ARTICLE

Growth Performance and Meat Quality of Broiler Chicks Fed Germinated and Fermented Soybeans

Dan-Won Lee, Jin-Ho Shin, Jung-Min Park, Jae-Chul Song[1], Hyung-Joo Suh[2], Un-Jae Chang[3], Byoung-Ki An, Chang-Won Kang, and Jin-Man Kim*

Department of Food Science and Biotechnology of Animal Resources, Konkuk University, Seoul 143-701, Korea
[1]*Department of Food and Nutrition, Ulsan University, Ulsan 640-749, Korea*
[2]*Department of Food and Nutrition, Korea University, Seoul 136-703, Korea*
[3]*Department of Food and Nutrition, Dongduk Women's University, Seoul 136-714, Korea*

Abstract

This study was conducted to investigate the dietary effects of germinated and fermented (with *Monascus pupureus*) soybean screenings (GFS) on growth performance and meat quality in broiler chicken. A total of 750 1-day-old Ross × Ross male broiler chicks were randomly allocated into five groups (five replications with 30 birds each) and fed experimental diets for 5 wks as follows: Group 1, negative-control (antibiotics-free diet); Group 2, positive-control (negative-control with 10 ppm of Avilamycin); Group 3, negative-control with 0.3% GFS; Group 4, negative-control with 0.5% GFS; Group 5, negative-control with 1% GFS. The final body weight of each group fed a diet containing 1% GFS was significantly higher than that of the negative-control group. The feed conversion ratios of all groups fed diets containing GFS and the positive-control group were significantly improved compared to the negative-control group during the whole period ($p<0.05$). The relative weights of various organs along with the activities of serum glutamic oxaloacetic transaminase (GOT) and glutamic pyruvic transaminase (GPT) were not influenced by the dietary treatments. The levels of total serum cholesterol in groups fed diets containing 0.5% and 1% GFS were more significantly lowered compared to those of the control groups without GFS ($p<0.05$). There were no significant differences in the cecal microflora profiles among the groups. Further, the dietary treatments did not influence the physico-chemical properties of the edible meat, including the shear force, pH, meat color (CIE L*, a* and b*), and content of malondialdehyde (MDA). Cooking loss of breast muscle in the groups fed GFS was significantly lowered compared to that of the negative control group ($p<0.05$). These results indicate that dietary GFS could improve growth performance in broiler chicken and may affect meat quality in some instances.

Key words: germinated and fermented soybean, growth performance, blood cholesterol, broiler chicken

Introduction

Legumes are cultivated for their seeds, and are also called pulses. Their seeds are used for human and animal consumption or for the production of oils for industrial uses. Legumes, including beans, lentils, lupins, peas, and peanuts, have been cultivated for thousands of years, although many of the varieties of beans and peas that are commonplace today had been unknown until recently. Legumes play a major role in the traditional diets of many regions throughout the world. It is hard to think of the cuisines of Asia, India, South America, the Middle East, and Mexico without picturing soybeans, lentils, black beans, chickpeas, and pinto beans, respectively. In contrast, in many Western countries, beans trend to play only a minor dietary role despite the fact that they have abundant nutrition values. So that, bean intake has decreased in the past century in most European countries (Hellendoorn, 1976).

Monascus purpureus (Van, 1884) is a homothallic fungus. It is classified under the *Ascomycetes* family *Monascaceae*. Among 24 known species of this genus, isolated from traditional oriental foods are characterized as from the genus *Monascus*, which is categorized into four species: *M. pilosus*, *M. purpureus*, *M. rubber*, and *M. froridanus* (Juzlova *et al.*, 1996). Species of *Monascus*, which have been used in the production of traditional oriental foods similar to red mold rice, can produce different useful secondary metabolites, including red pigments, (natu-

---

*Corresponding author: Jin-Man Kim, Department of Food Science and Biotechnology of Animal Resources, Konkuk University, Seoul 143-701, Korea. Tel: 82-2-450-3688, Fax: 82-2-455-1044, E-mail: jinmkim@konkuk.ac.kr

ral coloring agents), c-aminobutyric acid (GABA, anti-hypertensive), and monacolin K (MONK, a cholesterol-lowering drug) (Juzlova *et al*., 1996). Some *Monascus* compounds have applications as pharmaceuticals or food additives (Kraiak *et al*., 2000). In the former case, mona-colin K was found to inhibit cholesterol synthesis and thus, to reduce hypolipidemia (Chairote *et al*., 2008; Lee *et al*., 2007). Previous studies showed that *Monascus pur-pureus* significantly reduced the low density lipoprotein-cholesterol (LDL-C), total cholesterol, triglycerides, and apolipoprotein B levels, and was well tolerated in patients with hyperlipidemia (Huang *et al*., 2007; Lin *et al*., 2005).

Seeking to improve the nutritive value of soybeans, preparation techniques have been developed to raise the bioavailability of their nutrients. (Chah *et al*., 1975) reported that diets containing soybeans fermented by *Aspergillus oryzae* significantly improved weight gain and feed efficiency in broiler chicks. Germination pro-cesses have been also used to increase the nutritive value and health qualities of the seeds (Urbano *et al*., 2005; Zanabria *et al*., 2006). Germination induces a substantial increase in the concentration of estrogenic compounds and all phytosterols, particularly â-sitosterol. But only limited information is available on the data about feeding of germinated and fermented soybeans in poultry.

In addition, the extensive uses of subtherapeutic antibi-otics to improve growth and prevent infectious diseases have led to problems of drug residues in animal products and emerge of new antibiotic-resistance bacteria. In this regard, the use of antibiotics in animal feed was less com-mon and endeavors are made to alternate means, in place of antibiotics, to prevent intestine from infectious dis-eases. The objectives of this experiment were to evaluate the growth performance, meat characteristics and physio-logical parameters in broiler chicks fed non-medicated diets containing germinated and fermented soybean screenings.

Materials and Methods

Preparation of unmarketable soybeans

Unmarketable soybean varieties commonly grown in Yonchon, Korea were obtained for use in this study. The soybeans were washed three times in distilled water at an ambient temperature for 10 h. The soaked soybeans were drained and germinated in an incubator at 20°C for about 38 h, and then cooked in an autoclave at 121°C for 20 min. The cooked soybeans were cooled to room tempera-ture and inoculated with *Monascus purpureus* KCCM

12002, mixed, and fermented in an incubator for 7 d. Then the fermented samples were dried in a hot-air oven at 60°C for 24 h. After the drying, the germinated and fer-mented soybeans (GFS) were stored at 4°C until they were used.

Experimental design and diets

All the procedures were performed at the Department of Food Science and Biotechnology of Animal Resources of Konkuk University and met the requirements of the departmental standard. A total of 1-d-old 750 Ross male broiler chicks were used. The chicks were divided into five groups (five treatment groups × five replication groups × 30 birds each) and fed the following diets for five wk. Group 1 was the negative control group (antibi-otics-free); Group 2, the positive control group (negative control with 10 ppm of Avilamycin); Group 3, the nega-tive control group with 0.3% GFS; Group 4, the negative control group with 0.5% GFS; and Group 5, the negative control group with 1% GFS. The formula and chemical composition of the basal diets are shown in Table 1. GFS was substituted at the expense of control diet at 0.3, 0.5 or 1% levels on weight basis. Other nutrients and energy levels met or exceeded the minimum requirements of the National Research Council (NRC, 1994). The chicks were provided free access to the feeds and water. The feed intake and body weight of each group were recorded weekly. All animal care procedures were approved by the Institutional Animal Care and Use Committee at Konkuk University. At the end of the experiment period, eight chicks from each group were selected, weighed individu-ally and then killed by asphyxiation with carbon dioxide. At the necropsy, the immune organs (the spleen and bursa of Febricius), abdominal fat, breast muscle, and leg mus-cle were immediately removed and weighed.

Blood profiles

At the end of the experiment period, eight chicks from each group were selected and weighed individually. About 8 mL of the blood was drawn from the jugular vein using a syringe to determine the concentration of various lipid fractions and components. The serum was separated from each blood sample via centrifugation and stored at -30°C until it was used. The concentration of the total cholesterol (Total-C) and the activity of the glutamic-oxaloacetic transaminase (GOT) and the glutamic-pyru-vic transaminase (GPT) in the serum were measured according to the colorimetric method using cholesterol diagnostic kits (Cholesterol E kit, Youngdong Medical

Table 1. Formula and chemical composition of the basal diets

Ingredients	Starter	Finisher
Yellow corn	47.35	48.84
Wheat bran	10.00	10.00
Soybean meal	21.76	19.97
Corn gluten meal	6.15	5.57
Tallow	3.75	4.85
Rice polishing	2.50	2.50
Rapeseed meal	5.00	5.00
Vit.+Min. mixture[1]	0.22	0.20
L-lysine HCl (78%)	0.17	0.16
DL-methionine (99%)	0.19	0.03
Dicalcium phosphate	1.53	1.28
Limestone	1.05	1.21
Choline-Cl (50%)	0.07	0.10
Salt	0.25	0.25
L-threonine (100%)	0.01	0.03
Total	100	100
Calculated values		
TMEn[2], kcal/kg	3,160	3,220
Crude protein, %	20.50	19.49
Crude fat, %	6.04	6.90
Ca, %	0.90	0.90
Total P, %	0.66	0.62
Available P, %	0.40	0.35
Lysine, %	1.07	1.02

[1]The Vit.+Min. mixture provided the following nutrients per kg of diet: vitamin A, 18,000 IU; vitamin D_3, 3,750 IU; vitamin E, 30 IU; vitamin K_3, 2.7 mg; vitamin B_1, 3.0 mg; vitamin B_2, 9.0 mg; vitamin B_6, 4.5 mg; vitamin B_{12}, 30.0 μg; niacin, 37.5 mg; pantothenic acid, 15 mg; folic acid, 1.5 mg; biotin, 0.07 mg; Fe, 75.0 mg; Zn, 97.5 mg; Mn, 97.5 mg; Cu, 7.5 mg; I, 1.5 mg; and Se, 0.2 mg.
[2]TMEn, nitrogen corrected true metabolizable energy.

Corporation, Korea) and GOT-GPT assay kits (GOT-GPT assay kit, Youngdong Medical Corporation, Korea).

Cecal microbial population

The cecal digesta homogenates in the PBS were serially diluted from 10^{-1} to 10^{-7}. The dilutions were subsequently plated on duplicate selective agar media for the enumeration of the target bacterial strains. The total microbes, coliforms, and *Lactobacillus* spp. were enumerated using nutrient agar, MacConkey agar, and MRS agar, respectively, via traditional methods (Tuohy *et al.*, 2002). Each plate was incubated aerobically or anaerobically at 37°C, for 24-72 h, after which the colonies were counted. The results were presented as base-10 logarithm colony-forming units per gram of cecal digesta.

Meat quality

The pH values of the breast muscle were measured in duplicate with a pH meter (340, Mettler-Toledo, Switzerland). About 5 g of the sample was cut into small pieces and homogenized with 20 mL of distilled water for 60 s in an Ultra-Turrax (T25, Janken & Kunkel, Germany). The pH values were measured immediately after the homogenization. Objective color readings were determined in duplicate on a freshly cut breast muscle surface 24 h post-mortem. The samples were placed on a styrofoam tray and over-wrapped with an oxygen-permeable film. After a 30 min bloom at 4°C, the color was determined using a chromameter (CR 210, Minolta, Japan), which was set at CIE L*, a* and b*. The shear force values were determined with a Warner-Bratzler shear attachment on a texture analyzer (TA-XT2i, Stable Micro System Ltd., UK) with the following operating parameters: load cell, 50 kg and cross-head speed, 200 mm/min. Each core sample was sheared once across the center of the core, perpendicular to the muscle fiber. The shear force value was the mean of the maximum forces required to shear each set of core samples. Styrofoam, the 1.5 cm thick steaks that weighed about 80 g was put in a polyethylene bag. The packages were heated in a water bath at 75°C for 30 min and cooled at room temperature for 30 min. The cooking loss percentage was determined from the steak weights before and after cooking.

The lipid oxidation was assessed on the basis of the malondialdehyde (MDA) that was formed during the refrigerated storage. The MDA, which is used as an index of lipid peroxidation, was determined using the selective third-order derivative spectrophotometric method (Botsoglou *et al.*, 1994). Briefly, the meat samples were homogenized (Philips HP 2870, Philips, Eindhoven, Netherlands) in 8 mL of 5% aqueous trichloroacetic acid (Sigma Chemical Co., St. Louis, MO, USA) and 5 mL of 0.8% butylated hydroxytoluene in hexane, and the mixture was centrifuged. The top was discarded, and a 2.5 mL aliquot from the bottom layer was mixed with 2 mL of 0.8% aqueous 2-thiobarbituric acid, for further incubation at 70°C for 30 min. After the incubation, the mixture was cooled under tap water and subjected to conventional spectrophotometry (DU 640 Beckman Coulter, Inc., USA) in the range of 400-650 nm. Third-order derivative spectra were produced via digital differentiation of the normal spectra using a derivative wavelength difference setting of 21 nm. The concentration of the MDA in the analyzed samples (μg/g meat) was calculated on the basis of the height of the third-order derivative peak at 521.5 nm by referring to the slope and intercept data of the computed least-squares fit of the standard calibration curve that was

prepared using 1,1,3,3,-tetraethoxypropane, the precursor of MDA.

Statistical analysis

All the statistics were computed using the GLM procedures of the SAS software (SAS Institute, 2002). A software program that uses Duncan's multiple range test to compare treatment means was applied. One replicate was considered as the experimental unit for each performance parameter. The experimental unit was put on each bird for the other parameters. All the data were expressed as the mean±SD.

Results and Discussion

Growth performance and carcass characteristics

The dietary effects of the GFS on the growth of the broiler chicks are shown in Table 2. The final body weight of the positive-control group was the highest, but that of the chicks that were fed diets containing 1% GFS also significantly increased than in the negative-control group ($p<0.05$). The dietary treatment did not have significant effects on the feed intake during growing and finishing stages. The daily BW gains of chicks significantly increased by supplementation of 0.3, 0.5 or 1% GFS as compared with negative-control group during finishing stage (22-35 d) ($p<0.05$). The positive-control and 1% GFS groups have shown higher the daily BW gain than that of the negative-control group during the whole period (1-35 d) ($p<0.05$). The feed conversion rate during the whole period in chicks fed diets containing GFS and positive-control group significantly improved than that of the negative-control group ($p<0.05$).

The results of this study suggest that dietary GFS exerts an improvement in weight gain and feed efficiency and these are in agreement with those reported by Chah et al. (1975) with chickens and Zamora and Veum (1979) with growing pigs. Broiler chicks fed diets containing soybeans fermented by Aspergillus family had greater weight gain and feed efficiency as compared with those of untreated soybean group (Chah et al., 1975). Min et al. (2009) also reported that the apparent ileal N and amino acid digestibility were linearly increased as fermented soy protein levels were increased and a similar effect showed on growth performance in weaned pigs. It is assume that the growth promoting effect of GFS can be largely attributed to a greater supply of the essential amino acids and/ or a higher availability of nutrients. In this study, the GFS produced by M. purpureus family, at the level of 1%, has the potential to improve the daily BW gain and feed conversion ratio and is a promising source for growth promotion in broiler diets.

The dietary treatment did not influence the relative weights of the liver, spleen, Bursa of Fabricius and breast and leg muscles (Table 3). The chicks fed diet containing 1% GFS had significantly lower ($p<0.05$) relative abdominal fat weight, expressed as a percentage of the live BW, than those of negative- and positive-control groups. There is little research conducted with fermented soybean on body fat deposition. On the other hand, it has been known

Table 2. Dietary effects of germinated and fermented soybean (GFS) on the growth performance in broiler chicken[1]

	(-) Control	(+) Control	GFS		
			0.3%	0.5%	1%
Initial BW, g/bird	40.4±1.24	40.0±1.23	40.4±1.28	42.1±1.89	40.6±1.16
Final BW, g/bird	1437.2±6.76[b]	1526.7±18.86[a]	1495.1±25.45[ab]	1494.8±21.08[ab]	1509.6±9.40[a]
Feed intake, g/d/bird					
1-21d	47.50±0.97	47.36±0.93	47.43±0.33	47.82±0.84	47.27±1.00
22-35d	136.83±0.82	136.59±0.64	136.25±0.38	136.23±0.96	136.16±0.99
1-35d	76.02±0.46	76.06±0.56	76.55±0.59	75.54±0.82	75.89±0.61
BW gain, g/d/bird					
1-21d	29.68±0.36	31.41±2.47	30.60±3.22	30.55±0.65	30.63±0.28
22-35d	77.35±0.53[b]	82.71±1.29[a]	81.20±3.68[a]	81.11±2.10[a]	82.57±0.94[a]
1-35d	45.05±0.19[b]	47.95±1.73[a]	46.92±2.41[ab]	46.86±0.66[ab]	47.39±0.33[a]
FCR, feed/gain					
1-21d	1.62±0.03[ab]	1.52±0.04[c]	1.63±0.07[ab]	1.67±0.05[a]	1.58±0.03[bc]
22-35d	1.73±0.04[a]	1.66±0.02[bc]	1.68±0.07[abc]	1.71±0.03[ab]	1.65±0.02[c]
1-35d	1.72±0.01[a]	1.61±0.04[b]	1.64±0.07[b]	1.64±0.02[b]	1.62±0.02[b]

[1]GFS, germinated and fermented soybean; (-) Control, antibiotics-free diet without GFS; (+) Control, medicated diet without GFS.
[a,b,c] Values with different superscripts within a row differ significantly ($p<0.05$).

Table 3. Dietary effects of germinated and fermented soybean (GFS) on the relative weights of various tissues in broiler chicken[1]

	(-) Control	(+) Control	GFS		
			0.3%	0.5%	1%
			g/100g BW		
Spleen	0.10±0.01	0.12±0.02	0.11±0.01	0.11±0.01	0.12±0.01
Liver	2.22±0.09	2.19±0.06	2.43±0.09	2.27±0.07	2.33±0.06
Bursa of Fabricius	0.17±0.05	0.18±0.03	0.17±0.05	0.19±0.07	1.19±0.04
Abdominal fat	1.60±0.12[a]	1.68±0.11[a]	1.53±0.17[ab]	1.57±0.15[ab]	1.42±0.17[b]
Breast muscle	7.64±0.59	7.90±0.21	7.72±0.55	7.71±0.47	7.36±0.45
Leg muscle	9.06±0.96	9.31±0.78	9.23±0.43	9.33±0.41	9.23±0.47

[1]GFS, germinated and fermented soybean; (-) Control, antibiotics-free diet without GFS; (+) Control, medicated diet without GFS.
[a, b]Values with different superscripts differ significantly ($p<0.05$).

that dietary soy isoflavones is effective in lowering fat deposition in animals due to hormone-like action. Ali *et al*. (2004) have shown that soy isoflavones lowered fat deposition in four fat depots measured in experimental animals of obesity and diabetes. The abdominal fat pad weight was also decreased in the broiler chicken that was fed the low CP-amino acid diet with isoflavones (Payne *et al*., 2001b). It is obscure whether GFS isoflavones or combined with other protein fractions has effects on the reduction of abdominal fat, which need to be researched further.

Cecal microbial population and blood profiles

The profiles of the cecal microbes and blood metabolite are shown in Table 4. The number of total microbes, coliform bacteria, and lactic acid bacteria were not influenced by dietary treatments. The dietary treatment did not have significant effects on the activities of the GOT and GPT (Table 4). The serum enzymes measured are used as indicators of tissue damage because of exposure to certain toxins or anti-nutritional factors in avian species

(Lumeij, 1997). In addition, serum GOT and GPT is a valuable tool to determine a safe inclusion level for non-conventional feedstuff (Diaz *et al*., 2003). Thus, this result suggests that the GFS appeared safe at an inclusion rate of 1% without having adversary effects on physiological statue. The concentrations of serum total cholesterol in chicks fed diets containing 0.5 or 1% GFS were significantly lower than those of the negative- and positive-control groups ($p<0.05$).

The reduction of the blood's total and LDL cholesterol concentrations with the consumption of products that contain soy protein has been shown repeatedly in humans and several animal models (Goodman-Gruen and Kritz-Sliverstein, 2001). The exact component that is responsible for this action has yet to be identified. Isoflavone have been proposed to be the active ingredient that is responsible for the hypocholesterolemic effects of soy (Demonty *et al*., 2003). A previous study suggested that isoflavone-rich soy protein is considerably more effective than isoflavone-depleted soy protein, though this finding is controversial. The cholesterol-lowering effect is one of

Table 4. Dietary effects of germinated and fermented soybean (GFS) on the profiles of cecal microflora and blood in broiler chicken[1]

	(-) Control	(+) Control	GFS		
			0.3%	0.5%	1%
Cecal microflora					
Total microbes, Log cfu/g	6.23±0.51	6.17±0.47	6.41±0.62	6.29±0.61	6.21±0.45
Coli forms, Log cfu/g	5.95±0.57	5.44±0.44	5.30±0.41	5.47±0.32	5.37±0.44
Lactic acid bacteria, Log cfu/g	6.17±0.34	6.12±0.27	6.13±0.39	6.31±0.26	6.44±0.35
Blood					
GOT, U/L	210.85±1.88	209.25±1.66	195.75±1.66	212.5±1.85	207.60±1.60
GPT, U/L	14.41±0.91	14.34±1.06	17.36±0.91	16.53±1.17	17.46±0.95
Total-C, mg/dL	136.10±6.86[a]	128.13±3.05[ab]	122.79±3.85[bc]	117.93±2.47[c]	115.43±3.56[c]

[1]GFS, germinated and fermented soybean; (-) Control, antibiotics-free diet without GFS; (+) Control, medicated diet without GFS; GOT, glutamic-oxaloacetic transaminase; GPT, glutamic-pyruvic transaminase.
[a,b,c]Values with different superscripts differ significantly ($p<0.05$).

several proposed mechanisms by which soy reduces the risk of heart disease (Gardner *et al*., 2001). In a study that evaluated the effects of isoflavone-rich and isoflavone-depleted soy protein on the plasma lipid concentration in postmenopausal, moderately hypercholesterolemic women, the isoflavone-rich soy protein lowered the total and LDL cholesterol more than did the isoflavone-depleted soy protein, though no significant differences were observed in the levels of HDL cholesterol or triacylglycerol. More expensive research is needed to determine the effect of GFS on cholesterol levels, often in edible meats, in broiler chicks under varying rearing conditions.

Meat quality

The results of meat quality of breast muscles are shown in Table 5. There were no significant differences in the pH and CIE color score among groups. The data clearly show that the difference in shear force of breast muscles was not significant among groups ($p>0.05$). The cooking loss of all chicks fed diets containing GFS and positive-control group was significantly decreased than that of negative-control group ($p<0.05$). The concentration of MDA was slightly, but not significantly, decreased in breast muscles of 1% GFS supplemented group.

There has been very little research conducted on the effects of processed soybean on meat quality in broiler chickens. The dietary effects of soy isoflavones on meat quality were also somewhat variable. Payne *et al*. (2001a) demonstrated that the a* and b* CIE color scores in growing-finishing pigs decreased linearly as dietary isoflavones increased, but not significantly. The addition of daidzein in the maternal diet during late gestation did not also affect the meat color of the progeny (Rehfeldt *et al*., 2007). But, the feeding of isoflavones resulted in some desirable alterations, such as an improvement of L*

value in broiler chickens (Jiang *et al*., 2007). Our results show that dietary GFS does not significantly affect the pH and the CIE color score. In previous study, Shin et al. (2008) also reported that the yolk color was not affected by dietary GFS in laying hens.

The concentration of MDA in breast muscles was not affected by dietary treatment. The lack of effect of dietary GFS on muscle MDA level was somewhat unexpected, because isoflavone supplementation has been reported to frequently lower the MDA in the tissues and plasma (Yousef *et al*., 2004). Soybean isoflavone is effective in suppressing the formation of plasma lipid oxidation products in *in vivo* (Tikkanen *et al*., 1998; Wiseman *et al*., 2000). The concentrations of MDA in the plasma and tissues of male rabbits significantly decreased with isoflavone treatment (Yousef *et al*., 2004). Therefore, it is likely that the MDA-lowering effect of dietary soybean isoflavone does not always occur, because of differences in the isoflavone's optimum dose, feeding frequency, and duration of treatment. On the other hand, the cooking loss values in all the treated groups improved more significantly than that of negative-control group ($p<0.05$). The cooking loss is influenced by various factors, including age, sex, diet, slaughter method, storage time and temperature, and meat properties (Lawrie, 1991). Oxidative processes may contribute to the loss of membrane integrity. It have been known that certain antioxidants such as selenium being beneficial to reduce drip loss by it's antioxidant property (Peric *et al*., 2009). Soy isoflavones have been shown to exert antioxidant activity (Ruiz-Larrea *et al*., 1997), and this could be suggested as a possible reason for the reduction in cooking loss by feeding of GFS. However, the levels of MDA in breast muscles have no significant change in our study, and thus further studies are required to clarify the role of GFS on oxidative pro-

Table 5. Dietary effects of germinated and fermented soybean (GFS) on the physic-chemical meat quality in broiler chicken[1]

	(-) Control	(+) Control	GFS		
			0.3%	0.5%	1%
pH	6.10±0.06	6.17±0.07	6.11±0.06	5.97±0.09	5.96±0.03
CIE color score					
L*	51.75±0.85	50.22±0.68	52.36±0.94	50.20±0.31	52.42±0.70
a*	2.61±0.42	2.53±0.44	2.46±0.29	2.43±0.24	2.47±0.32
b*	10.55±0.83	10.40±0.89	11.59±0.78	10.80±0.44	12.03±0.96
Cooking loss (%)	19.80±0.26[a]	17.56±0.37[b]	17.80±0.34[b]	17.50±0.50[b]	17.48±0.30[b]
Shear force (kg)	2.21±0.10	2.26±0.13	2.33±0.15	2.02±0.08	2.31±0.12
MDA, µg/g	1.62±0.03	1.62±0.04	1.63±0.07	1.61±0.05	1.58±0.04

[1]GFS, germinated and fermented soybean; (-) Control, antibiotics-free diet without GFS; (+) Control, medicated diet without GFS; MDA, malondialdehyde.
[a, b]Values with different superscripts differ significantly ($p<0.05$).

cesses in chicken meats. In conclusion, chicks fed diets containing GFS had shown more improved growth performance and lowered total blood cholesterol and cooking loss in breast muscles. These results demonstrate that dietary GFS exerts growth-promoting and quality-enhancing effects in broiler chickens.

References

1. Ali. A., Velasquez, M. T., Hansen, C. T., Mohamed, A. I., and Bhathena, S. J. (2004) Effects of soybean isoflavones, probiotics, and their interactions on lipid metabolism and endocrine system in an animal model of obesity and diabetes. *J. Nutr. Biochem.* **15**, 583-590.
2. Botsoglou, N. A., Fletouris, D. J., Papageorgiou, G. E., Vassilopoulos, V. N., Mantis, A. J., and Trakatellis, A. G. (1994) Rapid, sensitive, and specific thiobarbituri acid method for measuring lipid peroxidation in animal tissue, food, and feedstuff samples. *J. Agric. Food Chem.* **42**, 1931-1937.
3. Chah, C. C., Carlson, C. W., Semeniuk, G., Palmerand, I. S., and Hesseltine, C. W. (1975) Growth-promoting effects of fermented soybeans for broilers. *Poult. Sci.* **54**, 600-609.
4. Chairote, E, Chairote, G., Niamsup, H., and Lumyong, S. (2008) The presence and the content of monacolins in red yeast rice prepared from Thai glutinous rice. *World J. Microbiol. Biotechnol.* **24**, 3039-3047.
5. Demonty, I., Lamarche, B., and Jones, P. J. H. (2003) Role of isoflavones in the hypocholesterolemic effect of soy. *Nutr. Rev.* **61**, 189-203.
6. Diaz, G. J., Roldan, L. P., and Cortes, A. (2003) Intoxication of Crotalaria pallida seeds to growing broiler chicks. *Vet. Hum. Toxicol.* **45**, 187-189.
7. Gardner, C. D., Newell, K. A., Cherin, R., and Haskell, W. L. (2001) The effect of soy protein with or without isoflavones relative to milk protein on plasma lipids in hypercholesterolemic postmenopausal women. *Am. J. Clin. Nutr.* **73**, 738-745.
8. Goodman-Gruen, D. and Kritz-Silverstein, D. (2001) Usual dietary isoflavone intake is associated with cardiovascular disease risk factor in postmenopausal women. *J. Nutr.* **131**, 1202-1206.
9. Huang, C. F., Li, T. C., Lin, C. C., Liu, C. S., Shih, S. C., and Lai, M. M. (2007) Efficacy of *Monascus purpureus* Went rice on lowering lipid ratios in hypercholesterolemic patients. *Eur. J. Cardiovasc. Prev. Rehabil.* **4**, 438-240.
10. Hellendoorn, E. W. (1976) Beneficial physiologic action of

beans. *J. Am. Diet Assoc.* **69**, 248-253.
11. Jiang, Z. Y., Jiang, S. Q., Lin, Y. C., Xi, P. B., Yu, D. Q., and Wu, T. X. (2007) Effects of soybean isoflavone on growth performance, meat quality, and antioxidation in male broilers. *Poult. Sci.* **86**, 1356-1362.
12. Juzlova, P., Martinkova, L., and Kern, V. (1996) Secondary metabolites of the fungus *Monascus*. a review. *J. Ind. Microbiol. Biotechnol.* **16**, 163-170.
13. Kraiak, S., Yamamura, K., Irie, R., Nakajima, M., Shimizu, H., and Chim-Anage, P. (2000) Maximizing yellow pigment production in fed-batch culture of *Monascus sp*. *J. Biosci. Bioeng.* **90**, 363-367.
14. Lawrie, R. A. (1991) Meat Science (5th ed.) Pergamon Press, Oxford, UK.
15. Lee, C. L., Hung, H. K., Wang, J. J., and Pan, T. M. (2007) Improving the ratio of monacolin K to citrinin production of *Monascus purpureus* NTU568 under Dioscorea medium through the mediation of pH value and ethanol addition. *J. Agric. Food Chem.* **55**, 6493-6502.
16. Lin, C. C., Lil, T. C., and Lai, M. M. (2005) Efficacy and safety of *Monascus purpureus* Went rice in subjects with hyperlipidemia. *Eur. J. Endocrinol.* **153**, 679-86.
17. Lumeij, J. T. (1997) In: Clinical Biochemistry of Domestic Animals (ed. J. J. Kanebo, J. W. Harvey, and M. L. Bruss, 5th) Avian Clinic. *Biochem. Academic Press* 857-883.
18. Min, B. J., Cho, J. H., Chen, Y. J., Kim, H. J., Yoo, J. S., Wang, Q., Kim, I. H., Cho, W. T., and Lee, S. S. (2009) Effects of replacing soy protein concentrate with fermented soy protein in starter diet on growth performance and ileal amino acid digestibility in weaned pigs. *Asian-Aust. J. Anim. Sci.* **22**, 99-106.
19. NRC (National Research Council) (1994) Nutrients Requirements of Poultry. 9th rev. ed. National Academic Press, Washington, DC.
20. Payne, R. L., Bidner, T. D., Southern, L. L., and Geaghan, J. P. (2001a). Effects of dietary soy isoflavones on growth, carcass traits, and meat quality in growing-finishing pigs. *J. Anim. Sci.* **79**, 1230-1239.
21. Payne, R. L., Bidner, T. D., Southern, L. L., and McMillin, K. W. (2001b) Dietary effects of soy isoflavones on growth and carcass traits of commercial broilers. *Poult. Sci.* **80**, 1201-1207.
22. Peric, L., Milosevic, N., Zikic, D., Kanacki, Z., Dzinic, N., Nollet, L., and Spring, P. (2009) Effect of selenium sources on performance and meat characteristics of broiler chickens. *J. Appl. Poult. Res.* **18**, 403-409.
23. Rehfeldt, C., Adamovic, I., and Kuhn, G. (2007) Effects of dietary daidzein supplementation of pregnant sows on carcass and meat quality and skeletal muscle cellularity of the progeny. *Meat Sci.* **75**, 103-111.
24. Ruiz-Larrea, M. B., Mohan, A. R., Paganga, G., Miller, N. J., Bolwell, G. P., and Rice-Evans, C. A. (1997) Antioxidant activity of phytoestrogenic isoflavones. *Free Radic. Res.* **26**, 63-70.
25. SAS. (2002) SAS User's guide. Statistics, ver. 8.e, Statistical Analysis System Institute. Inc., Cary, NC. USA.

26. Shin, J. H., Park, J. M., Bak, D. J., Jeon, W. M., Song, J. C., Kim, S. K., An, B. K., Kang, C. W., Jung, W. S., and Kim, J. M. (2008) Effects of germinated and fermented unmarketable soybean on laying performance and egg quality in laying hens. *Korean. J. Food Sci. Ani. Resour.* **28**, 667-674.

27. Tikkanen, M. J., Wahala, K., Ojala, S., Vihma, V., and Adlercreutz, H. (1998) Effect of soybean phytoestrogen intake on low density lipoprotein oxidation resistance. *Proc. Natl. Acad. Sci. USA* **95**, 3106-3110.

28. Tuohy, K. M., Ziemer, C. J., Klinder, A., Knobel, Y., Pool-Zobel, B. L., and Gibson, G. R. (2002) A human volunteer study to determine the probiotic effects of lactulose powder on human colonic microbiota. *Microb. Ecol. Health Dis.* **14**, 165-173.

29. Urbano, G., Aranda, P., Vilchez, A., Aranda, C., Cabrera, L., and Porres, J. S. M. (2005) Effects of germination on the composition and nutritive value of proteins in *Pisum sativum, L. Food Chem.* **93**, 671-679.

30. Van, T. P. (1884) Monascus, genre nouveau de l'ordre des Ascomycetes. *Bulletin de la Société de France* **31**, 26-31.

31. Wiseman, H., O'Reilly, J. D., Adlercreutz, H., Mallet, A. I., Bowey, E. A., Rowland, I. R., and Sanders, T. A. (2000) Isoflavone phytoestrogens consumed in soy decrease F(2)-isoprostane concentrations and increase resistance of low-density lipoprotein to oxidation in humans. *Am. J. Clin. Nutr.* **72**, 395-400.

32. Yousef, M. I., Kamel, K. I., Esmail, A. M., and Baghdadi, H. H. (2004) Antioxidant activities and lipid lowering effects of isoflavone in male rabbits. *Food Chem. Toxicol.* **42**, 1497-1503.

33. Zamora, R. G. and Veum, T. L. (1979) Whole soybeans fermented with *Aspergillus oryzae* and *Phizopus oligosporus* for growing pigs. *J. Anim. Sci.* **48**, 63-68.

34. Zanabria, E. R., Katarzyna, N., De Jong, L. E. Q., Birgit, H. B. E., and Robert, M. J. N. (2006) Effect of food processing of pearl millet (*Pennisetum glaucum*) IKMP-5 on the level of phenolic, phytate, iron and zinc. *J. Sci. Food Agric.* **86**, 1391-1398.