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Original Research

POULTRY

Influence of soybean bioactive peptides on performance, foot pad lesions and carcass characteristics in broilers

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Summary

The influence of different inclusion levels of a biologically active peptide derived from soybeans by enzymatic hydrolysis, on growth performance, foot pad lesions and carcass characteristics in broilers were examined in this study. Starter (1 to 21 d) and finisher (22 to 42 d) diets, based on maize and soybean meal, were subjected to seven inclusion levels of a commercial soybean bioactive peptide (SBP) product (Fortide, Chengdu Mytech Biotech Co. Ltd., Chengdu, Sichuan, China) at 0.0, 1.0, 2.0, 3.0, 4.0, 5.0 and 6.0 g/kg of diet. All diets were equivalent in respect of energy density, digestible amino acids and other nutrients. A total of 840, one-day-old male broilers (Ross 308) were allocated to 42 pens (20 birds/pen), which were randomly assigned to seven dietary treatments. During the starter period, there was no significant effect of SBP on weight gain and feed intake of the birds. However, a significant ($P < 0.05$) effect of SBP was observed for the feed conversion ratio (FCR), with SBP inclusion at 3.0 g/kg and above showing lower ($P < 0.05$) FCR values compared to the diet with no SBP. No effect of SBP was observed for weight gain and feed intake over the whole trial period. However, SBP inclusion tended ($P = 0.06$) to influence the FCR of birds. Increasing SBP inclusion level resulted in gradual decrease in FCR values, with SBP inclusion at 5.0 and 6.0 g/kg showing lower FCR values compared to the diet with no SBP. Overall, the present study suggests that dietary supplementation of SBP in broiler diets has the potential to improve FCR and to be used as a novel functional protein in poultry diets.

Keywords: **Soybean bioactive peptides: broilers: performance: foot pad lesions**

Introduction

Bioactive peptides are specific protein fragments that have a positive influence on body functions and health. Over the past decade, there has been growing interest in the use of these peptides as component of poultry diets. Bioactive peptides have been identified in many food ingredients, of both animal and plant origins, and normally comprise of 3-20 amino acids residues (Clare *et al.,* 2003). Bioactive peptides can be produced from a variety of food ingredients by microbial fermentation and, enzymatic, alkali or acid hydrolysis (Muir et al., 2013). These peptides that are produced during protein hydrolysis contain different amino acid profiles and deliver an array of functional properties (Alashi *et al.,* 2013).

Some peptides are capable of affecting a range of physiological and metabolic processes, through antioxidative, hypocholesterolemic, antimicrobial, antihypertensive, antiobesity, cytomodulatory and immunomodulatory activities (Yang *et al.,* 2009; He *et al.,* 2013; Singh *et al.,* 2014). Their role as antimicrobial agents can be through interacting with microbial host invaders or by suppressing or stimulating certain immune responses (Hancock and Sahl, 2006). Details regarding the effect of dietary plant bioactives on health and productivity of birds can be found in the comprehensive review of Wallace *et al.* (2010). In broiler chickens, the influence of bioactive peptides from canola (Karimzadeh *et al.,* 2016), meat and bone meal (Muir *et al.,* 2013), hydrolysed porcine mucosa (Frikha

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et al., 2011, 2014; Mateos *et al.*, 2014) and soybean (Feng *et al.,* 2007; Abdollahi *et al.,* 2017) have been studied.

Among different types of bioactive peptides, soybean is economically the most important source, as they are abundant (360–566 g/kg) and relatively inexpensive. The nutritional value of soy protein is comparable to that of animal proteins, with a high biological value (Singh *et al.,* 2014). Wynstra (1986) stated that soy proteins have antihypertensive, anticholesterolemic, antioxidative and anticancer activities. They reported that glycinin and ß-conglycinin are the most abundant soy proteins and precursors of most of the isolated peptides from soy proteins. Aglycin, a natural bioactive peptide isolated from soybeans, is refractory to digestive enzymes and has an antidiabetic potential (Lu et al., 2012). Oral administration of soy aglycin has been shown to reduce or prevent hyperglycaemia in diabetic mice (Lu et al., 2012).

The positive effect of soybean bioactive peptides (SBP) on small intestinal morphology of broiler chickens has been reported recently (Abdollahi *et al.,* 2017). These researchers found that birds fed the diet without SBP numerically had the lowest and the birds with SBP inclusion at 3.0 and 6.0 g/kg of feed showed the greatest villus height. SBP inclusion resulted in 5.7 and 6.3% increases in the apparent ileal digestibility of dry matter and nitrogen (N), respectively (Abdollahi *et al.,* 2017). The improvements in nutrient digestibility and retention with SBP have been attributed to the modulation of gut environment (Feng *et al.*, 2007), increased digestive enzyme activities (Feng *et al.*, 2007), improvement of beneficial intestinal microbial balance (Kiers *et al.*, 2003), improved intestinal morphology (Abdollahi *et al.,* 2017) and/or possible stimulation of the mucosal immune system.

Although it is documented that bioactive peptides may affect physiological and metabolic processes, information on the use of these peptides as functional ingredients in broiler nutrition is limited. The purpose of the present study was to evaluate the effects of different inclusion levels of a bioactive peptide, produced by enzymatic hydrolysis of soy protein, on the performance, foot pad lesions and carcass characteristics in broilers fed maize-soybean meal-based diets.

Materials and methods

A total of 840, one-day-old male broilers (Ross 308), obtained from a local hatchery, were individually weighed and allocated to 42 pens, so that the average initial bird weights per pen were similar. Each of the seven dietary treatments was randomly assigned to six pens, each housing 20 birds. The floor pens were housed in an environmentally controlled room with 20 h of fluorescent illumination per day. The temperature was maintained at 32°C during the first week and gradually decreased to 22°C by the end of the third week.

A two-phase feeding programme (starter and finisher) was used. The starter and finisher diets were offered from d 1 to 21 and 22 to 42, respectively. Seven diets, based on maize and soybean meal including a control (without SBP) and six diets containing different levels (1.0, 2.0, 3.0, 4.0, 5.0, and 6.0 g/kg; Tables 1 and 2) of a commercial bioactive peptide (Fortide, Chengdu Mytech Biotech Co. Ltd., Chengdu, Sichuan, China) were formulated to contain the same levels of apparent metabolisable energy (AME), amino acids and other nutrients (Tables 1 and 2). SBP was in powder from and contained biologically active peptides derived from soybean by enzymatic hydrolysis. Diets were mixed in a single-screw paddle mixer (Bonser Engineering Co. Pty. Ltd., Merrylands, Australia). Following mixing, all diets were steam-conditioned at 70°C for 30 seconds and pelleted using a pellet mill (Model Orbit 15; Richard Sizer Ltd., Kingston-upon-Hull, UK) capable of manufacturing 180 kg of feed/h and equipped with a die ring with 3 mm holes and 35 mm thickness.

Diets were offered *ad libitum*, and water was freely available throughout the 42-d trial. Body weight and feed intake were recorded on days 0, 21 and 42. Mortality was recorded daily. FCR values were corrected for the body weight of any bird that died or culled during the course of the experiment. On day 42, foot pad and hock burns lesions were visually scored using a four-point scale from 0 to 4 (0 = no lesions; 1 = initial lesions; 2 = initial lesions with necrotic areas; 3 = lesions with pronounced necrotic areas; 4 = necrotic area covering the whole foot pad) as described by Martins *et al.* (2011). The data were expressed as percentage of birds with foot pad lesions in each category.

On day 42, carcass data were collected from two randomly selected birds, per pen (those closest to the mean pen weight). The birds were fasted overnight, individually weighed, exsanguinated and the carcasses were plucked and eviscerated by removing the internal organs, the head, and the shank. The weights of eviscerated carcass, breast meat, legs (thighs and drumsticks), and abdominal fat pad were recorded.

Experimental procedures were in accordance with the Massey University Animal Ethics Committee guidelines.

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Table 1. Composition and analysis (g/kg as fed) of the starter diets (1–21 d).

	Soybean bioactive peptide inclusion (SBP; g/kg)						
Item	0.0	1.0	2.0	3.0	4.0	5.0	6.0
Maize	489.3	490.6	491.7	492.8	494.0	495.1	496.3
Soybean meal, 480 g/kg	316.7	315.7	315.1	314.6	314.0	313.4	312.8
Wheat bran	40.0	38.7	37.2	35.7	34.2	32.8	31.3
Maize gluten meal	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Canola meal	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Soybean oil	22.2	22.2	22.2	22.2	22.2	22.2	22.2
Dicalcium phosphate	17.0	17.1	17.2	17.3	17.3	17.3	17.4
Limestone	8.6	8.5	8.4	8.2	8.1	8.0	7.9
DL-methionine	3.2	3.2	3.2	3.2	3.2	3.2	3.2
L-lysine. HCl	3.4	3.4	3.4	3.4	3.4	3.4	3.3
L-threonine	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Sodium chloride	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Sodium bicarbonate	3.7	3.7	3.7	3.7	3.7	3.7	3.7
Vitamin premix[a]	0. 8	0.8	0.8	0.8	0.8	0.8	0.8
Trace mineral premix[a]	1.5	1.5	1.5	1.5	1.5	1.5	1.5
SBP[b]	0.0	1.0	2.0	3.0	4.0	5.0	6.0
Calculated analysis[c]							
Apparent metabolisable energy, MJ/kg	12.35	12.35	12.35	12.35	12.35	12.35	12.35
Digestible protein	202	202	202	202	202	202	202
Digestible methionine	6.5	6.5	6.5	6.5	6.5	6.5	6.5
Digestible methionine + cysteine	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Digestible lysine	12.8	12.8	12.8	12.8	12.8	12.8	12.8
Digestible threonine	8.6	8.6	8.6	8.6	8.6	8.6	8.6
Digestible arginine	13.7	13.7	13.7	13.7	13.7	13.7	13.7
Digestible valine	9.8	9.8	9.8	9.8	9.8	9.8	9.8
Digestible isoleucine	8.6	8.6	8.6	8.6	8.6	8.6	8.6
Digestible leucine	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Crude fat	45.8	45.8	45.7	45.7	45.7	45.7	45.7
Crude fibre	33.9	33.8	33.7	33.6	33.5	33.4	33.2
Calcium	9.8	9.8	9.8	9.8	9.8	9.8	9.8
Non phytate phosphorus	4.8	4.8	4.8	4.8	4.8	4.8	4.8
Sodium	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Chloride	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Potassium	9.2	9.2	9.2	9.2	9.2	9.2	9.2

[a] Supplied per kilogram of diet: antioxidant, 100 mg; biotin, 0.2 mg; calcium pantothenate, 12.8 mg; cholecalciferol, 60 µg; cyanocobalamin, 0.017 mg; folic acid, 5.2 mg; menadione, 4 mg; niacin, 35 mg; pyridoxine, 10 mg; trans-retinol, 3.33 mg; riboflavin, 12 mg; thiamine, 3.0 mg; dl-α-tocopheryl acetate, 60 mg; choline chloride, 638 mg; Co, 0.3 mg; Cu, 3.0 mg; Fe, 25 mg; I, 1 mg; Mn, 125 mg; Mo, 0.5 mg; Se, 200 µg; Zn, 60 mg.
[b] Fortide, Chengdu Mytech Biotech Co. Ltd., Chengdu, Sichuan, China. [c] NRC (1994) feed ingredient tables were used for calculation, except for digestible amino acid values. Bryden et al. (2009) feedstuffs digestibility values were used for calculation of digestible amino acids. The following values (g/kg) were used for calculation of digestible amino acids and other components for SBP: protein, 411; arginine, 36.4; cysteine, 5.8; isoleucine, 13.0; leucine, 21.9; lysine, 24.6; methionine, 6.4; threonine, 11.4; valine, 15.6; calcium, 30.9; phosphorus, 9.4; crude fat, 23.4 and crude fibre, 65.0.

For statistical analysis, pen means served as the experimental unit for all the parameters. The data were analysed by a one-way ANOVA using the General Linear Models procedure of the SAS Institute Inc. (2004) in a completely randomised design. Significant differences between means were separated by the Least Significant Difference test. Differences were considered to be significant at $P < 0.05$.

Results

Influence of different inclusion rates of SBP on the performance of broiler starters (1–21 d), finisher (22–42 d) and whole grow-out (1–42 d) period is summarised in Table 3. Average mortality during the whole grow-out (1–42 d) period was 5.1% and the deaths were not associated with any specific dietary treatment. During the starter period, there was no significant ($P > 0.05$) effect of SBP on weight gain and feed intake. A significant ($P < 0.05$) effect of SBP was observed for the FCR of birds. SBP inclusion of 3.0 g/kg of feed and above resulted in lower ($P < 0.05$) FCR compared to the diet with no SBP.

None of the performance parameters were influenced ($P > 0.05$) by SBP inclusion during the finisher period. Over the whole trial period, there was no significant ($P > 0.05$) effect of SBP on weight gain and feed intake. However, SBP inclusion tended ($P = 0.063$) to influence the FCR of birds. Increasing SBP inclusion level resulted in a gradual decrease in FCR values, with SBP inclusions at 5.0 and 6.0 g/kg showing lower FCR values compared to the diet with no SBP.

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Table 2. Composition and analysis (g/kg as fed) of the finisher diets (22–42 d).

	Soybean bioactive peptide inclusion (SBP; g/kg)						
Item	0.0	1.0	2.0	3.0	4.0	5.0	6.0
Maize	589.2	590.4	591.7	593.1	594.3	595.8	597.3
Soybean meal, 480 g/kg	218.2	217.2	216.2	215.2	214.2	213.2	212.2
Wheat bran	40.0	38.9	37.6	36.3	35.1	33.8	32.3
Maize gluten meal	50.0	50.0	50.0	50.0	50.0	50.0	50.0
Canola meal	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Soybean oil	28.1	28.1	28.1	28.1	28.1	28.1	28.1
Dicalcium phosphate	14.3	14.3	14.4	14.4	14.5	14.5	14.6
Limestone	6.8	6.7	6.6	6.5	6.3	6.2	6.1
DL-methionine	2.6	2.6	2.6	2.6	2.6	2.6	2.6
L-lysine. HCl	2.9	2.9	2.9	2.9	3.0	3.0	3.0
L-threonine	0. 8	0.8	0.8	0.8	0.8	0.8	0.8
Salt	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Sodium bicarbonate	2.5	2.5	2.5	2.5	2.5	2.4	2.4
Vitamin premix[a]	0. 8	0.8	0.8	0.8	0.8	0.8	0.8
Trace mineral premix[a]	1.5	1.5	1.5	1.5	1.5	1.5	1.5
SBP[b]	0.0	1.0	2.0	3.0	4.0	5.0	6.0
Calculated analysis[c]							
Apparent metabolisable energy, MJ/kg	12.98	12.98	12.98	12.98	12.98	12.98	12.98
Digestible protein	168	168	168	168	168	168	168
Digestible methionine	5.4	5.4	5.4	5.4	5.4	5.4	5.4
Digestible methionine + cysteine	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Digestible lysine	10.2	10.2	10.2	10.2	10.2	10.2	10.2
Digestible threonine	6.8	6.8	6.8	6.8	6.8	6.8	6.8
Digestible arginine	10.9	10.9	10.9	10.9	10.9	10.9	10.9
Digestible valine	8.3	8.3	8.3	8.3	8.3	8.3	8.3
Digestible isoleucine	7.1	7.1	7.1	7.1	7.1	7.1	7.1
Digestible leucine	17.9	17.9	17.9	17.9	17.9	17.9	17.9
Crude fat	54.1	54.1	54.1	54.1	54.1	54.1	54.1
Crude fibre	32.3	32.2	32.1	32.0	32.0	31.9	31.7
Calcium	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Non phytate phosphorus	3.9	3.9	3.9	3.9	3.9	3.9	3.9
Sodium	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Chloride	1.9	1.9	1.9	1.9	1.9	1.9	1.9
Potassium	7.7	7.6	7.6	7.6	7.6	7.6	7.6

[a] Supplied per kilogram of diet: antioxidant, 100 mg; biotin, 0.2 mg; calcium pantothenate, 12.8 mg; cholecalciferol, 60 µg; cyanocobalamin, 0.017 mg; folic acid, 5.2 mg; menadione, 4 mg; niacin, 35 mg; pyridoxine, 10 mg; trans-retinol, 3.33 mg; riboflavin, 12 mg; thiamine, 3.0 mg; dl-α-tocopheryl acetate, 60 mg; choline chloride, 638 mg; Co, 0.3 mg; Cu, 3.0 mg; Fe, 25 mg; I, 1 mg; Mn, 125 mg; Mo, 0.5 mg; Se, 200 µg; Zn, 60 mg.
[b] Fortide, Chengdu Mytech Biotech Co. Ltd., Chengdu, Sichuan, China. [c] NRC (1994) feed ingredient tables were used for calculation, except for digestible amino acid values. Bryden et al. (2009) feedstuffs digestibility values were used for calculation of digestible amino acids. The following values (g/kg) were used for calculation of digestible amino acids and other components for SBP: protein, 411; arginine, 36.4; cysteine, 5.8; isoleucine, 13.0; leucine, 21.9; lysine, 24.6; methionine, 6.4; threonine, 11.4; valine, 15.6; calcium, 30.9; phosphorus, 9.4; crude fat, 23.4 and crude fibre, 65.0.

The influence of SBP on foot pad lesion scores of broilers is shown in Table 4. There was no significant ($P > 0.05$) effect of SBP level on foot pad lesion scores. However, the average lesion scale decreased from 1.48 in diets without SBP to 1.02 at 6.0 g/kg SBP inclusion. None of the birds exhibited any hock burn lesions.

The effect of different inclusion rate of SBP on carcass characteristics of broilers is shown in Table 5. There was no significant ($P > 0.05$) effect of SBP on the relative weights of carcass, breast meat, legs, and abdominal fat pad.

Discussion

During the manufacture process of soybean meal and its protein concentrate, anti-nutritional substances in soybeans are largely eliminated. However, these products still contain significant amounts of protein-type allergens, such as glycinin and β-conglycinin and considerable quantities of phytic acid, lectins, oligosaccharides and steroid glycosides (Hou *et al.,* 2017). Enzymatic hydrolysis of soybeans may eliminate some of the adverse effects of these allergens on animal growth. The end products of protein hydrolysis process are oligopeptides, smaller peptides, and free amino acids (Kamnerdpetch *et al.,* 2007). Peptides which are produced during the hydrolysis process generally contain between three and 20 amino acid residues. Such peptides contain different length and different amino acid residue compositions and deliver a variety of functional properties (Dziuba *et al.,* 1999; Pihlanto-Leppälä, 2001; Alashi *et al.,* 2013). The reasons for the contradictory results in the literature regarding the

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Table 3. Influence of different inclusion rate of soybean bioactive peptide (SBP) on the weight gain (g/bird), feed intake (g/bird), FCR (g feed/g gain) and mortality (%) of broilers during starter (1–21 d), finisher (22–42 d) and whole grow-out (1–42 d) period[a].

	Starter (1–21 d)				Finisher (22–42 d)				Whole grow-out (1–42 d)			
SBP inclusion (g/kg of feed)	Weight gain	Feed intake	FCR	Mortality	Weight gain	Feed intake	FCR	Mortality	Weight gain	Feed intake	FCR	Mortality
No SBP	1095	1280	1.169a	0.83	2190	3770	1.732	4.3	3285	5050	1.540	5.0
1.0	1099	1270	1.158ab	0.00	2199	3768	1.733	3.3	3298	5038	1.537	3.3
2.0	1084	1254	1.157abc	0.00	2203	3758	1.722	2.5	3287	5012	1.532	2.5
3.0	1084	1245	1.152bc	0.83	2232	3785	1.727	5.9	3316	5030	1.532	6.7
4.0	1094	1255	1.148bc	0.00	2228	3778	1.711	6.7	3322	5033	1.521	6.7
5.0	1106	1261	1.143c	1.67	2265	3789	1.689	3.4	3371	5050	1.504	5.0
6.0	1102	1263	1.148bc	0.83	2272	3795	1.692	5.9	3374	5058	1.509	6.7
SEM[b]	18.5	20.4	0.0050	0.676	28.1	38.5	0.0152	2.31	33.3	50.2	0.0093	2.51
Probabilities, P ≤	0.975	0.929	0.019	0.527	0.281	0.994	0.225	0.822	0.315	0.997	0.063	0.835

[a] Each value represents the mean of six replicates (20 birds per replicate).
[b] Pooled standard error of mean.

benefits of hydrolysed protein sources in the diet are not clear, but may include differences in characteristics and inclusion rates of the test product, species (fish, pigs or broilers) and age of the animals (Mateos *et al.,* 2014).

Results from the present study showed that diet supplementation with different levels of SBP had no effect on weight gain and feed intake, but improved the FCR of birds during the starter and over the whole trial period. These results are consistent with a previous study (Abdollahi *et al.,* 2017), showing that 5.0 and 6.0 g/kg SBP inclusion in broiler diets (aged 1 to 21 d) resulted in significantly lower FCR compared to those fed the diet with no SBP. Previously, Frikha *et al.* (2011) reported that the inclusion of 25 g/kg hydrolysed porcine mucosa, as a peptide source, in the diet improved weight gain and FCR of broilers, mostly during the first 7 d of life. In subsequent study, Frikha *et al.* (2014) reported that the inclusion of hydrolysed porcine mucosa in broiler diets increased growth performance during the starter period, with effects being more pronounced during the first 14 d of life. Similar results have been observed by Wang (2005), Wang *et al.* (2011) and Mateos *et al.* (2014), who reported that the dietary supplementation of bioactive peptides resulted in higher weight gain and enhanced feed efficiency in broilers. Better feed efficiency in broilers fed bioactive peptides may be related to the increased intestinal enzyme activities (Feng *et al.*, 2007; Karimzadeh *et al.*, 2016) and higher absorptive capacity of the gut characterised by longer villi (Abdollahi et al., 2017). It is likely that by feeding bioactive peptides, a limited, but physiologically significant, amount of peptides are absorbed intact into the bloodstream and enterocytes (Gardner and Wood, 1989). These peptides can exert their physiological and regulatory actions at the intestinal level, and the intestinally-generated signals can be transmitted to the brain, the immune and endocrine system to positively impact the whole body (Hou et al., 2017).

In the current study, SBP supplementation above 2.0 g/kg reduced average foot pad lesion scores. An array of factors can affect the incidence of foot pad lesions in commercial poultry flocks, including those relating to litter, nutrition and the bird (Shepherd and Fairchild, 2010). Among the nutritional factors, level and source of dietary protein, and amino acid balance are potential factors. Nagaraj *et al.* (2007) reported that the incidence and severity of foot pad lesions is affected by the protein level and source. The inclusion of bioactive peptides in the diet can be expected to improve nutrient digestibility

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Table 4. Influence of different inclusion rate of soybean bioactive peptide (SBP) on the foot pad lesion scores (percentage of birds with foot pad lesions in each category) and average score of 42-d old broilers[a]

SBP inclusion (g/kg of feed)	0	1	2	3	4	Average score
No SBP	16.7	31.7	38.3	13.3	0.00	1.48
1.0	18.3	25.0	45.0	11.7	0.00	1.50
2.0	30.0	26.7	35.0	8.3	0.00	1.22
3.0	23.3	40.0	33.3	3.3	0.00	1.17
4.0	28.3	30.0	30.0	11.7	0.00	1.25
5.0	21.7	33.3	43.3	1.7	0.00	1.25
6.0	31.7	40.0	23.3	5.0	0.00	1.02
SEM[b]	8.40	6.21	8.04	3.62	–	0.188
Probabilities, P ≤	0.816	0.500	0.517	0.175	–	0.554

[a] Each value represents the mean of six replicates.
[b] Pooled standard error of mean.
Foot pad lesions were visually scored using a four-point scale from 0 to 4 (0 = no lesion; 1 = initial lesion; 2 = initial lesion with necrotic areas; 3 = lesions with pronounced necrotic areas; 4 = necrotic area covering the whole foot pad).

and intestinal mucosa morphology as most protein moieties in these products are present as free amino acids or small peptides (Gilbert *et al.,* 2008). Abdollahi *et al.* (2017) reported that inclusion of SBP in broiler feed, increased N digestibility by 6.3%. Furthermore, it has been reported by Feng *et al.* (2007) that feeding birds with fermented soybean meal (at 270–295 g/kg) increased the intestinal trypsin, lipase and protease activities during the starter period, and enhanced protease activity during the grower period. From the current results, along with previous work (Abdollahi *et al.,* 2017), it may be speculated that birds supplemented with SBP digested and utilised N more efficiently and their excreta contained less N, resulting in a better litter condition, less ammonia and subsequently less foot pad lesions. However, it is acknowledged that the improvements in N digestibility by SBP alone may not be sufficient to explain the lower average foot pad lesion scores.

Table 5. Influence of different inclusion rate of soybean bioactive peptide (SBP) on the carcass, breast meat, legs and abdominal fat pad weight (g per kg bodyweight)[a]

SBP inclusion (g/kg of feed)	Carcass	Breast meat	Legs[b]	Fat pad
No SBP	768	227	191	11.2
1.0	771	225	198	9.5
2.0	766	225	198	10.4
3.0	772	229	199	8.9
4.0	768	220	198	10.4
5.0	774	221	197	10.0
6.0	766	223	193	9.6
SEM[c]	3.2	5.3	3.5	0.64
Probabilities, P ≤	0.518	0.933	0.631	0.267

[a] Each value represents the mean of six replicates (two birds per pen).
[b] Legs = thighs and drumsticks.
[c] Pooled standard error of mean.

SBP inclusion did not affect the relative weights of eviscerated carcass, breast meat, legs (thighs and drumsticks), and abdominal fat pad. The authors are unaware of any previous report on the effects of SBP inclusion on carcass characteristics of broilers.

In general, the improvements in feed efficiency may be attributed to one or more of the following mechanisms, as proposed by Hou *et al.* (2017): i) better absorption of small peptides compared with an equivalent amount of free amino acids; ii) lower catabolism of small peptides by intestinal microbiota compared with an equivalent amount of free amino acids; iii) more balanced amino acids entering the portal vein by the intestinal transport of small peptides compared with individual amino acids; vi) more functional amino acids (e.g. glycine, arginine, glutamine, glutamate, proline, and taurine) available to increase anti-oxidative reactions and muscle protein synthesis; and v) some peptides being capable of improving the morphology and functionality of the gut (e.g. secretion, motility, and anti-inflammatory reactions) and endocrine status compared with an equivalent amount of free amino acids.

The findings of the current work support the necessity of further studies to investigate the effect of SBP on nutrient absorption, Immunomodulatory functions and antimicrobial and antioxidative activities, litter N level and welfare indicators in broilers. There is a need to identify the specific bioactive proteins/peptides or other biologic agents in soybeans.

Conclusions

In this trial, broilers showed significant improvement in feed efficiency with inclusion of SBP in the diet, which had an impact on other aspects, including reducing

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foot pad lesions, attributed to improved N digestion and reduced excretion, affecting litter quality. Further research is warranted to define the biological characteristics and mode of action(s) of SBP. The current data suggest that soybean bioactive peptides/protein hydrolysate may be used as a novel functional protein in poultry diets.

Declaration of interest

Y. Gu, W. Xiao and J. Jia are employees of Chengdu Mytech Biotech Co. Ltd, China.

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