PROCEEDING OF THE 9th INTERNATIONAL CONFERENCE ON INTEGRATION OF SCIENCE AND TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT 2021 (9th ICIST)

"Soil, water and environmental conservation, biological diversity, safety food and sustainable agriculture"

King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand.

November 19, 2021 (WEBINAR-ZOOM)

TABLE OF CONTENT

Juengjarernnirathorn, S., Thanuttamavong, M. and Lohsuwan, R. - Effects of draw solution and operating factors on forward osmosis for lime juice concentration 1-10

Lepcha, N. and Suwanmaneepong, S. - Cost and return analysis of organic potato in Gasa District, Bhutan 11-23

Pilajun, R., Lunsin, R., Yeanpet, C., Inthiseang, W. and Wanapat, M. - Growth performance and nutrient digestibility of Thai native compared with Lowline Angus crossbred beef cattle fed with regional feedstuffs 24-30

Effects of draw solution and operating factors on forward osmosis for lime juice concentration

Juengjarernnirathorn, S.[2], Thanuttamavong, M.[2] and Lohsuwan, R.[1] *

[1]Department of Environment Engineering, Kasetsart University, Bangkok, Thailand; [2]School of Integrated Science, Kasetsart University, Bangkok, Thailand.
*Corresponding Author: Lohsuwan R.; Email: rathanon.lo@ku.ac.th

Abstract Forward osmosis (FO) is a process that concentrates liquid food by slow water-transport which requires lower pressure, and the product from this process has similar quality to natural one. This study aimed to find suitable operating factors in FO process including temperature (10 - 30°C), circulation flow rate (200 – 350 ml/min), and concentration of NaCl (1 – 4M) for concentrating lime juice. By using commercial flat-sheet Reverse Osmosis membranes installed in a 3×8×12 cm membrane module with a 45 cm2 of cross-section area at the feed solution side, in order to study the effect of differences draw solution temperatures (10 to 30°C) on water flux value in a laboratory-scale. The result of the study found that using lower-temperature of draw solution achieves lower water flux value because of increasing viscosity values that also decreasing water flux. Moreover, increasing the circulation flow of draw solution is also increasing water flux and reducing membrane fouling during the process. Therefore, the suitable condition of Forward Osmosis is using 3M NaCl as Draw solution at 25°C, Synthetic lime at 20°C and operated with the circulation flow of draw solution side as 350 ml/min which result in a maximum average water flux is 2.33 l/m^2h at 90 minutes of operating time.

Keywords: Forward Osmosis, Lime Concentration, Temperature effect, Water Flux, Circulation flowrate

Introduction

Lime is one of the citrus plants that are important for both household and industrial economies in Thailand and are used as an ingredient in various foods and beverages. During drought or summer season often lacking lime period that was the lowest products and poorest quality yields of lime. Therefore, this issue was solved by preservation in lime concentrate form to facilitate storage, transportation, and distribution of the product as an economical operation. However, the thermal processes commonly applied for concentrating juice products, such as evaporation, have been reported to have detrimental impacts on the negative sensory and nutritional values of food products (Jesus *et al.,* 2007; Sant'Anna *et al.*, 2012).

Therefore, Forward osmosis (FO) process should be applied in the lime juice concentration process by this process archives without negative impacts on the sensory or nutritional values of juice products. In addition, FO process used more energy efficient as a concentration process than thermal evaporation and pressure-driven membrane processes, (Chekli *et al*., 2016). FO or another name. "Direction osmosis" is a diffusion phenomenon of water or solute through a membrane. (Semipermeable Membrane) with the Concentration Gradient. these is water diffuse from a low concentration solution called a "feed solution" to a high concentration solution called "Draw Solution" by Osmotic Pressure (Nagy, 2018). The water diffusion in this phenomenon was slow or fast depending on the osmotic pressure and applied external factors for improving process which has related physical and chemical factors such as pressure, temperature, viscosity, and the concentration of feed and draw solution within the forward osmosis process (Kim *et al.*, 2019), etc.

In this research, we investigated the possible improvement for lime juice concentration by FO process with the temperature-driven. This research focused on the physical factors of the draw solution that affecting the efficiency of the FO process in lab-scale which are temperature, circulation flow rate, and concentration. By using commercial flat-sheet Reverse Osmosis membranes because of these factors were directly related to osmotic pressure that achieved accelerating the diffusion of water in feed solution side to draw solution side and reducing the time of lime juice concentration with FO process. Lastly, there result also suggested improvements of FO process for lime juice concentration.

Materials and methods

Raw Material

Synthetic Lime solution was mixed with organic compounds in Lime juice refer to the most proportion of the organic chemicals in lime juice table (Tressler and Joslyn, 1961) that include AR Grade of Citric Acid Anhydrous (5.97 g./L.), Ascorbic Acid (0.03 g./L.) and Sucrose (3.2 g./L.) using as feed solution. the initial feed solution has the ph of feed solution equal 2.25±1 and the acidity of feed solution equal 0.02 g/100ml.. The draw solution was used 1, 2, 3 and 4M NaCl.

Forward osmosis module

The Forward osmosis experiments were proceeded with a polyamide thin-film composite RO membrane. The experiments were set using a 90 cm^2 surface area membrane with two sides in the 3x8x12 cm module as show in Figure 1. 6 L. container of NaCl as draw solution were fed by pass about 200 mL. of solution to the module by peristatic pump. A 3L. container of Synthetic Lime as feed solution were put in the container where the module had been set up inside

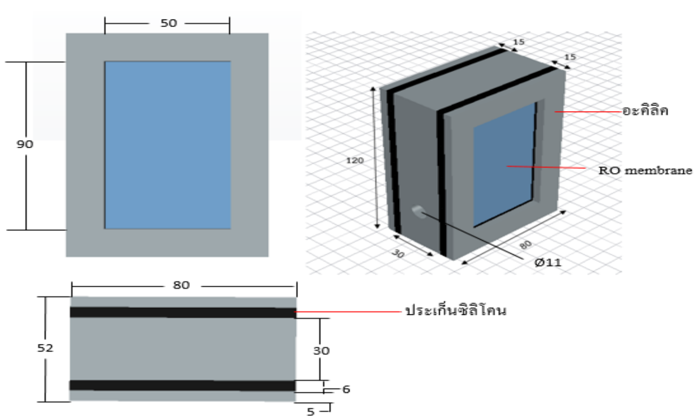


Figure 1. Forward osmosis module in experiments (unit; Milimeter)

Forward osmosis experiments

Forward osmosis experiments were carries out in three experiments. First, the effect of draw solution concentration on FO at 1,2,3 and 4M NaCl as draw solutions by fixed circulation flow rate at 300 ml/min for operating. Second, the effect of circulation flow rate on draw solution with 3M NaCl as draw solutions. Third, the effect of differential temperature on feed and draw solutions. The both temperature in first and second experiments were maintained in room temperature at around 30±1°C. the third experiment was separated the temperature control of feed and draw solutions which set up feed solution at 10 and 20 °C and draw solution at 10, 15, 20 and 25 °C, respectively.

Water Flux

Water flux (Nayak C. *et al.*, 2011) was calculated according to the following equation:

$$J = \frac{V_2 - V_1}{A \times t}. \qquad (1)$$

in which J is water flux. V_1 and V_2 are the draw solution volume at initial and monitoring times, respectively. A is the membrane surface area and t is the osmosis times (operating time).

Total Acidity

The total Acidity as Citric acid was calculated following to (A.O.A.C., 2012) method.

pH Brix Viscosity and salinity

The pH and salinity of sample was measured by pH meter; AMT03 AMTEST, Amtrast USA Inc., UAS. 2.7. Brix analysis
The °Brix of feed solution were measured by Brix refractometer; MR32ATC, Milwaukee, Massachusetts, USA. The viscosity of feed and draw solutions were measured by Viscometer; RV DV III, AMETEK Brookfield, Massachusetts, USA

Results

Effect of draw solution concentrations

The experiment 1 were resulted show in Figure 3. that 3M NaCl got higher water flux than other concentrations of NaCl solutions as Draw solution in equal temperature condition. The maximum average of water flux in 1, 2, 3 and 4 M NaCl at 1 hours of operating were 251.34 ,466.07 ,707.15 and 97.30 mL/m^{2}h, respectively. But the maximum water flux of 4 M NaCl was 114.31 mL/m^{2}h at 30 minutes of operating time and then the water flux decreasing to 0 mL/m^{2}h after 120 minutes of operating time but were found to continue to undergo forward osmosis, but 2M and 3M NaCl the water flux decreased until the forward osmosis was terminated at a time of 180 min in 1M 2M and 4M NaCl solution exception of 3M NaCl could be perform forward osmosis even after 3 hours of systemic operation.

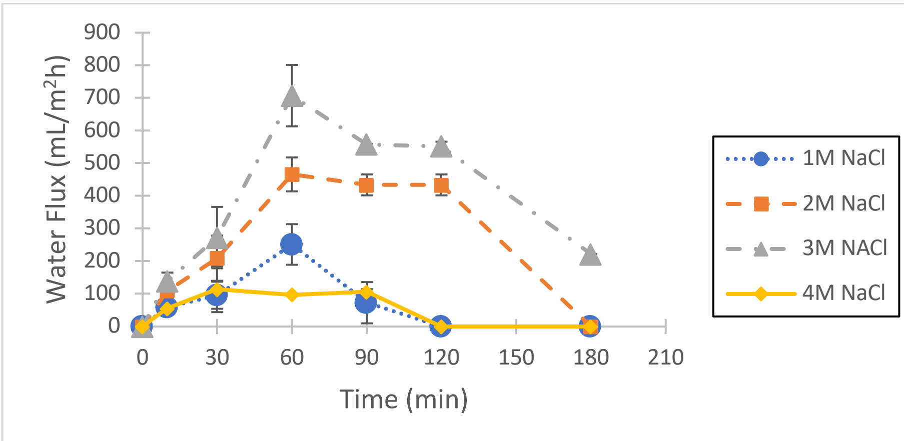


Figure 2. Water flux of concentrations of NaCl solution in 1, 2, 3 and 4 M as draw solution using a 300 ml / min. as draw solution flowrate

Effect of draw solution circulation flow

In Experiment 2, the results showed as Figure 4. that the effect of various flowrate of draw solution applied in FO was found the water flux in low to high flowrate were 456.93, 467.70, 707.15, and 903.09 mL/m^{2}h at 60 minutes that applied flowrate as 200, 250, 300 and 350 mL /min., respectively. According to the results of the experiment that increasing the flowrate with suction flow assist increases the water diffuse from the feed solution to draw solution.

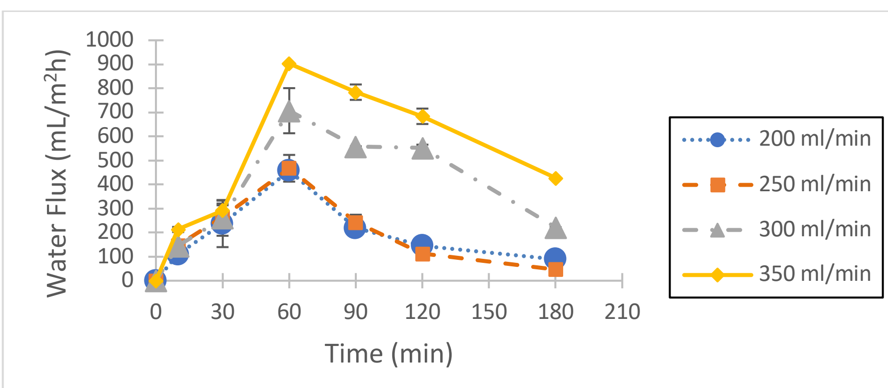


Figure 3. Water flux of 3M NaCl as draw solution with 200, 250, 300 and 350 ml./min as draw solution flowrate

Effect of draw solution and feed solution temperature

Before start the experiment 3, the viscosity of the draw and feed solutions was analyzed. Synthetic lime juice and NaCl solution at temperatures 10, 15, 20 and 25°C with the Brookfield viscometer was shown in Table 1. It was found that the viscosity of both solutions increased when the solution was at low temperature, corresponding to the viscosity theory of the solution Which describes the relationship between temperature and the viscosity of the solution is inversely proportional to the viscosity is the anti-flow force of the solution Therefore, high temperature operation results in better FO performance than low temperature operation (She *et al.*, 2016; Tang *et al.*, 2010).

Table 1. Viscosity of feed and draw solution at 10, 15, 20 and 25°C

Sample	Temperature (°C)	Viscosity (cP)	Shear stress (N/m^2)
Synthetic Lime (Feed)	25	1.92	4.70
	20	2.08	5.09
	15	2.24	5.48
	10	2.34	5.71
3M NaCl (Draw)	25	2.34	5.71
	20	2.46	6.03
	15	2.62	6.42
	10	2.78	6.81

The results of the operating of the synthetic lime juice at 10°C with NaCl solution at 10, 15, 20 and 25° C that shown as Figure 5. were found NaCl at 10 and 15 °C had the highest average water flux over 30 minutes of operating, where the maximum average water flux of the solution. NaCl at 10 and 15°C were 1,227.78 and 1,555.56 mL / m^2h, respectively. The FO characteristic of this first part of the system was a high-water flux from 10 to 30 minutes after 30 minutes of operation. System flux will be gradually reduced to complete a full 180 minutes of cycle. The system operation with solution NaCl at 20 and 25°C had the highest average water flux over 90 minutes of operating, where the highest mean water flux of NaCl solution at 20 and 25°C was 1,777.78 and 2,500.00 mL / m^2h in respect of These two FO system characteristics are that during 10-90 minutes the water flux will gradually increase up to 90 minutes, after which the water flux decreases so rapidly to the water flux is zero for the full 180 minutes of cycle.

The results of the operating experiment by controlling the temperature of synthetic lime juice at 20°C with NaCl solution at 10, 15, 20 and 25°C. NaCl at 10°C has the highest average water flux over 30 minutes of operating. The maximum average water flux of the solution. NaCl at 10 °C is equal to 1,518.52 mL / m^2h, the FO formation characteristic of this part of the system is similar to the FO formation characteristic of the experiment. Synthetic lime juice was obtained at 10 °C with NaCl solution at temperatures 10 and 15 °C before the part in the solution operation. NaCl at 15 and 20 ° C had the highest average water flux over 60 minutes of operation, where the maximum average water flux of the solution. NaCl at 15 and 20 °C were 1,777.78 and 1.833.33

mL / m^{2}h respectively. The FO characteristic of this system is that the water flux will increase gradually up to 60 minutes. A total of 180 minutes was completed. NaCl at 25 ° C has the highest average water flux over 90 minutes of operation. NaCl at 25 ° C is equal to 2,333.33 mL / m^{2}h, the FO-inducing behavior of the system in this section is similar to the FO-inducing behavior of the experiment, the temperature of synthetic lime juice was given to 20°C with NaCl solution at 15 and 20°C, but the water flux will increase up to 90 minutes of operating. After that, the water flux of the system will gradually decrease until the complete one cycle of operation.

The experiment was operating by FO system synthetic lime juice to 25°C with NaCl solution at 30°C. The maximum average water flux was within 90 minutes of operation where the maximum average water flux of the solution was obtained. NaCl at 25°C is 1,111.11 ml / m^{2}h, the FO characteristic of this part of the system is similar to the FO characteristic of experiment 2. Gradually decrease until the complete cycle of the system.

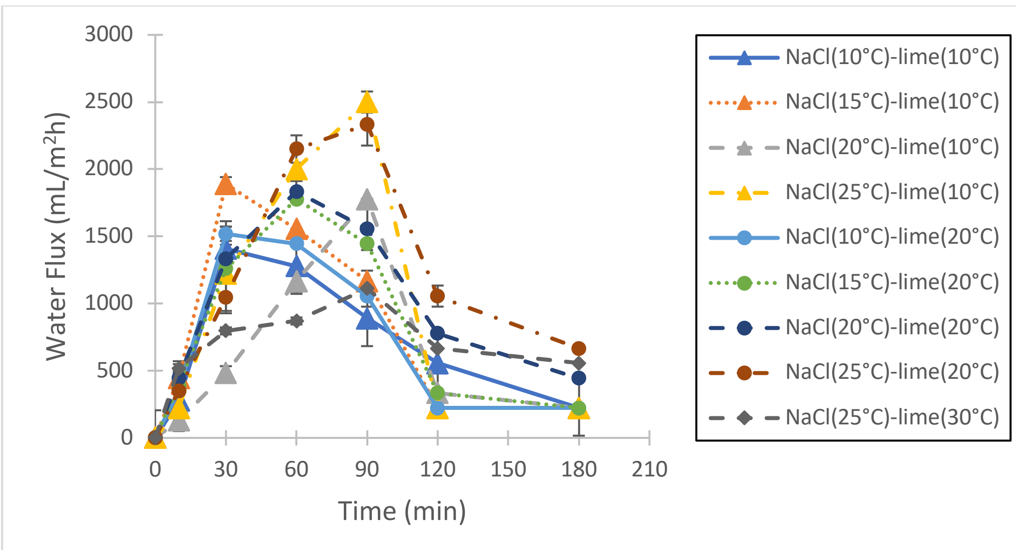


Figure 4. Water flux of 3M NaCl as draw solution at 10, 15, 20, 25 and 30°C and synthetic lime as feed solution at 10 and 20°C using 350 ml./min as draw solution flowrate (draw temp./feed temp.)

Feed Solution characteristics

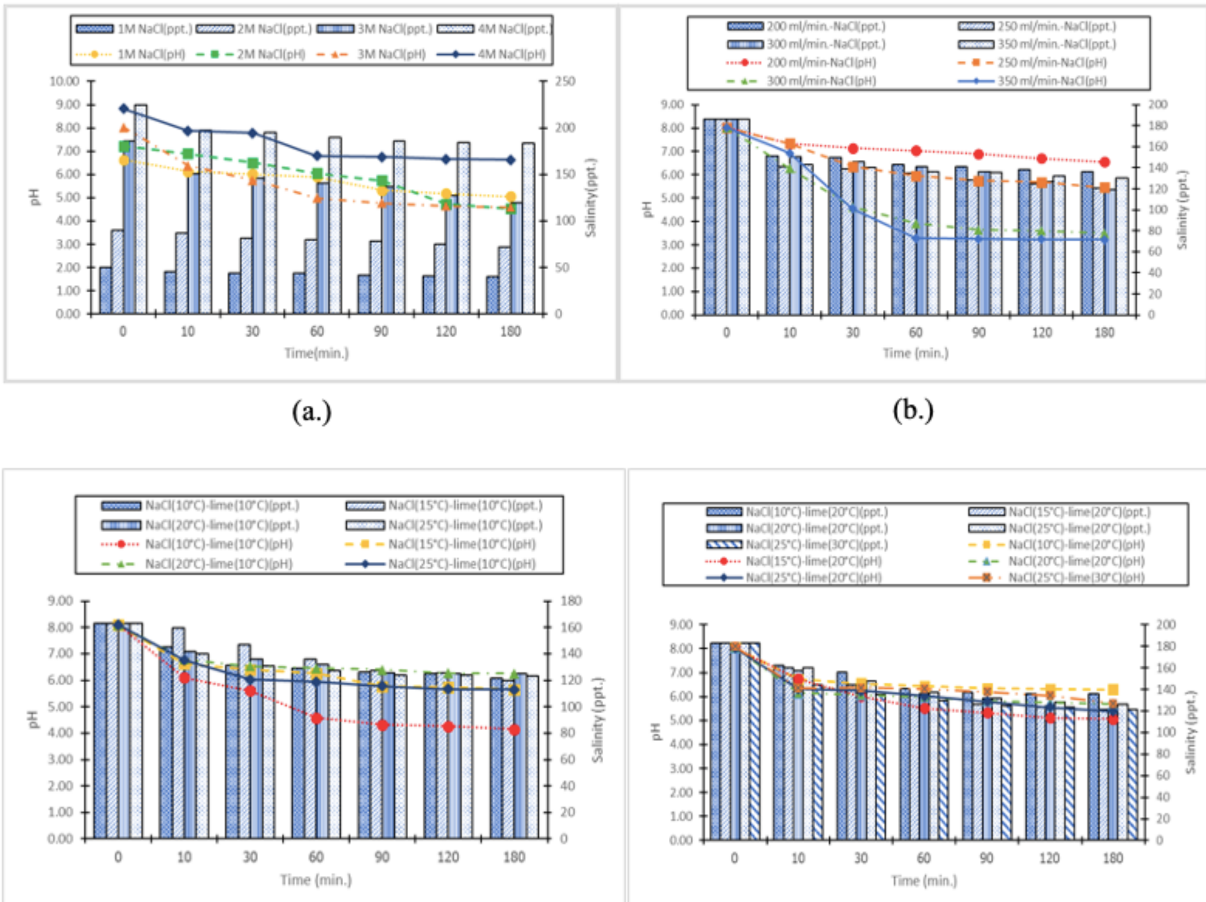
In synthetic lime solution, the feed solution is slighly change chemical characterized that show it Table. 2 but the water in feed solution is changed by volume. From experiment results 1-3 the factor that gives the highest water flux value in experiments was found that the initial feed solution volume decreased was 3 liters after 3 hours of operation, it was reduced feed volume to 2.95 liters (3M NaCl was used as the pulling solution), 2.94 liters (the draw solution flow rate was 350 ml./min.) and 2.85 liters (controlled temperature of feed solution at 20 °C and draw solution at 25 °C) respectively. It is assumed that this FO system can partially removing water in synthetic lime juice without degradation. Thus, the FO system has the potential to be applied in fresh lime juice.

Table. 2. Acidity of feed solution before and after operating FO in the best conditions of experiments (Exp.)

Time (min)	Acidity of feed solution (g/100 ml.)		
	Exp. 1	Exp. 2	Exp. 3
0	0.02	0.02	0.02
180	0.02 ±0.01	0.03 ±0.01	0.03 ±0.01

Draw Solution characteristics

The draw solution characteristics that shown in Figure 5. demonstrated results in terms of the pH and salinity of the draw solution. In all experiments, there was a change in this value, it was found that as the operating time increased, the pH of the draw solution decreased. Moreover, the salinity of draw solution was found that when operating for a long time, the salinity decreased which is related to the pH of the draw solution.



(a.) (b.)

(c.) (d.)

Figure 5. pH and Salinity of draw solution (a.) pH of draw solution experiment 1 (b.) pH of draw solution experiment 2 (c.) pH of draw solution in experiment 3 in synthetic lime at 10°C (d.) pH of draw solution in experiment 3 in synthetic lime at 20°C

Discussion

The results of first experiments were same as increasing beetroot water concentration by forward osmosis was found that the mean water flux in the system was 12.40 L / m^2h (Nayak *et al.*, 2011), which was less than that of research by Kim *et al.*, (2019) using NaCl solution. The 2M and 3M NaCl were draw solutions for increasing grapefruit concentrations by forward osmosis process. The average water flux values of forward osmosis process were 13.2 and 18.4 L / m^2h, respectively. Using a high-concentration draw solution will not always improve the efficiency of forward osmosis but also increases rapid fouling from the draw solution even though it gives a high flux value (Wang *et al.*,2016). The efficiency of the forward osmosis process depends on other factor such as the chemical composition, concentration and viscosity of the sample solution that also affect forward osmosis (Kim *et al.*, 2019; Nayak *et al.*, 2011). Therefore, the best condition in this experiment was using 3M NaCl that give a high-water flux as 707.15 mL/m^{2}h

The results of the second experiments were found that increasing the flowrate with suction flow assist increases the water diffuse from the feed solution to draw solution. Due to the high solution flowrate made the turbulent flow that creates a shear on the membrane surface, thereby reducing membrane fouling from Internal Concentration polarization in the membrane surface (Boo *et al.*, 2013). Moreover, the result was consistent with the experimental of Kim *et al.*, (2019), that increasing the flow rate of the draw solution improves the efficiency of the FO process.

The results of third experiments demonstrated that operating at high temperatures as well as solvents is the preferred method for significantly improving the efficiency of the FO system. In addition, this method reduces the viscosity of the two solutions, which is friction force and diffuses the particles in the solution, resulting in high temperature-controlled operation of both solutions with an average water flux. It was higher than the temperature-controlled system of the two solutions (Zhao *et al.*, 2012) because the highly viscous substance also had a high resistance to water diffusion. This occurs when the solution is in a low temperature state. Where temperatures have inverse viscosity relationships. That is why the system operation at low temperatures of both solutions is less efficient than the system that controls the high temperature of the solution.

The draw solution characteristics similar to the research of Saengrungnapaphan *et al.* (2019). Since Synthetic lime juice includes Citric acid and Ascorbic acid, it will break down in solutions that Proton (H^+) is smaller than water molecule during the FO process. H^+ particles pass through membrane pore with water molecules that results a rapid decrease in the pH of the draw solution. the research showed that the membrane material polyamine in this experiment allowed the H+ particles from the synthetic lime or feed solution side pass to the draw solution side (Saengrungnapaphan *et al.*, 2019).

Thus, the efficiency of the FO system in increasing the concentration of synthetic lime juice. It was found that the factors that increase the efficiency of the FO system were operation with increased flowrates, high temperatures and a suitable concentration of the draw solution. According to the high flow rate increases, it reduces membrane fouling due to shear force on the membrane surface that preventing accumulate some particle on the membrane surface. Less operating the system with a highly concentrated draw solution not only yields more water flux values over a period of time, but there will also be a chance of faster fouling in the system as a result of Concentration polarization on the membrane surface. The temperature of feed solution and the draw solution is one of factor that influences the efficiency of the FO system due to the inverse temperature relationship with the viscosity, which is the flow resistance of the solution. If operating the system with high solution temperature, it will reduce the viscosity of the solution and increase the efficiency of the FO system. Not only, the performance of the FO system depends on the factors of the draw solution but also the efficiency of the FO system depends the factors of the feed solution can also affect the performance of the FO system.

References

A.O.A.C. 2012. Official Methods of Analysis. 19th ed., The Association of Official Analytical Chemist, Washington.

Boo, C., Elimelech, M., Hong, S. (2013). Fouling control in a forward osmosis process integrating seawater desalination and wastewater reclamation. Journal of Membrane Science. 444: 148–156.

Chekli, L., Phuntsho, S., Shon,H. K. (2016). Acomprehensive review of hybrid forward osmosis systems: Performance, applications and future prospects. Journal of Membrane Science. 497: 430–449.

Jesus, D.F., Leite, M.F., Silva, L.F.M., Modesta, R.D., Matta, V.M., Cabral, L.M.C. (2007). Orange (Citrus sinensis) juice Zhao, S., Zou, L., Tang, C.Y., Mulcahy, D. (2012). Recent developments in forward osmosis: opportunities and challenges. Journal of Membrane Science. 396: 1–21. concentration by reverse osmosis. Journal of Food Engineering. 81: 287–291.

Kim, D.I., Gwak, G., Zhan, M., Hong, S. (2019). Sustainable dewatering of grapefruit juice through forward osmosis: improving membrane performance, fouling control, and product quality. C. 578: 53–60.

Nayak, C.A., Valluri, S.S., Rastogi, N.K. (2011). Effect of high or low molecular weight of components of feed on transmembrane flux during forward osmosis. Journal of Food Engineering. 106: 48–52.

Saengrungnapaphan, K., Thanuttamavong, M., Tongchitpakdee, S. (2019). Potential of forward osmosis on concentrated lime juice. Italian Journal of Food Science. 96–100.

Sant'Anna, V., Marczak, L.D.F., Tessaro, I.C. (2012). Membrane concentration of liquid foods by forward osmosis: process and quality view. Journal of Food Engineering. 111: 483–489.

She, Q., Wang, R., Fane, A.G., Tang, C.Y. (2016). Membrane fouling in osmotically driven membrane processes: a review. Journal of Food Engineering. 499: 201–233.

Tang, C.Y., She, Q., Lay, W.C.L., Wang, R., Fane, A.G. (2010). Coupled effects of internal concentration polarization and fouling on flux behavior of forward osmosis membranes during humic acid filtration. Journal of Membrane Science. 354: 123–133.

Tressler, D.K. and M.A. Joslyn. 1961. Fruit and vegetable juice processing technology. 1st ed. AVI Publ.Co., Westport, Connecticut.

Wang, B., Wen, X., Shen, B., Zhang, P. (2016). The current status and research advances in forward osmosis. Huanjing Kexue Xuebao/Acta Sci. Circumstantiae 36: 3118–3126.

Cost and return analysis of organic potato in Gasa District, Bhutan

Lepcha, N.* and Suwanmaneepong, S.

[1]School of Agricultural Technology, King Mongkut's Institute of Technology Ladkrabang, Ladkrabang Rd, Ladkrabang District, Bangkok 10520, Thailand.
Correspondence Author: Norden Lepcha; Email: nlepcha1@gmail.com

Abstract: Gasa District became the first district in Bhutan to fully embrace organic farming in 2004. The Government has been assertive to increase farmers' household earnings and alleviate poverty. Therefore, the study's objectives were to examine the cost and return analysis of organic potatoes (*Solanum tuberosom* L.) in the Gasa District. Purposive sampling was employed to select 43 organic potato farmers from Goenkhatoe *Gewog* (a group of villages in Bhutan) in the Gasa District. Primary data for the 2019 production and marketing cycle were gathered from September to October 2020, using a semi-structured questionnaire through face-to-face interviews. Descriptive statistics and cost-and-return analysis were used to analyze the data. According to the findings, the total production cost was 339,462.80 Ngultrum per hectare (Nu/ha) (1Nu=0.014 USD). The total variable cost was 338,211.89 Nu/ha, and the total fixed cost was 2,559.28 Nu/ha, comprising 99.63% and 0.75% of the total production cost, respectively. Within the variable costs, the total input cost was 142,427.99 Nu/ha, and the total labour cost was 195,783.89 Nu/ha, which made up 41.96% and 57.67% of the total production cost, respectively. The depreciation cost was the highest contributor within the fixed costs with 2,528.75 Nu/ha, comprising meagre 0.74% of the total production cost. The average yield of potato tuber was 7.48 metric tons per hectare (MT/ha). The average Gross margin (profit) was -202,708.47 Nu/ha. The break-even yield and price were 18.63 MT/ha and 45.58 Nu/ha, respectively. The benefit-cost ratio (B:C ratio) was 0.40, and Return on Investment (ROI) stood at -59.71. The Gross margin over cash and variable cost were 1,082.43 and -201,457.56 Nu/ha, respectively. Considering the lesser B:C ratio (<1), it indicated that organic potato farming is not a profitable venture in the current situation. For a profitable venture, the farmers either need to increase their yield or obtain a farm-gate price greater than the respective break-evens.

Keywords: farm household income; farm-gate price; potato production; production cost; profit.

Introduction

Organic farming is viewed as a means of increasing the sustainability of agriculture (Feuerbacher *et al.*, 2018). Additionally, many studies have shown that organic farming is profitable (Adhikari, 2011, Mendoza, 2004, Suwanmaneepong *et al.*, 2020). In 2019, organic farming accounted for 1.5% of total farmland worldwide, equivalent to 72.3 million hectares (ha). There were 3.1 million organic producers worldwide. Organic activities were conducted in 187 countries, with the organic market estimated at 106.4 billion euros. The per capita consumption of organic commodities was 14.0 euros (IFOAM, 2020).

In the wake of the global movement towards organic farming, Gasa District, one of Bhutan's 20 districts located in the West-Central part of the country, became a fully organic district in 2004 (Wangmo and Iwai, 2018). Bhutan is a tiny mountainous nation on the Himalayan southeast slope (D'Avanzo, 2008), and it has an ambitious goal to be a completely organic country in the globe (Department of Agriculture [DoA], 2006). Agriculture is a vital primary sector in Bhutan, providing livelihood and jobs to 43.9% of the population (Population & Housing Census of Bhutan [PHCB], 2017). Rice, maize, mandarin, apple, potato, and other vegetables, cardamom, and other spices are among the important crops grown in the country. Bhutan has largely smallholder farmers primarily involved in subsistence farming (National Statistical Bureau [NSB], 2017). After rice, maize, and wheat, the potato is the fourth most important crop in terms of calories. According to Bajgai (2018), the potato is one of Bhutan's most commonly grown, consumed, and traded horticultural crops, owing to favourable agro-ecological conditions. About 22% of the country's rural households cultivate it as a non-cereal crop, cash crop, and vegetable. Potato is a cash crop in Bhutan; it is primarily grown using conventional farming practices such as agrochemicals and mineral fertilizers (Lhamo, 2019). In the country, the total potato production in 2019 was 43,560 metric tonnes (MT), with a total area of 4,187 ha and average national yield of 10.40 MT/ha (Ministry of Agriculture and Forests (MoAF), 2020). Around 0.5%, equivalent to 20.34 ha of the country's total potato area, is certified organic. The certified potatoes are grown in the Gasa District, certified by a reliable Bhutanese government institution (Agriculture Research & Development Centre (ARDC)-Yusipang, 2019). The Bhutan Organic Standards is complied with by certified organic potato farmers.

Among others, poverty alleviation, increasing farm household income and job opportunities are vital priorities for the Royal Government of Bhutan (RGoB) (Ghimiray *et al.*, 2019). The Goenkhatoe *Gewog,* a research area for the study within Gasa District, has been producing certified organic potatoes since 2016 (Department of Agricultural Marketing and Cooperatives [DAMC] & DAS Gasa, 2016). However, there are no studies on the cost and return analysis of organic potatoes in Bhutan, especially in the Gasa District. Therefore, the study's objectives were to investigate the cost and return analysis (CRA) of organic potato farming and socio-demographic characteristics of the farmers in Bhutan's first and only organic district, Gasa. The CRA is a type of economic evaluation that considers both implicit and explicit farm expenditures (Ciaian *et al.*, 2013, Netayarak P, 2007). Actual expenses are classified as Explicit costs, but Imputed or Implied costs are classified as Implicit costs since they are unrelated to actual expenditure payments (Ciaian*, et al.*, 2013). In addition, a profitability performance metric indicates how effectively the farmer's resources are used to create revenue and profit (Kahan, 2010). Therefore, the application of economic indicators will be vital to measure the farm household income generated through organic potato farming.

Considering the country’s vision to be an organic state and the priorities of the RGoB, this study will help to understand the extent of farm household income generation from organic potato farming in the Gasa District and the country. Such empirical data are expected to help policymakers, obtain additional backing from agriculture officials and researchers, and assist farmers in making decisions about choosing a better potato farming system in Bhutan and around the globe. In addition, academicians and students will find it helpful in understanding field situations.

Materials and methods

Study area

The Gasa District, the first and only organic district in Bhutan, was chosen for the study. It is one of Bhutan's 20 districts located in the West-Central part of the country (ARDC-Bajo, 2020). With just 3,952 residents, Gasa is the country's least populated district, accounting for only 0.5% of the total population (Population & Housing Census of Bhutan [PHCB], 2017). The district's average annual temperature is 10°C, with a maximum of 15°C and a minimum of 6°C. It has a variety of climates, from temperate to alpine (NSB, 2011). It has around 30 ha under the total potato area with production of about 185 MT/year (MoAF, 2020).

Goenkhatoe *Gewog* (a group of villages in Bhutan) was purposively opted as a research site within Gasa District. The altitude in Goenkhatoe *Gewog* varies between 2,100 and 2,800 meters above mean sea level. The annual rainfall in the *Gewog* is approximately 2,241 millimetres (mm) (NSB, 2011). The National Soil Service Centre (NSSC), Thimphu, identified loamy and silty clay loam soil textures in the *Gewog* in 2020. Fig. 1. depicts the study area in Bhutan.

Figure 1. The study region is depicted on a map of Bhutan (encircled). Source: wikipedia.org/wiki/Districts of Bhutan, accessed 22/03/21.

Sampling procedure

The study sample was determined using a technique of purposive sampling. The Gasa District was selected for the organic potato evaluation because its local Government proclaimed it to be the first completely organic district since 2004 (Wangmo and Iwai, 2018). Goenkhatoe *Gewog*, one of four *Gewog*s in the district, was purposefully chosen for the study due to the availability of certified organic potato farmers. Purposive sampling is ideally suited to a small population with well-understood characteristics (Kothari, 2004). Forty-three organic farmers were chosen for the study. *Gasa Rangshin Sonam Detshen* is the organic farmers' group in the *Gewog* that cultivates organic potatoes and other crops. The group has been producing organic potatoes since 2016. Bhutan Agriculture and Food Regulatory Authority (BAFRA) has certified the group (Department of Agricultural Marketing and Cooperatives [DAMC] & DAS Gasa, 2016). Potatoes are the *Gewog*'s main cash-generating crop, but they also cultivate garlic, carrots, wheat, buckwheat, and barley.

Data collection

The information was randomly gathered from 43 organic potato farmers spread out across 17 villages in Goenkhatoe *Gewog*, Gasa District. Data was taken during September and October 2020. Face-to-face, individual farmer interviews were used to collect primary data. In addition, the head of the family or any family member actively involved in organic farming was interviewed during the individual farmer's interview. To collect data from farmers, a semi-structured questionnaire was used. It was divided into two parts: the first part covered the socio-demographic characteristics, and the second part on cost and return analysis data.

Assessment of content validity

The Item Objective Congruence (IOC) rating, interpretation, and decision as provided by (Rovinelli and Hambleton, 1977) were used to determine the content validity of the items of the questionnaire. To ensure that each questionnaire item captures the intended objectives, a draft semi-structured questionnaire was sent to three experts specific to the study field for review and feedback. Each question item with an IOC rating of 0.5 or higher was kept in the questionnaire. In addition, at least 30 potato farmers who did not belong to the sample study farmers were pre-tested with the questionnaire. In September 2020, pre-testing was carried out in Geney *Gewog*, Thimphu District, Bhutan.

Data analysis

Socio-demographic characteristics

Descriptive statistics such as frequencies, percentages, standard deviations, arithmetic means, maximum and minimum were used to analyze the socio-demographic variables.

Cost and return analysis (CRA)

The farm production costs may be divided into two categories: explicit and implicit costs, which are cash and non-monetary expenses, respectively (Mendoza, 2004, Suwanmaneepong*, et al.*, 2020). Microsoft Excel was used to compute the CRA. Cash costs encompassed those cash payments on farm inputs such as seeds, fuel, farm machinery rental, and hired labour payments. Non-cash expenses encompassed the farm machinery depreciation cost, own potato seeds, input support from the Government, and actual food and refreshments expenses for the exchange and family labour.

Total cost

The total cost (TC) was calculated using the equation as follows: (Chidiebere-Mark *et al.*, 2019, Suwanmaneepong*, et al.*, 2020):

TC=TVC + TFC -------------(i)

Where TC is a Total Cost, TVC is a Total Variable Cost, and TFC is a Total Fixed Cost.

The variable input costs, like raw materials, labour, and other variable overhead charges, are referred to as TVCs (Delaney and Whittington, 2011). TFCs, on the other hand, are production expenses that do not vary with output or production volume, like land rent (Thorpe and Thorpe, 2011). The non-cash expenses were computed using current market pricing for agriculture supplies. Labour expenses for hired, exchange and family labourers were determined (Kahan, 2013). The monetary expenses of hired labourers were based on the current agricultural labour rate, but the expenses of exchange and family labourers were determined on the farmers' real food and refreshment expenses (Tashi and Wangchuk, 2016).

The depreciation of farm implements and equipment is included in the TFCs (Charantimath, 2005). The straight-line approach gives the same depreciation expense each year (Robinson *et al.*, 2012).

Depreciation expense = (Asset cost - Salvage value)/Useful life of the asset--(ii)

Gross return

Gross return was calculated using the equation below (Adhikari, 2011, Tashi and Wangchuk, 2016).

Gross return (GR) = Q x P--------(iii)

Where GR is Gross Return, Q is yield, P is Selling Price (farm-gate price on this study).

Profitability

Profit, Gross Margin, or Net Income (NI) were calculated using the following calculation (Husin, 2012, Lyngbaek and Muschler, 2001):

Profit or GM or NI = GR – TC---------(iv)

where GM is Gross Margin, NI is Net Income; GR is Gross Return, TC is Total Cost

The Benefit: Cost (B:C) ratio

The following equation calculated the Benefit: Cost (B:C) ratio (Adhikari, 2011, Tashi and Wangchuk, 2016):

B:C ratio = GR/TC---------(v)

Where, B:C ratio is Benefit: Cost Ratio, GR is Gross Return, TC is Total Cost.

Return on Investment (ROI) (Chidiebere-Mark, *et al.*, 2019)

ROI = GM/TC expressed in %----------(vi)

Where GM is Gross Margin (profit), TC is Total Cost

Break-even analysis

In addition to other factors, analyses for break-even price (P) and yield (Y) were performed, as shown in the equations below, based on (Dillon, 1992):

Price (P_i) = ($VC_i + FC_i + \pi_i$)/ Y_i-------------(vii)

Yield (Y_i) = ($VC_i + FC_i + \pi_i$)/ P_i ------------(viii)

Where Pi is the output price of commodity i; Y_i is the yield of commodity i; VC_i are the variable costs incurred to produce commodity i; FC_i represents the fixed costs to produce commodity i; Break-even price or yield can be inspected by setting profits (π_i) equal to zero.

Yield calculation

The yield was calculated using the formula below (FAO, 2017):

Land productivity (yield) = Volume of output/Planted Area----------(ix)

The production volume was determined in metric tons (MT), while the planted area was determined in hectares (ha).

Results

Socio-demographic characteristics of farmers

The socio-demographic characteristics of the farmers are provided in Table 1. Gender, age, education, household members, family labour, farm size, experience in farming, farmers' training, farmers' group, and others were the parameters to study organic farmers' socio-demographic characteristics. The findings indicated that organic farmers had a higher female (69.77%) than male population (30.23%). The average age of organic farmers was 52 years, the minimum was 26, and the maximum was 84 years.

Most of the organic farmers (21%) who went to school did their primary schooling (1-6 grade). The highest educational achievement was the lower secondary (9-10 grade), with only 5% making it. Around 9% of organic farmers also went to non-formal education. More than half of organic farmers were illiterate (63%). Most organic farmers (88%) were married. The average household member was four, the minimum was one, and the maximum was 12.

The average family labour of organic farmers was two, the minimum was one, and the maximum was five. The average year of farming experience for organic farmers was 31 years, with a minimum of five and a maximum of 70 years. Organic farmers attended an average of two training per year, the minimum was zero, and the maximum was three. The average farm size of organic potato farmers was 1.17 ha, with a minimum of 0.13 and a maximum of 6.88 ha. Most of the farmers (95.3%) were a member of the organic farmers' group–*Gasa Rangsin Sonam Detchen.* The majority of farmers (83.7%) depended purely on farming for their income. More than half (72.1%) of the farmers frequently contacted the Agriculture Extension Agent for farming-related enquiries.

Cost and return analysis (CRA) of organic potatoes

The CRA is provided in Table 2. Organic potato cultivation cost a total of 340,771.17 Nu[*]/ha. The total variable cost per hectare was 338,211.89 Nu, accounting for 99.25% of the total production cost. The total fixed cost was 2,559.28 Nu/ha, and its proportion of total production cost was just 0.75%. The total cash cost per hectare was 135,671.90 Nu, whereas the total non-cash cost per hectare was 205,099.27 Nu. The Government offered input support in the form of seeds and bio-pesticides worth an average of 1,308.37 Nu/ha. As a result, with this input assistance, the real cost of organic potato production to a farmer was 339,462.80 Nu/ha. The labour cost was more than the input cost under variable costs. The total input cost per hectare was 142,427.99 Nu, accounting for 41.96% of the total production cost. The highest input cost was spent while acquiring potato seeds, which was 62,565.50 Nu/ha and accounted for 18.43% of the total production cost. While the cost of bio-pesticides resulted in the lowest input cost of 145.38 Nu/ha, accounting for just 0.04% of the total production cost. The total labour cost was 195,783.89 Nu/ha, accounting for 57.67% of the total production cost. It was the highest contributor to the total cost of production.

Weeding and earthing up activities incurred the highest labour cost of 86,655.70 Nu/ha, accounting for 25.53% of the total production cost. While applying biopesticides had the lowest labour cost of 83.73 Nu/ha, it accounted for just 0.02% of the total production costs. Under fixed costs, the depreciation cost contributed the most, amounting to 2,528.75 Nu/ha, accounting for just 0.74% of the total production cost. Farmers got an average farm-gate price of 18.29 Nu/kg, with a negative gross margin (GM) or a profit of -202,708.47 Nu/ha. The gross margin over cash and

[*] Nu=Ngultrum (Bhutanese currency); 1 Nu= 0.014 USD

variable costs was 1082.43 Nu/ha and -201,457.56 Nu/ha, respectively. The average organic potato yield was 7.48 MT/ha. The break-even yield and prices were 18.63 MT/ha and 45.58 Nu/kg, respectively, with a benefit-cost ratio (B:C ratio) of 0.40 and a return on investment (ROI) of -59.71%.

Table 1. Socio-demographic characteristics of organic potato farmers (n=43).

Item	Frequency	%	Mean	Std. Dev	Min	Max
Gender						
Male	13	30.23				
Female	30	69.77				
Age (years)			52.35	13.90	26	84
Education attainment						
Illiterate	27	62.79				
Non-formal education	4	9.30				
Primary School	9	20.93				
Middle School	1	2.33				
Lower secondary	2	4.65				
Marital status						
Single/widow/er/divorce	5	11.70				
Married	38	88.37				
Household members			4.49	2.43	1	12
Family labour (persons)			1.98	0.91	1	5
Farming experience (years)			31.05	19.81	5	70
Attend farmers' training (numbers per year)			1.65	0.92	0	3
Farm size (ha)			1.17	1.07	0.13	6.88
Membership in a farmers' group						
Member	41	95.30				
Non-member	2	4.70				
Off-farm income						
None	36	83.70				
Yes	7	16.30				
Consult Agriculture Extension Agent						
Never	6	14.00				
Frequently	31	72.10				
Seldomly	6	14.00				

Table 2. Cost and return analysis of organic potatoes.

Item	Cash (Nu)	Non-cash (Nu)	Total (Nu)	%
A) Variable costs (VCs) (Nu/ha)				
1) Input cost				
i) Seed	9,321.90	53,243.60	62,565.50	18.43
ii) Farmyard Manure (FYM) and other organic fertilizers	1,550.39	56,792.70	58,343.09	17.19
iii) Bio-pesticides	0	145.38	145.38	0.04
iv) Fuel & rental	21,374.03	0	21,374.03	6.30
Total input cost (Nu/ha)	**32,246.32**	**110,181.68**	**142,427.99**	**41.96**
2) Labour cost				
i) Land preparation	8,681.41	14,998.68	23,680.09	6.98
ii) Compost/FYM application	6,570.37	6,801.57	13,371.94	3.94
iii) Planting	13,814.76	8,338.41	22,153.17	6.53
iv) Weeding & earthing up	43,861.92	42,793.78	86,655.70	25.53
v) Bio-pesticides application	0	83.73	83.73	0.02
vi) Harvesting/curing	30,466.60	19,372.67	49,839.27	14.68
Total labour cost (Nu/ha)	**103,395.05**	**92,388.84**	**195,783.89**	**57.67**
Total Variable Cost (TVC) (Nu/ha)	**135,641.37**	**202,570.52**	**338,211.89**	**99.63**
B) Fixed Costs (FCs) (Nu/ha)				
1) Land tax	30.53	0	30.53	0.01
2) Land rent	0	0	0	0.00
3) Depreciation cost	0	2,528.75	2,528.75	0.74
Total Fixed cost (TFC) (Nu/ha)	**30.53**	**2,528.75**	**2,559.28**	**0.75**
Total Cost (TC) = (TVC + TFC) (Nu/ha)	**135,671.90**	**205,099.27**	**340,771.17**	
Total cost with deductions of an average Govt. support on seeds & bio-pesticides worth of Nu.1,308.37/ha. (Nu/ha)	**135,671.90**	**203,790.90**	**339,462.80**	
Gross Return (GR) (Nu/ha) (Q x P)			136,754.33	
Yield (kg/ha) (Q)			7,477	
Farmgate price (Nu/kg) (P)			18.29	
Gross margin (GM) (profit) (Nu/ha) (GR-TC)			-202,708.47	
Break-even productivity (kilograms/ha)			18,631.56	
Break-even price (Nu/ha)			45.58	
Benefit-cost ratio (B:C ratio) (GR/TC)			0.40	
Return on Investment (GM/TC x 100) (%)			-59.71	
Gross margin over cash cost (Nu/ha) (GR-Total cash cost)			1,082.43	
Gross margin over variable cost (Nu/ha) (GR-TVC)			-201,457.56	

Nu=Ngultrum (Bhutanese currency); 1 Nu= 0.014 USD

Discussion

Socio-demographic characteristics

In the study, more female than male population composed the organic potato farmers. Suwanmaneepong*, et al.* (2020) also found more women than men practising organic rice farming. It was found that organic potato farmers were ageing. Takagi *et al.* (2020) also found that more than half of organic farmers were above 50 years old. More than half of organic farmers were illiterate. According to the (Population & Housing Census of Bhutan [PHCB], 2017), the Gasa District has the lowest literacy rate in the country.

Organic farmers had only two-family farm labourers on average signifying farm labour shortage. The shortages are becoming more of a concern in Bhutan, owing mostly to rising rural-to-urban migration (Population & Housing Census of Bhutan [PHCB], 2017). The study indicated that the organic potato farmers were well experienced in their field, and additionally, they were regularly receiving technical training from the Agriculture Department. Suwanmaneepong*, et al.* (2020) also found that organic rice growers attended more training. The average farm size of organic potato farmers was comparable with the national mean landholding in rural areas of 1.18 ha (Population & Housing Census of Bhutan [PHCB], 2017). Most of the farmers belonged to the organic farmers' group in the district, and a majority of them depended purely on farming for their income. Many organic potato farmers were in constant touch with the Agriculture Extension officer for farming-related enquiries.

An ageing population, higher illiteracy rate, and more female gender observed with the organic farmers could affect the farmers' performance, subsequently affecting the crop yield and other farm outputs. In addition, farmers' education level (Andaregie and Astatkie, 2020, Nyagaka *et al.*, 2010) and age (Chemak *et al.*, 2014) influenced the potato production efficiency.

Cost and Return Analysis

It was found that most of the production cost was due to the variable cost, whereas the fixed cost was a negligible one. Kahan (2013) stated that small scale farmers often have a low level of fixed costs. Much of the time, they do not have to bother about distributing fixed expenses across farm businesses. The variable costs are almost all their expenses. The total non-cash cost was greater than the total cash cost; it was mainly due to higher expenses on the labour cost incurred on serving the food and refreshments to the exchange and family labour. The actual cost of production to an organic potato farmer was reduced due to farm inputs support of the Government on the potato seeds, bio-pesticides, and other inputs. It was observed that the labour cost exceeded the input cost under variable costs.

Additionally, the total labour cost was the highest contributor to the total production cost. Within the labour cost weeding and earthing up activities incurred the highest cost. Other organic and conventional rice research supports this finding (Mendoza, 2004, Tashi and Wangchuk, 2016) and organic and conventional maize (Adamtey *et al.*, 2016). The lowest labour cost on the application of bio-pesticides and also being the lowest input cost suggest that organic farmers do not use it much for plant protection activities. Tashi and Wangchuk (2016) also reported that conventional rice producers in Bhutan paid considerably high for agrochemicals. Regarding lesser input costs, Morshedi *et al.* (2017) also stated that organic farming lowers the expense of purchasing farm raw materials.

Many organic potato farmers perceived that the average farm-gate prices obtained by them were below the normal prevailing rates. They reasoned that the general poor appearance of organic potato tubers than the conventional potatoes characterized by smaller tuber size and rough appearance led to lower price. The average yield of organic potato was lower than the average national potato yield. This finding agrees with (Ierna and Parisi, 2014, Maggio *et al.*, 2008) on lower yields in organic potatoes. It contradicted with the findings of (Tashi and Wangchuk, 2016), where no significant differences in rice grain yields were observed between organic and conventional rice in Bhutan. Organic potato production had a B:C ratio of <1 and a negative ROI, indicating that it was not lucrative. If the B:C ratio is larger than one, the benefits outweigh the costs; if it is less than one, the costs outweigh the benefits, and the business is unprofitable (Hay, 1982). A prominent indicator for assessing a company's profitability is the return on investment (ROI) (Rosenbaum *et al.*, 2013, Tiffany and Peterson, 2011).

The organic potato was unprofitable mainly owing to low yield and a lower farm-gate price. Therefore, organic potato farmers either need to increase their yield or obtain farm gate prices higher than their respective break-evens to ensure profitability. Additionally, there is a need to research to find the actual causes of the low yield of organic potatoes and generate appropriate technologies. There is also a need to implement market research to increase the income of the organic potato farmers in the Gasa District, Bhutan.

Acknowledgement

Thailand's King Mongkut Institute of Technology Ladkrabang provided funding for this research. The finances for the study were provided by the grant number KDS 2019/013. In addition, we are grateful to *Gewog* local officials and organic potato farmers in Bhutan for their support in data gathering.

References

Adamtey, N., Musyoka, M. W., Zundel, C., Cobo, J. G., Karanja, E., Fiaboe, K. K. M., Muriuki, A., Mucheru-Muna, M., Vanlauwe, B., Berset, E., Messmer, M. M., Gattinger, A., Bhullar, G. S., Cadisch, G., Fliessbach, A., Mader, P., Niggli, U. and Foster, D. (2016). Productivity, profitability and partial nutrient balance in maize-based conventional and organic farming systems in Kenya. Agriculture Ecosystems & Environment, 235:61-79

Adhikari, R. K. (2011). Economics of organic rice production. Journal of Agriculture and Environment, 12:97-103

Agriculture Research & Development Centre (ARDC)-Yusipang, 2019. Annual report (2018-2019), ARDC-Yusipang, Royal Government of Bhutan. In: D.o. Agriculture (ed), 2019, (Department of Agriculture, Thimphu), i-x, 106

Andaregie, A. and Astatkie, T. (2020). Determinants of technical efficiency of potato farmers and effects of constraints on potato production in Northern Ethiopia. Experimental Agriculture, 56:699-709

ARDC-Bajo, 2020. About ARDC Bajo. 2020, (Agriculture Research & Development Centre (ARDC)-Bajo, Wangduephodrang

Bajgai, Y. (2018). Standard evaluation guideline for potato germplasm. In: Lakey ed, Standard evaluation guidelines for field & horticultural crops, Agriculture Research & Extension Division (Ared), Department Of Agriculture, Ministry of Agriculture & Forests, Thimphu, Thimphu, pp. 27-39.

Charantimath, P. M. (2005). Entrepreneurship Development and Small Business Enterprise, Pearson Education, pp.

Chemak, F., Allagui, L. and Ali, Y. (2014). Analysis of the technical performance of potato growers in Tunisia, A non parametric approach. New Medit, 13:72-80

Chidiebere-Mark, N., Ohajianya, D., Obasi, P. and Onyeagocha, S. (2019). Profitability of rice production in different production systems in Ebonyi State, Nigeria. Open Agriculture, 4:237-246

Ciaian, P., PALOMA, S. and Delincé, J. (2013). Literature review on cost of production methodologies. The First Scientific Advisory Committee Meeting, 1-19 p.

D'Avanzo, C. (2008). Mosby's Pocket Guide to Cultural Health Assessment - E-Book, Elsevier Health Sciences, pp.

Delaney, P. R. and Whittington, O. R. (2011). Wiley CPA Examination Review, Outlines and Study Guides, New Jersey, Wiley, pp. 1008.

Department of Agricultural Marketing and Cooperatives [DAMC] & DAS Gasa, 2016. Gasa Dzongkhag leading the way in organic crop production. 2016, (MoAF, Thimphu),

Department of Agriculture [DoA], 2006. National Framework for Organic Farming in Bhutan In: D.o. Agriculture (ed), 2006, (Department of Agriculture, Royal Government of Bhutan (RGoB), Thimphu, Bhutan), 44

Dillon, C. R. (1992). Microeconomic effects of reduced yield variability cultivars of soybeans and wheat. Journal of Agricultural and Applied Economics, 24:121-133

FAO. (2017). Productivity and Efficiency Measurement in Agriculture - Literature Review and Gaps Analysis Food and Agriculture Organization of the United Nations (FAO), pp. 77.

Feuerbacher, A., Luckmann, J., Boysen, O., Zikeli, S. and Grethe, H. (2018). Is Bhutan destined for 100% organic? Assessing the economy-wide effects of a large-scale conversion policy. PloS one, 13:24

Ghimiray, M., Katwal, T. B., Tshering, K., Dorjee, Dukpa, W., Lakey, Phuntsho, L., Dendup, S., Gyalmo, T. and Ngawang, 2019. Agriculture Research Strategy 2018-2028. In: D.o. Agriculture (ed), 2019, (Agriculture Research and Extension Division (ARED), Department of Agriculture., Thimphu, Bhutan), 56

Hay, W. W. (1982). Railroad Engineering, Wiley, pp.

Husin, L. (2012). Productivity and income peformance comparison of smallholder oil palm plantation at dry land and wet land of South Sumatra Indonesia. APCBEE Procedia, 3:270-275

Ierna, A. and Parisi, B. (2014). Crop growth and tuber yield of "early" potato crop under organic and conventional farming. Scientia Horticulturae, 165:260-265

IFOAM, 2020. Annual Report 2020 Consilidated Annual Report of IFOAM - Organics International & its Action Group. 2020, 22

Kahan, D. (2010). Farm business analysis
using benchmarking, Rome, Food and Agriculture Organization of the United Nations (FAO), pp.

Kahan, D. (2013). Economics for farm management extension, Food and Agriculture Organization of the United Nations (FAO) pp. i-vi, 1-97.

Kothari, C. R. (2004). Research methodology: Methods and techniques, New Delhi, India, New Age International Publishers, pp. i-xvi, 1-401.

Lhamo, P., 2019. In Phobji and Gangtey, farmers compete to use more fertilisers. 2019, (kuensel,

Lyngbaek, A. E. and Muschler, R. G. (2001). Productivity and profitability of multistrata organic versus conventional coffee farms in Costa Rica. Agroforestry systems, 53:205-213

Maggio, A., Carillo, P., Bulmetti, G. S., Fuggi, A., Barbieri, G. and De Pascale, S. (2008). Potato yield and metabolic profiling under conventional and organic farming. European Journal of Agronomy, 28:343-350

Mendoza, T. C. (2004). Evaluating the benefits of organic farming in rice agroecosystems in the Philippines. Journal of Sustainable Agriculture, 24:93-115

Ministry of Agriculture and Forests (MoAF), 2020. Agriculture Statistics 2019. In: D.o. Agriculture (ed), 2020, (Renewable Natural Resources Ststistics Division (RSD), Thimphu, Bhutan), I-VII, 1-123

MoAF, 2020. Agriculture Statistics 2019. In: D. Services (ed), 2020, (Renewable Natural Resources Statistics Division (RSD), Royal Government of Bhutan, Thimphu), I-VII, 1-123

Morshedi, L., Lashgarara, F., Hosseini, S. J. F. and Najafabadi, M. (2017). The Role of Organic Farming for Improving Food Security from the Perspective of Fars Farmers. Sustainability, 9:13

National Statistical Bureau [NSB], 2017. Bhutan living standards survey report 2017. 2017, (National Statistics Bureau (NSB), Royal Government of Bhutan, Bhutan), i-xvi, 1-210

Netayarak P. (2007). Agricultural economics, Bangkok, Thammasat University Press, pp.

NSB, 2011. Annual Dzongkhag Statistics 2011 (Dzongkhag Administration Gasa). In: N.S. Bureau (ed), 2011, (National Statistics Bureau, Bhutan), i-iii, 1-48

Nyagaka, D. O., Obare, G. A., Omiti, J. M. and Nguyo, W. (2010). Technical efficiency in resource use: Evidence from smallholder Irish potato farmers in Nyandarua North District, Kenya. African Journal of Agricultural Research, 5:1179-1186

Population & Housing Census of Bhutan [PHCB], 2017. Population & Housing Census of Bhutan (PHCB) 2017 2017, (National Statistics Bureau, Royal Government of Bhutan Bhutan), i-xvii,1-268

Robinson, T. R., Henry, E., Pirie, W. L., Broihahn, M. A. and Cope, A. T. (2012). International Financial Statement Analysis, New Jersey, Wiley, pp.

Rosenbaum, J., Pearl, J., Perella, J. R. and Harris, J. (2013). Investment Banking: Valuation, Leveraged Buyouts, and Mergers and Acquisitions, Wiley, pp.

Rovinelli, R. and Hambleton, R. (1977). The use of content specialists in the assessment of criterion-referenced test item validity: 1977. Dutch J Edu Res, 2:49-60

Suwanmaneepong, S., Kerdsriserm, C., Lepcha, N., Cavite, H. J. and Llones, C. A. (2020). Cost and return analysis of organic and conventional rice production in Chachoengsao Province, Thailand. Organic Agriculture, 10:1-10

Takagi, C., Purnomo, S. H. and Kim, M. K. (2020). Adopting Smart Agriculture among organic farmers in Taiwan. Asian Journal of Technology Innovation:16

Tashi, S. and Wangchuk, K. (2016). Organic vs. conventional rice production: comparative assessment under farmers' condition in Bhutan. Organic Agriculture, 6:255-265

Thorpe, E. and Thorpe, S. (2011). The Pearson CSAT Manual 2011, Dorling Kindersley (India) Pvt. Ltd., New Delhi,

Tiffany, P. and Peterson, S. D. (2011). Business Plans For Dummies, Wiley, pp.

Wangmo, S. and Iwai, C. B. (2018). Performance of Organic Agriculture (OA) based on Emergent Properties of Agriculture System in Gasa, Bhutan. Khon Kaen Agriculture Journal, 1985:1202-1210

Growth performance and nutrient digestibility of Thai native compared with Lowline Angus crossbred beef cattle fed with regional feedstuffs

Pilajun, R.[1*], Lunsin, R.[2], Yeanpet, C.[1], Inthiseang, W.[1] and Wanapat, M.[3]

[1] Department of Animal Science, Faculty of Agriculture, Ubon Ratchathani University, Ubon Ratchathani, Thailand 34190; [2] Department of Animal Science, Faculty of Agriculture, Ubon Ratchathani Rajabhat University, Ubon Ratchathani, Thailand 34000; [3] Tropical Feed Resources Research and Development Center, Faculty of Agriculture, Khon Kaen University, Khon Kaen, Thailand 40000
*Corresponding Author: Pilajun, R.; Email: ruangyote.p@ubu.ac.th

Abstract Cassava starch residue and oil palm meal are massive industrial by-products which can be used as animal diet in Thailand. The aim of this study was to investigate voluntary feed intake, nutrient digestibility, and growth performance of Thai native cattle compared with Lowline Angus x Thai native crossbred beef cattle fed with those two local feedstuffs as supplement. Yeast fermented cassava starch residue mixed with oil palm meal prior fed to beef cattle at 1.50% BW, while rice straw was given in *ad libitum* during 6 months of experimental period. It was found that total intake and intakes of roughage and supplement did not different among breed of beef cattle. Growth rate and final body weight of Thai native cattle were greater than the crossbred but that caused by differences in initial body weight (covariate effect), then growth performance was similar between cattle group. Feed per gain of Thai native cattle (11.6 g/g) did not different from the crossbred (12.1 g/g). Moreover, Thai native cattle and Lowline Angus x Thai native crossbred beef cattle had similar in nutrient digestibility including dry matter, organic matter, crude protein, crude fat, and fiber fractions. Therefore, Lowline Angus x Thai native crossbred beef had similar ability of local feed resources utilization and growth performance as Thai indigenous cattle.

Keywords: cassava starch residue, oil palm meal, nutrient digestibility, growth performance, Thai native cattle

Introduction

In Thailand, indigenous cattle and their crossbred with Brahman distributed more than 60% of total population (Department of Livestock Development, 2017) since they are suited to Thai raising conditions. These cattle have high lean percentage and tenderness with lower fat percentage which good for local dish such as Goy and Lap (raw or cooked beef with specific condiments and herbs). However, due to inferior of growth rate, carcass percentage, and marbling score (required for steak cooking or modern dish) of indigenous and Brahman crossbred (Opatpatanakit *et al*., 2010), *Bos taurus* was improted for crossbreeding to improve their production traits. Kampangsan beef, Tak beef, Kabinburi beef, and Thai black are example of crossbred beef strains in Thailand. The crossbred especially with Charolais >50% play importance role in beef production of Thailand particularly feedlot cattle to produce high quality meat (Bunmee *et al*., 2018). However, large type breed like Thai native x Brahman with Charolais or other Europe breed may not suitable for smallholder farmer cuased high production cost. Thai native x Lowline Angus crossbred cattle, medium size, has been develop by Sawasdipan since 2003 to be another choice for farmer. These cattle had adapted and then present similar heat tolerance but with higher growth rate than Thai native cattle under condition (Pakdeerat, 2010; Pilajun *et al*., 2019).

Deficiency of high quality roughage during dry season is a large problem especially in the Northeast of Thailand. Consequently, supplementation of concentrate with low quality roughage such as rice straw are strategy often conduct. Utilization of several local low-cost feedstuffs particularly by-product or residue of rice, cassava, sugarcane, and oil palm have been interpreted (Wanapat, 1999). Cassava pulp is the residue from cassava starch production. Farmers accepted to use dried cassava pulp as feed ingredient to reduce the production cost when the price of other carbohydrate sources was high (Yimmongkol, 2009). However, due to low nutritive value with high moisture content therefore improving their nutritive value by fermentation with several additives have been conduct. Khampa *et al*. (2014) is primary work about improving nutritive value of cassava starch residue with yeast (*Saccharomyces cerevisiae*) fermentation then wildly use as animal diet in Thailand. Fermented cassava starch residue with yeast and enzyme improved nutrient component and digestibility has been reported in our previous work (Pilajun and Wanapat, 2016). In term of oil palm industry by-products, crude oil palm meal had lower crude protein content with high proportions of fiber, ash, and lignin from seed shell (Chanjula *et al*., 2018). However, they reported the optimal level of palm kernel cake in concentrate for goat should be lower than 35% to reduce production cost. In addition, not exceed 20% of oil palm meal inclusion in concentrate for milking cow has been endorse (Lunsin, 2018).

The objective of this study was to investigate growth performance and feed utilization of Lowline Angus x Thai native crossbred beef compared with Thai native purebred cattle fed with usefully local feed resources.

Materials and methods

The experiment was conducted under the control and advice of the Office of Laboratory and Farming Center, Faculty of Agriculture, Ubon Ratchathani University by followed EU standards for the protection of animals used for scientific purposes.

Experimental design, Animals and Feeds

Growth performance and nutrient digestibility of Thai native cattle (TN) was compared with Lowline Angus x Thai native crossbred beef (LAC) in Completely Randomized design. Five, 2-year-old castrated male with 148±4.20 kg and 139±3.54 kg initial BW of TN and LAC, respectively, were receive rice straw in *ad libitum* while yeast fermented cassava starch residue mixed with oil palm meal was supplemented at 1.5% BW on dry matter basis. Fermented cassava starch residue was prepared by the method of Pilajun *et al*. (2018). In brif, cassava starch residue from the industrial factory for cassava manufacture was ferment with yeast (*Saccharomyces cerevisiae*), urea, and molasses (0.33 g, 3.3 kg, and 4.2 kg per 100 kg DM, respectively) at least 21 days before use. Crude oil palm meal (COPM) bought from crude palm oil factoty. Chemical composition of experimental diet was showed in Table 1. Three portion of yeast fermented cassava starch residue (YFCSR) was mixed with COPM prior feeding in each meal. Animals were raised in individual pen with appropriate feeding and watering spaces, and free access to mineral block.

Data collection, Samples and Analysis

After 15 days of adaptation period, the experiment was conducted for 6 months. Feed and refusal were recorded daily while body weight was determined in every month for feeding adjustment and growth rate assessment. Feed samples was sampled every month while cattle's feces was collected by rectal grab sampling in five consecutive days of 3rd and 6th months. Samples were dried at 60ºC for 72 h, ground and analyzed for dry matter (930.15), total ash (942.05), nitrogen (968.06) and ether extract (920.39) according to AOAC (1995), while fiber fractions including neutral detergent fiber and acid detergent fiber were followed Van Soest *et al*. (1991). Acid insoluble ash was analyses and used as internal indicator for nutrient digestibility estimation (Van Keulen and Young, 1977).

Statistical analysis

All data were statistically analyzed by using ANCOVA procedures of SAS (2006) by using initial body weight as covariance. Differences among means were analyzed by t-test with $P<0.05$ level of significance.

Table 1. Chemical composition of experimental diets (Mean±SD, g/Kg DM)

Chemical composition	RS	YFCSR	COPM
Dry matter	921±34	163±16	876±65
Organic matter	893±55	951±52	917±77
Crude protein	26.5±2.3	123±9.2	70.2±3.9
Ether extract	6.42±0.6	13.1±1.5	35.4±2.2
Neutral detergent fiber	726±61	411±42	741±58
Acid detergent fiber	543±27	217±26	562±39
Acid detergent lignin	112±18	30.3±4.2	106±24

RS, rice straw; YFCSR, yeast fermented cassava starch residue; COPM, crude oil palm meal

Results

Production performance

Total feed intake and intakes of roughage and supplement were comparable among group of beef cattle ($P>0.05$). Body weight, average daily gain, as well as feed per gain of Lowline Angus crossbred did similar with Thai native cattle as shown in Table 2 ($P>0.05$).

Nutrient digestibility

Digestibility of dry matter, organic matter, crude protein, ether extract and fiber fractions did not different between beef cattle ($P>0.05$; Table 3). Dry matter digestibility presented a little bit low, 62.3% vs 63.1%, due to type of roughage (rice straw) as low digestibility of NDF and ADF presented.

Table 2 Growth performance of Thai native compared with Lowline Angus crossbred beef cattle (Mean±SD)

Items	Thai native	Lowline Angus crossbred	P-value
Total intake (kg/d)[1]	5.59±0.22	5.28±0.34	0.323
Rice straw intake (kg/d)[1]	1.95±0.31	1.86±0.28	0.199
YFCSR+COPM intake (kg/d)[1]	3.64±0.29	3.42±0.38	0.241
Body weight (BW, kg)			
Initial BW	148±4.20	139±3.54	0.247
3 month BW[1]	181±6.41	167±5.74	0.163
6 month BW[1]	227±5.19	213±6.24	0.371
Average daily gain (ADG, g/d)			
3 month ADG	362±26.6	341±24.8	0.546
6 month ADG	516±23.1	484±30.2	0.683
Feed per gain (FCG)			
3 month FCG	14.3±1.28	15.7±2.46	0.433
6 month FCG	11.6±1.04	12.1±1.84	0.567

[1] Covariate effect from initial body weight

Table 3 Nutrient digestibility of Thai native compared with Lowline Angus crossbred beef cattle (Mean, SE)

Digestibility, %	Thai native	Lowline Angus crossbred	P-value
Dry matter	62.3±1.41	63.1±1.22	0.561
Organic matter	65.7±0.97	67.8±0.85	0.631
Crude protein	68.1±0.56	70.2±0.71	0.785
Ether extract	72.4±2.89	70.7±2.44	0.432
Neutral detergent fiber	53.6±1.28	55.6±1.45	0.324
Acid detergent fiber	46.8±1.82	45.2±1.36	0.399

Discussion

Crude protein of rice straw and yeast fermented cassava starch residue were in ranged of previous report. Although several agriculture by-products in Thailand are capable to use as ruminant diet, low nutritive value of them lead to limit of utilization (Wanapat, 1999). Chemical composition of cassava starch can be enriching by fermented with microorganism especially yeast (*Saccharomyces cerevisiae*) with some additives (Khampa *et al*., 2012; Pilajun *et al*., 2018). Crude palm oil meal contained high proportion of lignin from seed shell as reported by Wan Zahari *et al*. (2012). Simple or fermented cassava starch residue are accepted to use as ruminant feed with a few restrictions (Yimmongkol, 2009); in contrast, crude oil palm meal still has queries. Comprising of seed shell, hard with lignin and ash, which almost undigestible resulted in low digestibility (Chanjula *et al*., 2018). In addition, using of COPM as ruminant diet have to consider the development of teeth of animal

These agreed with our previous study (Pilajun *et al*., 2020) which found grazing Lowline Angus x Thai native crossbred beef cattle and Thai native cattle with fermented cassava pulp supplementation had similar growth rate. However, several study about crossbred beef cattle reported higher growth rate when compared with indigenous cattle. Widiati *et al*. (2019) reported that the Simmental and Limousin crossbred with the local cows in Yogyakarta-Indonesia showed greater performance than indigenouse purebred. Moreover, Crossbreeding using both taurine and zebu breeds is recommended to increase beef cattle performance in southern Brazil (Leal *et al*., 2018), from maternal breed additive and heterosis effects. Absent of superior performance of Lowline Angus crossbred in the present study may related poor quality of all diet. The high fiber, silica and lignin contents of straw resulted poor nutrient (dry matter and protein) digestibility (<50%) has been reported in review article of Aquino *et al*. (2020). Non-protein nitrogen (urea) remain in fermented cassava starch residue may indue nutrient imbalance in the rumen of crossbred beef cattle (Pilajun and Wanapat, 2018), lead to low feed efficiency in this study. Hard and high lignin content of palm seed shell in crude oil palm meal may affected voluntary intake and digestibility of animal. Lowline Angus crossbred beef has been developed in farm of Ubon Ratchathani University since 2003 (Sawasdipan, 2003), long period adaptation of this cattle under tropical area should improve their existence.

Our previouse study (Pilajun *et al*., 2016) also found Thai native cattle and Lowline Angus crossbred beef had similar nutrient digestibity when fed with rice straw, rice straw with concentrate supplement, or Pangola hay. Agreed with Silvestre *et al*. (2021) who reported dairy heifer purebred Gyr and Holstein x Gyr crossbred (F1) had similar feed digestibility but higher CP digestibility than purebred Holstein. This indicated that F1 capable adapt to local environment may be by moternal effect. Apparent total tract digestibility of organic matter, gross energy, and fiber fractions were not affect by breed type, Angus vs Hereford × Angus cross, although the crossbred had greater body condition score than purebred (Andresen *et al*., 2020). In contrast, Nouala *et al*. (2009) reported N'Dama x Jersey crossbred cattle had significantly lower organic matter and NDF digestibilities than pure N'Dama, The Gambia indigenous cattle. Warm-season perennial C4 grasses are the dominant forages in tropical and subtropical regions. The resilience of C4 grasses under adverse conditions caused reduced nutritive value compared with forages from temperate climates (Cooke *et al*., 2020) may related with the different of digestibility of *Bos indicus* and *Bos taurus*.

Based on the results it could be concluded that Lowline Angus x Thai native crossbred beef had similar ability of local feed resources utilization resulted unexcess growth performance as Thai indigenous cattle. Production performance of the crossbred trial with high quality feed based on local resource should be conducted.

Acknowledgement

The authors are grateful for the financial support from Faculty of Agriculture, and research facilities provided by Office of Laboratory and Farming, Faculty of Agriculture, Ubon Ratchathani University.

References

Andresen, C. E., Wiseman, A. W., McGee, A., Goad, C., Foote, A. P., Reuter, R. and Lalman, D. L. (2020). Maintenance energy requirements and forage intake of purebred vs. crossbred beef cows. Translational Animal Science 4:1182–1195.

AOAC. (1995). Official Method of Analysis (16th ed.). Animal Feeds: Association of Official Analytical Chemists, Virginia.

Aquino, D., Barrio, A. D., Trach, N. X., Hai, N. T., Khang, D. N., Toan, N. T. and Hung, N. V. (2020). Rice Straw-Based Fodder for Ruminants. In: Gummert M., Hung N., Chivenge P., Douthwaite B. (eds) Sustainable Rice Straw Management. Springer, Switzerland. pp. 111-129.

Bunmee, T., Chaiwang, N., Kaewkot, C. and Jaturasitha, S. (2018). Current situation and future prospects for beef production in Thailand - A review. Asian-Australasian Journal of Animal Science 31:968–975.

Chanjula, P., Somnook, K., Pongprayoon, S. and Kongpan, S. (2018). Utilization of oil palm meal from oil extraction of dry method by using solvent in goat ration. Final report, Prince of Songkla University, Thailand. 56 pages.

Cooke, R. F., Daigle, C. L., Moriel, P., Smith, S. B., Tedeschi, L. O. and Vendramini, J. M. B. (2020). Cattle adapted to tropical and subtropical environments: social, nutritional, and carcass quality considerations. Journal of Animal Science 98(2):1–20.

Department of Livestock Development, (2020). Data of livestock population in Thailand year 2020. Information and Communication Technology Center, Department of Livestock Development, Ministry of Agriculture and Cooperatives, Thailand [Online]. https://ict.dld.go.th/webnew/images/stories/stat_web/monthly/2564/jun64/1---Cattle.pdf

Khampa, S., Koatedoke, U. and Ittarat, S. (2014). Utilization of yeast fermented sassava pulp (YFCP) as diets on feed intake and rumen pH in dairy heifers. Prawarun Agricultural Journal 11(1):83-90.

Leal, W. S., MacNeil, M. D., Carvalho, H. G., Vaz, R. Z. and Cardoso, F. F. (2018). Direct and maternal breed additive and heterosis effects on growth traits of beef cattle raised in southern Brazil. Journal of Animal Science 96:2536–2544.

Lunsin, R. (2018). Effect of oil palm meal on nutrient utilization and milk production in lactating dairy cows fed with urea-treated rice straw. Agriculture and Natural Resources 52(3):285-289.

Nouala, F. S., Muetzel, S., Hoffmann, E. and Becker, K. (2009). Feed intake and digestion by two cattle breeds fed of baby corn stovers and groundnut hay supplemented with graded levels of concentrate and Moringa leaves. Livestock Research for Rural Development 21:10. http://www.lrrd.org/lrrd21/10/noua21163.htm

Opatpatanakit, Y., Tunvisoottikul, K. and Sethakul, J. (2007). Factors affecting carcass quality of Thai-French beef. *In*: Proceedings of 53rd International Congress of Meat Science and Technology. 5-10 August 2007, Beijing, China. pp. 125–126.

Pakdeerat, E. (2010). A comparison of the physiology, behavior, digestibility and growth performance between Lowline Angus crossbred and Thai native cattle under grazing conditions. (Master Thesis). Ubon Ratchathani University, Thailand.

Pilajun, R., Inthiseang, W., Kaewluan, W., Wanapat, M. and Lunsin, R. (2020). Nutritional status of grazing Lowline Angus crossbred supplemented with fermented cassava starch residue. Tropical Animal Health and Production 52:2417–2423.

Pilajun, R., Thummasaeng, K. and Wanapat, M. (2016). Nutrient digestibility and rumen fermentation of Thai native purebred compared with Thai native x Lowline Angus crossbred beef cattle. Journal of Applied Animal Research 44:355-358.

Pilajun, R., Thummasaeng, K. Sawasdiphan, S., Suwanlee, S., Inthisaeng, W. and Wanapat, M. (2019). Growth performance of Lowline Angus x Thai native crossbred beef under tropical condition. Tropical Animal Health and Production 51:2253–2261.

Pilajun, R. and Wanapat, M. (2018). Voluntary feed intake, rumen fermentation and microbial protein synthesis of beef cattle fed fermented cassava starch residue. *In*: Proceeding of The 17th Asian-Australasian Association of Animal Production Societies Animal Science Congress, 22-26 August 2016, Fukuoka, Japan. pp. 724-733.

Pilajun, R. and Wanapat, M. (2018). 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.

SAS, Procedures Guide, Second Edition, 2006. SAS Institute Inc., Cary, NC, USA
Sawasdipan, S. (2003). Research and development of Thai native x lowline Angus crossbred beef cattle (*In Thai*). Final report for Faculty of agriculture, Ubon Ratchathani University, Thailand.
Silvestre, T., Lima, M. A., dos Santos, G. B., Pereira, L. G. R., Machado, F. S., Tomich, T. R., Campos, M. M., Jonker , A., Rodrigues, P. H. M., Brandao, V. L. N. and Marcondes, M. I. (2021). Effects of feeding level and breed composition on intake, digestibility, and methane emissions of dairy heifers. Animals 11:586. https://www.mdpi.com/2076-2615/11/3/586
Van Keulen, J. and Young, B. A. (1977). Evaluation of acid-insoluble ash as a natural marker in ruminant digestibility studies. Journal of Animal Science 44:282-287.
Van Soest, P. J., Robertson, J. B. and Lewis, B. A. (1991). Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. Journal of Dairy Science 74: 3583–3597.
Wanapat, M. (1999). Feeding of Ruminants in the Tropics based on Local Feed Resources. Khon Kaen Publishing Company Ltd., Khon Kaen, Thailand. 236 pp.
Wan Zahari, M., Alimon, A. R. and Wong, H. K. (2012). Utilization of oil palm co-products as feeds for livestock in Malaysia. In: Biofuel co-products as livestock feed: opportunities and challenges. FAO Publications, Rome, Italy, pp. 243-262.
Widiati, R., Nurtini, S., Kusumastuti, T. A., Syahlani, S. P. and Muzayyanah, M. A. U. (2019). Performance and economic incentives of cow-calf operation crossbred in the smallholder cattle in Yogyakarta-Indonesia. International Journal of Business and Society 20(1):417-431.
Yimmongkol, S. (2009). Research and development projects on improvement of the potential use of dried cassava pulp and cassava leaf meal in concentrate of feedlot cattle. (Doctor of Philosophy Thesis). Kasetsart University, Thailand.