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Research Article
Performance and Economic Evaluation of Broilers Fed Varying Dietary Levels of Mao Pomace

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Abstract

Background and Objective: The nutritive value of mao pomace includes a high concentration of organic acids, which can be exploited in broiler chicken production. The performance and economic characteristics were evaluated of broilers fed varying dietary levels of mao pomace. **Materials and Methods:** In total, 400 days old Cobb broilers were randomly allocated based on a completely randomized design into 4 treatments with 5 replications (20 birds/replicate). Dietary treatments consisted of (1) Basal diet (CON), (2) Basal diet+0.5 g kg^{-1} of mao pomace from the juice industry (MPJ1), (3) Basal diet+1.0 g kg^{-1} of mao pomace from the juice industry (MPJ2) and (4) Basal diet+1.5 g kg^{-1} of mao pomace from the juice industry (MPJ3). Data were analyzed by general linear models, using a completely randomized design (CRD), the means were compared with Duncan' s test ($p<0.05$) using Tukey's test. **Results:** The results showed that the feed intake and feed conversion ratio were higher in MPJ2 ($p<0.05$) during age 7-14 days, whereas, viability was unaffected after dietary supplementation during the starter period ($p>0.05$). In addition, body weight gain, feed intake, average daily gain and production index were unaffected during age 15-42 days ($p>0.05$). The feed conversion ratio increased in MPJ2 during the overall period, whereas, viability improved in MPJ1, MPJ2 and MPJ3 during the overall period relative to the control ($p<0.05$). Moreover, the feed cost per gain and net profits per bird increased in MPJ3, whereas, the return of investment in comparison with the control group was significantly suppressed in MPJ2 ($p<0.05$). **Conclusion:** The MPJ-supplemented birds exhibited better viability and it was better to supplement the basal diet during age 7-14 days. Further detailed study is required on the mechanism and meat quality analysis in broilers.

Key words: *Antidesma* sp., broilers, economic characteristics, mao pomace, viability rate

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

In Thailand, particularly the Northeastern region, ripe fruits are traditionally used for medicinal purposes for gastric intestinal problems, such as diabetes, dysentery, indigestion and constipation[1]. *Antidesma* sp. (know as mao in Thailand) is a fruit native to the Northeast, which is more common in the Phu Phan Mountain Range in Sakon Nakon province[2]. The fruits are fragrant, round or avoid with a dark red color and are borne in clusters like cranberries but are less acidic and slightly sweet when fully ripe[3]. The ripened fruits are believed to be a good source of natural antioxidants[4] and contain amounts of some nutrients such as catechin, epicatechin, rutin, quercetin, proacthocyanidin B1, procyanidin B2, gallic acid and ferrulic acid[5]. Mao is marketed as fresh fruit. The mao trading process involves the collection and distribution of products to the processing plant followed by product distribution to restaurants, shops and department stores. Moreover, mao is processed into juice and wine because people are paying increased attention to their health and healthy food consumption, resulting in many customers seeking mao[6]. Mao juice and wine industry have become more popular in Thailand. This industry generates a number of wastes and by-products, most notably mao pomace[7]. Lokaewmanee and Sansupha[8] reported that the amounts of dry matter, total carbohydrate, total dietary fiber, insoluble fiber, total calories, vitamin B1, vitamin E in the alpha-tocopheral, cystine, tartaric acid, malic acid and citric acid of mao pomace from juice production are higher than in mao pomace from wine production. Mao seeds and mao marces are abundant sources of polyphenols (97.32-130 mg gallic acid equivalents g^{-1}) and proantocyanidins[9]. Fresh mao pomace from the juice and wine industry contains anthocyanin 14.473 and 15.720 mg mL^{-1}, respectively, whereas, dried mao pomace from the juice and wine industries contains anthocyanin 11.360 and 12.801 mg mL^{-1}, respectively[10]. Phytochemicals in mao pomace include antioxidant, anti-inflammatory, anti-apoptotic and anti-carcinogenic activities[11]. Based on the benefits mentioned above, mao pomace is an excellent potential feed for goat[12,13] and pig[14]. Lokaewmanee[15] recommended 0.5% mao pomace from wine production to reduce the feed cost per dozen eggs. In addition, Sirilaophaisan *et al.*[16] suggested that dietary supplementation of mao pomace at 1.0% in the laying hen diet could improve egg production and egg quality and decrease blood cholesterol. Supplementation of mao pomace in the diet of broilers could increase the efficiency of by-products utilization in the feeding systems. However, mao pomace has not been investigated for use as a feed additive for broiler chickens. Therefore, the objective of this study was to investigate the effect of mao pomace supplementation on broiler productive performance and economic return.

MATERIALS AND METHODS

Study site: This study was performed in November, 2016 at Kasetsart University Chalermphrakiat Sakon Nakhon province campus in Sakon Nakhon province, Thailand.

Preparation of mao pomace from juice industry (MPJ): Mao pomace was obtained as a waste product from the mao juice industry. MPJ was collected at the plant of Wanawong Industry, Sakon Nakhon province, Thailand. The mao pomace samples were dried in a hot air oven at 50°C for 2 days and then they were ground using an electronic grinder (DY 360, Zhengxhou Diying Machine Equipment Co., Ltd., China) and kept at room temperature until mixed with the basal diet. The contents of dry matter, crude protein, crude fiber, crude fat and crude ash were determined using methods according to the AOAC[17] and as shown in Table 1.

Birds and experimental design: The experiment was managed in accordance with the guidelines and rules for animal experiments, Kasetsart University, Thailand. A sample of 400 Cobb male broilers was used in this study with an age range of 7-42 days old. Male broilers were allocated randomly to 4 treatment groups of 100 birds each. Each group was distributed into 5 replicates with 20 birds per replicate. All birds were fed a starter diet from age 7-21 days, followed by a growing diet from age 22-42 days. The basal diet was based on corn and soybean meal (Table 2) and was balanced to meet the nutrient requirements for broiler chickens according to NRC[18]. The birds were reared on concrete flooring covered with wood shavings as litter material. The dietary treatments consisted of: basal diet (CON group) and basal diet supplemented with 0.5, 1.0 or 1.5 g kg^{-1} mao pomace from the juice industry, respectively (MPJ1, MPJ2 and MPJ3). Feeding was carried out twice daily between the hours of 07.00-08.00 am and 5.30-6.30 pm. Water was provided

Table 1: Chemical composition of mao pomace from juice production[a]

Chemical analysis	Mao pomace from juice production (MPJ)
Dry matter (%)	96.01
Crude protein (%)	7.16
Crude fiber (%)	15.95
Crude fat (%)	5.48
Crude ash (%)	3.81
Gross energy (kcal kg^{-1})	4,590.80

[a]Dry matter

Table 2: Ingredients and nutrient composition of starter diet and grower diet

Ingredients	Starter diet (7-21 days)	Grower diet (22-42 days)
Maize	513.00	620.00
Soybean meal	328.00	250.00
Fish meal	61.00	34.00
Rice bran oil	64.00	63.00
Oyster shell	11.00	11.00
Dicalcium phosphate	9.00	8.00
Salt	4.00	4.00
DL-methionine	2.00	2.00
Concentrate mixture[a]	8.00	8.00
Nutrient composition (g kg^{-1})		
Crude protein	230.00	200.00
Crude fiber	40.00	40.00
Crude fat	40.00	60.00
Calcium	10.00	8.00
Available phosphorus	5.00	4.00
ME (MJ kg^{-1})	13.40	13.40

[a]Concentrate mixture including (per kg of diet): Trans-retinyl acetate 12,000 IU, cholecalciferol 2,000 IU, DL-α-tocopheryl acetate 12 IU, menadione 1.50 mg, thiamine 1.50 mg, riboflavin 4 mg, pyridoxine 2 mg, cyanocobalamine 15 µg, biotin 0.30 mg, pantothenic acid 10 mg, folic acid 0.5 mg, nicotinic acid 60 mg, copper 6 mg, manganese 60 mg, zinc 60 mg, iron 20 mg, preservative 6.25 mg and feed supplement 25 mg

ad libitum. The light program consisted of 24 h light and birds were reared in open-sided houses with the temperature maintained at 33°C during the rainy season in Northeastern Thailand.

Production performance and economic return measurement: The initial weights of the birds were taken at the start of the study and subsequently live weight measurements were recorded on a weekly basis. The feed intake was determined on a daily basis as the difference between the quantity of feed fed the previous day and the quantity left the next morning. The feed conversion ratio was calculated as the ratio of the feed intake over the body weight gain. All pens were checked for mortality daily. Feed cost per gain, salable net return, net profits return per bird and return of investment were calculated and compared with the control group.

Data analyses: All data collected were subjected to one-way ANOVA according to the procedure of Steel and Torrie[19]. Significantly different means were separated according to the method of Duncan[20]. Differences between means were analyzed at a significance level of 0.05 using Tukey's test. The results of the statistical analysis were shown as mean±standard error.

RESULTS AND DISCUSSION

Experimental results showed that the treatments significantly increased ($p<0.05$) feed conversion ratio at age 7-14 days (Table 3). The feed intake (FI) in the MPJ2 group was significantly increased ($p<0.05$) compared with the CON group at age 7-14 days. Viability in the MPJ1, MPJ2 and MPJ3 groups was significantly higher than in the CON group at ages 22-28 and 29-35 days. The FI in the MPJ1 group significantly increased ($p<0.05$) compared with the CON group at age 36-42 days. Viability in the MPJ1 group was significantly higher than in the CON group at age 36-42 days. The feed conversion ratio (FCR) in the MPJ3 group was significantly higher than in the CON group at age 7-42 days. Viability in the MPJ1, MPJ2 and MPJ3 groups was significantly higher than in the CON group at age 7-42 days. The results obtained in this study suggest that incorporation of MPJ significantly improved the FCR of broilers chickens. These results showed that viability by inclusion of 0.5, 1.0 or 1.5 g kg^{-1} MPJ in diets for the whole experimental period increased by 1.80, 1.40 and 1.60%, respectively, compared to the basal diet. Vasupen *et al.*[14] reported that native (Kadon) pigs fed a diet with 1.5% fresh mao pomace increased body weight gain, feed conversion ratio and the feed cost for 1 kg of weight gain compared with pigs fed a diet with 1.5% organic acids ($p<0.05$). Fresh mao contains organic acids (such as malic acid, citric acid and tartaric acid) and other nutrients and this might increase the growth performance of native (Kadon) pigs. Experiments with pigs have shown that several organic acids, including citric acid, fumaric acid, formic acid and propionic acid, have a positive influence on growth performance[21]. Moreover, fresh mao pomace is highly promising because beneficial effects have been shown through their mode of action turning feed inputs into higher performance and profitability. Suphanphuwong *et al.*[12] found that dried mao pomace could increase the utilization of nutrient in goats because digestible nutrient intakes and the calculated microbial crude protein content were higher in goats fed dried mao pomace when compared with goats fed wet mao pomace ($p<0.05$). Gunan *et al.*[7] investigated the effect of mao pomace levels on degradability and rumen gas production using *in vivo* gas production techniques. The dietary treatments were supplemented by mao pomace at 0, 4, 8, 12, 16 or 20 mg with 0.5 g of roughage and a concentrate ratio at 60:40. It was found that the gas production from the insoluble fraction, cumulative gas production at 96 h and *in vivo* dry matter degradability were not affected by mao pomace supplementation. Sirilaophaisan *et al.*[22] stated that diets supplemented with 0.5 and 1.0% mao pomace groups significantly improved body weight gain and improved the feed conversion ratio when compared with the 0% mao pomace group. In particular, a diet supplemented with 0.5% mao pomace improved the growth performance of Cherry Valley ducks aged 1-56 weeks ($p<0.05$). Moreover,

Table 3: Effect of mao pomace from the juice industry on growth performance of broilers

	Diet treatments[1]				
Parameters	CON	MPJ1	MPJ2	MPJ3	SEM
7-14 days					
BWG (g)	223.76±2.54[a]	217.60±2.17[ab]	215.72±3.20[b]	213.01±0.90[b]	2.28
FI (g)	52.56±0.34[b]	54.28±0.74[ab]	54.82±0.91[a]	53.48±0.78[ab]	0.49
ADG (g)	31.97±0.36[a]	31.09±0.31[ab]	30.82±0.46[b]	30.43±0.13[b]	0.33
FCR	1.65±0.03[b]	1.75±0.02[a]	1.78±0.02[a]	1.76±0.03[a]	0.03
PI	194.66±5.10[a]	178.13±3.31[b]	173.35±3.78[b]	173.32±3.25[b]	5.06
Viability (%)	99	100	100	100	-
15-21 days					
BWG (g)	319.86±7.69	315.50±3.68	312.76 ±4.41	306.21±2.75	2.86
FI (g)	80.56±0.17	80.519±0.19	80.43±0.17	80.67±0.53	0.05
ADG (g)	45.69±1.10	45.07±0.53	43.74±0.63	44.68±0.39	0.41
FCR	1.77±0.04	1.79±0.02	1.84±0.03	1.81±0.02	0.02
PI	259.71±12.40	252.39±5.41	238.09±6.54	247.57±4.59	4.53
Viability (%)	99	100	100	100	-
22-28 days					
BWG (g)	387.35±6.82	393.58±2.81	396.39±7.19	316.64±4.85	19.04
FI (g)	107.39±1.29	106.04±0.2	106.03±0.07	103.49±2.62	0.81
ADG (g)	55.34±0.97	56.22±0.40	56.63±1.03	56.66±0.69	0.31
FCR	1.94±0.03	1.89±0.01	1.83±0.06	1.83±0.05	0.03
PI	282.92±11.23	298.18±4.21	302.82±10.86	311.20±10.83	5.93
Viability (%)	98[b]	100[a]	100[a]	100[a]	-
29-35 days					
BWG (g)	540.02±9.42	519.84±14.98	530.97±16.60	529.30±27.75	4.13
FI (g)	134.96±0.62	132.18±4.29	135.95±0.51	136.11±0.36	0.91
ADG (g)	77.31±1.38	74.31±2.16	75.85±2.37	73.04±3.12	0.93
FCR	1.75±0.03	1.79±0.10	1.80±0.05	1.88±0.08	0.027
PI	437.63±18.90	422.71±34.15	424.67±25.66	395.18±34.76	8.93
Viability (%)	98[b]	100[a]	100[a]	100[a]	-
36-42 days					
BWG (g)	546.37±21.45	567.80±15.53	568.69±23.84	530.46±47.48	9.21
FI (g)	157.01±3.90[b]	166.53±0.004[a]	163.17±3.19[ab]	163.17±3.36[ab]	1.99
ADG (g)	78.05±3.10	81.12±2.22	81.25±3.41	75.78±6.78	1.32
FCR	2.02±0.06	2.06±0.06	2.02±0.20	2.22±0.18	0.05
PI	381.77±25.52	396.28±21.47	397.65±27.43	357.80±57.03	9.25
Viability (%)	97[b]	100[a]	98[ab]	99[ab]	-
7-42 days					
BWG (g)	2017.35±26.67	2014.62±26.59	2017.98±42.44	1964.17±26.83	13.14
FI (g)	106.49±1.07	107.91±0.97	108.08±0.79	107.39±0.83	0.36
ADG (g)	57.64±0.76	57.56±0.76	57.66±1.21	56.12±0.77	0.38
FCR	1.83±0.021[b]	1.85 ±0.026[ab]	1.86±0.023[ab]	1.90±0.023[a]	0.02
PI	308.18±8.50	309.54±9.57	307.32±10.79	297.01±4.40	2.87
Viability (%)	98.20[b]	100.00[a]	99.60[a]	99.80[a]	-

[a,b] Means in the same row with different superscripts differ significantly (p<0.05), [1]CON group, basal diet, MPJ1, MPJ2 and MPJ3 group, basal diet containing 0.5, 1.0, 1.5 g kg^{-1} mao pomace from the juice industry, respectively. BWG: Body weight gain, F: Feed intake, ADG: Average daily gain, FCR: Feed conversion ratio, PI: Productive index, Data represented as Mean±SE

phytochemical analysis of the mao confirmed the presence of varying amounts of phenolic acids, flavonoids and anthocyanins[23]. Puangpronpitag *et al.*[9] reported that mao seed and mao marcs were an abundant source of polyphenols (97.32-130 mg gallic acid equivalents g^{-1}, respectively) and proanthocyanidins. Dechayont *et al.*[24] found that the dried mao marc contained the highest phenolic contents of 85.77±0.34 mg GAE g^{-1}. The trend of results obtained in this study suggests that incorporation of 0.5 g kg^{-1} MPJ in the diet of broilers showed beneficial promotion of the health status because there was no mortality in this group. As observed earlier, mao pomace consists mainly of total phenolic contents and organic acids. The potential of hydrogen (pH) properties which are the stimulation of growth, increased protein digestibility and/or a limited number of pathogens[14] and reduced the digestion pH, increased pancreatic secretion and the trophic effects on the gastrointestinal mucosa[25]. It is probable that with MPJ inclusion, these active components of mao pomace were able to create a harmonious gut environment suitable for the release and assimilation of

Table 4: Effect of mao pomace from the juice industry on economic characteristics of broilers (Mean±SE)

	Diet treatments[1]				
	CON	MPJ1	MPJ2	MPJ3	SEM
FCG (baht/bird)	29.05±0.71[b]	29.51±0.92[ab]	29.65±0.79[ab]	30.20±0.81[a]	0.24
SBR (baht/bird)	107.41±7.15	90.74±45.56	111.47±7.96	107.17±6.76	4.59
NPR (baht/bird)	26.51±0.73[b]	27.02±0.96[ab]	27.19±0.76[ab]	27.69±0.84[a]	0.24
ROI (%)	44.92±1.74[a]	42.99±2.16[ab]	41.89±1.06[b]	42.94±2.20[ab]	0.63

[a,b]Means in the same row with different superscripts differ significantly (p<0.05), [1]CON group, basal diet; MPJ1, MPJ2 and MPJ3 groups, basal diet containing 0.5, 1.0 and 1.5 g kg^{-1} mao pomace from the juice industry, respectively. FCG: Feed cost per gain, SBR: Salable net return, NPR: Net profits return per bird and ROI: Return of investment compared with the control group, Data were represented as Mean±SE

digestive nutrients necessary for promoting the health status. At a higher level of MPJ, this harmonious gut environment may have been distorted by nutrient imbalances and an improper metabolism. Further studies are needed to explore the specific mechanism because of the complicated nutrition composition and chemical structure of MPJ.

The feed cost per gain (FCG) and net profits return per bird (NPR2) in the MPJ3 were significantly higher than those of the CON group (Table 4). The return of investment compared with the control group (ROI) in the MPJ2 was significantly lower than for the CON group (p<0.05). However, dietary MPJ had no effect on the salable net return (SBR). As the nutritional composition of diets in all groups was almost the same, not only the higher FCG and NPR2 but also the lower ROI seem to have been induced by MPJ. No information is available about the impact of dietary MPJ on the economic characteristics of broilers. The higher FCG and SBR in broilers fed with the MPJ3 may have been due to fiber in the waste from the mao juice industry. The crude fiber value obtained in the present study was higher than the crude fiber value of 14.59% reported by Lokaewmanee[10]. The high fiber content (12.00%) of neem leaf meal (*Azadirachta indica*) resulting in insufficient consumption of digestible nutrients (particularly protein and energy required to sustain growth) could account for the depressed body weights observed above the 0.5% level of neem leaf meal inclusion[26]. This was attributed to the antinutritional factors inherent in the plants[27]. This trend of an increase in the FCG and SBR with MPJ3 does not agree with the earlier findings of Onyimonyi *et al.*[26], that a decreased cost of feed consumed by using neem leaf meal increased the economic benefit. Further detailed study is required of the mechanism and meat quality analysis in broilers.

CONCLUSION

Dietary supplementation with MPJ improved the viability rate and in particular, this response indicated that MPJ can be a potential alternative to antibiotic growth promoters to improve health status. However, dietary MPJ showed no effect on SBR. Further studies are needed to investigate in detail the potential effect of MPJ on chicken muscle characteristics and meat quality, including the taste of valuable parts.

SIGNIFICANCE STATEMENTS

This study discovers the performance and economic characteristics of broilers fed dietary mao pomace that can be beneficial for viability rate. It has a great commercial value in broiler production. Finding of this study will guide the researcher to work on a poultry nutrition and poultry production.

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