Tropical Animal Health and Production (2022) 54: 133
https://doi.org/10.1007/s11250-022-03127-5

REGULAR ARTICLES

Replacement of soybean meal by red yeast fermented tofu waste on feed intake, growth performance, carcass characteristics, and meat quality in Thai Brahman crossbred beef cattle

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Received: 2 October 2021 / Accepted: 24 February 2022 / Published online: 8 March 2022

Abstract
This study aimed to determine the effect of replacing soybean meal (SBM) by red yeast fermented tofu waste (RYFTO) on feed intake, growth performance, carcass characteristics, and meat quality in Brahman crossbred beef cattle. A total of 12 cattle (1.5–2 years old and 275.0 ± 6.1 kg of initial body weight) were randomly allotted to three dietary treatments in completely randomized design. There were three dietary treatments as following: Control (SBM), 50%replacing SBM by red yeast fermented tofu waste (RYFTO50), and 100% replacing SBM by red yeast fermented tofu waste (RYFTO100) in concentrate diet raised for 60 days. Rice straw was used as roughage source and fed ad libitum. The results found that cattle received the diet with replacing SBM by RYFTO both RYFTO50 and RYFTO100 group affect roughage intake, total dry matter intake, and ADG ($P < 0.05$) except the digestibility and FCR ($P > 0.05$). The feed cost of roughage, concentrate, and total feed cost were lowest in RYFTO100 group when compared to the control ($P < 0.05$). Blood urea nitrogen was deducted when cattle received RYFTO100 when compared to the control and RYFTO50 ($P < 0.05$). However, the carcass characteristics and meat quality were similar among treatments ($P > 0.05$). In conclusion, the 100% replacing SBM by RYFTO in concentrate diet affect roughage intake and ADG without negative effect on concentrate intakes, digestibility, carcasses and meat quality. Therefore, RYFTO could be used as a protein source for partial replacement of SBM in the, concentrate diet at 50% which can lower feed cost. This study suggested that the further study should be conducted for longer period to gain the benefits of carotene in red yeast on carcass and meat quality.

Keywords Red yeast fermented tofu waste · Feed intake · Animal performance · Carcass characteristics · Meat quality

Introduction

Recently, the beef cattle farming industry has been more expanded due to the demand of consumption, especially the requirement of the high-quality meat which accord with agricultural policy that has been accelerated to increase the yield of beef cattle and promote farming under the beef cattle strategy in 2018–2022. The Office of Agricultural Economics of Thailand in 2020 reported that the population of beef cattle was at 5.62 million which increased by 7.12% from 2019. Moreover, the feed costs must be considered as it is cover up to 70% of production cost especially the protein sources such as soybean meal. Therefore, local feed resources use for animal feed ingredients can reduce the cost of production and increase profits for the farmers. Currently, agricultural by-products can be utilized as a source of ruminant

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feed which was available with low cost and has suitable nutritional value to be used in the formula to replace deficient raw materials.

Tofu waste is a by-product of industrial soy milk and tofu production, and it is interesting to use as a feedstuff as it is inexpensive and available where soybeans cultivate. Moreover, tofu waste has a good nutritional value especially amino acid profile. However, the protein content itself not much enough to use as the main protein sources in concentrate feed. Therefore, it is very interesting to improve its protein content. Yeast is a single-cell protein used in agro-industrial fermentation and is popular to improve nutritional value. Maungthipmalai et al. (2019) reported that wet soybean waste fermented with yeast culture could increase protein content from 18.1 to 38.4%. Moreover, there is another group of yeast such as *Rhodotorula* sp., the yeast gives the red pigments of the carotenoids group that carotenoid is a precursor of vitamin A which has beneficial on the health for ruminants and red yeast is a good source of protein. However, the studies on improving the nutritional value of red yeast fermented tofu waste (RYFTO) are limited. Therefore, this research aimed to determine the effects of replacing soybean meal by RYFTO on growth performance, carcass characteristics, and meat quality of Brahman crossbred beef cattle.

Material and methods

All animal care and experimental protocols used in this study were approved by the Animal Care and Use Committee of Maejo University Approval No. MACUC**049**A/**2561.**

Red yeast fermented tofu waste (RYFTO) preparation and yeast strain

Tofu residue was obtained from a soy milk and tofu factory in Chiangmai province, Thailand, and used as a raw material for fermentation. Fermentation solution was based on the method modified from Polyorach et al. (2013) as the following:

Solution A: Yeast *Rhodotorula rubra* TISTR5134 strain was used. The microorganism was grown in a yeast malt medium (YM) containing 3 g of yeast extract, 3 g of malt extract, 5 g of peptone, and 10 g of glucose and then mixed with 100-ml distilled water and filled O2 using air pump at room temperature for 48 h.

Solution B: Preparation was used 10 g of molasses dissolved in a 100-ml distilled water and then added 80 g of urea and adjusted pH of the solution using H_2SO_4 to achieve a final pH goal of 4–5.

Mixed solution A and B (1:1 ration) in bucket and filled O_2 by using air pump, then incubated at room temperature for 60 h to be yeast media solution. Yeast media solution was mixed with tofu waste at the ratio of 1:10 (v/w) by solid-state fermentation with drying under shade for 2–3 days and followed by sun-drying for 5–6 days then the red yeast fermented tofu waste (RYFTO) can used as protein source to replace soybean meal in this experiment.

Animals and samples

Twelve Brahman crossbred steers with average age of 1.5–2 years old and initial weight of 275.0 ± 6.1 kg were raised for 60 days at dairy-cattle farm of Faculty of Animal Science and Technology, Maejo University, Thailand. Steers were randomly allocated to three dietary treatments (4 replicates/treatment) in a completely randomized design, and dietary treatments were as follows: Control (SBM), 50% replacing SBM by RYFTO (RYFTO50) and 100% replacing SBM by RYFTO (RYFTO100). The concentrate ingredients and chemical composition of all treatments are shown in Table 1. Animals were fed concentrate at 1.7% body weight (BW) twice daily at 07.00 a.m. and 4.00 p.m. and rice straw was fed ad libitum. Clean water and mineral block were available all the time.

Samples collection and chemical analysis

Feed measurement was recorded daily by weighing the offered and refusals during the morning feeding. The feed intake was calculated daily for each steer at the DM offered minus the DM refusals (Dykier et al. 2020). Feed samples were randomly collected for determining chemical composition such as dry matter, ash, and crude protein according to the standard method of AOAC (1998), while neutral detergent fiber (NDF) and acid detergent fiber (ADF) were analyzed according to Goering and Van Soest (1970). Acid insoluble ash (AIA) analysis was analyzed according to Van Keulen and Young (1977). Steers were weighed at the start and the end of the experiment and at 7-day intervals during the experiment. The average daily gain (ADG) was calculated from BW at the end of the period of the experiment minus the initial BW and dividing by the number of the trial day. Feed conversion ratio was determined as the ratio of dry matter intake (DMI) to ADG (Dykier et al. 2020). The fecal samples were collected 5 consecutively days before the end of the experiment from each steer using grab or rectal sampling method. Fecal samples were collected at approximately 500 g of total fresh weight and kept in a refrigerator

Table 1 Ingredients and chemical composition of dietary treatments and rice straw used in experiment

Items	Dietary treatments			Rice straw
	Control	RYFTO50	RYFTO100	
Ingredients (%)				
Cassava peel	60.0	60.0	60.0	
Rice bran	16.0	16.0	16.0	
Soybean meal	20.0	10.0	0.0	
TOFRY	0.0	10.0	20.0	
Urea	1.0	1.3	1.6	
Mineral premix	1.0	0.8	0.5	
Molasses	1.0	1.0	1.0	
Sulfur	0.5	0.5	0.5	
Salt	0.5	0.4	0.4	
Total	100	100	100	
Chemical composition				
Dry matter (%)	85.3	85.0	84.5	89.2
Organic matter (% of DM)	93.9	94.5	94.6	85.9
Crude protein (% of DM)	15.6	15.9	15.5	2.4
Neutral detergent fiber (% of DM)	16.2	17.0	14.3	87.4
Acid detergent fiber (% of DM)	7.0	7.3	7.1	55.8
Ash (% of DM)	6.1	5.5	5.4	14.1
Cost (Baht/kg)	11.2	10.3	9.9	2.0

RYFTO red yeast fermented tofu waste, *Control* basal diet, *RYFTO50* replacement of soybean meal with RYFTO at 50%, *RYFTO100* replacement of soybean meal with RYFTO at 100%

and pooled by the animal at the end of each day for chemical analysis and calculation for digestibility coefficient. Blood samples were collected before feeding at 0 h and 4 h after feeding via jugular vein at approximate 10 ml for blood urea nitrogen (BUN) analysis according to Crocker (1967).

Beta-carotene analysis

Samples of tofu, red yeast fermented tofu waste (RYFTO), and three dietary treatments were collected and analyzed for beta-carotene, optical absorbance measurement by Spectrophotometer, modified method from Hornero-Méndez and Mínguez-Mosquera (2001).

Sampling and carcass and meat quality measurements

Following slaughter, the organs and offal include gastrointestinal tract of each animal which was washed and weighed. Then, each carcass was cut in half with an electric saw and weighed. The hot carcass weight (HCW) was measured and then was stored at 4 ºC for 24 h. The cold carcass weight (CCW) was recorded before and after chilling process (approximately 45 min and 24 h post-mortem) (Moreno Díaz et al., 2020).

pH, color (American Meat Science Association, 2012), and loin eye area: After 45 min and 24 post-mortems, carcass pH was measured by using a portable pH meter (Hanna HI9025), and the electrodes were stabbed into LD muscle and SM muscle approximately 1 cm between the 12th and 13th thoracic vertebrae. At 24-h post-mortem, the carcasses were measured for fat thickness and loin eye area using a Planimeter. Carcass and meat colors were recorded at 45 min, 24 h postmortem by using a Minolta chroma meter, following the L*, a*, and b* system, and afterward recorded again in 7 days.

Water holding capacity (WHC): Cut LD muscle and SM muscle samples were packaged in bags, aged for 7 days, and stored at 4 ºC for cooking loss, drip loss, and freezing loss analysis. The cooking loss method was use by cutting of meat samples of 2.5cm thick (100 g) and weigh, pack them in bags, and cook in water bath at 80 ºC until the internal temperature reached 72 ºC by thermometer. Each meat samples were weighed after cooking, recorded all weight and calculated according to the following equation: (raw weight – cooked weight/raw weight) × 100 (Bernardo et al., 2021). The drip loss method was used by cutting of meat samples into 2.5cm thick (100 g) and weighed and wrapped the meats with a gauze cloth. The meats were packed in bags and a string was used to tie them tightly and hang them in a plastic bag to keep away 1–5 inches above the bottom, and then it was stored in the refrigerator at 4 °C for 48 h, and the recorded weight was calculated according to the following equation: (raw weight – drip weight/raw weight) × 100 (Bernardo et al., 2021). In the freezing loss method, after weighed, the meat samples were kept in a refrigerator at − 20 °C for 1 month, and then frozen sample meats were thawed at a temperature of 4 °C for 24 h, and the recorded weight was calculated according to the following equation: (raw weight – freeze weight/ raw weight) × 100.

Shear force: After cooking, the meats were cut into 1 cm for measurement of the shear force (N) by using an Instron Universal Testing Machine Model (Instron corporation, USA) with a speed of 500 mm/min according to Boccard et al. (1981).

Laboratory analyses: Samples of LD and SM muscle were trimmed for approximately 100 g, and the meat was grinder thoroughly using a blender (Moulinex 645, Mexico) to proximate analysis following the AOAC (1998).

Chemical composition of experimental feeds and beta-carotene

The feed ingredients and chemical composition of dietary treatments are presented in Table 1. The chemical compositions of Control, RYFTO50, and RYFTO100 consisting of DM, OM, CP, NDF, ADF, and ash were at 84.5–85.3, 93.9–94.6, 15.5–15.9, 14.3–17.0, 7.0–7.3, and 5.4–6.1 on DM basis, respectively. The beta-carotene in tofu waste, RYFTO, and three dietary treatments (Control, RYFTO50 and RYFTO100) were found at 0.5, 1.5, 0.6, 1.1, and 1.1 mg/100 g, respectively, which are presented in Table 2.

Table 2 Beta-carotene composition of Tofu waste, red yeast fermented tofu waste and experimental feeds

Items	Content of beta-carotene (mg/100 g)
Tofu waste	0.5
RYFTO	1.5
Control	0.6
RYFTO50	1.1
RYFTO100	1.1

RYFTO red yeast fermented tofu waste, *Control* basal diet, *RYFTO50* replacement of soybean meal with RYFTO at 50%, *RYFTO100* replacement of soybean meal with RYFTO at 100%

Statistical analysis

All data were subjected to analysis of variance according to completely randomized design using the general linear model's procedures (SAS, 2018). Treatment means were statistically compared using Duncan's multiple range test to identify differences between means. significant effects were identified at $P < 0.05$.

Results

Intake, digestibility, and animal performance

The effect of replacing SBM by RYFTO on feed intake and digestibility in Brahman crossbred beef cattle is presented in Table 3. Replacing SBM by RYFTO affects the concentrate intake, roughage intake, and total DM intake ($P < 0.05$) except the digestibility coefficient which is not affected by treatments ($P > 0.05$). In addition, Table 4 presents the performance of animals fed by replacing SBM with RYFTO in the diet. Overall initial BW, final BW, and BW gain were similar among treatments ($P > 0.05$), while the ADG was affected by the treatments which was found lower in cattle receiving RYFTO100 group when compared to other groups ($P < 0.05$), while the FCR was not affected by the treatments ($P > 0.05$). Moreover,

Table 3 Effect of replacing soybean meal by red yeast fermented tofu waste on feed intake and digestibility in Brahman crossbred beef cattle

Items	Control	RYFTO50	RYFTO100	SEM	*P* value
Concentrate					
kg/d	5.2	5.0	4.7	0.214	0.285
%BW	1.7	1.7	1.7	0.050	0.752
g/kg $BW^{0.75}$	71.1	70.3	69.5	0.554	0.585
Roughage					
kg/d	3.1^{a}	2.7^{b}	2.7^{b}	0.072	0.004
%BW	1.0	0.9	0.9	0.048	0.734
g/kg $BW^{0.75}$	42.4	38.1	38.7	1.241	0.204
Total DM intake					
kg/d	8.3^{a}	7.7^{ab}	7.3^{b}	0.164	0.047
%BW	2.7	2.6	2.6	0.041	0.859
g/kg $BW^{0.75}$	113.5	108.4	108.2	1.724	0.062
Digestibility coefficient (%)	84.3	86.2	85.1	0.757	0.640

RYFTO red yeast fermented tofu waste, *Control* basal diet, *RYFTO50* replacement of soybean meal with RYFTO at 50%, *RYFTO100* replacement of soybean meal with RYFTO at 100%, [a,b] Mean within a row with no common superscripts are significantly different ($P < 0.05$)

Table 4 Effect of replacing soybean meal by red yeast fermented tofu waste on production performance and blood metabolite in Brahman crossbred beef cattle

Items	Control	RYFTO50	RYFTO100	SEM	*P* value
Initial weight, kg	281.1	272.4	271.5	8.040	0.887
Final weight, kg	330.4	317.1	302.7	9.033	0.759
BW gain, kg	49.3	44.7	31.2	3.892	0.489
ADG, kg/d	0.8^{a}	0.7^{ab}	0.5^{b}	0.063	0.049
FCR, kg/kg	10.4	11.0	13.6	1.530	0.268
Concentrate feed cost, Baht	4096.5^{a}	3635.7^{ab}	3302.6^{b}	89.382	0.037
Roughage cost, Baht	417.0^{a}	364.7^{b}	363.1^{b}	6.926	0.049
Total feed cost, Baht	4513.5^{a}	4000.4^{b}	3665.7^{b}	87.556	0.039
BUN (mg/dL)					
0 h-after feeding	14.2^{a}	14.9^{a}	8.3^{b}	1.012	0.001
4 h-after feeding	17.0^{a}	19.2^{a}	11.2^{b}	1.169	0.002
Mean	15.6^{a}	17.1^{a}	9.7^{b}	1.074	0.001

RYFTO red yeast fermented tofu waste, *Control* basal diet, *RYFTO50* replacement of soybean meal with RYFTO at 50%, *RYFTO100* replacement of soybean meal with RYFTO at 100%, ^{a,b} Means within a row with no common superscripts are significantly different ($P < 0.05$). *ADG* average daily gain, *FCR* feed conversion ratio, *BUN* blood urea nitrogen

the feed cost of roughage, concentrate, and total feed cost was lowest in RYFTO100 group when compared to the control ($P < 0.05$). However, blood urea nitrogen was reduced ($P < 0.01$) when replacing SBM by RYFTO, and the lowest was found in cattle receiving RYFTO100.

Carcass characteristics

The effect of replacing SBM by RYFTO on carcass characteristics in Brahman crossbred beef cattle is presented in Table 5. Replacing RYFTO50 and RYFTO100 in the concentrate diets did not affect slaughter weight, hot carcass weight, cold carcass weight, hot carcass percentage, cold carcass percentage, carcass length, back fat thickness, and loin eye area. The retail cut percentage of the beef cattle was not affected by the treatments except flank steak and tendon which was increased by RYFTO50 and RYFTO100 replacement in the concentrate diet ($P < 0.05$). On the other hand, the retail cut percentage of the offal and organ was similar among treatments ($P > 0.05$).

Meat quality

The effect of RYFTO replacement in concentrate diet on the color and chemical composition of LM and SM muscle is illustrated in Table 6. It was found that the color (L^*, a^*, and b^* values) and chemical composition of both LM and SM muscle were not changed by the inclusion of RYFTO in the diet ($P > 0.05$) on postmortem at 45 min, 24 h, and 7 days. The pH 45 min (pH_1) and 24 h (pH_u) postmortem of LM and SM muscle were not significantly different ($P > 0.05$) among treatments. No significant difference attributable to dietary treatment was observed in cooking loss, dripping loss, and shear force value of LM and SM muscle. However, freezing loss of LD muscle was deducted by RYFTO100 but not in SM muscle ($P > 0.05$) (Table 7).

Discussion

Chemical composition of experimental feeds and beta-carotene

Tofu waste (okara or soybean curd residue or soy waste) is a by-product from the manufacture of tofu and soymilk, which is abundant in cellulose and high-quality protein, especially essential amino acid (Li et al., 2013), which makes it more difficult to digest and dissolve the fiber. However, the current study revealed that the NDF value of concentrate using RYFTO is quite similar among treatments which means that the NDF of SBM is close to RYFTO. Rahman et al. (2014) reported that the use of soy waste as ruminant feed can be used by three ways as follows: raw soy waste, ensiled soy waste with other feeds, and dried soy waste (Amaha et al., 1996). In this study, the chemical composition of dietary treatments was contained similar in nutrient compositions. The CP was similar all treatment and NDF and ADF were higher than those in the control group when used RYFTO50 in diet. Hu et al. (2019) improve soybean residue fermentation with *K. marxianus* that shows an increase in crude fat (24.5%), soluble dietary fibers (158%), and polysaccharides (262%).

The beta-carotene of tofu waste, RYFTO, and 3 dietary treatments were between 0.53 and 1.11 mg/100 g. In previous studies, the biomass production ranged from 4 g/L (Martin et al., 1993) to 15 g/L (Martelli et al., 1990; Frengova

Table 5 Effect of replacing soybean meal by red yeast fermented tofu waste on carcass characteristics

Items	Control	TOFRY50	TOFRY100	SEM	*P* value
Slaughter wt, kg	330.4	317.1	302.7	11.482	0.723
Hot carcass wt, kg	170.8	168.8	157.8	5.500	0.694
Hot carcass percentage, %	51.7	53.3	52.2	0.435	0.406
Cold carcass wt, kg	168.8	166.0	154.8	5.537	0.664
Cold carcass percentage, %	51.1	52.4	51.1	0.379	0.362
Carcass length, cm	129.0	121.7	113.0	4.432	0.424
Back fat thickness, mm	13.8	11.0	11.7	0.919	0.528
Loin eye area, cm^2	59.9	51.9	53.4	2.039	0.279
Retail cut percentage					
Chuck	4.3	4.9	4.4	0.249	0.637
Brisket	5.8	6.3	5.9	0.352	0.897
Short rib A	1.2	1.2	1.3	0.081	0.878
Bavette	0.9	1.0	1.1	0.061	0.197
Shank	5.5	5.4	5.2	0.123	0.709
Strip loin	3.3	3.2	3.6	0.149	0.647
Tender loin	1.6	1.6	1.7	0.039	0.752
Bottom round	5.6	5.5	5.7	0.138	0.868
Top round	6.1	5.9	6.4	0.161	0.405
Sirloin	5.1	5.2	5.4	0.173	0.845
Sirloin tip	3.8	3.7	3.9	0.140	0.920
Flank steak	0.5^{a}	0.6^{b}	0.7^{b}	0.028	0.012
Bone	16.0	16.6	17.2	0.654	0.839
Tendon	2.6^{a}	2.2^{ab}	1.9^{b}	0.130	0.033
Fat	7.9	8.6	7.4	0.587	0.809
Lean meat	11.4	10.8	11.8	0.452	0.741
Trimming	2.2	0.8	0.9	0.394	0.288
Offal, %					
Heart	0.4	0.4	0.4	0.017	0.740
Liver	1.3	1.5	1.4	0.052	0.749
Lung	0.9	1.1	1.1	0.059	0.495
Spleen	0.4	0.4	0.4	0.027	0.659
Gastric	0.4	0.4	0.5	0.025	0.245
Small intestine	1.4	1.4	1.4	0.027	0.891
Large intestine	0.9	0.7	0.7	0.097	0.834
Organ, %					
Head and Horn	3.0	4.1	3.0	0.295	0.368
Skin	11.3	10.5	8.6	0.666	0.301
Shin and hoof	2.2	2.3	2.1	0.083	0.520
Tail	0.5	0.5	0.5	0.037	0.812
Penis	1.1	1.1	0.9	0.065	0.628
Tongue	0.3	0.5	0.4	0.059	0.316

RYFTO red yeast fermented tofu waste, *Control* basal diet, *RYFTO50* replacement of soybean meal with RYFTO at 50%, *RYFTO100* replacement of soybean meal with RYFTO at 100%, ^{a,b} Means within a row with no common superscripts are significantly different ($P < 0.05$)

et al., 1994) for these Rhodotorula strains. The result of the study shows that β-carotene from tofu waste fermented with *R. rubra* TISTR5134 be able to produce β-carotene at 1.5 mg/100 g may be cause by the influence of factors in yeast due to environmental factors inappropriate on growth. In addition, sun-drying affected the loss of β-carotene for approximately 40–50% (up to the strength of the sun) according to Ndawula et al. (2004), who reported that open sun-drying method caused the greatest β-carotene and vitamin C loss (58% and 84%, respectively).

Table 6 Effect of replacing soybean meal by red yeast fermented tofu waste on color and chemical composition of *Longissimus dosri* muscle and *Semimembranosus* muscle of Brahman crossbred beef cattle

Items		Control	RYFTO50	RYFTO100	SEM	*P* value
Color at 45 min postmortem						
LD	L^*	42.2	41.9	37.0	1.397	0.256
	a^*	19.1	16.3	15.4	0.828	0.132
	b*	0.8	0.5	0.2	0.196	0.620
SM	L^*	35.9	36.9	37.6	0.881	0.811
	a^*	16.0	16.6	16.4	0.478	0.926
	b^*	0.3	1.2	0.4	0.279	0.467
Color at 24 h postmortem						
LD	L^*	48.0	47.5	46.6	0.733	0.827
	a^*	18.9	18.8	19.8	0.343	0.547
	b^*	4.5	3.5	4.5	0.430	0.680
SM	L^*	39.4	39.6	39.1	0.185	0.625
	a^*	13.4	13.5	11.1	0.576	0.130
	b^*	1.8	1.9	1.2	0.223	0.525
Color at 7 days postmortem						
LD	L^*	48.5	46.0	43.7	1.189	0.290
	a^*	20.7	21.8	21.7	0.305	0.345
	b^*	4.7	4.7	4.0	0.274	0.528
SM	L^*	48.8	44.1	44.5	1.094	0.130
	a^*	21.5	21.1	22.2	0.377	0.584
	b^*	5.2	3.9	5.8	0.553	0.453
Longissimus dorsi, %						
Moisture		71.8	72.1	73.9	0.611	0.372
Ash		5.1	7.6	6.6	0.536	0.139
Protein		21.5	24.5	24.1	0.969	0.501
Fat		4.6	6.6	5.4	0.839	0.719
Semimembranosus, %						
Moisture		73.2	69.7	71.2	1.186	0.599
Ash		7.1	6.5	5.3	0.408	0.236
Protein		21.2	21.0	19.7	0.350	0.077
Fat		11.1	14.7	12.6	0.959	0.370

RYFTO red yeast fermented tofu waste, *Control* basal diet, *RYFTO50* replacement of soybean meal with RYFTO at 50%, *RYFTO100* replacement of soybean meal with RYFTO at 100%

Intake, digestibility, and animal performance

Vohra et al. (2016) review several researches which have showed that young ruminants fed live yeast culture supplemented feedstuffs showed positive effects on performance, evidenced by improved feed consumption, feed conversion efficiency, and increase in body weight gain. In this study, replacing SBM by RYFTO affect the roughage intake and total dry matter intake (kg/d), which show in decreasing in animals fed with RYFTO, especially RYFTO100 group ($P < 0.05$). However, roughage intake and total dry matter intake in terms of %BW and g/kgBW$^{0.75}$ as well as concentrate intake were similar among treatments ($P > 0.05$). Even the form of concentrate was quite similar among treatments that were in the powder form; however, the RYFTO form is quite hard in the hard plate form with 1–4 cm size after sun-dried processing which may affect feed intake. However, Yasuda et al. (2016) reported that finishing Japanese black steers, fed with soybean curd residue and soy sauce cake, did not affect DM intake. In contrast, Kim et al. (2012) reported the increases of DM intake and ADG when Hanwoo steers were fed diets including raw soybean curd residue at 25% and 35% in the final fattening period. The difference of roughage intake and total DM intake may be due to the different of each animal when received the treatments. However, the digestibility coefficient is not significant ($P > 0.05$) among treatments and ranged between 84.3 and 86.2%, which was higher than the study of Odeyinka et al. (2003) who reported that goats fed concentrate diets

Table 7 Effect of replacing soybean meal by red yeast fermented tofu waste on meat quality of Brahman crossbred beef cattle

Items	Control	RYFTO50	RYFTO100	SEM	*P* value
pH_1					
LD	6.7	6.7	6.9	0.045	0.127
SM	6.5	6.5	6.7	0.071	0.407
pH_u					
LD	5.4	5.6	5.6	0.043	0.063
SM	5.5	5.7	5.7	0.043	0.260
Cooking loss, %					
LD	35.4	37.6	36.8	0.544	0.276
SM	36.0	35.1	35.8	0.486	0.823
Dripping loss, %					
LD	9.4	9.0	7.8	0.391	0.260
SM	8.1	6.9	6.2	0.437	0.241
Freezing loss, %					
LD	9.9[a]	9.7[a]	7.9[b]	0.426	0.037
SM	7.3	7.5	7.4	0.254	0.986
Shear force, kg					
LD	5.1	4.3	5.2	0.228	0.352
SM	4.3	4.7	4.7	0.175	0.724

RYFTO red yeast fermented tofu waste, *Control* basal diet, *RYFTO50* replacement of soybean meal with RYFTO at 50%, *RYFTO100* replacement of soybean meal with RYFTO at 100%, [a,b] Means within a row with no common superscripts are significantly different ($P < 0.05$)

with tofu residue had higher digestibility coefficient of nutrients (reported at 64.3%) than other groups. Moreover, Tian et al. (2020) reported diet supplemented with fermented okara (FO) improved ADG and reduced feed gain ratio of growing pigs. In the present study, the initial weight, final weight, BW gain, and FCR are not significant ($P > 0.05$) among treatments. The ADG was lower in RYFTO100 than other groups ($P < 0.05$). Takizawa et al. (2001) reported decreases of ADG when Holstein steers were fed a diet including raw soybean curd residue at 20% and 10% on TDN basis in the first and second halves of the fattening periods, respectively. Blood urea nitrogen (BUN) at 0 and 4 h after feeding of RYFTO100 had lower than control and RYFTO50 and the mean were at 15.59, 17.08, and 9.74 mg/dL, respectively. The lower BUN of steers received RYFTO may be due to the lower amount of protein digestion in the rumen which leading to lower in BUN, unfortunately this research did not measure protein digestion and NH_3-N which is the product of protein digestion in the rumen and directly related to BUN. Butler et al. (1996) reported that BUN were increased 4–6 h after the cows were fed. Lin et al. (2004) reported that Korean native steers fed alcohol-fermented feeds (50% commercial beef cattle feed + 30% alcohol-fermented soybean curd dregs + 20% rice straw) affect the reduction of BUN concentration in steers up to 450 kg of BW), alteration of protein metabolism in the body since BUN is generated during the excretion of ammonia in urine through the urea cycle (Weiner et al., 2015). In addition, Hammond (1997) reported that a deficiency in protein (nitrogen) intake can limit dry matter utilization and intake.

Carcass characteristics

The carcass characteristics when steers fed a diet including RYFTO50 and RYFTO100 on the basal diet did not affect slaughter weight, hot carcass, cold carcass, hot carcass percentage, cold carcass percentage, carcass length, back fat, and loin eye area. In contrast, Kim et al. (2012) reported that Hanwoo steers fed dietary soybean curd residues (SCR) could not influence meat quality grade although carcass weight or chemical composition was changed by dietary SCR in the study. In contrast, Yamada et al. (1993) reported a slight improvement in the carcass dressing percentage when Japanese Black steers were fed with diets including SCR silage at 40% on FM basis.

Meat quality

The color of LD and SM muscle when steers fed a diet including RYFTO50 and RYFTO100 on the basal diet did not affect the L^*, a^*, and b^* values at 45 min, 24 h, and 7 days postmortem. Yasuda et al. (2016) reported the change in meat color is considered to be associated with fat content (Priolo et al., 2002), animal age (Dohgo et al., 1995), and diet (Sugimoto et al., 2009). The pH of LD and SM muscle 45-min postmortem averaged in 6.74 and 6.62, and the pH of LD and SM muscle 24-h postmortem averaged in 5.48 and 5.63. Wick et al. (2019) reported that in postmortem muscle, however, conversion to lactate remains the sole source of buffering hydrogen ion accumulation in muscle, but with time, these ions ultimately lower muscle pH from 7.0 to 5.7–5.5. In addition, the effect of dietary treatment did not affect cooking loss, dripping loss, freezing loss, and shear force. Morgan et al. (1991) reported that shear force values exceeding 3.9 kg are considered unacceptable in terms of tenderness, but this study animal had quite high shear force value which may be due to meat samples aged at a short time. Crouse et al. (1989) reported that meats of Brahman cattle with low marbling had an influence on the toughness of the meat.

The chemical composition of LD and SM muscle consisted of moisture, crude protein, lipid, and ash that did not affect by dietary treatments which could be due to all diet groups having the same nutritional level of protein and lipid (Hes, 2017). The protein content of LD and SM was averaged 20.64 and 23.34%, respectively. The fat content of LD and SM were ranged between 4.6 to 6.6% and 11.1 to 14.7%, respectively, which higher in fat content of SM probably from yeast *Rhodotorula rubra* that is used to fermented tofu waste; this genus yeast has a characteristic of fat source (Squina et al., 2002) resulting in high fat content in meat.

Conclusion

Based on the results, it could be summarized that 100% replacement of SBM by RYFTO in concentrate diet affects roughage intake and ADG without negative effect on concentrate intakes, digestibility, carcasses, and meat quality. This study suggested that RYFTO could be used as a protein source for partial replacement of SBM in the concentrate diet at 50% which can lower feed cost. However, further study should be conducted for longer period to gain the benefits of carotene in red yeast on carcass and meat quality.

Acknowledgements The authors would like to express our sincere thanks to the Agricultural Research Development Agency (Public Organization) for the research funding and special thanks to the Faculty of Animal Science and Technology, Maejo University, for providing places and research facilities, and thanks to the Graduate School, Maejo University, for providing some part of scholarship for this research.

Author contributions SF, TS, AC, NR, and JP conceived and designed research. SF, TS, and JP conducted experiments. TS and SF analyzed data. TS, SF, and JK wrote the manuscript. All authors read and approved the manuscript.

Funding This research was supported by Agricultural Research Development Agency (Public Organization) and Contract No. CRP6205031800.

Data availability All mean data are presented in the tables. The individual data may be obtained from the corresponding author with a reasonable request.

Code availability Not applicable.

Declarations

Ethics approval All animal care and experimental protocols used in this study were approved by the Animal Care and Use Committee of Maejo University Approval No. MACUC**049**A/**2561.**

Consent to participate Not applicable.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing interests.

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