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Effect of different diets on growth performance and carcass characteristics of Nu Phuk (*Bandicota indica*) raised under a circle cement pond

Thip-uten, S.[1], Jitjak, T.[1], Saensri, P.[1], Kaewsena, T.[1], Muangkhot, W.[1], Thip-uten, T.[2], Butrlakorn, C.[3], Mingjaidee, M.[3] and Subepang, S.[4*]

[1]Department of Animal Science, Faculty of Agricultural Technology, Sakon Nakhon Rajabhat University, Mueang Sakon Nakhon District, Sakon Nakhon Province, Thailand; [2]Department of Fishery Science, Faculty of Agricultural Technology, Sakon Nakhon Rajabhat University, Mueang Sakon Nakhon District, Sakon Nakhon Province, Thailand; [3]Ban Muang Subdistrict Administrative Organization, Ban Muang District, Sakon Nakhon Province, Thailand; [4]Department of Animal Science, Faculty of Liberal Arts and Science, Sisaket Rajabhat University, Mueang Sisaket District, Sisaket Province, Thailand 33000.

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Abstract The results showed that growth performance, chemical composition, fatty acid profile, and amino acid profile in edible meat were significant different (P<0.05) but, carcass traits were no significant different (P>0.05). In conclusion, edible meat of Nu Phuk (*Bandicota indica*) was shown to be abundant essential fatty acid and essential amino acid, thereby promoting future food, end hunger, achieve food security and improved nutrition and sustainable agriculture.

Keywords: Amino acid, Animal feed, Carcass, Fatty acid, Rat meat

Introduction

The global demand for animal protein continues to rise as the human population grows, projected to reach 9.9 billion by 2050 (FAO, 2006). This surge in demand, particularly for beef and dairy products, has significant environmental and economic implications. Traditional ruminant livestock production, such as cattle, contributes heavily to greenhouse gas emissions, utilizing vast amounts of feed and land resources (de Boer *et al*., 2011; Hristov *et al*., 2013). Consequently, alternative protein sources that require less land, produce lower emissions, and have faster growth cycles are gaining attention.

Rodents, particularly *Bandicota* sp. (Bandicoot rats), *Rattus argentiventer* (rice field rat), and *Rattus rattus* (roof rat) are natural of rodent pests that have

[*]**Corresponding Author:** Subepang, S., **Email:** sayanneng@gmail.com

been found in many ecosystems and are among the most widespread and problematic invasive animals affecting agriculture lands, due to it short time for pregnancy (Burhanuddin *et al.*, 2023). Fiedler (1990) reported that the lists 71 rodent genera and more than 89 species that are consumed by human, one of them is a rat.

Gruber (2016) noted that many regions of the world have a long-standing custom of using rodents as food. Many countries, including Thailand, Ghana, China, Vietnam, parts of India, Laos, Myanmar, Cambodia, and portions of the Philippines and Indonesia, widely recognize the regular consumption of rats as food (Meyer-Rochow *et al*., 2015). Furthermore, South and Central America highly values a number of rodent species as food, raising some in a manner similar to that of pigs and cows. Rodent meat is so popular in some Asian nations that stores sell it. Rats are canned in the Philippines, marketed in supermarkets as "STAR meat" (rats spelled backwards), frequently consumed during weddings in Vietnam, and, for the most part, regarded as delicacies by most Southeast Asians. Grant Singleton stated that he is an expert in rodent biology and management at the International Rice Research Institute in the Philippines (Gruber, 2016). According to Doyle (2014), during the height of the "rat season," Cambodia transfers up to two tons of wild rats to Vietnam every day. Because it is an omnivore, can thrive on a variety of diets and has a rapid reproductive cycle, making it a potential candidate for sustainable meat production. Despite its potential, little scientific attention has been given to optimizing its growth performance or evaluating the nutritional quality of its meat. This study aims to address this gap by evaluating the effects of different dietary formulations on the growth performance, carcass characteristics, and fatty acid profiles of Nu Phuk (*Bandicota indica)* raised in controlled environments.

The objectives of this study were to determine the optimal dietary protein level for maximizing growth and to assess the resulting meat quality in terms of amino and fatty acid composition, with a focus on the potential use of Nu Phuk as an alternative protein source for food security.

Materials and methods

The experiment was carried out at the Department of Animal Science, Facultry of Agricultural Technology, Sakon Nakhon Rajabhat University, Thailand, from May to July 2021.

Animal, treatments and experimental design

Eighty 60-day-old weaned Nu Phuk (*B. indica*) (40 males and 40 females) were allocated to four treatment groups in a randomized complete block design, with five rats per replicate and four replicates per treatment. The rats were housed in vertically stacked cement ponds (60 cm height, 80 cm diameter). The experimental diets consisted of three formulated concentrate diets containing 13% (T1), 17% (T2), and 21% (T3) crude protein (CP), while T4 was a cereal-based diet containing sunflower seeds, paddy rice seeds, ripe palm fruit, and sugarcane (Table 1 and 2). All groups were provided 300 grams of fresh Napier grass stems per day and concentrate was offered at 5% of body weight. Clean water was supplied *ad libitum* throughout the 60-day experimental period.

Table 1. Ingredients of concentrate pellet used in this experimental

Ingredients (%)	T1=CP13%	T2=CP17%	T3=CP21%
Grounde seeds Corn	12.00	8.00	3.00
Starch powder	2.00	2.00	1.00
Cassava chips	50.00	48.00	46.80
Rice bran	2.00	2.00	1.00
Plam kernel cake	3.00	3.00	1.00
Soybean meal	12.80	15.00	12.00
Leucaena leaves	8.00	7.00	2.00
Fish meal	2.00	6.80	25.00
Oil plam	1.00	1.00	1.00
Skim milk	2.00	2.00	2.00
Salt	0.20	0.20	0.20
Limestone powder	0.50	0.50	0.50
Dicalcuim phosphate	0.50	0.50	0.50
Mixed minerals	1.00	1.00	1.00
Mixed vitamin	1.00	1.00	1.00
DL-Methionine	1.00	1.00	1.00
L-Lysine	1.00	1.00	1.00
Total	100	100	100

T1 = concentrate 13 %CP + 300 gram of Fresh Napier grass (stems), T2 = concentrate 17 %CP + 300 gram of Fresh Napier grass (stems), T3 = concentrate 21 %CP + 300 gram of Fresh Napier grass (stems), T4 = Grain and cereals (sunflower seeds 30% + paddy rice seed 55% + ripe palm fruit 5% + sugar cane 5% + 5 % fresh Napier grass (stems))

Data collection and analyses

Growth performance parameters, including body weight, average daily gain, and feed intake, were recorded weekly. At the end of the trial, rats were fasted for 24 hours and then euthanized by cervical dislocation. Carcass characteristics, including visceral organ weights, skin, and muscle tissues, were evaluated. Edible meat samples were analyzed for moisture, protein, ether extract (fat), and ash content using AOAC (1990) standard methods. Fatty acid and amino acid compostion in rat meat were determined according to standard method approved by Central Laboratory (Thailand) Company Limited, branch Khon Kaen Province.

Table 2. Anzlyzed chemical compositions of dietary treatments (% of dry matter basis)

Parameters	T1	T2	T3	T4				
				Whole Sunflo wer seeds	Paddy Rice Seeds	Whole Palm fruits	Sugarcane stem	Fresh Napier grass (stems)
Dry matter	88.15	87.88	88.41	94.00	90.67	66.67	36.40	16.00
Ash	4.29	5.26	8.13	4.53	3.16	1.05	1.32	4.72
Organic matter	95.71	94.74	91.87	95.47	96.84	98.95	98.68	95.28
Crude protein	13.14	17.02	21.18	30.8	6.8	5.3	2.5	12.8
Ether extract	1.48	2.52	4.12	43.99	0.45	69.10	0.41	1.20
Crude fiber	8.45	8.31	8.24	19.6	0.6	35.4	9.6	28.2

T1 = concentrate 13 %CP + 300 gram of Fresh Napier grass (stems), T2 = concentrate 17 %CP + 300 gram of Fresh Napier grass (stems), T3 = concentrate 21 %CP + 300 gram of Fresh Napier grass (stems), T4 = Grain and cereals (sunflower seeds 30% + paddy rice seed 55% + ripe palm fruit 5% + sugar cane 5% + 5 % fresh Napier grass (stems))

Statistical analysis

All data were analyzed using the general linear model procedure of SAS (1996) version 6.12 according to a randomized complete block design. The treamtment mean values were compared by Duncan's New Multiple Rang Test. Significant differences were shown at $P < 0.05$ unless otherwise noted.

Results

The growth performance and dietary intake

The growth performance data showed significant differences in final body weight, body weight gain, average daily gain, feed conversion ratios, water intake, total feed intake, grass intake and concentrate intake among treatments (Table 3). Rats on the T3 diet (21% CP) exhibited the highest final body weight (647.80 g) and average daily gain (6.63 g/day), while those on T4 had significantly lower values (511.20 g final body weight and 4.43 g/day average daily gain). The T1, T2 and T3 diet had also resulted in the most efficient feed conversion ratio (0.081- 0.087 feed/gain), whereas T4 had the least efficient feed conversion (0.121 feed/gain) $P<0.05$.

Carcass characteristic and chemical composition in meat of B. indica

Carcass characteristics and chemical composition in meat (Table 4) revealed that significant differences in shrunk, empty body weights, abdominal fat, moisture, fat, and ash ($P<0.05$), while visceral organs, liver, body skin, front legs, hidden legs, edible meat, and crude protein were no significant difference

(P>0.05). The T3 group showed the highest shrunk body weight (718.00 g) and edible meat yield without bone (38.20%). In contrast, T4 rats exhibited higher abdominal fat content (11.72%), which may indicate less efficient nutrient utilization for muscle growth in cereal-based diets.

Table 3. Effect of different diets on growth performance and diet intake of Nu Phuk (*B. indica*) raised under circle cement pond

Parameters	Treatment				SEM	P-value
	T1	T2	T3	T4		
Initial body weight (g)	245.20	259.90	249.90	245.40	8.24	0.913
Final body weight (g)	539.20^{b}	635.85^{a}	647.80^{a}	511.20^{b}	10.69	<0.001
Body weight gain (g)	294.00^{b}	375.95^{a}	397.90^{a}	265.80^{c}	6.61	<0.001
Average daily gain (g/day)	4.89^{b}	6.26^{a}	6.63^{a}	4.43^{c}	0.08	<0.001
Feed convertion ratio (feed/gain)	0.083^{b}	0.081^{b}	0.087^{b}	0.121^{a}	0.002	<0.001
Water intake (ml/rat/day)	39.81^{b}	55.36^{a}	54.30^{a}	53.44^{a}	0.89	0.001
Total Feed intake (g DM/rat/day))	24.16^{b}	30.59^{a}	32.87^{a}	31.48^{a}	0.64	0.002
Napier grass intake (g DM/rat/day)	3.75^{a}	3.25^{b}	3.30^{b}	4.06^{a}	0.06	0.001
Concentrate intake (g DM/rat/day)	20.41^{b}	27.34^{a}	29.57^{a}	-	0.75	0.006
Paddy rice seed intake (g DM/rat/day)	-	-	-	13.33	-	-
Sunflower seeds intake (g DM/rat/day)	-	-	-	6.38	-	-
Ripe palm fruit intake (g DM/rat/day)	-	-	-	2.86	-	-
Sugar cane intake (g DM/rat/day)	-	-	-	4.84	-	-

T1 = concentrate 13 %CP + 300 gram of Fresh Napier grass (stems), T2 = concentrate 17 %CP + 300 gram of Fresh Napier grass (stems), T3 = concentrate 21 %CP + 300 gram of Fresh Napier grass (stems), T4 = Grain and cereals (sunflower seeds 30% + paddy rice seed 55% + ripe palm fruit 5% + sugar cane 5% + 5 % fresh Napier grass (stems)), SEM = standard error of mean, $^{a\text{-}c}$Mean with different superscripts within rows was significantly differed (P < 0.05).

Table 4. Effect of different diets on carcass characteristic and chemical composition of Nu Phuk (*B. indica*) raised under circle cement pond

Parameters	Treatment				SEM	P-value
	T1	T2	T3	T4		
Shrunk body weight (g)	555.75^{b}	702.25^{a}	718.00^{a}	702.25^{a}	8.89	0.006
Empty body weight (g)	363.00^{c}	467.50^{a}	444.75^{ab}	392.75^{bc}	9.83	0.020
	-------------% of Empty body weight-------------					
Visceral organs	23.32	20.77	24.77	19.97	1.30	0.562
Liver	4.17	4.22	4.05	4.05	0.23	0.989
Abdominal fat	7.80^{b}	7.30^{b}	6.47^{b}	11.72^{a}	0.50	0.020
Whole body skin	25.55	25.80	25.97	27.10	0.86	0.92
Whole front legs with bone	10.32	10.65	9.92	10.07	0.38	0.91
Whole hidden legs with bone	19.85	18.30	23.12	17.30	1.00	0.25
Edible Meat without bone	33.37	36.02	38.20	32.47	0.90	0.182
Chemical composition of Edible meat (%)						
Moisture	67.94^{c}	69.23^{b}	70.69^{a}	63.89^{d}	0.04	<0.001
Crude protein	26.03	24.94	25.32	27.25	0.02	0.439
Ether extract	29.19^{b}	34.97^{a}	30.34^{b}	29.19^{b}	0.30	0.005
Ash	12.91^{c}	18.08^{b}	30.83^{a}	10.45^{d}	0.02	<0.001

T1 = concentrate 13 %CP + 300 gram of Fresh Napier grass (stems), T2 = concentrate 17 %CP + 300 gram of Fresh Napier grass (stems), T3 = concentrate 21 %CP + 300 gram of Fresh Napier grass (stems), T4 = Grain and cereals (sunflower seeds 30% + paddy rice seed 55% + ripe palm fruit 5% + sugar cane 5% + 5 % fresh Napier grass (stems)), SEM = standard error of mean, $^{a\text{-}d}$Mean with different superscripts within rows was significantly differed (P < 0.05).

Amino acid profile in meat of B. indica

The amino acid profile of *B. indica* in meat is shown in Table 5. The results showed significantly differences (P<0.05) between treatments for almost all essential and non-essential amino acids except for histidine, isoleucine, and tryptophan.

Essential amino acids

Arginine content showed that T2 contained the largest amount of essential amino acids (3.43g), followed by T3, T4, and T1. T1 had the lowest amount (P<0.05). Histidine levels ranged from 0.62g to 0.74g, with no significant difference found between treatments (P>0.05). There were no notable variations in isoleucine between the treatments (P>0.05), however it rangedfrom 1.42g to 1.65g. Regarding leucine content, T3 had the greatest level (3.33g), which was considerably higher than that of the other treatments (P<0.05). T3 (6.70g) had the highest lysine level, followed by T2 (6.51g), and differed considerably from T1 and T4 (P<0.05). The greatest level of methionine in T3 (1.25g) was significantly differed from other treatments (P<0.05). With substantial differences (P<0.05), T3 had the greatest phenylalanine value (2.83g), whereas T4 had the lowest (2.17g). T3 (1.69g) contained the highest amount of threonine, and there were significantly variations (P<0.05) between treatments. Tryptophan levels ranged from 0.35g to 0.41g, with no discernible changed across treatments (P>0.05). T3 had the maximum valine content (2.93g), which was considerably higher than that of the other treatments (P<0.05).

Non-essential amino acids

T2 (1.74g) had the lowest alanine content (P<0.05), whereas T3 (2.60g) recorded the greatest alanine level. T2 had the highest concentration of aspartic acid (5.33g), and there were significantly variations across the treatments (P<0.05). Cysteine the results indicated a significant difference, T1 had the highest value (0.52g) and T4 had the lowest (0.26g) (P<0.05). Cystine in T2 was 0.62 g which showed the largest content, which was considerably different from T1 (0.33g) (P<0.05). With respect to glutamic acid content, T2 had the greatest level (9.34g), which was substantially different from the other treatments (P<0.05). Glutamine, with a concentration of 4.04g in T2 showed the greatest and differed considerably from other treatments (P<0.05). T4 had the lowest glycine content (1.54g), while T3 had the highest (1.97g) (P<0.05). Proline was shown notable variations, with T3 (2.35g) exhibiting the highest amount (P<0.05). The therapy with the greatest serine content in T3 was 1.38g which differed considerably from the other treatments (P<0.05).

Table 5. Effect of different diets on amino aicds in meat of Nu Phuk (*B. indica*) raised under circle cement pond (g/100g of meat)

Amino acids	T1	T2	T3	T4	SEM	P-value
Essential						
Arginine	2.65^{c}	3.43^{a}	3.25^{b}	3.11^{b}	0.022	0.001
Histidine	0.65	0.66	0.74	0.62	0.017	0.152
Isoleucine	1.54	1.65	1.51	1.42	0.045	0.423
Leucine	2.95^{b}	2.66^{c}	3.33^{a}	2.52^{c}	0.023	0.001
Lysine	4.16^{c}	6.51^{a}	6.70^{a}	5.64^{b}	0.074	0.001
Methionine	1.11^{b}	1.10^{b}	1.25^{a}	1.05^{b}	0.012	0.001
Phenylalanine	2.62^{b}	2.46^{c}	2.83^{a}	2.17^{d}	0.021	0.001
Threonine	1.31^{c}	1.54^{b}	1.69^{a}	1.32^{c}	0.014	0.001
Tryptophan	0.41	0.35	0.41	0.37	0.011	0.184
Valine	2.34^{b}	2.24^{bc}	2.93^{a}	2.12^{c}	0.023	0.001
Non-Essential						
Alanine	2.06^{b}	1.74^{d}	2.60^{a}	1.94^{c}	0.015	0.001
Aspartic acid	3.55^{d}	5.33^{a}	4.73^{b}	4.04^{c}	0.015	0.001
Cysteine	0.52^{a}	0.33^{bc}	0.36^{b}	0.26^{c}	0.013	0.001
Cystine	0.33^{c}	0.62^{a}	0.56^{ab}	0.52^{b}	0.012	0.002
Glutamic acid	4.83^{d}	9.34^{a}	6.54^{b}	5.73^{c}	0.018	0.001
Glutamine	4.04^{a}	2.84^{c}	4.05^{a}	3.46^{b}	0.040	0.001
Glycine	1.53^{b}	1.45^{b}	1.97^{a}	1.54^{b}	0.022	0.001
Proline	2.05^{b}	1.97^{b}	2.35^{a}	1.83^{c}	0.020	0.001
Serine	1.08^{b}	1.34^{a}	1.38^{a}	1.08^{b}	0.018	0.005
Tyrosine	1.61^{c}	1.75^{b}	2.04^{a}	1.65^{bc}	0.020	0.004

T1 = concentrate 13 %CP + 300 gram of Fresh Napier grass (stems), T2 = concentrate 17 %CP + 300 gram of Fresh Napier grass (stems), T3 = concentrate 21 %CP + 300 gram of Fresh Napier grass (stems), T4 = Grain and cereals (sunflower seeds 30% + paddy rice seed 55% + ripe palm fruit 5% + sugar cane 5% + 5 % fresh Napier grass (stems)), SEM = standard error of mean, $^{a\text{-}d}$Mean with different superscripts within rows was significantly differed ($P < 0.05$).

Fatty aicds profile in meat of B. indica

Fatty acid analysis demonstrated that T3 resulted in the lowest levels of saturated fatty acids (C14:0 and C16:0) which are known to improve meat quality (Table 6). The total polyunsaturated fatty acid (PUFA) content was highest in T4 (7.813 g/100g), with a particularly high concentration of linoleic acid (C18:2n6), while T3 had the most balanced ratio of unsaturated to saturated fats.

Table 6. Effect of different diets on fatty aicds in meat of Nu Phuk (*B. indica*) raised under circle cement pond (g/100g of meat)

Fatty acids	T1	T2	T3	T4	SEM	P-value
C14:0 (Myristic)	0.413^{b}	0.489^{a}	0.033^{c}	0.490^{a}	0.003	0.001
C16:0 (Palmitic)	7.143^{c}	7.818^{b}	0.391^{d}	8.755^{a}	0.079	0.001
C18:0 (Stearic)	3.453^{c}	4.044^{b}	0.024^{d}	4.419^{a}	0.028	0.001
C16:1n7 (Palmitoleic)	0.435^{c}	0.650^{a}	0.669^{a}	0.541^{b}	0.006	0.001
C18:1n9c (cis-9-Oleic acid)	16.753^{a}	16.465^{c}	11.332^{e}	15.611^{c}	0.003	0.001
C18:2n6 (cis-9,12-Linoleic)	3.335^{b}	2.757^{c}	2.238^{d}	7.396^{a}	0.005	0.001
C18:3n6 (gamma-Linolenic)	0.026^{a}	0.015^{b}	0.017^{b}	0.027^{a}	0.002	0.001
C18:3n3 (alpha-Linolenic)	0.127^{a}	0.145^{a}	0.093^{ab}	0.049^{b}	0.009	0.001
C20:2 (cis-11,14-Eicosadienoic)	0.059^{b}	0.047^{c}	0.038^{d}	0.084^{a}	0.007	0.009
C20:3n6 (cis-8,11,14-Eicosatrienoic)	0.052^{b}	0.056^{b}	0.065^{a}	0.047^{c}	0.008	0.018
C22:6n3 (cis-4,7,10,13,16,19-Docosahexaenoic)	0.079	0.156	0.306	0.194	0.036	0.251
Total saturated	11.728^{c}	12.989^{b}	10.072^{d}	14.337^{a}	0.025	0.001
Total unsaturated	21.053^{b}	20.516^{c}	14.953^{d}	24.161^{a}	0.003	0.001
Total monounsaturated	17.037^{a}	17.155^{a}	12.029^{c}	16.163^{b}	0.043	0.001
Total polyunsaturated	3.666^{b}	3.196^{c}	2.750^{d}	7.813^{a}	0.020	0.001
Total unsaturated/Total saturated	1.796^{a}	1.580^{c}	1.486^{d}	1.683^{b}	0.003	0.001

T1 = concentrate 13 %CP + 300 gram of Fresh Napier grass (stems), T2 = concentrate 17 %CP + 300 gram of Fresh Napier grass (stems), T3 = concentrate 21 %CP + 300 gram of Fresh Napier grass (stems), T4 = Grain and cereals (sunflower seeds 30% + paddy rice seed 55% + ripe palm fruit 5% + sugar cane 5% + 5 % fresh Napier grass (stems)), SEM = standard error of mean, $^{a\text{-}d}$Mean with different superscripts within rows was significantly differed (P < 0.05).

Discussion

This study is highlighted the impact of dietary protein levels and cereal-based supplementation on the growth and carcass characteristics of Nu Phuk (*B. indica*). The superior performance of rats fed the T3 diet, which provided a 21% crude protein concentrate, aligns with previous findings that higher dietary protein promotes muscle accretion and improves feed efficiency (He *et al.*, 2016). The lower feed conversion ratios observed in T3 compared to T4 suggested that mixed cereal diets may be less efficient in supporting optimal growth.

Hanusová *et al*. (2022) stated that meat represents an important part of a blanced humen food as an essential sourcs of nutrens. Proteins are a vital nutrient that is present in large quantities. Essential amino acids, which are necessary for the repair and development of bodily cells, make up proteins. This work found that crude protein in edible meat of *B. indica* rang from 24.94 to 27.25 percentage, highest reported of Mardari and Leonte (2016) who reported that protein in nutria meat (*Myocastor coypus* M.) was 18.45 percentage. Moreover, Jones *et al*. (2021) conducted the comparison protein in meat between domestical animals' rabbit, chicken, versus wildlife animal which guina pig (*Cavia porcellus*) and agouti (*Dasyprocta leporina)*, who found that the protein content was 20.43, 7.58, 15.19, and 22.18 percent, respectively.

Essentail amino acids content (arginine, isoleucine, leucine, lysine, phenylalanine, and valine) in meat of *B. indica* from this research shown the highest in meat of nutria (*M. coypus*) where rodent specie from work of Hanusová *et al*. (2022). May be a cause from feeds ingreints especially fish meal could provide amino acid to meet the requirement of animal, beside this work we fed concentrate at 5 percentage of body weight. According to Li *et al*. (2007), amino acids raise the body's pH, aid in cell repair, give energy, and help to rebuild bones and cells. According to Wu *et al*. (2001), glutamic acids function as neurotransmitters and aid in nerve cell and brain communication. Agrignin has a critical role in the immune system's development. Cysteine plays a role in maintaining cell shape. Amino acids are also required for vitamins and minerals to carry out all their vital functions. Essential amino acids have numerous other functions. The human body cannot operate normally in the absence of certain vital amino acids, and in certain severe situations, their absence can result in death.

The fatty acid composition of edible meat further underscores the nutritional benefits of higher protein diets. Chizzolini *et al*. (1999) reported that saturated fatty acids are important in different biological function as being a source of metabolic energy and in cell membrane structure formation. Although fatty acids have an important impact on humen health, the high consumption of saturated fatty acids is associated with cardiovascular disease and obesity (Lichtenstein *et al*., 2006). The lower saturated fat content levels in T3-fed rats can enhance meat quality and reduce health risks associated with high saturated fat intake (Wood *et al*., 2008).

Conversely, the high linoleic acid, total saturated, total unsaturated, and total polyunsaturated content in T4 may offer some nutritional benefits but must be balanced against its potential pro-inflammatory effects (Simopoulos, 2016).

In conclusion showed that T3 diet is offered a promising dietary strategy for optimizing the growth performance and meat quality of Nu Phuk (*B. indica*) under condition of raised a circle cement pond, making it is a viable candidate for sustainable protein production in developing regions.

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