Effectiveness of Early Supplementation of a Processed Soy Protein Product and Route of Application for Broiler Chickens

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Primary Audience: Poultry Nutritionists, Researchers, Feed manufacturers

SUMMARY

The effect of early supplementation of a processed soy protein product (**PSP**) and its route of application for broiler chickens was studied. A total of 252 day-old male Ross 308 chicks were randomly placed on 4 treatments as: (1) control diet; (2) control diet + PSP paste (PSP1); (3) diet with 100 g PSP/kg only (PSP2); and (4) diet with 100 g PSP/kg + PSP paste (PSP3). The PSP paste was withdrawn after 5 d, while the starter diets with or without PSP were provided until day 10. Each treatment was replicated 7 times, with 9 birds per replicate. On 10 d, birds on 100 g PSP/kg plus PSP paste consumed the lowest feed, while body weight gain (**BWG**) and feed conversion ratio (**FCR**) were not affected by the treatments. On day 35, birds on control diet had significantly ($P < 0.05$) lower BWG and FCR than the treatment groups with feed intake unaffected. The dressing percentage of broiler carcass at slaughter was significantly improved by the supplementation of PSP in diet or as paste. The ileal digestibility of nutrients was not affected by the treatments, except for potassium, which was better utilized by birds fed the control diet plus PSP paste. Early supplementation of PSP in diet and as paste can be beneficial to growth in broiler chickens. The PSP paste may be beneficial for use in in-hatchery or on-site early feeding systems. The values of PSP as a dietary supplement are well known but this is the first insight into its application as a paste.

Key words: body weight, broiler chick, early nutrition, pre-starter diet, processed soy protein

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DESCRIPTION OF PROBLEM

The first few days of life of broiler chickens have been considered to be an important period and correspond to about 17% of their total production cycle, during which the birds gain between 8% and 10% of their final weight gain [1]. If this period of growth is compromised, with consequent weight loss soon after hatching, performance is impaired until slaughter [2]. A long hatching window [3] and the management practices adopted by the poultry industry in the early phase of a bird's life can potentially lead to such a compromise [4]. The hatched chicks are

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removed from the incubator only when a majority of the birds have hatched. Thus, early hatched birds remain without feed and water during this period. This is further complicated by hatchery operations such as sexing, vaccination, packaging, and transportation from the hatchery to the farm where the chicks would be reared. The latter is especially critical for birds that are transported over a long distance [5]. Hence, birds' access to feed and water may be delayed for 48–72 h prior to placement on farms.

There is a need for the development of both early- and late-phase feeding strategies [6]. The use of specialized pre-starter diets may be useful as a means of providing newly hatched chicks with early access to feed immediately after hatch, and subsequently few days, post-hatch. In recent times, interest has continued to grow in this regard and certain dietary products have been developed for use as supplements in the hatchery or during transportation of the newly-hatched chicks. The form in which these products would be presented to the chicks is also an important factor to consider. There are relatively few papers that have reported the use of such specialized solid, semi-solid, or liquid diets that can be provided to chicks immediately after hatch.

Noy and Sklan [7] reported that feeding solid, semi-solid, or liquid nutrients immediately after hatch improved body weight, which was maintained until market age in both chicks and poults, but without any differences between the feed forms used in early feeding. Henderson et al. [8] also studied a similar product, in comparison to no supplementation in a simulated 24 h chick holding or shipping period and reported a 2.7% increase in body weight at slaughter but concluded that the supplement did not completely compensate for the delayed access to feed.

Generally, these findings show that early nutrition with supplementation of special nutrients may help mitigate or alleviate the negative effects of delayed access to feed in newly-hatched chicks. However, their potential in advancing performance until the end of broiler chicken rearing period still remains uncertain. Again, how they may improve other physiological responses associated with improved growth needs to be investigated. In conventional feeding for newly-hatched chicks, it has also been suggested that the moistening capacity of the crop during the first few weeks, post-hatch for a standard solid diet could be a limiting factor for optimal functioning of the digestive system [9]. Hence, a gap exists for suitable supplements, which can singly or in combination with a pre-starter diet, and in a form palatable (semi-solid or liquid) to newly-hatched chicks, enhance early growth and sustain this to slaughter age when provided to chicks immediately after hatch.

Therefore, the objective of the current study is to determine the effectiveness of early supplementation of a processed soy protein product (**PSP**) and route of its application or supplementation on growth, carcass quality, nutrient digestibility, and digestive function in broiler chickens.

MATERIALS AND METHODS

This experiment was approved by the Animal Ethics Committee of the University of New England (Approval number AEC15-043). Health and animal husbandry practices complied with the Code of Practice for the Use of Animals for Scientific Purposes issued by the Australian Bureau of Animal Health [10].

Experimental Design and Bird Management

This experiment was set up to investigate the effectiveness of early supplementation of a processed soy protein product (PSP) made by co-processing yeast and soy[1] and its route of application for broiler chickens. A total of 252 day-old male Ross 308 chicks[2], (initial weight, 46.20 ± 7.10 g), were randomly placed on 4 treatments as follows: (1) control diet; (2) control diet + PSP paste (PSP1); (3) diet with 100 g PSP/kg only (PSP2); and (4) diet with 100 g PSP/kg + PSP paste (PSP3). The PSP paste was withdrawn after 5 d, while the starter diets with or without PSP were provided to the birds for 10 d. Each treatment was replicated 7 times with 9 birds in each replicate. The nutritional profile of PSP is presented in Table 1, while the nutrient composition

[1]Hamlet Protein, Horsens A/S, Denmark.
[2]Baidia Farms, Tamworth, NSW, Australia.

Table 1. Nutrient Composition of the Processed Soy Protein (PSP) Tested in the Study.

Nutrient (g/kg)	
Dry matter	930.0
ME poultry (kcal/kg)	2,284
Crude protein	556.0
Crude fat	25.0
Starch	30.0
Amino acids (g/kg)	
Arginine	38.9
Lysine	32.2
Methionine	7.5
Cysteine	7.8
Methionine + Cysteine	15.3
Tryptophan	7.5
Glycine	23.7
Histidine	14.2
Leucine	41.4
Isoleucine	25.6
Phenylalanine	27.5
Threonine	21.7
Tyrosine	19.5
Valine	26.7
Serine	28.6
Alanine	24.6
Aspartic acid	62.2
Glutamic acid	99.4
Proline	9.6
Minerals (g/kg)	
Calcium	2.50
Sodium	0.40
Total phosphorus	8.00
Chloride	0.625
Magnesium	3.5
Iron (mg/kg)	200.0
Manganese (mg/kg)	50.0
Zinc (mg/kg)	60.0

of the pre-starter diets is presented in Table 2. After 10 d, birds were provided similar pelleted commercial-type grower diet (11–24 d) and finisher diet (25–35 d) for the rest of the feeding trial (Table 2). All diets were formulated following the breeder's recommendation. Titanium dioxide (TiO_2), an indigestible marker, was added to the grower diet at a rate of 5 g/kg diet for the purpose of assessing nutrient digestibility. Feed and water were supplied ad libitum. Chickens were reared in multi-tiered brooder cages (600 $\times$ 420 $\times$ 23 cm^3) placed in a climate-controlled room until the end of the trial. The room temperature was gradually decreased from 33°C on day 1 to 24°C $\pm$ 1°C on 35 d. Lighting was provided following Ross 308 management specification.

On days 5, 10, 24, and 35, the birds and feed were weighed to measure the body weight gain (**BWG**), feed intake (**FI**), and feed conversion ratio (**FCR**; feed intake/weight gain). On 10 d, 1 bird of average group weight was selected from each replicate, while 2 birds were similarly selected on 24 d and were killed by cervical dislocation. The abdominal cavity of the birds was opened and the internal organs were removed and weighed. On both days, the whole pancreas and a part of the proximal jejunum were collected for the measurement of digestive enzyme activities. Also, ileal digesta was collected in plastic containers on day 24 and stored at -20°C until samples were analyzed for nutrient digestibility. The collected ileal digesta samples were later freeze-dried [11] and ground using a small coffee grinder. The ground samples were stored at 4°C in airtight plastic containers until analyzed for TiO_2, minerals, crude protein (**CP**), gross energy (**GE**), and amino acids (**AA**). Carcass weight and the weight of breast meat, (without bone), thighs, drumsticks, and wings were taken from sampled birds and recorded at day 35. The relative part weight was calculated as mass per unit live BW (g/kg of live BW).

Preparation of PSP Paste

The paste supplied to the birds within the first 5 d was a simple mixture of MilliQ (**MQ**) water and PSP. To obtain a firm and consistent paste that the birds were able to feed on, MQ water and PSP were mixed in a ratio of 1.03:1 (w/w), i.e., 0.97 g of PSP was mixed with 1 g of water. The dry matter content of the paste was approximately 24.30%. The paste was prepared fresh every morning all through the 5 d of supplementation.

Ileal Digestibility of Nutrients

The Ti and other mineral contents of the ileal digesta and feed samples were determined according to the method described by Morgan et al. [12] using the inductively coupled plasma-optical emission spectrometry (ICP-OES) [13]. The concentrations of Ti and of nutrients in the ileal digesta and feed samples were used to calculate the coefficient of digestibility of CP, GE, and AA. The nitrogen content of ileal digesta

Table 2. Ingredient and Nutrient Composition of the Starter Diets Used in the Study.

	Starter diets		Grower diet	Finisher diet
PSP level (g/kg)	0	100	0	0
Ingredients (g/kg)				
Corn	440	460	450	480
Wheat	104	107	100	150
Soybean meal	280	187	262	186
Canola meal	60	50	60	60
Meat and bone meal	55.6	34.7	53.4	50
Canola Oil	32.6	28.1	46.8	49.6
PSP[1]	-	100	-	-
Limestone	6.2	9.0	5.4	4.8
Dical Phos[2]	6.2	9.5	4.5	3.3
Salt	1.0	1.2	1.5	1.2
Na bicarb[3]	2.0	2.2	1.4	1.9
TiO_2	-	-	50	-
Vit. and minerals premix[4]	2.0	2.0	2.0	2.0
Choline chloride	1.0	1.5	1.0	1.0
L-Lysine	3.2	2.9	1.8	2.9
DL-methionine	3.6	3.4	3.0	2.8
L-threonine	1.9	1.4	1.2	3.7
Avizyme 1300[5]	0.5	0.5	0.5	0.5
Ronozyme Hi-Phos[6]	0.5	0.5	0.5	0.5
Nutrient composition				
ME (MJ/kg)	2997.5	2997.5	3097.8	3200.5
Crude protein	230	230	219.6	195
Dig. Lysine	13.0	13.2	11.5	10.6
Dig. methionine	6.7	6.5	6.0	5.5
Dig. Arginine	13.7	13.9	13.1	11.0
Dig. methionine + cysteine	9.5	9.5	8.7	8.0
Dig. threonine	8.6	8.6	7.7	9.3
Calcium	9.6	9.6	8.7	7.8
Available phosphorus	4.8	5.1	4.4	3.9
Sodium	1.6	1.6	1.6	1.6
Choline	1.68	1.70	1.60	1.50

[1]Processed soy protein.
[2]Dicalcium phosphate.
[3]Sodium bicarbonate.
[4]Vitamin and mineral premix (supplied activity per ton of feed): Cu (sulphate), 8 g; Fe (sulphate), 60 g; I (iodide), 1.0 g; Se (selenate), 0.3 g; Mn (manganese), 80 g; Zn (sulphate and oxide), 60 g; Mo (molybdenum), 1 g; Co (cobalt), 0.3 g; vitamin A (retinol), 12 MIU; vitamin D3 (cholecalciferol), 3.5 MIU; vitamin E (tocopherol acetate), 40 g; vitamin K3 (menadione), 2 g; thiamine (Vitamin B1), 2 g; riboflavin (B2), 6 g; niacin (B3), 50 g; pantothenic acid (B5), 11 g; pyridoxine hydrochloride (B6), 5 g; folate (vitamin B9), 1.5 g; biotin (vitamin H), 100 mg; cyanocobalamin (vitamin B12), 20 mg; antioxidant, 25 g.
[5]Xylanase + amylase + protease.
[6]Phytase.

and feed samples was determined according to the Dumas combustion technique as described by Sweeney [14] using LECO® TruSpec Carbon and Nitrogen Analyser[3]. The GE value of the samples was obtained as MJ/kg directly using a digital bomb calorimeter[4]. The AA contents of ileal digesta and feed samples were analyzed at the Australian Proteome Analysis

[3]LECO® Corporation, St. Joseph, MI.

[4]C7000, IKA® – WERKE GmbH & Co., Staufen, Germany.

Facility (APAF) located at Macquarie University, Sydney[5].

The digestibility coefficient of nutrients was calculated using the following equation:

$$\text{Digestibility coefficient} = 1 - \frac{Digesta\ nutrient\ \left(\frac{g}{kg}DM\right)/Digesta\ TiO2\left(\frac{g}{kg}DM\right)}{Diet\ nutrient\ \left(\frac{g}{kg}DM\right)/Diet\ TiO2\left(\frac{g}{kg}DM\right)}.$$

Tissue Protein Content and Digestive Enzyme Activities

To evaluate the activity of digestive enzymes and protein concentration, the jejunal tissue was processed according to the method describe d by Susbilla et al. [15]. The pancreas was processed in a similar way, except that the pancreas tissue was entire homogenized. The homogenate was then centrifuged at 30,000 × g[6] for about 15 min at 4°C. Subsamples of supernatant were taken in duplicate into 1.5 mL into Eppendorf tubes and stored in a freezer (−20°C) until assayed for enzyme activities. The specific activities of jejunal maltase and sucrase were assessed by incubation with fixed substrate concentrations as standardized for poultry by Iji et al. [16], while aminopeptidase activity was assessed as described by Caviedes-Vidal and Karasov [17]. The pancreatic trypsin and chymotrypsin activities were assessed using methods described by Erlanger et al. [18] and modified by Caviedes-Vidal and Karasov [17]. The concentration of protein in both the jejunal and pancreatic tissue homogenate was measured using the Comassie dye-binding procedure described by Bradford [19].

Statistical Analysis

Statistical analyses were performed using Minitab® 17 [20]. The data were subjected to one-way analysis of variance and tested for significance between the treatment means by Fisher's multiple range test at $P \leq 0.05$.

RESULTS AND DISCUSSION

Gross Performance

The results of early in-diet and paste supplementation of PSP on the gross performance of broiler chickens are presented in Table 3. On day 5, birds fed with PSP3 had lower body weight ($P < 0.05$) than those on PSP1, while birds from both groups were significantly ($P < 0.05$) lighter than the other 2 comparable groups in FI and BWG. The FCR was significantly ($P < 0.05$) higher in the birds on control diet and those on PSP2 than the other 2 groups. Between hatch and 10 d, birds on PSP3 consumed the lowest ($P < 0.05$) amount of feed compared to the birds on the control diet, while BWG and FCR were not affected significantly by the treatments.

After 24 d, FI and FCR were not affected by the treatments. Body weight gain was significantly ($P < 0.05$) higher in birds fed PSP2, compared to the other groups. On day 35, birds on control diet had significantly ($P < 0.05$) lower BWG and FCR than the treatment groups. The periodic gross responses of broiler chickens to the different treatments were recorded and are presented in Table 4. Only BWG between the period of 10 and 24 d was affected by the treatments, with birds in the PSP2 group showing a significantly ($P < 0.05$) higher value compared to the control and PSP3 groups.

In the present study, early supplementation of processed soy protein paste, in addition to in-diet inclusion improved the growth of broiler chickens. Within the first days of life and feeding, birds fed the paste only or in combination with in-diet inclusion performed poorly in FI and BWG, although their FCR was better within the first 5 d and then was at par with other groups until day 24. However, BWG after 10 d was improved in response to

[5]Samples were subjected to 24-hour liquid hydrolysis in 6M HCL at 110°C. After hydrolysis, all amino acids were analyzed using high sensitivity amino acid quantification technique of Waters AccQTag Ultra chemistry on a Waters ACQUITY UPLC system.

[6]Avanti R _ Centrifuge, Model J-E 369001, Beckman Coulter, Inc., USA.

Table 3. Effect of Supplementation of PSP in Diet and as Paste on Gross Responses of Broiler Chicken Between Hatch and 35 d of Age.

		Control	PSP1	PSP2	PSP3	SEM
1–5 d	BWG	87.1[a]	72.4[b]	84.8[a]	61.4[c]	2.39
	FI	81.5[a]	57.3[b]	80.7[a]	46.1[c]	3.17
	FCR	0.94[a]	0.79[b]	0.95[a]	0.75[b]	0.018
1–10 d	BWG	281.8	268.3	272.9	261.9	2.88
	FI	283.4[a]	264.7[a,b]	268.0[a,b]	248.2[b]	4.03
	FCR	1.01	0.99	0.98	0.95	0.012
1–24 d	BWG	1245.8[b]	1264.1[a,b]	1317.0[a]	1238.9[b]	11.10
	FI	1550.1	1535.4	1560.1	1503.8	9.85
	FCR	1.24	1.22	1.19	1.21	0.010
1–35 d	BWG	2265.2[b]	2442.4[a]	2472.6[a]	2415.0[a,b]	28.1
	FI	3502.9	3421.9	3474.3	3403.7	35.2
	FCR	1.55[a]	1.40[b]	1.41[b]	1.41[b]	0.018

[a,b]Mean values on the same row not sharing a superscript are significantly different, ($P < 0.05$); BWG = body weight gain; FI = feed intake; FCR = feed conversion ratio; SEM = standard error of mean. PSP1 = control diet + PSP paste; PSP2 = diet with 100 g PSP/kg only; PSP3 = diet with 100 g PSP/kg + PSP paste.

Table 4. Periodic Gross Responses of Broiler Chickens to Supplementation of PSP in Diet and as Paste Between Hatch and 35 d of Age.

		Control	PSP1	PSP2	PSP3	SEM
5–10 d	BWG	195.0	196.0	188.1	200.4	1.71
	FI	202.0	207.4	187.3	202.1	3.16
	FCR	1.04	1.06	1.00	1.01	0.016
10–24 d	BWG	971.1[b]	996.0[a,b]	1044.1[a]	977.1[b]	9.86
	FI	1267.0	1271.0	1292.2	1256.0	9.08
	FCR	1.30	1.28	1.24	1.29	0.012
24–35 d	BWG	1008.0	1178.3	1156.0	1176.1	29.3
	FI	1925.0	1887.0	1914.3	1900.0	31.0
	FCR	1.91	1.61	1.71	1.63	0.047

[a,b]Mean values on the same row not sharing a superscript are significantly different, ($P < 0.05$); BWG = body weight gain; FI = feed intake; FCR = feed conversion ratio; SEM = standard error of mean. PSP1 = control diet + PSP paste; PSP2 = diet with 100 g PSP/kg only; PSP3 = diet with 100 g PSP/kg + PSP paste.

the supplement. Many researchers believe that feeding wet feed enhances nutrient hydrolysis process, hence, improving FI [21, 22]. Contrary to the foregoing, FI was not increased by side feeding of the paste at the early stage. However, the reduced FI and weight gain observed within the first 10 d may be attributed to reduced feed consumption as it was observed that the birds were feeding more on the paste than the diet, unlike the birds without the paste, which started eating the diets from the start. The flavor or smell of the paste may also have been a major attraction to the chicks at this stage. At the end of the experiment, BWG, and feed conversion were better in birds fed PSP paste with or without diets containing PSP, while there was no difference in the FI of birds from the different groups. The reason for the improvement in BWG and feed conversion in the present study may be the early supplementation of the processed soy product in the diet and as paste; and probably, its inclusion have improved development of early digestive function and growth at the later phase of the cycle. The wet form in which the paste was presented may have had a positive effect on growth performance as well.

The findings of this study tend to agree with the reports of Yasar and Forbes [23], who fed broilers with an addition of 1.3 to 2.0 kg of water/kg dry feed and observed an increase in FI and BWG. Also, Khoa [9] reported that birds fed wet diet increased FI by about 48% and BWG by 85% during the starter phase and continued to increase by 39% and 86%, respectively, during the grower phase in favor of the wet diet. Creating a paste from PSP may facilitate faster penetration of digestive enzymes and probably increase nutrient utilization. Wetting the product may enhance nutrient solubilisation and hydrolysis, when added to dry feed within the first 5 d, and this will aid similar processes and speed up digestion in the gut. It is also possible that the paste may reduce dehydration in the birds, although this was not tested in the present study.

There may have been an additional benefit of having PSP in the diet as well, but this is only obvious later in life. However, PSP paste seemed to produce similar results obtained by the use of other commercially available products that were tested by other researchers [5, 7, 8] in terms of growth performance and as such could be an alternative to these products, with sustained early advantages to day 35 when the study was terminated.

Visceral Organ Development

On day 10, the treatments did not have any significant ($P > 0.05$) effect on the relative weight of visceral organs, with the exception of the relative weight of small intestine, which was lower ($P < 0.05$) in birds on the control diet than in the group fed PSP1 (Table 5). After 24 d, no significant ($P > 0.05$) difference in relative weights of visceral organs was observed with the various treatments any further.

On day 10, early supplementation of PSP in diet and as paste improved the relative weight of the small intestine of the birds. Mostly, early supplementation increased the relative weight of the small intestine in birds fed the control diet and supplemented with PSP paste for 5 d. This finding agrees with those of other researchers on the effect of early feeding of specialized diets on the development of the digestive tract [24–27].

A rapid development of the intestine in birds fed PSP paste within the first 5 d may have accounted for the subsequent growth observed in the birds that initially lagged behind in body weight up to 5 d, as birds in the former treatment may be more capable of digesting nutrients. This suggests that early supplementation of PSP in diet and as paste for broiler chickens may boost body growth, as a result of an increase in the relative growth of internal organs in broiler chickens. An improvement in the development of the GIT and organ growth in early phase of growth will allow for a more efficient uptake of nutrients for muscle development [28].

Carcass Parts Yield

Supplementation of PSP in diet or as paste significantly ($P < 0.05$) improved the dressing percentage of broiler carcass at slaughter (Table 6). Birds on PSP2 had higher carcass dressing weight compared to those on control diet. Also, the treatments did not have any significant ($P > 0.05$) effect on the relative weights of the carcass parts.

The carcass dressing percentage of birds at 35 d was improved by PSP inclusion in the diet or in combination with PSP paste. Early supplementation of PSP in diet, in combination with PSP paste may facilitate early increase in satellite cell mitotic activity in birds, although this was not measured in the present study. The first 6 wk of broiler chicken life, which is the entire production cycle, is characterized by a high level of satellite cell mitotic activity, which is responsible for later phase muscle growth [29]. A compensatory growth effect may also have contributed to the development of muscles, especially in the birds fed PSP paste with the diet, which showed an initially slow growth at the early phase. This finding tends to agree with Noy and Sklan [7], who reported improved meat yield at market age with the early supplementation of another early life supplement.

Ileal Digestibility of Nutrients

There was no significant ($P > 0.05$) difference resulting from the effects of various treatments on the ileal digestibility of CP, GE, and AA (data not shown). In the set of minerals assayed for digestibility, only K was significantly ($P < 0.05$) affected by the treatments, with birds fed PSP1 recording a higher ileal digestibility compared to the birds on only control diet after 24 d (Table 7).

The results of this study showed that early supplementation of PSP in diet and as paste for broiler chickens did not affect the nutrient digestibility of the birds. Crude protein digestibility was only increased by 1.41% and GE by 6.35% in birds that were fed PSP paste within the first 5 d, although these were not significant. However, in terms of mineral digestibility, potassium utilization was significantly improved by early PSP paste supplementation. It is important

Table 5. Effect of Supplementation of PSP in Diet and as Paste on Internal Organs Weight (Absolute, g) of Broiler Chicken on 10 and 24 d of Age.

		Control	PSP1	PSP2	PSP3	SEM
10 d	Heart	3.0	3.0	2.9	3.0	0.07
	Liver	13.2	13.0	12.6	14.0	0.34
	SI	22.0[b]	25.0[a]	23.0[a,b]	23.0[a,b]	0.49
	G + P	18.4	18.0	16.4	17.0	0.42
	Pancreas	1.1	1.4	1.3	1.3	0.05
	Bursa	0.5	0.6	0.6	0.5	0.03
	Spleen	0.2	0.4	0.3	0.3	0.02
24 d	Heart	9.1	8.6	9.2	8.9	0.25
	Liver	33.9	36.7	34.2	32.0	1.04
	SI	66.0	62.0	69.0	60.0	2.14
	G + P	39.4	37.4	37.5	39.3	1.35
	Pancreas	3.1	3.3	3.5	3.3	0.08
	Bursa	3.0	3.2	3.0	3.0	0.16
	Spleen	1.1	1.4	1.2	1.2	0.06

[a,b]Mean values on the same row not sharing a superscript are significantly different, ($P < 0.05$); SEM = standard error of mean; SI = small intestine; G + P = gizzard plus proventriculus. PSP1 = control diet + PSP paste; PSP 2 = diet with 100 g PSP/kg only; PSP3 = diet with 100 g PSP/kg + PSP paste.

Table 6. Effect of Supplementation of PSP in Diet and as Paste on Dressing Percentage (%) and Carcass Parts Relative Weights (g/kg Body Weight) of Broiler Chickens on Day 35.

	Control	PSP1	PSP2	PSP3	SEM
Dressing %	72.0[b]	74.0[a,b]	75.6[a]	75.1[a,b]	0.41
Breast meat	190.0	193.6	204.2	191.0	0.22
Thighs	96.1	97.5	95.7	96.0	0.09
Drumsticks	86.5	83.7	85.6	86.4	0.08
Wings	73.1	72.6	73.2	75.1	0.04

[a,b]Mean values on the same row not sharing a superscript are significantly different, ($P < 0.05$); SEM = standard error of mean. PSP1 = control diet + PSP paste; PSP 2 = diet with 100 g PSP/kg only; PSP3 = diet with 100 g PSP/kg + PSP paste.

Table 7. Effect of Supplementation of PSP in Diet and as Paste on Nutrient (CP, GE, and Minerals) Digestibility of Broiler Chickens on Day 24.

	Control	PSP1	PSP2	PSP3	SEM
Crude protein	0.70	0.71	0.70	0.70	0.010
Gross energy	0.61	0.65	0.61	0.65	0.009
P	0.60	0.67	0.61	0.60	0.015
K	0.53[b]	0.63[a]	0.56[a,b]	0.56[a,b]	0.013
Mn	0.60	0.63	0.60	0.60	0.012
Zn	0.60	0.63	0.60	0.60	0.018
Mg	0.62	0.65	0.60	0.60	0.013
S	0.49	0.55	0.47	0.55	0.018

[a,b]Mean values on the same row not sharing a superscript are significantly different, ($P < 0.05$); P = phosphorus; K = potassium; Mn = manganese; Zn = zinc; Mg = magnesium; S = sulphur; SEM = standard error of mean. PSP1 = control diet + PSP paste; PSP 2 = diet with 100 g PSP/kg only; PSP3 = diet with 100 g PSP/kg + PSP paste.

to mention that the PSP is richer in potassium (23 g/kg) than in the other minerals; hence, there may have been a considerable intake of potassium from PSP and other ingredient sources. At the time of this study, there was no published report on the mineral digestibility of PSP in broiler chickens.

The digestibility of AA in this study was not affected by early supplementation of PSP in diet or as paste. This is similar to what Batal and Parsons [5, 30] reported in their study with another early nutrition protein product. The test supplement (PSP) may not directly stimulate protein digestion and amino acid absorption. Sklan and

Noy [31] reassessed protein nutrition during the first week after hatch and observed that the effect of some essential amino acid levels, especially on body growth was detected at 7 d of age but not at 4 d.

Tissue Protein Content and Digestive Enzyme Activities

There was no significant ($P > 0.05$) difference in tissue protein concentrations and activities of digestive enzymes measured at 10 and 24 d of age in the pancreas and jejunum resulting from early supplementation of PSP in diet and as paste (data not shown). In this study, early supplementation of PSP in diet and as paste did not affect tissue protein content as well as digestive enzyme activities. There is also the tendency to exert some effect on digestive enzyme activities at both the early and late stages of broiler chicken growth with the early supplementation of PSP in diet and as paste. In a previous study by Beski and Iji [32], where PSP was fed to broilers, digestive enzyme activities were only affected as a result of PSP's interaction with grain type used in the diet, which was not a consideration in the present study.

CONCLUSIONS AND APPLICATIONS

1. Early supplementation of PSP in diet and as paste could be beneficial to growth in broiler chickens. At the end of rearing cycle, it was observed that BWG and FCR were both improved by PSP supplementation in diet and as paste. Initially, birds that fed the paste lagged behind in terms of FI and BWG, but it seemed that such birds may have benefitted from the supplement through early development of digestive organs.
2. The PSP paste may be beneficial for use in in-hatchery or on-site early feeding systems. Its value as a dietary supplement is well known, but this is the first insight into its application as a paste.
3. The use of PSP paste in addition to PSP in diet is a promising feeding strategy during the early age of broilers and there is, hence, the need for further studies on this strategy to better understand the mechanism involved in the responses observed, and possibly, validate the findings in this study.
4. The test product was co-processed with yeast. It is possible that some of the observed effects may have resulted from the presence of some yeast components in the test product. However, this was not covered in the present study, and hence, any effect from the yeast is not asserted. Further study in this regard is recommended.

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