EFFECT OF SPECIALTY PROTEIN SOURCES IN EARLY CHICK DIETS ON THE PRODUCTION PERFORMANCE, EXCRETA QUALITY AND CARCASS CHARACTERISTICS OF BROILERS

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ABSTRACT

Plant and animal specialty protein sources supplemented in early chick diets were tested to determine the effects on the production performance, excreta quality, and carcass characteristics of broilers. Seven hundred twenty, day-old Cobb 500 broiler chicks were allotted to six treatments using the randomized complete block design (RCBD) with 12 replicates and 10 birds each. The dietary treatments were: 1) Corn-Soybean meal diet (Negative control, NC), 2) NC+5% enzyme-treated soybean meal (ESBM1) at booster stage, 3) NC+5% hydrolyzed peptone (HP), 4) NC+5% pork meal (PM), 5) NC+5% soy protein concentrate (SPC), and 6) NC+5% ESBM at booster and 2.5% at starter stages (ESBM2). Broilers fed diets with various specialty protein sources did not significantly affect BW, ADG, ADFI, viability, PEI, excreta scores, and carcass characteristics (*P*>0.05). Supplementing SPC, HP, and ESBM2 in broiler diets improved feed efficiency (F/G, *P*<0.01) at the finisher stage. Feed cost was lesser for broilers fed diets with ESBM at booster and SPC (*P*<0.05). Specialty protein sources included in the booster and starter broiler diets at 5% did not negatively affect overall growth performance, carcass characteristics, and production efficiency. Replacing 5% of SBM with SPC and ESBM was effective in improving the F/G, excreta quality, and feed cost.

Keywords: broiler chicks, specialty proteins, hydrolyzed porcine mucosa, enzyme-treated soybean meal

INTRODUCTION

Early chick nutrition is a critical stage for proper development and good broiler performance. During the early stages of broiler development, the capacity to digest feed and utilize nutrients is limited thus, selecting feed ingredients that will maximize the performance of broilers is one of the primary objectives in formulating early chick diets (Ravindran and Abdollahi, 2021). Due to lower protein digestibility and concerns with antigenic factors effects in chicks, soybean meal is used sparingly in booster diets (Choct *et al*., 2010; Beski *et al*., 2015; Kim *et al*., 2016). Specialty protein sources from either plant or animal origin are often included in chick booster diets to stimulate feed intake, ensure better gut health, and

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improve growth performance. In general, specialty protein ingredients mixed with feeds have greater amino acid and energy digestibility and have no to limited concentrations of anti-nutritional factors compared with soybean meal (Parsons *et al*. 1997; Sulabo *et al*., 2013; Kong *et al*., 2014).

Pork meal, a by-product of the swine meat packaging industry is a high-quality protein source, however, contains a lesser amount of valine and isoleucine which could negatively affect growth and carcass characteristics (Veldkamp and van Harn, 2010). Soy protein concentrate, produced via ethanol extraction, contains 80% lesser oligosaccharides and lower antigenic compounds such as glycinin, and β-conglycinin making it more digestible than soybean meal (Peisker, 2001). Enzyme-treated soybean meal, a product of enzyme hydrolysis of SBM has shown to have greater total metabolizable energy, CP, amino acids, and NSP digestibility (Marsman *et al*., 1997; Graham *et al*., 2002). Hydrolyzed porcine mucosa, manufactured by hydrolysis of intestinal mucosa of pigs after removing heparin and sprayed with high protein SBM could positively affect growth performance (Frikha *et al*., 2014).

However, there is limited research evaluating the effects of these protein sources as an alternative to SBM on a weight-by-weight basis (w/w) in chick booster diets. Hence, the study aimed to evaluate the effect of replacing 5% of SBM with different specialty protein sources (w/w) in early chick diets on production performance, excreta quality, and carcass characteristics of broilers.

MATERIALS AND METHODS

The study protocol was approved by the Institutional Animal Care and Use Committee (IACUC) of the University of the Philippines Los Baños, College, Laguna.

Seven hundred twenty, day-old Cobb 500 broiler chicks were weighed and randomly assigned to six dietary treatments using the randomized complete block design (RCBD) with initial weight as the block. Each treatment had 12 replicates with 10 birds in each cage. Individual feeders and waterers were provided for each cage for ad libitum feeding and drinking. An incandescent bulb installed in each cage served as a light and heat source during the two-week brooding period. The experiment was completed in 33d.

The dietary treatments were: 1) Corn-Soybean meal diet (Negative control; NC); 2) NC+5% enzyme-treated soybean meal (ESBM1) in chick booster; 3) NC+5% hydrolyzed porcine mucosa (HP); 4) NC+5% pork meal (PM); 5) NC+5% soy protein concentrate (SPC); and 6) NC+5% enzyme-treated soybean meal (ESBM2) in chick booster meanwhile, 2.5% in broiler starter (Tables 1-3). The specialty protein source in treatments 2 to 6 was added at the expense of the soybean meal. Birds were given a common broiler finisher diet. Dietary treatments were formulated following a 3-phase feeding. Phase 1 to 3 diets were offered from d 0 to 14 (chick booster), d 15 to 24 (broiler starter), and d 25 to 33 (broiler finisher), respectively. Dietary treatments were formulated to satisfy the nutrient requirements of broilers. Broilers were fed with the chick booster and broiler starter diets in crumble form, and broiler finisher diet in pellet form.

Feeds offered and refusals were weighed at d 0, 14, 24, and 33. The data were adjusted for mortalities and used to calculate BW, ADG, F/G, viability, ME intake, and caloric efficiency. The metabolizable energy intake (MEI) was calculated by multiplying the total feed intake in the period by the corresponding ME of the diet. Caloric efficiency was

Table 1. Ingredient composition (as-fed basis) of chick booster (d 0 to 14) diets.

Item	Dietary Treatment				
	Control	**ESBM 1,2**	**HP**	**PM**	**SPC**
Ingredient, %					
Yellow corn	50.713	53.056	46.787	52.313	54.975
Soybean meal	39.600	32.625	39.000	35.942	31.220
Enzyme-treated soybean meal	--	5.000	--	--	--
Hydrolyzed peptone	--	--	5.000	--	--
Pork meal	--	--	--	5.000	--
Soy protein concentrate (SPC)	--	--	--	--	5.000
Coconut oil	4.701	4.344	4.760	3.478	3.757
L-lysine HCl	0.224	0.243	0.040	0.196	0.256
DL-HMTBA	0.527	0.529	0.470	0.511	0.533
L-threonine	0.135	0.132	0.040	0.190	0.135
L-valine	0.074	0.07	--	0.039	0.073
Monocalcium phosphate 21%	1.268	1.172	1.100	0.319	1.264
Limestone	1.536	1.606	1.580	0.789	1.563
Salt	0.470	0.470	0.470	0.470	0.470
Choline chloride 60%	0.250	0.250	0.250	0.250	0.250
Vitamin premix[1]	0.130	0.130	0.130	0.130	0.130
Mineral premix[1]	0.100	0.100	0.100	0.100	0.100
Antioxidant	0.013	0.013	0.013	0.013	0.013
Anti-mold	0.200	0.200	0.200	0.200	0.200
Phytase	0.010	0.010	0.010	0.010	0.010
Coccidiostat	0.050	0.050	0.050	0.050	0.050
Total	100.00	100.00	100.00	100.00	100.00

[1]Provided the following quantities of vitamins and minerals per kilogram of complete feed: Vitamin A, 14,300 IU; Vitamin D, 6,500 IU; Vitamin E, 65 mg; Vitamin K, 4 mg; thiamine, 3 mg; riboflavin, 9 mg; pyridoxine, 4 mg; niacin, 52 mg; pantothenic acid, 20 mg; vitamin B12, 0.02 mg; folic acid, 1.95 mg; Fe, 92 mg; Cu, 8 mg; Zn, 60 mg; Mn, 50 mg; I, 0.70 mg; Se, 0.15 mg.

calculated by dividing MEI by total BW gain. Finally, the production efficiency index (PEI) was estimated by multiplying the ADG with the viability divided by F/G with a factor of 10. Throughout the experiment, the birds were given consistent care and management.

The excreta quality score of each cage was assessed twice daily on d 3, 7, and 10 by 3 independent evaluators. Excreta scores ranged from 1 to 5 with 1 being dry, well-formed with white uric acid cover to 5 being extremely wet with little to no white uric acid cover (Garcia *et al*., 2019). Intact fecal samples per cage were visually scored in the morning and

Table 2. Calculated composition (as-fed basis) of chick booster (d 0 to 14) diets.

Item	Dietary Treatment				
	Control	ESBM 1,2	HP	PM	SPC
Calculated composition, %					
DM	89.20	89.30	89.50	89.10	89.00
AME_n[1], kcal/kg	2,961	2,961	2,959	2,961	2,961
CP (N × 6.25)	23.32	23.07	25.03	24.48	23.01
ADF	3.97	3.59	3.83	3.79	3.83
NDF	10.18	9.74	9.65	10.00	10.27
Crude fiber	2.93	2.85	2.93	2.80	2.83
Crude fat	7.74	7.38	7.77	6.97	6.85
Ca	0.95	0.95	0.95	0.95	0.95
P, available	0.48	0.48	0.48	0.48	0.48
SID[2] Lys	1.37	1.37	1.37	1.37	1.37
SID Thr	0.89	0.89	0.89	0.89	0.89
SID Met	0.76	0.76	0.75	0.76	0.76
SID Met+Cys	1.10	1.10	1.10	1.10	1.10
SID Trp	0.26	0.25	0.28	0.25	0.25
SID Ile	0.89	0.89	0.99	0.89	0.89
SID Val	1.03	1.03	1.07	1.03	1.03
SID Arg	1.47	1.44	1.43	1.51	1.49
SID His	0.58	0.57	0.63	0.58	0.57
SID Leu	1.77	1.78	1.91	1.80	1.78
SID Phe	1.04	1.03	1.13	1.03	1.03
SID Phe+Tyr	1.81	1.79	1.98	1.80	1.78

[1]AME_n = N-corrected apparent metabolizable energy, kcal/kg.
[2]SID = Standardized ileal digestible, %.

afternoon and the average scores from 3 evaluators were recorded. The overall excreta quality score for each treatment was calculated using the data.

At d 34 of the experiment, 2 birds (1 male and 1 female) from each replicate were randomly selected for carcass data collection. After a 12-h fasting, the birds were weighed and brought to the Animal Product Science and Technology Division, IAS, UPLB for dressing and carcass evaluation. Birds were bled by cutting their jugular vein, scalded, plucked, and eviscerated. The abdominal fat and giblets (gizzard, liver, and heart) were removed from the abdomen and weighed using a precision digital scale (0.01 g) shortly after evisceration. Wing, leg quarters, and breast cuts were collected from the eviscerated carcass, and all cuts were weighed. Dressing yield and commercial cut-ups yield were calculated and expressed as a percentage of the broiler's live weight.

All data were analyzed using the MIXED procedure of SAS with the cage as the experimental unit. Diet was a fixed variable, while the block was a random effect in the model.

Table 3. Ingredient and calculated composition (as-fed basis) of broiler starter (d 15 to 24) and broiler finisher (d 25 to 33) diets.

Item	Broiler Starter		Broiler Finisher
	Control	ESBM2	
Yellow corn	54.582	55.604	59.004
Soybean meal	34.982	31.631	30.900
Enzyme-treated soybean meal	-	2.500	-
Coconut oil	6.396	6.242	6.000
L-lysine HCl	0.222	0.227	0.160
DL-HMTBA	0.403	0.403	-
DL-Methionine	-	-	0.263
L-threonine	0.131	0.128	0.090
L-valine	0.073	0.069	-
Monocalcium phosphate 21%	1.010	0.961	1.270
Limestone	1.403	1.437	1.270
Salt	0.350	0.350	0.350
Choline chloride 60%	0.120	0.120	0.100
Vitamin premix[1]	0.130	0.130	0.130
Mineral premix[1]	0.100	0.100	0.100
Antioxidant	0.013	0.013	0.013
Anti-mold	0.025	0.025	0.200
Phytase	0.010	0.010	0.100
Coccidiostat	0.050	0.050	0.050
Total	100.001	100.000	100.000
Calculated composition, %			
DM	89.30	89.20	89.15
AMEn[2], kcal/kg	3100	3100	3,090
CP (N x 6.25)	21.40	21.30	19.64
ADF	3.80	3.60	-
NDF	10.10	9.90	-
Crude Fiber	2.80	2.80	2.72
Crude Fat	9.40	9.40	9.05
Ca	0.94	0.94	0.82
Available P	0.32	0.32	0.37

Table 3. Continuation...

Item	Broiler Starter		Broiler Finisher
	Control	ESBM2	
SID[3] Lys	1.25	1.25	1.10
SID Thr	0.82	0.82	0.72
SID Met	0.63	0.63	0.54
SID Met+Cys	0.95	0.95	0.83
SID Trp	0.23	0.23	0.21

[1]Provided the following quantities of vitamins and minerals per kilogram of complete feed: Vitamin A, 14,300 IU; Vitamin D, 6,500 IU; Vitamin E, 65 mg; Vitamin K, 4 mg; thiamine, 3 mg; riboflavin, 9 mg; pyridoxine, 4 mg; niacin, 52 mg; pantothenic acid, 20 mg; vitamin B12, 0.02 mg; folic acid, 1.95 mg; Fe, 92 mg; Cu, 8 mg; Zn, 60 mg; Mn, 50 mg; I, 0.70 mg; Se, 0.15 mg

[2]AME_n = N-corrected apparent metabolizable energy, kcal/kg

[3]SID = Standardized ileal digestible, %.

The least-square means were calculated for each independent variable. Least-square means were separated using the PDIFF option and adjusted for pairwise mean comparison using the Tukey Kramer test. Orthogonal contrasts were tested for group comparison: 1) NC vs. Animal protein sources, and 2) NC vs. Plant protein sources. The significance and tendencies between means were determined at the 0.05 and 0.1 levels, respectively.

RESULTS AND DISCUSSION

Broilers fed varying specialty protein sources and their combinations did not significantly (P>0.05) affect birds' body weight at d 14, 24, and 33 (Table 4). Specialty proteins included in the booster diets did not show any improvement (P>0.05) in the ADG, ADFI, and F/G of broilers during the first stage (d 0 to 14). Replacing SBM each with 5% ESBM, 5% SPC, 5% HP, and 5% PM did not affect the growth of broiler chicks.

From d 15 to 24, the same trend in performance was observed. During this stage, the broilers were fed a standard corn-soybean meal starter diet except for treatment 6, where the diet was formulated including 2.5% ESBM. This was to determine if the provision of a specialty protein source in the starter stage could give an additional improvement in growth performance compared to just including it in the booster diet. Additional EBSM supplemented in the starter diet did not significantly improve (P>0.05) the ADG, ADFI, and F/G in broilers compared to those fed a common starter diet. Again, the growth performance of broilers from the control group was similar to those fed with specialty protein sources in the booster stage and even those given diets with an additional specialty protein.

From d 25 to 33, the broilers were fed a common finisher diet to determine solely the impact of specialty protein sources supplemented at the booster stage and the starter stage, in the case of treatment six. The ADG and ADFI did not differ (P>0.05), meanwhile, feed efficiency was improved (P<0.01) for broilers fed diets with 5% SPC, 5% HP, and 5% (booster) - 2.5% (starter) ESBM compared with corn-soybean meal diets with other treatments being intermediate. Broilers fed diets with plant and animal proteins had better F/G (P=0.001) compared to those fed NC.

Table 4. Effect of specialty protein sources in early chick diets on growth performance of broilers[1].

	Dietary Treatment							*P*-value		
d 0 to 14:	**Corn-Soya**	**5% ESBM**	**5% HP**	**5% PM**	**5% SPC**	**5% ESBM**	**SEM**	**Diet**	**Contrast**	
d 15 to 24:	**Corn-Soya**	**Corn-Soya**	**Corn-Soya**	**Corn-Soya**	**Corn-Soya**	**2.5% ESBM**			**NC vs Animal**	**NC vs Plant**
Body weight, g										
d 0	46	46	46	46	46	46	0.41	0.87	0.69	0.52
d 14	351	343	344	336	343	334	7.73	0.55	0.19	0.16
d 24	972	945	963	942	962	951	21.66	0.89	0.43	0.42
d 33	1,843	1,804	1,841	1,817	1,837	1,822	27.99	0.89	0.67	0.48
d 0 to 14										
ADG, g	21.74	21.12	21.00	20.65	21.15	20.37	0.55	0.53	0.15	0.15
ADFI, g	31.85	31.50	31.51	31.19	31.79	31.05	0.57	0.80	0.38	0.45
F/G	1.47	1.50	1.51	1.52	1.50	1.53	0.03	0.78	0.26	0.21
d 15 to 24										
ADG, g	61.50	59.38	60.94	59.98	61.97	61.79	1.64	0.78	0.57	0.79
ADFI, g	96.73	95.27	96.22	97.32	96.07	94.36	1.59	0.78	0.98	0.40
F/G	1.58	1.62	1.59	1.63	1.55	1.53	0.03	0.11	0.36	0.70
d 25 to 33										
ADG, g	96.81	94.85	97.59	97.24	97.25	96.74	1.36	0.74	0.71	0.73
ADFI, g	160.68	151.89	154.85	155.75	153.87	152.98	2.43	0.15	0.07	0.006
F/G	1.66[a]	1.60[ab]	1.59[b]	1.60[ab]	1.58[b]	1.58[b]	0.02	0.01	0.001	0.0004

Table 4. Continuation...

	Dietary Treatment						SEM	P-value		
d 0 to 14:	Corn-Soya	5% ESBM	5% HP	5% PM	5% SPC	5% ESBM		Diet	Contrast	
d 15 to 24:	Corn-Soya	Corn-Soya	Corn-Soya	Corn-Soya	Corn-Soya	2.5% ESBM			NC vs Animal	NC vs Plant
d 0 to 33										
ADG, g	53.95	52.18	52.94	53.04	53.88	53.41	0.96	0.74	0.38	0.45
ADFI, g	86.15	82.96	83.52	84.59	84.33	83.13	1.13	0.33	0.12	0.038
F/G	1.60	1.60	1.58	1.60	1.57	1.56	0.02	0.40	0.59	0.19
Viability[2], %	97.50	95.83	92.50	97.50	98.33	97.50	1.49	0.07	0.17	0.87
PEI[3]	330.82	315.48	311.67	325.67	339.44	334.84	11.45	0.40	0.36	0.94

[1]Data are least-square means of 12 replicates with 10 birds each.

[2]Viability = number of birds at the end of the experiment divided by the initial number of birds multiplied by 100.

[3]Production Efficiency Index (PEI) = [ADG x %viability]/ [ADFI x 10].

[a,b]Means in a row without a common superscript letter differ ($P<0.05$).

Overall, the growth performance of broilers did not significantly differ (*P*>0.05) among the specialty protein sources. Specialty protein sources were added to Phase 1 (Booster stage) diets of broilers primarily to increase feed consumption and digestibility of nutrients promoting body weight gain and feed efficiency; yet in the study, these specialty ingredients failed to improve the overall growth performance of the broilers.

Replacing SBM with 5% ESBM, 5% SPC, 5% HP, and 5% PM did not affect the growth of broiler chicks during the booster stage. Studies showed that specialty protein sources such as ESBM, SPC, and HP supplemented in the booster stage improve market weight (Zakaria and Ata, 2020), ADG (Mateos *et al*., 2014; Frikha *et al*., 2014; Ma *et al*., 2019) and feed efficiency (Frikha *et al*., 2014; Zhang *et al*., 2021) in broilers and nursery pigs (Stein, 2002). In contrast, other studies indicated no (Vieira and Lima, 2005; Guzmán *et al*., 2016; Li *et al*., 2019) or depressing effect (Ruckman *et al*., 2020; Jones *et al*., 2018; Yang *et al*., 2021) of specialty protein sources on the growth performance of broilers, piglets, and hybrid groupers. The use of plant proteins in piglet diets enhances colon health (Li *et al*., 2019) while animal proteins supplemented in broiler diets had better feed intake, FCR, and heavier weight at 35 d (Hossain *et al*., 2013).

Based on an earlier study conducted by Basinillo (2016), the addition of 2.5% and 5% ESBM to diets fed at d 0 to 5 and d 6 to 10 did not significantly (*P*>0.05) affect body weight, ADG, ADFI, and F/G. In the current study, the 4% improvement of feed efficiency in the finisher stage may be attributed to specialty protein sources supplemented in the booster and starter stage, even though given a common finisher diet. Therefore, the use of 5% SPC, 5% HP, and 5% ESBM in the booster diet- 2.5% ESBM in the starter diet to replace SBM were effective in improving F/G for the last feeding phase, although did not affect the ADG and ADFI in the early stages. The current study results conform with the study of Batal and Parsons (2003) that the feed efficiency of broilers at the first 3 weeks was similar for those fed diets with casein, soybean meal, and soy protein isolate, although birds fed with SPC had an inferior feed efficiency compared the other treatments. The observed improvement in F/G of broilers at the last stage may be due to the more enhanced digestive capacity of birds for utilizing the SPC and ESBM each having increased nutrient availability compared with SBM by removing anti-nutritional factors and consequently improving amino acid digestibility (Navarro *et al*., 2017; Peisker, 2001; Ravindran and Abdollahi, 2021). The absence of significant growth response in the early stages (0 to 24d) could indicate that some nutrients in SPC, ESBM, and HP may not be as digestible for broiler chicks (Batal and Parsons, 2003). However, in contrast, there are studies where the effects of specialty protein sources given until the starter stage were not significant during the finisher stage (Frikha *et al*., 2014; Mateos *et al*., 2014).

The addition of specialty protein sources in diets did not affect (*P*>0.05) the viability or livability of broilers. Specialty proteins did not affect the viability of broilers in other studies (Vasconcelos *et al*., 2016). The PEI of broilers did not differ (*P*>0.05) even with the provision of more digestible protein sources at the booster stage. The PEI value combines growth rate, viability, and feed efficiency, to assess any effects on health, environment, or feed quality. Some studies also showed similar PEI with broilers fed diets with specialty protein ingredients such as SPC (Zhang *et al*., 2021) as with the current study.

Metabolizable energy intake and caloric efficiency were not significant (*P*>0.05) among the dietary treatments (Table 5). Supplementation of various specialty protein sources did not improve utilization of energy to gain a kg thus, no difference compared to corn-soya-based diets.

Excreta scoring was done at d 3, 7, and 10 (Table 6). Broilers fed treatment diets did not differ in the d 3 and 7 excreta scores. The ratings range from 1.48 to 2.04 which denotes dry and solid feces. Excreta scores of broilers at d 10 were greater (P<0.01) for broilers fed 5% SPC compared to those fed animal-based specialty protein sources (5% HP and 5% PM) with ESBM and control diets being intermediate. However, the values indicate normal excreta quality.

The addition of the respective specialty protein sources (ESBM and SPC) in diets improved the excreta quality of broilers (Basinillo, 2016) and pre-starter pigs (Guzmán *et al*., 2016; Ruckman *et al*., 2020; Li *et al*., 2021). On the contrary, feeding HP and a plant-based diet (corn-soybean meal) produced extremely wet excreta (Vieira and Lima, 2005; Li *et al*., 2019).

Carcass characteristics of broilers did not significantly differ (P>0.05) among dietary treatments (Table 7). Live weight, dressed weight, and abdominal fat did not significantly vary (P>0.05) among treatments. Carcass and commercial cut yields computed relative to the bird's weight were shown to be insignificant (P>0.05) for the broilers fed diet with specialty protein sources. Replacing soybean meal with SPC increased dressing yield in broilers but had no effect on other carcass characteristics parameters (Zakaria and Ata, 2020; Zhang *et al*., 2021).

The dietary treatment price per kg is presented in Table 8. Diet with HP had the greatest price per kg followed by diets with ESBM and SPC and then the diet with PM and finally, the corn-soybean diet. Diet economics of broilers fed different specialty protein sources did not differ except for the feed cost and feed cost per kg gain. Feed cost was lesser for diets with ESBM at booster and SPC. Feed cost per broiler was lesser (P<0.05) for diets with SPC compared to diets formulated with HP at 5% while other diets were intermediate. The reduction in feed cost could be explained by the better F/G of broilers fed SPC. The birds were able to attain an increase in the body weight gain with less amount of feed despite the greater price per kg of the ESBM and SPC compared to NC. The value of gain was shown to be the same (P>0.05) among the dietary treatments. Regardless of the differences in feed cost and feed cost per kg gain, broilers fed diets with specialty protein sources, margin over feed cost did not significantly improve (P>0.05). With the supplementation of animal and plant specialty protein sources in the current study, the value of gain and the margin were not significantly affected which means they can replace a portion of SBM when SBM is least available and when these sources have lesser unit price. Replacing the portion of SBM by 5% SPC could increase the margin by 0.91 Php.

Inclusion of animal or plant-based specialty protein sources at 5% in booster and starter broiler diets did not negatively affect overall growth performance, carcass characteristics, and production efficiency as reported in the study. However, the use of SPC and ESBM to replace SBM was effective in improving the F/G at finisher, excreta quality, and feed cost.

Table 5. Effect of specialty protein sources in early chick diets on ME intake and caloric efficiency of broilers[1].

	Dietary Treatment							*P*-value		
d 0 to 14	Corn-Soya	5% ESBM	5% HP	5% PM	5% SPC	5% ESBM	SEM	Diet	Constrast	
d 15 to 24	Corn-Soya	Corn-Soya	Corn-Soya	Corn-Soya	Corn-Soya	2.5% ESBM			NC vs Animal	NC vs Plant
MEI[2], kcal	9138.56	8918.97	9416.84	8997.99	8819.26	8813.34	191.75	0.19	0.76	0.18
Caloric efficiency[3], kcal ME/kg BW gain	5095.84	5080.36	5249.82	5085.43	4932.10	4964.90	101.93	0.25	0.54	0.35

[1]Data are least-square means of 12 replicates with 10 birds each.
[2]ME Intake (MEI) = ADFI x ME of the diet.
[3]Caloric efficiency = ME intake / ADG.

Table 6. Effect of specialty protein sources in early chick diets on excreta scores of broilers[1,2].

	Dietary Treatment							*P*-value		
d 0 to 14	Corn-Soya	5% ESBM	5% HP	5% PM	5% SPC	5% ESBM	SEM	Diet	Constrast	
d 15 to 24	Corn-Soya	Corn-Soya	Corn-Soya	Corn-Soya	Corn-Soya	2.5% ESBM			NC vs Animal	NC vs Plant
d 3	1.60	1.68	1.38	1.48	1.62	1.57	0.09	0.21	0.13	0.83
d 7	1.99	1.89	1.79	1.93	2.04	2.04	0.08	0.22	0.21	0.96
d 10	1.72[ab]	1.73a[b]	1.70[b]	1.62[b]	1.88[a]	1.75[ab]	0.05	0.003	0.28	0.15

[1]Data are least-square means of 12 replicates with 10 birds each.
[2]Excreta quality scoring was assessed by 3 individual evaluators, with a score ranging from 1 (dry, well-formed excreta with characteristic white uric acid cover) to 5 (extremely wet excreta with little or no white uric acid cover) (Garcia *et al.*, 2019).
[a,b]Means in a row without a common superscript letter differ ($P<0.05$).

Table 7. Effect of specialty protein sources in early chick diets on carcass characteristics of broilers[1].

	Dietary Treatment						SEM	*P*-value		
d 0 to 14:	Corn-Soya	5% ESBM	5% HP	5% PM	5% SPC	5% ESBM		Diet	Contrast	
d 15 to 24:	Corn-Soya	Corn-Soya	Corn-Soya	Corn-Soya	Corn-Soya	2.5% ESBM			NC vs Animal	NC vs Plant
Live weight, g	1772	1825	1797	1738	1778	1741	50.22	0.77	0.94	0.86
Dressed weight, g	1344	1375	1361	1298	1354	1314	43.56	0.72	0.77	0.93
Dressed weight with giblets, g	1409	1453	1434	1380	1413	1394	44.12	0.81	0.96	0.82
Abdominal fat, g	16	15	15	15	15	13	1.29	0.70	0.70	0.30
Breast weight, g	485	494	497	456	484	478	18.46	0.54	0.67	0.97
Leg weight, g	368	372	371	365	371	358	11.89	0.95	0.98	0.91
Wing weight, g	158	164	159	159	156	157	4.49	0.81	0.86	0.83
Dressing yield, %	75.79	75.19	75.79	74.59	76.09	75.42	0.65	0.51	0.40	0.74
Abdominal fat yield, %	1.17	1.07	1.13	1.17	1.11	1.02	0.09	0.81	0.84	0.31
Breast yield, %	36.08	35.89	36.51	35.15	35.65	36.33	0.56	0.57	0.72	0.86
Leg yield, %	27.38	27.13	27.24	28.11	27.41	27.27	0.32	0.30	0.44	0.77
Wing yield, %	11.82	12.00	11.70	12.33	11.57	11.98	0.23	0.25	0.50	0.93

[1]Data are least-square means of 10 replicates with 2 birds (1 male and 1 female) per replicate slaughtered at d 34.

Table 8. Diet economics of broilers fed diets containing specialty protein sources[1, 2].

	Dietary Treatment						SEM	P-value		
d 0 to 14:	Corn-Soya	5% ESBM	5% HP	5% PM	5% SPC	5% ESBM		Diet	Contrast	
d 15 to 24:	Corn-Soya	Corn-Soya	Corn-Soya	Corn-Soya	Corn-Soya	2.5% ESBM			NC vs Animal	NC vs Plant
Feed cost[3], ₱	62.05^{ab}	60.61^{b}	64.61^{a}	61.20^{ab}	60.66^{b}	61.15^{ab}	0.96	0.029	0.45	0.25
Value of gain[4], ₱	152.71	149.45	152.56	150.50	152.23	150.94	2.38	0.89	0.67	0.48
Feed cost/gain[5], ₱/kg	34.59^{ab}	34.54^{ab}	36.02^{a}	34.58^{ab}	33.91^{b}	34.45^{ab}	0.46	0.021	0.17	0.55
Margin over feed cost[6], ₱	90.66	88.84	87.95	89.30	91.57	89.79	1.90	0.74	0.35	0.77

[1]Data are least-square means of 12 replicates with 10 birds each.
[2]Price of diets: Chick booster- Corn-Soya (₱22.82), ESBM1 (₱24.32), HP (₱29.91), PM (₱23.12), SPC (₱23.88), ESBM2 (₱24.32); Broiler starter- Corn-Soya, ESBM1, HP, PM & SPC (₱22.95), ESBM2 (₱23.70); Broiler Finisher 1 (₱22.11); Broiler finisher 2 (₱21.94).
[3]Feed cost per broiler (₱) = Total feed intake x Price per kg feed.
[4]Value of gain per broiler (₱) = Total weight gain x Live weight price per kg broiler.
[5]Feed cost/ gain (₱/kg) = Feed cost per broiler / Total weight gain.
[6]Margin over feed cost, (₱) = Value of gain per broiler – Feed cost per broiler.
[a,b]Means in a row without a common superscript letter differ ($P<0.05$).

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REFERENCES

Basinillo ALA. 2016. Effect of diet complexity and stage feeding in early broiler chick diets on growth performance, fecal quality, caloric efficiency, and diet economics. *Undergraduate Thesis*. College of Agriculture and Food Science, University of the Philippines Los Baños.

Batal AB and Parsons CM. 2003. Utilization of different soy products as affected by age in chicks. *Poult Sci* 82(3):454-462.

Beski SSM, Swick RA and Iji PA. 2015. Specialized protein products in broiler chicken nutrition: A review. *Anim Nutr* 1(2):47-53.

Choct M, Dersjant-Li Y, Mcleish J and Peisker M. 2010. Soy oligosaccharides and soluble non-starch polysaccharides: a review of digestion, nutritive and anti-nutritive effects in pigs and poultry. *Asian Australas J Anim Sci* 23(10):1386-1398.

Frikha M, Mohiti-Asli M, Chetrit C and Mateos GG. 2014. Hydrolyzed porcine mucosa in broiler diets: effects on growth performance, nutrient retention, and histomorphology of the small intestine. *Poult Sci* 93(2):400-411.

Garcia BAA, Aguire-Reyes ATA, Decena KS and Sulabo RC. 2019. Effect of a performance enhancer mixture as replacement for antibiotic growth promoters on production performance, excreta quality and carcass characteristics of broilers. *Philipp J Vet Anim Sci* 45(1):34-47.

Graham KK, Kerley MS, Firman JD and Allee GL. 2002. The effect of enzyme treatment of soybean meal on oligosaccharide disappearance and chick growth performance. *Poult Sci* 81(7):1014-1019.

Guzmán P, Saldana B, Cámara L and Mateos GG. 2016. Influence of soybean protein source on growth performance and nutrient digestibility of piglets from 21 to 57 days of age. *Anim Feed Sci Technol* 222:75-86.

Hossain MA, Islam AF and Iji PA. 2013. Growth responses, excreta quality, nutrient digestibility, bone development and meat yield traits of broiler chickens fed vegetable or animal protein diets. *S Afr J Anim Sci* 43(2):208-218.

Jones AM, Wu F, Woodworth JC, Tokach MD, Goodband RD, DeRouchey JM and Dritz SS. 2018. Evaluating the effects of fish meal source and level on growth performance of nursery pigs. *Transl Anim Sci* 2(2):144–155.

Kim SK, Kim TH, Lee SK, Chang KH, Cho SJ, Lee KW and An B. 2016. The use of fermented soybean meals during early stage affects subsequent growth and physiological response in broiler chicks. *Asian Australas J Anim Sci* 29:1287-1293.

Kong C, Kang HG, Kim BG and Kim KH. 2014. Ileal digestibility of amino acids in meat meal and soybean meal fed to growing pigs. *Asian Australas J Anim Sci* 27:990–995.

Li R, Chang L, Hou G, Song Z, Fan Z, He X and Hou DX. 2019. Colonic microbiota and metabolites response to different dietary protein sources in a piglet model. *Front Nutr* 6:151.

Li H, Yin J, He X, Li Z, Tan B, Jiang Q, Chen J and Ma X. 2021. Enzyme-treated soybean meal replacing extruded full-fat soybean affects nitrogen digestibility, cecal fermentation characteristics and bacterial community of newly weaned piglets. *Front Vet Sci* 8:639039.

Ma X, Shang Q, Hu J, Liu H, Brøkner C and Piao X. 2019. Effects of replacing soybean meal, soy protein concentrate, fermented soybean meal or fish meal with enzyme-treated soybean meal on growth performance, nutrient digestibility, antioxidant capacity, immunity, and intestinal morphology in weaned pigs. *Livest Sci* 225:39-46.

Marsman GJ, Gruppen H, van der Poel AF, Kwakkel RP, Verstegen MW and Voragen AG. 1997. The effect of thermal processing and enzyme treatments of soybean meal on growth performance, ileal nutrient digestibilities, and chyme characteristics in broiler chicks. *Poult Sci* 76(6):864-872.

Mateos GG, Mohiti-Asli M, Borda E, Mirzaie S and Frikha M. 2014. Effect of inclusion of porcine mucosa hydrolysate in diets varying in lysine content on growth performance and ileal histomorphology of broilers. *Anim Feed Sci Technol* 187:53-60.

Navarro DMDL, Liu Y, Bruun TS and Stein HH. 2017. Amino acid digestibility by weanling pigs of processed ingredients originating from soybeans, 00-rapeseeds, or a fermented mixture of plant ingredients. *J Anim* 95(6):2658–2669.

Parsons CM, Castanon F and Han Y. 1997. Protein and amino acid quality of meat and bone meal. *Poult Sci* 76:361-368.

Peisker M. 2001. Manufacturing of soy protein concentrate for animal nutrition. *CIHEAM-IAMZ* 54:103-107.

Ravindran V, and Abdollahi MR. 2021. Nutrition and digestive physiology of the broiler chick: state of the art and outlook. *Animals* 11(10):2795.

Ruckman LA, Petry AL, Gould SA, Kerr BJ and Patience JF. 2020. The effects of enzymatically treated soybean meal on growth performance and intestinal structure, barrier integrity, inflammation, oxidative status, and volatile fatty acid production of nursery pigs. *Transl Anim Sci* 4(3):1-16.

Stein HH. 2002. *The effect of including DPS 50RD and DPS EX in the stage 2 diets for weanling pigs*. South Dakota State University:Brookings.

Sulabo RC, Mathai JK, Usry JL, Ratliff BW, Mckilligan DM, Moline JD, Xu G and Stein HH. 2013. Nutritional value of dried fermentation biomass, hydrolyzed porcine intestinal mucosa products, and fish meal fed to weanling pigs. *J Anim Sci* 91: 2802-2811.

Vasconcelos LG, Mello HHC, Stringhini JH, Andrade MA, Cysneiros CSS, Arnhold E, Mascarenhas AG, Resende MQ and Xavier HPF. 2016. Use of soy protein concentrate in pre-Starter and starter diets for broilers. *Braz J Poultry Sci* Special Issue Nutrition:001-008.

Veldkamp T and van Harn J. 2010. *Effect of pork meat meal in broiler diets on performance, processing yields and foot pad lesions*. XIIIth European Poultry Conference, Tours, France.

Vieira SL and Lima IL. 2005. Live performance, water intake and excreta characteristics of broilers fed all vegetable diets based on corn and soybean meal. *Int J Poult Sci* 4(6):365-368.

Yang X, Wang G, Zhao X, Dong X, Chi S and Tan B. 2021. Addition of hydrolysed porcine mucosa to low-fishmeal feed improves intestinal morphology and the expressions of intestinal amino acids and small peptide transporters in hybrid groupers (*Epinephelus fuscoguttatus*♀× *E. lanceolatus*♂). *Aquacultur*e 535:736389.

Zakaria H and Ata MR. 2020. Efficacy of soya protein concentrates on the performance and immunity of broiler chickens. *Front Vet Sci* 7:539.

Zhang Q, Zhang S, Cong G, Zhang Y, Madsen MH, Tan B and Shi S. 2021. Effects of soy protein concentrate in starter stage diet on growth performance, blood biochemical indices, carcass traits, immune organ indices and meat quality of broilers. *Animals* 11(2):281.