava pulp fermented (CtFCp) in concentrate. Another hand, protozoal population, fungus, rectum pH, and blood urea nitrogen (BUN) were unaffected and agreed to Sommai et al. (2020); Phesatcha et al. (2022); Dagaew et al. (2022) use fermented cassava pulp substituted or supplemented in concentrate but Morm et al. (2023), disagreed which is replaced fermented cassava pulp in concentrate. The rumen pH was not influenced by using CtFCp in animal diet and was reported to rank 6.17-6.70 (Hung et al., 2013). Rumen pH was not affected could be CtFCp production process uses yeast (*Saccharomyces cerevisiae),* that is produced high live yeast content production. Used CtFCp-50 and CtFCp-*ad libitum* may also have no bearing on rumen pH. The correlation between Lactate-using bacteria (LUB), 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 in Thai native cattle making the rumen pH sustainable (Dagaew et al., 2022). TVFA profile did not change when used CtFCp supplemented concentrate at any level, and it was supported (Cherdthong et al., 2019; Gunun et al., 2022). Who used yeast waste as a protein source to replace soybean meal or treated cassava pulp substitute in soybean meal. The recent results revealed that the VFA rumen concentration in CON, CtFCp-50, and CtFCp-*ad libitum* were 111.94, 116.37, and 113.85 mmol/L were closed results (Sommai et al., 2020; Khejornsart et al., 2022; Gunun et al., 2023), but there were disagreed (Dagaew et al., 2022; Gunun et al., 2023) were reported between 64.36-68.00 mmol/L, and (Norrapoke et al., 2022) found 123.6-127.7 mmol/L. Our studies have shown that C2 and C3 were unaffected by using all levels of CtFCp; it has high fiber content levels and low fermentation fraction that lead to low substrate supply to generate C2 and C3 in the rumen. Meanwhile, C3 is an activity of rumen microorganism fermentation; a small amount of rumen microorganism can impact C3 (Gunun et al., 2022). Our current outcomes found that the protozoal population was not changed; it could be related to a high fiber content

that lowers the number of digestible nutrients and results in a low fermentation yield (Gunun et al., 2018). Additionally, protozoal population in the current research's bi-groups in the current research were 4.75, 4.60, and 4.74 log cells/mL, similar results (Norrpoke et al., 2022) using fermented cassava pulp with 4% urea in beef cattle, but fungal zoospores were less. Triglycerides are stored in the lipids in the blood; calories from any feed move into the triglycerides, and there is energy. Afterward, hormones release triglycerides for energy between meals. Whereas creatinine in CON, CtFCp-50, and CtFCp-*ad libitum* was 1.27, 1.34, and 1.17 mg/dL higher than standard (1.04 mg/dL for female), so all animals faced kidney disease, but glucose was normal (Stringer et al., 2015).

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Substantially, most of small or medium scale-farming cropping cassava is focused on the main root for commercial benefit and stems for their propagation, some for selling to their local market or outselling in their areas. Regrettably, after harvesting cassava top was neglected. Cassava top is a roughage feed source; it provides a sustainable nutrient to the ruminant. Moreover, cassava pulp is an industrial waste, and some feeding industries have been abandoned, whereas it can be modified to benefit human daily use and ruminant feed. Due to cassava top and cassava pulp being potential residues for ruminants' feedstuffs were assigned to the research study. The fresh and dried cassava top and pulp were fermented to determine the suitable level through the *in vitro* method before application to the ruminant. Thai native x Lowline Angus crossbreed cattle were selected to evaluate growth performance, feed efficiency, nutrient intake, rumen fermentation, and blood metabolites by using dried cassava top fermented cassava pulp to substitute or supplement in concentrate to feeding to the cattle. The results of the study are summarized below:

5.1.1 Gas kinetics, rumen characteristics, and *in vitro* degradability of varied levels of dried and fresh cassava top fermented cassava pulp

Based on this study, CS fermented with DCT at 5% to 10% DM can enhance crude protein content in silage, *in vitro* dry matter disappearance (IVDMD), and gas production from the immediately soluble fraction while lowering the protozoa population. Further studies should be conducted *in vivo* to validate the impact of CS ensilage with DCT.

5.1.2 Thai native x Lowline Angus crossbred cattle on feed intake, feed digestibility, rumen microorganisms, and fermentation: The effects of using cassava products to replace concentrate

Feeding dried cassava top fermented pulp (CtFCp-33) improved nutrient intake and nutrient digestibility more than CtFCp-67 in Thai native x Lowline Angus crossbreed cattle. Therefore, diets in the CtFCp-33 and control (CON) groups

increased total volatile fatty acids and butyrate. In conclusion, dried cassava top fermented cassava pulp (CtFCp) could substitute concentrate up to 33% without harming feed intake, digestibility, or ruminal fermentation. Substitution of dried cassava top fermented cassava pulp (CtFCp-33) in concentration is an efficient strategy for improving Thai native cattle sources and could contribute to controlling environmental contamination. Further studies should be conducted to investigate the effects of CtFCp-30 on cattle growth performance or dairy cattle to evaluate milk production and quality.

5.1.3 Effects of using dried cassava top fermented cassava pulp on ruminal parameters, blood metabolites, and growth performance of Thai native x Lowline Angus crossbred cattle

The CtFCp-50 or CtFCp-*ad libitum* was not affected in blood metabolism, microorganism synthesis, or digestibility as potentially digestible standards. In conclusion, CtFCp-50 or CtFCp-*ad libitum* was a potential roughage to be supplied directly to cattle without any dismissive affected on cattle, enhancing cattle growth performance and digestibility in Thai native x Lowline Angus crossbred cattle. Thus, CtFCp-50 or CtFCp-*ad libitum* are recommended to evaluate the ruminant feed source on growth rate or dairy cattle to evaluate milk production and quality for further research.

5.2 Recommendation

Cassava pulp was found to be very low in crude protein, approximately 2.99%, while cassava top used in dried and fresh form to ensile in cassava pulp enhanced nutrient content. A fresh form of cassava top administered at 5, 10, and 15% ensiled cassava pulp derives the benefit of crude protein increasing between 9.45 and 9.93%. Whereas dried cassava top was used at the same level as fresh cassava top, fermented cassava pulp revealed that crude protein increased between 10.17 and 11.05% in the experiment **(I)**. The 15% dried cassava top to ensile with cassava pulp was selected to conduct the experiment **(II)**, which found that replacing 33% of previous feedstuff in concentrate without having a negative impact on feed intake, digestibility, or ruminal fermentation. So that this feedstuff carried on to the experiment **(III)**, results found that it improved growth performance and feed conversion ratio (FCR) while

supplementing dried cassava top fermented cassava pulp 50% or supplied *ad libitum* in the concentrate. As a result of the experiments (**I**, **II**, and **III**), benefits to native beef cattle were derived. Moreover, cassava residue is an efficient strategy for improving alternative sources of animal feed and could contribute to controlling environmental contamination. Furthermore, cattle-feeding developers should include 15% cassava top-ensiled cassava pulp. Additionally, all levels of cattle farming (small, medium, and large scale) should use dried cassava tops because they can be kept and used for the whole year, whereas fresh can be collected only during harvesting time to supply the cattle but can't be resistant for a whole year. In addition, the production of cassava top provides a high yield while harvesting at 4-6 months of cropping, also remaining a properly roots yield production that can be used as cattle feed sources. Thus, cattle investigators have been recommended for cassava cropping and harvesting at 4-6 months of age.

REFERENCES

REFERENCES

Ayodeji O. F. "Nutrient Composition and Processing Effects on Cassava Leaf (Manihot esculenta, Crantz) Antinutrients ", **Pakistan Journal of Nutrition.** 4(1): 37-42; May, 2005.

Agwu A. E. and Anyaeche C. L. "Adoption of improved cassava varieties in six rural communities in Anambra State, Nigeria", **African Journal of Biotechnology**. 6(2): 089-098; January, 2007.

Asaolu V. O. **Utilization of cassava peels and *Gliricidia sepium* (JACQ) Steud in the diet of West African Dwarf sheep**. Doctor's Thesis (Dissertation): The Obafemi Awolowo University, 1988.

Anna E.B. and et al. "Total cyanide content of cassava food production in Australia", **Journal of Food Composition and Analysis**. 25(1): 79–82; February, 2012.

Aro S.O. and et al. "Preliminary investigation on the nutrients, anti-nutrients and mineral composition of microbially fermented cassava starch residues", in **the Proceeding 33rd Annual Conference Nigeria Society for Animal Production (NSAP)**. p. 248-251. Ayetoro: Ogun State, Nigeria, 2008.

Aro S. O. and et al. "Nutritional potentials of cassava tuber wastes: A case study of a cassava starch processing factory in south-western Nigeria", **Livestock Research for Rural Development**. 22(11): 1-9; November, 2010.

Ashbell G. and et al. "The effects of temperature on the aerobic stability of wheat and corn silages", **Journal of Industrial Microbiology and Biotechnology**. 28(5): 261-263; November, 2002.

Ayele H.H., Latif S. and Müller J. " Pretreatment of the Leaves of Ethiopian Cassava (Manihot Esculenta Crantz) Varieties: Effect of Blanching on the Quality of Dried Cassava Leaves", **Applied Sciences**. 12(21): 11231; November, 2022.

Agle M. and et al. "Effect of dietary concentrate on rumen fermentation, digestibility, and nitrogen losses in dairy cows", **Journal of Dairy Science**. 93(9): 4211-4222; September, 2010.

REFERENCES (CONTINUED)

Australian Center for International Agricultural Research (ACIAR). **Best Practice Health and Husbandry of Cattle, Cambodia**. Phnom Penh, Cambodia: ACIAR, 2009.

Arun S. **National Assessment of Cambodia's Main Crop and Fodder Resources**. Phnom Penh, Cambodia: Centre for Livestock and Agriculture Development (CelAgrid), 2012.

AOAC. **Official Methods of Analysis Chemists**. 15th ed. Washington, D.C.: Association of Official Analytical Chemists, 1990.

AOAC. **Official Methods of Analysis Chemists**. 16th ed. Gaithersburg, M.D.: Association of Official Analytical Chemists, 1997.

Amin A.B. and Mao S. "Influence of Yeast on Rumen Fermentation, Growth Performance and Quality of Products in Ruminants: A review", **Animal Nutrition**. 7(1): 31-41; March, 2021.

Berry N.R. et al. "Selection, intake and excretion of nutrients by Scottish Highland suckler beef cows and calves, and Brown Swiss dairy cows in contrasting Alpine grazing systems", **The Journal of Agricultural Science**. 139(4): 437-453; March, 2002.

Bailey D.W. and et al. "Relationship between terrain use and performance of beef cows grazing foothill rangeland", **Journal of Animal Science**. 79(7): 1883–1891; July, 2001.

Braghieri A. and et al. "Time budget, social and ingestive behaviours expressed by native beef cows in Mediterranean conditions", **Livestock Science**. 141(1): 47-52; October, 2011.

Bauman D.E., Davis C.L. and Bucholtz H.F. "Propionate Production in the Rumen of ows Fed Either a Control or High-Grain, Low-Fiber Diet", **Journal of Dairy Science**. 54(9): 1282-1287; September, 1971.

Boonnop K. and et al. "Enriching nutritive value of cassava root by yeast fermentation", **Scientia Agricola**. 66(5): 629-633; September, 2009.

Bokanga M. "Processing of Cassava Leaf for Human Consumption", **Acta Horticulture**. 375(2): 203-207; March, 1994.

REFERENCES (CONTINUED)

Birger L.M. "Functional of diversifications of cyanic glucosides", **Current option in plant biology**. 13(3): 338-347; June, 2010.

Blumenthal S.G. and et al. "Cyanide metabolism in higher plants. The formation of β-Cyanoaline", **Journal of Biological Chemistry**. 243(1): 5302-5307; September, 1968.

Bradbury J.H. and Holloway W.D. "Chemistry of tropical root crops; significance for the nutrient and agriculture in the Pacific", **Australian Center for International Agricultural Research (ACIAR)**. 6(1): 1-20; June, 1988.

Brown M.S., Ponce C.H. and Pulikanti R. "Adaptation of Beef Cattle to High-Concentrate Diets: Performance and Ruminal Metabolism", **Journal of Animal Science**. 84(13): 25-33; April, 2006.

Burns A. E. and et al. "Variations in the chemical composition of cassava (*Manihot esculenta* Crantz) leaves and roots as affected by genotypic and environmental variation", **Journal of Agricultural and Food Chemistry**. 60(19): 4946-4956; May, 2012.

Boukhers I. and et al. "Nutrition, Healthcare Benefits and Phytochemical Properties of Cassava (Manihot Esculenta) Leaves Sourced from Three Countries (Reunion, Guinea, and Costa Rica)", **Foods**. 11(14): 2027; July, 2022.

Castellanos R., Altamirano S.B. and Moretti R.H. "Nutritional characteristics of cassava (Manihot esculenta Crantz) leaf protein concentrates obtained by ultrafiltration and acidic thermocoagulation", **Plant foods for human health**. 45(4): 357-63; June, 1994.

Chavalparit O. and Ongwandee M. "Clean technology for the tapioca starch industry in Thailand", **Journal of Cleaner Production**. 17(2): 105-110; January, 2009.

Chauynarong N. and et al. "Variation in nutrient composition of cassava pulp and its effects on *in vitro* digestibility", **Asian Journal of Poultry Science**. 9(4): 203-212; March, 2015.

REFERENCES (CONTINUED)

Chompunuch V. and et al. "Cassava pulp enzymatic hydrolysis process as a Preliminary step in bio-alcohols production from waste starchy resources", **Journal of Cleaner Production**. 39(2013): 273-279; January, 2013.

Chumpawadee S . and Soychuta S. "Nutrient enrichment of cassava starch industry by-product using rumen microorganism as inoculums source", **Pakistan Journal of Nutrition**. 8(9): 1380-1382; September, 2009.

Chuelong. and et al. "Supplementation Levels of Palm Oil in Yeast (*Saccharomyces cerevisiae*) Culture Fermented Cassava Pulp on Rumen Fermentation and Average Daily Gain in Crossbred Native Cattle", **Pakistan Journal of Nutrition**. 10(12): 1115-1120; December, 2011.

Supapong C. and Cherdthong A. "Effect of Sulfur and Urea Fortification of Fresh Cassava Root in Fermented Total Mixed Ration on the Improvement Milk Quality of Tropical Lactating Cow", **Veterinary Medicine and Science**. 7(3): 1-13; July, 2020.

Chaucheyras-Durand F. and et al. "Live Yeasts Enhance Fibre Degradation in the Cow Rumen through an Increase in Plant Substrate Colonization by Fibrolytic Bacteria and Fungi", **Journal of Applied Microbiology**. 120(3): 560-570; March, 2016.

Carta F.S. and et al. "Production of fumaric acid by fermentation of enzymatic hydrolysates derived from cassava bagasse", **Bioresource Technology**. 68(1): 23-28; April, 1999.

Cherdthong A. and Supapong C. "Improving the nutritive value of cassava bioethanol waste using fermented yeast as a partial replacement of protein source in dairy calf ration", **Tropical Animal Health and Production**. 51(8): 2139-2144; May, 2019.

Chirinang P. and Oonsivilai R. "Physicochemical properties, In vitro binding capacity for lard, cholesterol, bile acids and assessment of prebiotic potential of dietary fiber from cassava pulp", **International Food Research Journal**. 25(1): S63-S74; December, 2018.

REFERENCES (CONTINUED)

Cherdthong A. and et al. "Inclusion of Yeast Waste as a Protein Source to Replace Soybean Meal in Concentrate Mixture on Ruminal Fermentation and Gas Kinetics Using in Vitro Gas Production Technique", **Animal Production Science**. 59(9): 1682-1688, 2018.

Djuma'ali N. and et al. "Cassava pulp as biofuel feedstock of an enzymatic hydrolysis process", **MAKARA of Technology**. 15(2): 183-192; November, 2011.

Dagaew G. and et al. "Manipulation of in Vitro Ruminal Fermentation and Feed Digestibility as Influenced by Yeast Waste-Treated Cassava Pulp Substitute Soybean Meal and Different Roughage to Concentrate Ratio", **Fermentation**. 7(3): 196; September, 2021.

Dagaew. and et al. "The effects of fermented cassava pulp with yeast waste and different roughage-to-concentrate ratios on ruminal fermentation, nutrient digestibility, and milk production in lactating cows", **Heliyon**. 9(4): e14585; March, 2023.

De Sá LRV. and et al. "Simultaneous analysis of carbohydrates and volatile fatty acids by HPLC for monitoring fermentative biohydrogen production", **International Journal of Hydrogen Energy**. 36(23): 15177-15186; November, 2011.

Dagaew G. and et al. "The Effects of Fermented Cassava Pulp with Yeast Waste and ifferent Roughage-to-Concentrate Ratios on Ruminal Fermentation, Nutrient Digestibility, and Milk Production in Lactating Cows", **Heliyon**. 9(4): e14585, 2023.

Desnoyers M. and et al. "Effect of Concentrate Percentage on Ruminal PH and Time-Budget in Dairy Goats", **Animal**. 2(12): 1802-1808; January, 2008.

Dumont B. and et al. "Effects of livestock breed and grazing intensity on biodiversity and production in grazing systems. 1. Nutritive value of herbage and livestock performance", **Grass Forage Science**. 62(1): 145–158; June, 2007.

De Alba Becerra R. and et al. "Diets of 3 cattle breeds on Chihuahuan Desert rangeland", **Journal of Range Management**. 51(3): 270–275; May, 1998.

REFERENCES (CONTINUED)

D'Hour P. and et al. "Variations in grazing behaviour of Salers and Limousin heifers during time spent in the paddock in a rotational system", **Annales de zootechnie**. 43(3): 289-289; March, 1994.

Duff G.C. and et al. "Influence of beef breeds (brangus, Charolais, or hereford) on locoweed consumption", **The Professional Animal Scientist**. 18(1): 33–37; March, 2002.

De Souza Gomes H. **Forage Preference and Grazing Behavior of Hereford and Barzona Cattle on Southern Arizona Range**. Master's Thesis: University of Arizona, 1983.

Estell R. and et al. "Diet selection of Raramuri Criollo and angus x hereford crossbred attle in the Chihuahuan Desert", **Journal of Arid Environments**. 205(2022): 104823; October, 2022.

Euis H. And et al. "Potential utilization of cassava pulp for ethanol production in Indonesia", **Scientific Research and Essays**. 7(2): 100-106; January, 2012.

Forbes T.D.A. **A compilation of research results involving tropically adapted beef cattle Breeds**. Louisiana: Southern Cooperative Series Bulletin, 2005.

Forbes T.D.A., Rouquette F.M. and Holloway J.W. "Comparisons among Tuli-, brahman-, and angus-sired heifers: intake, digesta kinetics, and grazing behavior", **Journal of Animal Science**. 76(1): 220–227; January, 1998.

Faccio-Demarco. and et al. "Effect of Yeast Products Supplementation during Transition Period on Metabolic Profile and Milk Production in Dairy Cows", **Trop Animal Health and Production**. 51(8): 2193–2201; November, 2019.

Fathima. A.A. and et al. "Cassava (Manihot Esculenta) Dual Use for Food and Bioenergy: A Review", **Food and Energy Security**. 12: e380; March, 2023.

REFERENCES (CONTINUED)

Ganiyu O. "Nutrient enrichment of cassava peels using a mixed culture of Saccharomyces cerevisae and Lactobacillus spp solid media fermentation techniques", **Electronic Journal of Biotechnology**. 9(1): 46-49; January, 2006.

Ginja C. and et al. "The genetic ancestry of American Creole cattle inferred from Uniparental and autosomal genetic markers", **Scientific reports**. 9(2019): 11486; Agust, 2019.

Gumisiriza R. and et al. "Biomass waste-to-energy valorization technologies: A review case for banana processing in Uganda", **Biotechnology for biofuels**. 10(11): 2-29; January, 2017.

Granum G. and et al. "A Comparative Study on the Effect of Cassava Hay Supplementation in swamp buffaloes (Bubalus bubalis) and cattle (Bos indicus)", **Asian-Australian Journal of Animal Science**. 20(9): 1389 - 1396; September, 2007.

Ghimire A., Sen R. and Annachhatre AP. "Biosolid Management Options in Cassava Starch Industries of Thailand: Present Practice and Future Possibilities", **Procedia Chemistry**. 14(2015): 66-75; December, 2015.

Galyean M. **Laboratory Procedures in Animal Nutrition Research**. New Mexico: New Mexico State University, 1989.

Gunun N. and et al. "Utilization of Mao (Antidesma Thwaitesianum Muell. Arg.) Pomace Meal to Substitute Rice Bran on Feed Utilization and Rumen Fermentation in Tropical Beef Cattle", **Veterinary Sciences**. 9(11): 585; October, 2022.

Gunun P. and et al. "Replacing Concentrate with Yeast- or EM-Fermented Cassava Peel (YFCP or EMFCP): Effects on the Feed Intake, Feed Digestibility, Rumen Fermentation, and Growth Performance of Goats", **Animals**. 13(4):551; February, 2023.

REFERENCES (CONTINUED)

Gunun P. and et al. "In Vitro Rumen Fermentation and Methane Production as Affected by Rambutan Pee Powder", **Journal of Applied Animal Research**. 46(1):1-6; September, 2017.

Hobbs, N.T. "Modification of ecosystems by ungulates", **The Journal of Wildlife Management**. 60(4): 695–713; January, 1996.

Hackmann T. and Firkins J. "Maximizing efficiency of rumen microbial protein production", **Frontiers in Microbiology**. 6(465): 1-16; May, 2015.

Hermiati E. and et al. "Improvement of microwave-assisted hydrolysis of cassava pulp and tapioca flour by addition of activated carbon", **Carbohydrate Polymers**. 87(1): 939-942; January, 2012.

Hawashi M. and et al. "Optimization of Process Conditions for Tannin Content Reduction in Cassava Leaves during Solid State Fermentation Using *Saccharomyces Cerevisiae*", **Heliyon**. 5(8): e02298; Agust, 2019.

Hue K.T. and et al. "Effect of Adaptation Strategies When Feeding Fresh Cassava Foliage on Intake and Physiological Responses of Lambs", **Tropical Animal Health and Production**. 44(2): 267-276; February, 2012.

Hung L. V., Wanapat M. and Cherdthong A. "Effects of Leucaena Leaf Pellet on Bacterial Diversity and Microbial Protein Synthesis in Swamp Buffalo Fed on Rice Straw", **Livestock Science**. 151(2-3): 188-197; February, 2013.

International Research Development Center (IRDC). **For Hunger-proof Cities: Sustainable Urban Food Systems**. Ottawa, Canada: IRDC, 1999.

INRA. **INRA feeding system for ruminants**. Wageningen, Netherlands: INRA, 2018.

Jyothi A.N. and et al. "Optimization of glutamic acid production from cassava starch factory residues using Brevibacterium divaricatum", **Process Biochemistry**. 40(11): 3576 -3579; November, 2005.

Julie A. M., Christopher R. D. and Tanumihardjo A. "Nutritional Value of Cassava for Use as a Staple Food and Recent Advances for Improvement", **Comprehensive reviews in food science and food safety**. 8(3): 181-194; June, 2009.

REFERENCES (CONTINUED)

Küme T. and et al. "Evaluation and comparison of Abbott Jaffe and enzymatic creatinine methods: Could the old method meet the new requirements?", **Journal of Clinical Laboratory Analysis**. 32(1): e22168; Janaury, 2018.

Kosugi A. and et al. "Production of ethanol from cassava pulp via fermentation with a surface engineered yeast strain displaying glucoamylase", **Renewable Energy**. 34(5): 1354-1358; May, 2009.

Kortei N.K., Dzogbefia V.P. and Obodai M. "Assessing the effect of composting cassava peel based substrates on the yield, nutritional quality, and physical characteristics of Pleurotus ostreatus (Jacq. ex Fr.) Kummer", **Biotechnology research international**. 14(2): 1-9; December, 2014.

Katherine A. and et al. "Livestock and livelihoods of smallholder cattle-owning households in Cambodia: the contribution of on-farm and off-farm activities to income and food security", **Tropical Animal Health and Production**. 50(8): 1747-1761; December, 2018.

Keo S., Khieu B. and Preston T R. "Survey on feed utilization for cattle production in Takeo province", **Livestock Research for Rural Development**. 20(8): 18-26; May, 2008.

Kock B. and et al. "The biosynthesis of cynaoglucosides in seedlings of cassava", **Archives of Biochemistry and Biophysics**. 292(1): 141-50; January, 1992.

Kosugi A. and et al. "Production of ethanol from cassava pulp via fermentation with a surface engineered yeast strain displaying glucoamylase", **Renewable Energy**. 34(5): 1354-1358; May, 2009.

Khampa S. and et al. "Supplementation of Yeast Fermented Cassava Chip as a Replacement Concentrate on Rumen Fermentation Efficiency and Digestibility of Nutrients in Heifer", **Journal of Animal and Veterinary Advances.** 8(6): 1091-1095; September, 2009.

Khampa S., Ittharat S. and Koatdoke U. " Enrichment value of yeast-malate fermented cassava pulp and cassava hay as protein source replace soybean meal in concentrate on rumen ecology in crossbred native cattle", **Pakistan Journal of Nutrition**. 10(12): 1126-1131; December, 2011.

REFERENCES (CONTINUED)

Kittivorawate S. **The effect of the source and level of protein on the relationship ween the synthesis of protein by micro-organisms, the correlation of digestibility and metabolism in the bloodstream of water buffalo**. Doctor's Thesis: Khon Kaen University, 1996.

Khejornsart P., Meenongyai W. and Juntanam T. "Cassava Pulp Added to Fermented tal Mixed Rations Increased Tropical Sheep's Nutrient Utilization, Rumen Ecology, and Microbial Protein Synthesis", **Journal of Advanced Veterinary and Animal Research**. 9(4): 754-760; December, 2022.

Keaokliang O. and et al. "Chemical composition and nutritive values of cassava pulp for cattle", **Animal Science Journal**. 89(8): 1120-1128; May, 2018.

Kleiber M. "Reviews", **Physiological Reviews**. 27(4): 511-541; October, 1947.

Kelly A.K. and et al. "Relationship between Body Measurements, Metabolic Hormones, Metabolites and Residual Feed Intake in Performance tested Pedigree Beef Bulls", **Livestock Science**. 135(1): 8-16; January, 2011.

Keulen J.V. and Young B.A. "Evaluation of Acid-Insoluble Ash as a Natural Marker in Ruminant Digestibility Studies", **Journal of Animal Science**. 44(2): 282-287; February, 1997.

Lounglawan P. and et al. "Utilization of cassava peel as energy source of silage", in **Proceeding of the 14th AAAP Animal Science Congress**. p.23-27. Pingtung: Taiwan, 2010.

Lounglawan P., Khungaew M. and Suksombat W. "Silage production from cassava pel and cassava pulp as energy source in cattle diets", **Asian Journal of Animal and Veterinary Advances**. 10(8): 1007-1011; August, 2011.

Li M. and et al. "Silage Fermentation and Ruminal Degradation of Cassava Foliage Prepared with Microbial Additive", **AMB Express**. (180):2-9; November, 2019.

Latif S. and Müller J. "Potential of cassava leaves in human nutrition: A review", **Trends in Food Science & Technology**. 44(2): 147-158; April, 2015.

REFERENCES (CONTINUED)

Leguizamón A J. and et. "Nutritional evaluation of three varieties of cassava leaves (*Manihot esculenta* Crantz) grown in Formosa, Argentina", **Journal of Food Composition and Analysis.** 101(3): 103986; May, 2021.

Li.L. E.N.M. and et al. "Comparison of feeding diets diluted with sorghum-sudangrass silage or low-quality grass on nutrient intake and digestibility and growth performance of Holstein dairy heifers", **Journal of Dairy Science**. 102(11): 9932-9942; November, 2019.

Mizrahi I., Wallace R.J. and Morais S. "The rumen microbiome: Balancing food security and environmental impacts", **Nature Reviews: Microbiology**. 19(6): 553-566; September, 2021.

Morgavi D.P. and et al. "Review: Reducing enteric methane emissions improves energy metabolism in livestock: is the tenet right?", **The International Journal of Animal Biosciences**. 17(3): 100830; April, 2023.

Morris S.T., Parker W.J. and Grant D.A. "Herbage intake, liveweight gain, and grazing behaviour of friesian, piedmontese × Friesian, and belgian blue × friesian bulls", **New Zealand Journal of Agricultural Research**. 36: 231–236; December, 1993.

Marquardt S., Soto D. and Joaquin N. "Foraging behavior of Criollo vs. Brahman ×Criollo crossbreds in the Bolivian chaco: case study", **Rangeland Ecology and Management**. 71(6): 757–761; November, 2018.

Modig T., Liden G. and Taherzadeh J. "Inhibition effects of furfural on alcohol dehydrogenase, dehydrogenase and pyruvate dehydrogenase", **The Journal of Biochemistry**. 363(3): 769-776; May, 2002.

Ministry of Agriculture, Forestry and Fisheries (MAFF). **Annual report in 2020 and planning in 2021 of agriculture, forestry and fisheries**. Phnom Penh, Cambodia: MAFF, 2021.

Ministry of Agriculture, Forestry and Fisheries (MAFF). **Annual report in 2021 and planning in 2022 of agriculture, forestry, and fisheries**. Phnom Penh, Cambodia: MAFF, 2022.

REFERENCES (CONTINUED)

Ministry of Planning (MP). **Census of Agriculture in Cambodia**. Phnom Penh, Cambodia: MP, 2015.

Mob S. and et al. "Cattle production systems in NW Cambodia", **Livestock Research and Rural Development**. 26(3): 1-12; March, 2014.

MIRANDA P. and et al. "Cattle Feeding and Management Practices of Small-holder Farmers in Kampong Cham Province, Cambodia", **International Journal of Environmental and Rural Development**. 1(1): 132-138; March, 2010.

Meenongyai W. and Khumpeerawat P. "Effects of cassava flour industry by-products in diets on finishing lambs productive performance", **Khon Kaen Agricultural Journal**. 38(2): 385-394; March, 2010.

Morgan N.K. and Choct M. "Nutrient Composition and Nutritive Value in Poultry Diets", **Animal Nutrition**. 2(4): 253-261; December, 2016.

Morm S. and et al. "Review: Toxicity Volatiles of Dried Techniques for Detoxification in Cassava Leave (Manihot Esculenta Crantz)", **International Journal of Scientific Engineering and Science**. 6(6): 1-6; June, 2022.

Moss A.R., Jouany J.P. and Newbold J. "Methane Production by Ruminants: Its Contribution to Global Warming", **Animal Research**. 49(3): 231-253; May, 2000.

Morm S., Kong S. and Iv S. "Effect of Different Rates of Cassava Leaves Hay on Growth Performance and Fecal Parasitic Eggs in Gastro- Intestinal Cattle", **Asian Journal of Agricultural and Environmental Safety**. 2021(1): 24-27; June, 2021.

Morm S. and et al. "Gas Kinetics, Rumen Characteristics, and In Vitro Degradability of Varied Levels of Dried and Fresh Cassava Leaf Top Fermented with Cassava Pulp", **Tropical Animal Science Journal**. 46(1): 105-111; March, 2023.

REFERENCES (CONTINUED)

Mao L. and et al. "Silage fermentation and ruminal degradation of cassava foliage prepared with microbial additive", **AMB Express**. 9(1): 180; November, 2019.

Menke K. H. and Steingass H. "Estimation of the energetic feed value obtained from chemical analysis and gas production using rumen fluid", **Animal Research Development**. 28(1): 7-55; November, 1988.

Nyamuryekung'e S. and et al. "Foraging behavior of heritage vs commercial rangeland beef cows in relation to dam-offspring interactions Contact Patterns", **Rangeland Ecology & Management**. 74(2021): 43-49; January, 2021.

_____. "Movement, activity, and landscape use patterns of heritage and commercial beef cows grazing Chihuahuan Desert rangeland", **Rangeland Ecology & Management**. 199(2022): 104704; April, 2022.

Nweke F. I., Spencer D. S. C. and Lynam J. K. **The Cassava Transformation: Africa's best kept secret**. East Lansing, USA: Michigan State University, 2002.

Nartey F. "Studies on cassava cynogenisis-biosynthesis of aspargines-C14 from C14 labelled hydrogen cyanide and it relation with cyanogenesis", **Physiologia Plantarum**. 22(5): 1085-1096; April, 1968.

Nambisan B. and Sundaresan S. "Distribution of linamarin and its metabolizer enzymes in cassava tissues", **Journal of the Science of Food and Agriculture**. 66(4): 503-507; December, 1994.

Norrapoke T. and et al. "Improvement of Nutritive Value of Cassava Pulp and *in Vitro* Fermentation and Microbial Population by Urea and Molasses Supplementation", **Journal of Applied Animal Research**. 46(1): 242-247; January, 2018.

Norrapoke V. and et al. "Microbial population, chemical composition and silage ermentation of cassava residues", **Animal Science Journal**. 86(9): 842–848; March, 2015.

REFERENCES (CONTINUED)

Norrapoke T. and et al. "Improvement of nutritive value of cassava pulp and *in vitro* fermentation and microbial population by urea and molasses supplementation", **Journal of Applied Animal Research**. 46(1): 242-247; March, 2017.

Norrapoke N. and et al. "Improvement of cassava pulp nutritive value and *in vitro* fermentation by urea and molasses treatment", **Khon Kaen Agriculture Journal**. 44(1): 405-412; June, 2016.

Newbold C. J. and et al. "The role of ciliate protozoa in the rumen", **Frontiers in Microbiology**. 26(6): 1313; November, 2015.

National Research Council Nutrient Requirements of Domestic Animals. **Nutrient equirements of Beef Cattle**. Bangkok: NRC, 2000.

Ortigues-Marty I. and et al. "Contribution of nutrient fluxes to the evolution of the net energy systems, example of the inra feeding system for beef cattle", **Translational Animal Science**. 3(3): 1048-1063; June, 2019.

Orr R.J. and et. "Effects of livestock breed and rearing experience on foraging behaviour of yearling beef cattle grazing unimproved grasslands", **Grass Forage Sciene**. 69(1): 90–103; March, 2014.

Odediran O. F. and et al. "Awareness of Cassava Peel Utilization Forms among Cassava Processors in Rural Communities of Southwest, Nigeria", **International Journal of Applied Agricultural and Apicultural Research**. 11(1-2): 93-102; january, 2015.

Oboh G. "Nutrient enrichment of cassava peels using a mixed culture of *Saccharomyces cerevisae* and *Lactobacillus* spp. solid media fermentation", **Electronic Journal of Biotechnology**. 9(1): 46-49; January, 2006.

Ornvimol K. and et al. "Chemical composition and nutritive values of cassava pulp for cattle", **Animal Science Journal**. 89(8): 1120-1128; May, 2018.

Okrathok S. and et al. "Effects of cassava pulp fermented with Aspergillus oryzae as a feed ingredient substitution in laying", **Journal of Applied Poultry Research**. 27(2): 188-19; June, 2018.

REFERENCES (CONTINUED)

Oni A.O. and et al. "Effect of Additives on Fermentation of Cassava Leaf Silage and Ruminal Fluid of West African Dwarf Goats", **Archivos de Zootecnia**. 63(243): 449-459; January, 2014.

Pitt D. and et al. "Demography and rapid local adaptation shape Creole cattle genome diversity in the tropics", **Evolutionary Applications**. 12(1): 105–122; May, 2019.

Sprinkle E. **Fecal Output of Different Biological Types of Beef Cattle on Native Range throughout a Production Year**. Doctor's Thesis (Dissertation): Montana State University, 1992.

Polyorach S. and et al. "Microbial Fermented Liquid Supplementation Improves Nutrient Digestibility, Feed Intake, and Milk Production in Lactating Dairy Cows Fed Total Mixed Ration", **Animals.** 13(5): 933; March, 2023.

Pauler C.M. and et al. "Influence of Highland and production-oriented cattle breeds on pasture vegetation: a pairwise assessment across broad environmental gradients", **Agriculture, Ecosystems and Environment**. 284(2019): 106585; July, 2019.

Pauler C.M. and et al. "Choosy grazers: influence of plant traits on forage selection by three cattle breeds", **Functional Ecology**. 34(5): 980–992; February, 2020b.

Pauler C.M. and et al. "Grazing allometry: anatomy, movement, and foraging behavior of three cattle breeds of different productivity", **Frontiers in Veterinary Science**. 14(7): 1–17; August, 2020a.

Pandey A. and et al. "Biotechnological potential of agro-industrial residues. II: cassava bagasse", **Bioresource Technology**. 74(1): 81-87; August, 2000.

Payne W.J.A. and Hodges J. **Tropical Cattle Origins, Breed and Breeding Policies**. Oxford: UK, 1997.

Payne W.J.A. **Cattle production in the tropics. Vol. 1. General introduction and breeds and breeding**. London: Longman, 1970.

REFERENCES (CONTINUED)

Panichnumsin P. and et al. "Production of methane by co-digestion of cassava pulp with various concentrations of pig manure", **Biomass and Bioenergy**. 34(8): 1117-1124; August, 2010.

Pen M. and et al. "Cattle feeding and management practices of small-holder farmers in Kampong Cham Province, Cambodia", **International Journal of Environmental and Rural Development**. 1(1): 132-138; March, 2010.

Prado F.C., Vandenberghe L.P.S. and Soccol C.R. "Relation between citric acid production by solid-state fermentation from cassava bagasse and respiration of Aspergillus niger LPB 21 in Semi-Pilot Scale", **Brazilian Archives of Biology and Technology**. 48(SPE): 29-36; June, 2005.

Pilajun R. and Wanapat M. "Chemical Composition and in Vitro Gas Production of Fermented Cassava Pulp with Different Types of Supplements", **Journal of Applied Animal Research.** 46(1): 81-86; November, 2018.

Phesatcha K. and et al. "Addition of Active Dry Yeast Could Enhance Feed Intake and Rumen Bacterial Population While Reducing Protozoa and Methanogen Population in Beef Cattle", **Fermentation**. 7(172): 1-9; August, 2021.

Paengkoum P. and Bunnakit. K. "Nutritional evaluation of extrusion-processed mixture of cassava pulp and urea using in vitro gas production technique", **Animal Feed Science and Technology**. 12(3): 315-324; September, 2012.

Polyorach S., Wanapat W. and Cherdthong A. "Influence of yeast fermented cassava chip protein (YEFECAP) and roughage to concentrate ratio on ruminal fermentation and microorganisms using *in vitro* gas production technique", **Asian-Australasian Journal of Animal Sciences**. 27(1): 36-45; July, 2014.

Phesatcha K. and et al. "The effect of yeast and roughage concentrate ratio on ruminal pH and protozoal population in Thai native beef cattle", **Animals**. 12(1): 1-11; December, 2022.

Quezada M.A.L. **Evaluation of Forage Intake, Digestibility and Efficiency in Barzona, Beefmaster and Brangus Cattle Grazing Semidesert Range**. Doctor's Thesis: New Mexico State University, 1998.

REFERENCES (CONTINUED)

Rom´an-Trufero A. and et al. "Foraging behaviour and performance of steers from two local breeds (Asturian valley and Asturian mountain) grazing in Cantabrian (N Spain) summer pastures", **Spanish Journal of Agricultural Research**. 17(1): 1–10; March, 2019.

Russell M.L. and et al. "Grazing distribution and diet quality of angus, brangus, and brahman cows in the chihuahuan desert", **Agriculture, Ecosystems and Environment**. 65(4): 371–381; July, 2012.

Robert T. and Ignatious K. "Cyanogenic potential of cassava peels and their detoxification for utilization as livestock feed", **Veterinary and Human Toxicology**. 44(6): 366-369; December, 2002.

Rattanachomsri U. and et al. "Simultaneous non-thermal saccharification of cassava pulp by multi-enzyme activity and ethanol fermentation by Candida tropicalis", **Journal of Bioscience and Bioengineering**. 107(5): 488-493; May, 2009.

Ravindran V. and Rajaguru A.S.B. "Effect of stem pruning on cassava root yield and leaf growth", **Sri Lankan Journal of Agricultural Science**. 25(2): 32-37; December, 1988.

Ruiz-Guti6rrez V. & Barron L.J.R. "Review: Methods for the analysis of triacylglycerols", **Journal of Chromatography**. 671(1-2): 133-168; September, 1995.

Ravindran V. "Preparation of cassava leaf products and their use as animal feeds. In: Roots, Tubers, plantain and bananas in animal feeding", **Food and Agriculture Organization**. 95(4): 111-25; February, 1991.

Ravindran V. and et al. "Cassava leaf meal as a replacement for coconut oil meal in broiler diets", **Poultry Science**. 65(9): 1720-7; September, 1986.

Robinson P.H. and et al. "Evaluation of NRC, UC Davis and ADAS Approaches to Estimate the Metabolizable Energy Values of Feeds at Maintenance Energy Intake from Equations Utilizing Chemical Assays and in Vitro Determinations", **Animal Feed Science and Technology**. 114(1-4), 75-90; May, 2004.

REFERENCES (CONTINUED)

Sheehy C.M. **Comparison of Spatial Distribution and Resource Use by Spanish and British Breed Cattle in Northeastern Oregon Prairie Ecosystems**. Doctor's Thesis: Oregon State University, 2007.

Smith S.B., Gotoh T. and Greenwood P.L. "Current situation and future prospects for global beef production: overview of special issue", **Asian-Australasian Journal of Animal Sciences**. 31(7): 927–932; May, 2018.

Spiegal S. and et al. "Seasonal divergence of landscape use by heritage and conventional cattle on desert rangeland", **Agriculture, Ecosystems and Environment**. 72(4): 590-601; July, 2019

Sprinkle J.E. and et al. "Digesta kinetics, energy intake, grazing behavior, and body temperature of grazing beef cattle differing in adaptation to heat", **Journal of Animal Science**. 78(6): 1608–1624; June, 2000.

Stricklin W.R., Wilson L.L. and Graves H.B. "Feeding behavior of angus and chrolais- angus cows during summer and winter", **Journal of Animal Science**. 43(3): 721–732; September, 1976.

Scimone M. and et al. "Effects of livestock breed and grazing intensity on grazing systems: 3. Effects on diversity of vegetation", **Grass and Forage Science**. 62(4): 172-184; December, 2007.

Salami R. I. and Odunsi A. A. "Evaluation of processed cassava peel meals as substitutes for maize in the diets of layers", **International Journal of Poultry Science**. 2(2): 112-116; October, 2003.

Supreena S., Wisitiporn S. and Pipat L. "Fresh cassava peel in dairy cattle diet: Effects On milk production, hygienic quality of raw milk and somatic cell counts", **Songklanakarin Journal of Science and Technology**. 40(4): 977-984; July, 2018.

Srimuang T. and Polprasert S. "Utilization of Cassava Pulp and Cassava Wastewater for Bioethanol Production", **RMUTP Research Journal**. 13(2): 167-175; Deecember, 2019.

REFERENCES (CONTINUED)

Nwokoro S. O., Adegunloye H. D. and Ikhinmwin A. F. "Nutritional composition of garri sievates collected from some locations in Southern Nigeria", **Pakistan Journal of Nutrition**. 4(4): 257-261; April, 2005.

Sinha S.K. and Nair T.V.R. "Studies on the variability of the cyanogenic glucoside content in cassava tuber", **The Indian Journal of Agricultural Sciences**. 38(2): 958-963; April, 1968.

Sowcharoensuk C. **Thailand industry outlook 2023-25: Cassava industry**. Bangkok: Krungsri, 2023.

Sriroth K. and et al. "Processing of cassava waste for improved biomass utilization", **Bioresource Technology**. 71(1): 63-69; January, 2000.

Srinorakutara T. and et al. Utilization of waste from cassava starch plant for Ethanol production. in **Proceedings of The Joint International Conference on Sustainable Energy and Environment (SEE)**. p.344-349. Bangkok: Kesetsart University, 2004.

Suksombat W., Lounglawan P. and Noosen P. "Energy and protein evaluation of five feedstuffs used in diet in which cassava pulp as main energy source for lactating dairy cows", **Suranaree Journal of Science and Technology**. 14(1): 99-107; January, 2007.

Souza J. G., Ribeiro C. V. D. M. and Harvatine K. J. "Meta-analysis of rumination behavior and its relationship with milk and milk fat production, rumen pH, and total-tract digestibility in lactating dairy cows", **Journal of Dairy Science**. 105(1): 2022; January, 2022.

Sommai S. and et al. "Replacing soybean meal with yeast-fermented cassava pulp **(**YFCP**)** on feed intake, nutrient digestibilities, rumen microorganism, fermentation, and N-balance in Thai native beef cattle", **Tropical and Health and Production**. 52(4): 2035–2041; July, 2020.

Supapong C. and et al. "*In vitro* fermentation, digestibility and methane production as influenced by Delonix regia seed meal containing tannins and saponins", **Animal Feed Science and Technology**. 26(2): 123-130; June, 2017.

REFERENCES (CONTINUED)

Serment A. and et al. "Effects of the percentage of concentrate on rumen fermentation, nutrient digestibility, plasma metabolites, and milk composition in mid-lactation goats", **Journal of Dairy Science**. 94(8): 3960–3972; August, 2011.

So S., Cherdthong A. and Wanapat M. "Growth performances, nutrient digestibility, ruminal fermentation and energy partition of Thai native steers fed exclusive rice straw and fermented sugarcane bagasse with Lactobacillus, cellulase and molasses", **Journal of Animal Physiology and Animal Nutrition**. 106(1): 45–54; January, 2022.

Suriyapha C. and et al. "Utilization of yeast waste fermented citric waste as a protein source to replace soybean meal and various roughage to concentrate ratios on in vitro rumen fermentation, gas kinetic, and feed digestion", **Fermentation**. 7(3): 1-14; July, 2021.

Sutton J.D. and et al. "Rates of production of acetate, propionate, and butyrate in the rumen of lactating dairy cows given normal and low-roughage diets", **Journal of Dairy Science**. 86(16): 3620–3633; November, 2003.

Stringer K.A. and et al. "Whole Blood Reveals More Metabolic Detail of the Human etabolome than Serum as Measured by 1H-NMR Spectroscopy: Implications for Sepsis Metabolomics", **Shock**. 44(3): 200-208; September, 2015.

Taborda P.A.B., Saravia C.T. and Espasandin A.C. "Physiological responses and animal behavior in bonsmara-hereford crosses vs. Hereford purebred on environment stress", **The Journal of Agricultural Science**. 75(6): 479–485; December, 2018.

Tofastrud M. and et al. "Weight gain of free-ranging beef cattle grazing in the boreal forest of south-eastern Norway", **Livestock Science**. 233(2020): 103955; February, 2020.

Tewe O. O. **The global cassava development strategy: cassava for livestock feed in Sub-Saharan Africa**. Ibadan, Nigeria: The University of Ibadan, 2004.

REFERENCES (CONTINUED)

The Working Committee of Thai Feeding Standard for Ruminants (WSTR). **Nutrient Requirements of Beef Cattle in Thailand**. Bangkok: WSTR, 2009.

Tawida S. and Supawadee P. "Utilization of Cassava Pulp and Cassava Wastewater for Bioethanol Production", **RMUTP Research Journal**. 13(2): 167-175; January, 2019.

Thang C.M., Ledin I. and Bertilsson J. "Effect of Using Cassava Products to Vary the level of Energy and Protein in the Diet on Growth and Digestibility in Cattle", **Livestock Science**. 128(1-3): 166-172; January, 2010.

Tilley J. M. A. and Terry R.A. "A two-stage technique for the digestion of forage crops", **Grass Forage Science**. 18(2): 104–111; June, 1963.

Tavares L.A. and et al. "Use of Saccharomyces Cerevisiae-Based Products and Effects Rumen Environment and Performance of Sheep Subjected to Dietary Changes", **Ciencia Rural**. 51(2): 1-12; February, 2021.

Thongchul N., Navankasattusas S. and Yang S.T. "Production of lactic acid and ethanol by Rhizopus oryzae integrated with cassava pulp hydrolysis", **Bioprocess and Biosystems Engineering**. 33(3): 407-416; March, 2010.

USAID. (2012). "Animal feed assessment: Final report (Cambodia MSME 2/BEE Project)", **United States Agency for International Development (USAID)**. http://pdf.usaid.gov/pdf_docs/pnaec939.pdf. 14 June, 2022.

Virunanon C. and et al. "Cassava pulp enzymatic hydrolysis process as a preliminary step in bio-alcohol production from waste starchy resources", **Journal of Cleaner Production**. 39(2013): 273-279, 2013.

Van Soest P. J. and Robertson J. B. A. **Analysis of Forages and Fibrous Foods: A Laboratory Manual for Animal Science 613**. Ithaca (NY): Cornell University, 1985.

Van Soest P.J., Robertson J.B. and Lewis B.A. "Methods for Dietary Fiber, Neutral Detergent Fiber, and Nonstarch Polysaccharides in Relation to Animal Nutrition", **Journal of Dairy Science**. 74(10): 3583-3597; October, 1991.

REFERENCES (CONTINUED)

VanWagoner H.C. and et al. "Differences among beef sire breeds and relationships between terrain use and performance when daughters graze foothill rangelands as cows", **Applied Animal Behaviour Science**. 97(2-4): 105–121; May, 2006.

Wanapat M. and Cherdthong et al. "Use of Real-Time PCR Technique in studying rumen cellulolytic bacteria population as affected by level of roughage in Swamp buffalo", **Current Microbiology**. 58(4): 294-9; November, 2009.

Suksombat W., Homkaow J. and Meeprom C. "Effects of ensiled Aspergillus oryzae and Saccharomyces cerevisiae cassava pulp as replacement for concentrate on ruminal fermentation in rumen-fistulated cows", **Songklanakarin Journal of Science and Technology**. 40(4): 896-903; August, 2018.

White Pas T.W. and Saxton A.M. "Forage feeding behavior of hereford and hereford crossbred steers during the summer", **Applied Animal Behaviour Science**. 14(1): 62–67; March, 1998.

Winder J.A. and et al. "Breed and stocking rate effects on Chihuahuan Desert cattle production", **Rangeland Ecology and Management**. 53(1): 32–38; January, 2000.

Winder J.A., Walker D.A. and Bailey C.C. "Effect of breed on botanical composition of cattle diets on Chihuahuan desert range", **Rangeland Ecology and Management**. 49(3): 209–214; May, 1996.

Wiener P. **Genetics of Behaviour in Cattle**. 2nd ed. Croydon: CPI, 2014.

Wanapat M. and Kang S. " Cassava chip (Manihot esculenta Crantz) as an energy source for ruminant feeding", **Animal Nutrition**. 1(4): 266–270; December, 2015.

Waiboonya P. and et al. "Effects of fermented cassava pulp on dry matter intake, onception rate and performance in dairy heifers", in **Proceeding, Seminar in Agriculture**. p.26-27. Khon Kaen: Khon Kaen University, 2010.

REFERENCES (CONTINUED)

Wilkinson J. M. and Davies D. R. "The aerobic stability of silage: key findings and recent developments", **Grass and Forage Science**. 68(1): 1-19; March, 2013.

Wojciechowski A.L. and et al. "Xanthan gum production from cassava bagasse hydrolysate with Xanthomonas campestris using alternative sources of nitrogen", **Applied Biochemistry and Biotechnology**. 118(1-3): 305 -312; July, 2004.

Wanapat M. "Manipulation of Cassava Cultivation and Utilization to Improve Protein to Energy Biomass for Livestock Feeding in the Tropics", **Asian-Australasian Journal of Animal Sciences**. 16(3): 463-472; January, 2003.

Wanapat M. and et al. "Strategic supplementation of cassava top silage to enhance rumen fermentation and milk production in lactating dairy cows in the tropics", **Tropical animal Health and Production**. 50(7): 1539-1546; October, 2018.

Wobeto C. and et al. "Antinutrients in the cassava (*Manihot esculenta* Crantz) leaf powder at three ages of the plant", **Food Science and Technology International**. 27(1): 108–112; January, 2007.

Zheng Y. and et al. "Feeding value assessment of substituting cassava (Manihot Esculenta) residue for concentrate of dairy cows using an in vitro gas test", **Animals**. 11(2): 1-11; January, 2021.

Zhang M. and et al. "Biorefinery approach for cassava-based industrial wastes: current status and opportunities", **Bioresource Technology**. 215(2): 50-62; April, 2015.

Zhang J., Zhou L. and Zhang Y. "Diagnostic Values of Blood Urea Nitrogen (BUN), Creatinine (Cr), and the Ratio of BUN to Cr for Distinguishing Heart Failure from Asthma and Chronic Obstructive Pulmonary Disease", **Computational and Mathematical Methods in Medicine**. 2022(4586458): 2-7; July, 2022.

APPENDICES

APPENDIX A
TOOLS

The instrument or material during data collection

1. 75% Holstein-Friesian crossbred dairy steers for donor fluid collection

Figure A.1 75% Holstein-Friesian crossbred dairy steers

2. Thai native x Lowline Angus crossbred cattle

Figure A.2 Thai native x Lowline Angus crossbred cattle

3. The production performance of Thai native x Lowline Angus crossbred cattle

Figure A.3 Production performance of Thai native x Lowline Angus crossbred cattle

4. Rumen fluid collection sampling

Figure A.4 Rumen fluid collection sampling

5. Yeast activation and fermented fresh and dried cassava top with cassava pulp

Figure A.5 Dried and fresh cassava top fermented cassava pup

6. Artificial saliva inoculum for in vitro technique and gas production kinetic measurement

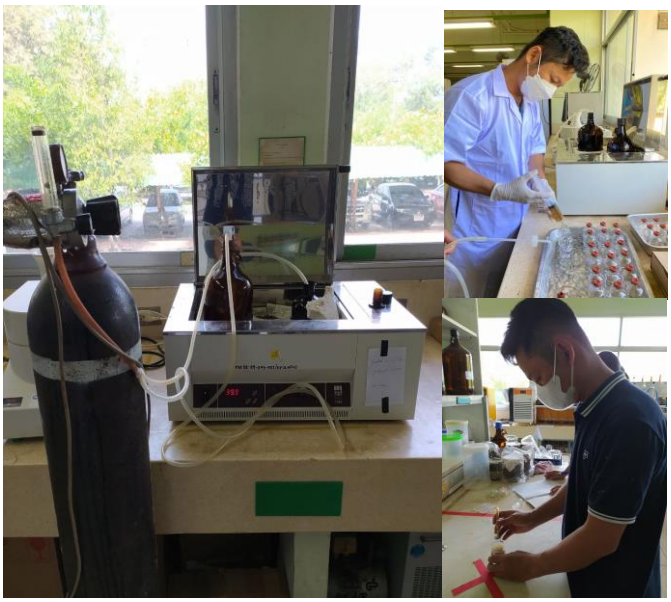


Figure A.6 Artificial saliva inoculum and gas production kinetic measurement

7. Concentrate mixing by an SM-3.0CR, 3HP, Hz 50, VOLTS 220, AMPS 20.0, r/min 1450, and JIS C 4004 JP 22 JC machine

Figure A.7 Concentrate mixing an SM-3.0CR, 3HP, Hz 50, VOLTS 220, AMPS 20.0, r/min 1450, and JIS C 4004 JP 22 JC machine

8. Cassava tops

Figure A.8 Drying cassava top under ambient temperature

9. H_2SO_4 (0.005 mol/L) mobile phase

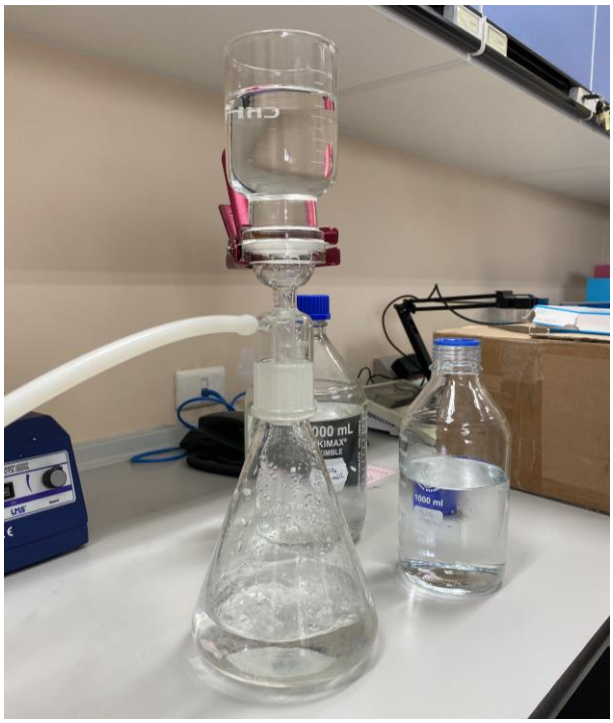


Figure A.9 H2SO4 (0.005 mol/L) mobile phase

10. Dionex UHPLC Thermo Scientific UltiMate 3000

Figure A.10 Dionex UHPLC Thermo Scientific UltiMate 3000

APPENDIX B
PUBLICATION AND CONFERENCE PROCEEDING

Publications: Journal and Conference Proceeding

Morm S., Lunpha A., Pilajun A., Cherdthong A. “Gas Kinetics, Rumen Characteristics, and In Vitro Degradability of Varied Levels of Dried and Fresh Cassava Leaf Top Fermented with Cassava Pulp”, **Tropical Animal Science Journal**. 46(1):105-111, 2023. (Impact factor=0.80).

Morm S., Lunpha A., Pilajun R., Cherdthong A. “Review: Toxicity Volatiles of Dried Techniques for Detoxification in Cassava Leave (Manihot esculenta Crantz)”, **International Journal of Scientific Engineering and Science.** 6(6):1-6, 2022.

Morm S., Lunpha A., Pilajun A., Cherdthong A. “The effect of dried and fresh Manihot esculenta Crantz tops fermented cassava pulp on nutritive value, gas kinetics, rumen fermentation, and in vitro digestibility”, **Thai Journal of Animal Science**. Abstract proceeding. 1(2565).

VITAE

NAME	Mr. Sophany Morm
DATE OF BIRTH	February 15, 1988
NATIONALITY	Cambodian
ADDRESS	Romchek 4 Village, Rattanak Commune, Battambang Town, Battambang Province, 21403 Cambodia
MOBILE	(855)16 66 99 06/ 11 66 99 05
E-MAIL ADDRESS	sophanymorm@gmail.com
EDUCATION	2013-2015, Master of Science (Conservation Agriculture) University of Battambang, Cambodia (GPAX=4.0) 2010-2012, Bachelor of Science (Animal Science) University of Battambang, Cambodia (GPAX=3.50) 2006-2008, Associate of Science (Farming System) Royal University of Agriculture, Cambodia (GPAX=3.50)
SCHOLARSHIPS	Higher Education Improvement Project of Cambodia: HEIP
WORK EXPERIENCES	2019-Present, Faculty of Agriculture and Food Processing, National University of Battambang (NUBB) 2017-2019, Extension Office, Pailin Provincial Department of Agriculture, Forestry and Fisheries 2014-2016, Animal Health and Production Office, Pailin Provincial Department of Agriculture, Forestry and Fisheries 2010-2013, Animal Science Laboratory Technician, University of Battambang (UBB) 2009-2010, Animal Husbandry Technician, University of Battambang (UBB)
POSITION	Head of the Department
CURRENT OFFICE	Department of Animal Science
PUBLICATION	6 Papers 5 Proceeding of the National Conference