Effects of a Natural Extract of Chestnut Wood on Digestibility, Performance Traits, and Nitrogen Balance of Broiler Chicks

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ABSTRACT Currently, feed ingredients containing tannin are attracting more interest as substitutes for antibiotic growth promoters in animal and poultry feeding. This study investigated the influence of a natural extract of chestnut wood (Silvafeed ENC) on broiler digestibility (experiment 1) and on the growth performance, carcass quality, and nitrogen balance of broilers (experiment 2). Results showed that the inclusion of ENC did not influence the apparent digestibility of organic matter, CP, and ether extract. Chick growth performance showed a quadratic or cubic response with increasing levels of ENC. When chicks were fed ENC from 14 to 56 d of age, the ENC had a positive effect on average daily gain in the first 2 wk of addition, whereas this effect was not evident in the last 2 wk compared with the control group. Similar trends were also shown for daily feed intake. Overall, the chicks fed 0.20% ENC had significantly better growth performance than the control group. Carcass analysis showed no gross lesions in organs and no significant differences in thigh and breast composition among groups. Noteworthy is the fact that the ENC-treated groups had less total litter nitrogen; in particular, chicks fed 0.15 and 0.20% ENC showed a significant difference in total litter nitrogen compared with the control group. No significant difference in nitrogen balance was observed. Addition of 0.20% ENC seemed to have a positive influence on chick feeding.

Key words: natural extract of chestnut wood, digestibility, performance trait, nitrogen balance, broiler

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INTRODUCTION

In 2006, the European Union banned the use of antibiotic growth promoters in animal feeding. Consequently, many approaches have been attempted to control or prevent subclinical diseases and to maximize growth performance and economic viability. Different plant compounds (i.e., herbs, organic acids, essential oils) seem to be candidates of interest as alternatives to antibiotic growth promoters (Hernández et al., 2004), and tannins represent one of several categories of useful antimicrobial phytochemicals (Cowan, 1999). Tannins of different plant species have specific physical and chemical properties; thus, they have very different biological activities, and detailed study is required to characterize their potential beneficial effects (Mueller-Harvey, 2006). Generally, tannins are chemically classified as condensed tannins and hydrolyzable tannins. From a nutritional point of view, tannins in animal feeds are a double-edged sword (Pell et al., 1999). For a long time, tannins were considered antinutrients that reduced digestibility (in particular, CP) and consequently, the growth performance in monogastric species (Treviño et al., 1992; Smulikowska et al., 2001). However, results appear more promising (Mueller-Harvey, 2006; Tabacco et al., 2006) in ruminant nutrition. In recent years, the dietary role of tannins has been attracting increasing interest because they have been shown to reduce gastrointestinal parasites in mammals (Butter et al., 2001; Min et al., 2005) and pheasants (Marzoni et al., 2005).

The role of tannins in poultry nutrition requires further investigation. Condensed tannins from sorghum do not seem to be absorbed, but completely excreted (Jimenez-Ramsey et al., 1994), whereas the fate of hydrolyzable tannins is not well known. Recently, a new commercial product, Silvafeed ENC (**ENC**), a purified natural extract of sweet chestnut (*Castanea sativa*) wood rich in hydrolyzable tannins such as castalagin, has been proposed for poultry feeding. Graziani et al. (2006), who evaluated the in vitro antimicrobial activity of this product, observed a positive effect on different bacterial strains, such as *Escherichia coli, Bacillus subtilis, Salmonella enterica* serovar Enteritidis, *Clostridium perfringens, Staphylococcus aureus*, and *Campylobacter jejuni*. Previously, similar findings were obtained by Li and Song (2004), who used a natural

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Table 1. Ingredients and chemical composition of the basal diet used in experiments 1 and 2

Item	Amount
Ingredient (%)	
Corn	32.50
Wheat	20.00
Soybean meal (44% CP)	36.40
Animal fat	6.10
Calcium carbonate	1.70
Dicalcium phosphate	1.30
Sodium chloride	0.19
DL-Met	0.19
L-Lys	0.12
Phytase[1]	0.10
Vitamin-mineral premix[2]	5.00
Analyzed composition (% of DM)	
DM	87.50
CP	22.90
Ether extract	14.20
Crude fiber	2.30
Ash	8.40
ME[3] (MJ/kg)	12.34

[1]3-Phytase (EC 3.1.3.8).

[2]Supplied per kilogram of diet: vitamin A, 8,000 IU; cholecalciferol, 2,000 IU; vitamin B_1, 1.5 mg; riboflavin, 3.0 mg; vitamin B_6, 1.5 mg; vitamin B_{12}, 15 μg; DL-α-tocopheryl acetate, 75 IU; niacin, 25.0 mg; D-pantothenic acid, 8.0 mg; choline chloride, 500.0 mg; cobalt, 0.2 mg; iron, 30.0 mg; iodine, 1.4 mg; manganese, 80 mg; copper, 1.5 mg; zinc, 30.0 mg.

[3]Based on NRC (1994) ingredient composition.

extract of chestnut shell. Moreover, in practical conditions, some breeders have suggested that dietary use of ENC can improve broiler chicken performance and reduce mortality. The aim of this paper was to study the effect of different levels of natural extract of chestnut ENC on the digestibility, growth performance, carcass quality, and N balance of broiler chicks.

MATERIALS AND METHODS

Bird Husbandry

Two experiments were carried out to evaluate the effects of ENC on broiler chicks. Digestibility was studied in experiment 1, whereas growth performance, carcass quality, and N balance were studied in experiment 2. In both experiments, broiler chicks (Cobb 508, male) were provided with ad libitum access to feed and water. The basal diet was formulated as reported in Table 1, with the ENC added as follows: 0% (**ENC0**), 0.15% (**ENC15**), 0.20% (**ENC20**), and 0.25% (**ENC25**). The ENC was premixed with 1 kg of basal diet and successively mixed into an appropriate quantity of basal diet to obtain the prefixed inclusion level. The ENC (supplied by SilvaTeam, San Michele di Mondovì, Italy) is extracted from chestnut wood by a heat and low-pressure treatment; only the water-soluble fraction is retained and subsequently dehydrated. The product is commercially available as a fine brown powder (92 to 95% DM) with a pure tannin content of 77% on a DM basis (Tabacco et al., 2006). Chemical composition of the ENC batch used in experiments 1 and 2 was as follows: water, 2.9%; tannin, 77.8%; nontannin, 17.7%; insolubles, 1.6%; crude fiber, 0.24%; and ash, 1.7% (pH 3.26, 10% solution). Tannin percentage was obtained by gravimetric analysis of vegetable tanning agents by using the filter Freiberg-Hide powder method (Küntzel, 1954).

Nutrient Digestibility

In experiment 1, thirty-two 37-d-old chicks were randomly allotted to the 4 diets and kept individually in 2-floor cages, taking care that chicks were evenly distributed across treatment. One percent Celite (external marker, Celite 545 coarse, Fluka, Buchs, Switzerland) was added to the 4 experimental diets (8 chicks per diet) to study digestibility in vivo by means of acid-insoluble ash (**AIA**; Sales and Janssens, 2003). After a 1-wk preadaptation, the digestibility test was performed between d 44 and 46. During the tests, trays were placed beneath each cage and excreta were sampled daily. Excreta were dried to a constant weight in a forced-draft oven at 40°C. Before analysis, excreta of each chicken from 3 d of collection were combined.

Diets and excreta were analyzed for chemical composition (AOAC, 2000) and AIA (Vogtmann et al., 1975). The apparent digestibility (**AD**) of organic matter (**OM**; **ADOM**), CP (**ADCP**), and ether extract (**EE; ADEE**) were calculated from the following formula:

$$\text{AD (\%)} = 100 - [100 \times (\%\text{AIA}_{\text{diet}}/\%\text{AIA}_{\text{excreta}}) \times (\%\text{X}_{\text{excreta}}/\%\text{X}_{\text{diet}})]$$

where X represents OM, CP, or EE.

Growth Trial, Body Composition, and N Balance

In experiment 2, 204 one-day-old chicks were purchased from a commercial hatchery. In the first 2 wk, heating was provided to keep room temperature in accordance with standard brooding practices. On d 14, chicks were weighed and randomly assigned to the same 4 diets as in experiment 1 (Table 1), with 3 replicates (17 chicks/pen). Each pen (1.7 m^2) was furnished with rice hulls and wood chips (50:50 wt/wt) as litter. Each chick was identified by a wing tag. Mortality was recorded daily. Weekly individual BW and feed consumption per pen were recorded. Successively, the overall BW, average daily gain (**ADG**), feed conversion ratio (**FCR**), daily feed intake (**DFI**), and protein efficiency ratio (**PER**) per pen on a flock basis were calculated.

At the end of experiment 2 (56 d of age), 4 chicks per group were randomly chosen from 2 pens, killed by intravenous sodium pentobarbital injection, and dissected to measure the weight of the carcass, liver, left thigh, and left breast and the length of the duodenum and ceca. Dressing percentages were then calculated, and the thigh and breast meat were analyzed for chemical composition. Susceptibility of the pectoralis major muscle to lipid oxidation by means of thiobarbituric acid-reactive

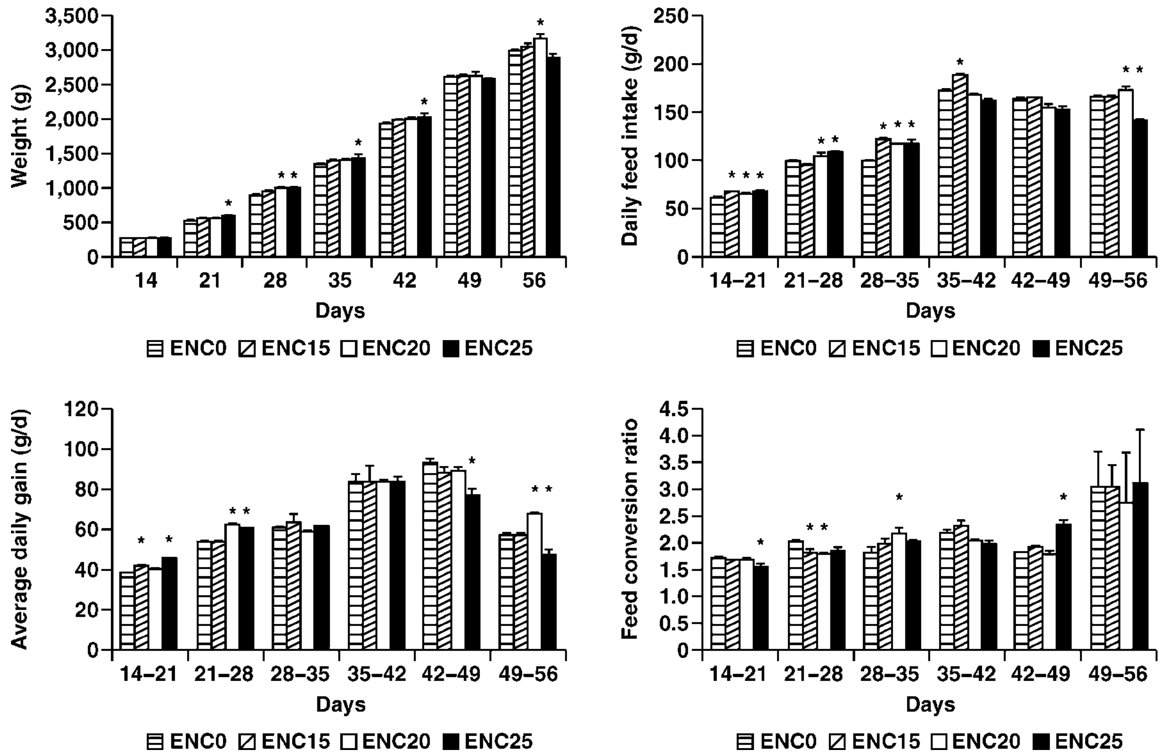

Figure 1. Trends in BW, daily feed intake, average daily gain, and feed conversion ratio from d 14 to 56 in broiler chicks fed different levels of ENC (mean ± SEM). *Indicates a difference when each treatment was compared with the control (Dunnett's *t*-test, $P < 0.05$). ENC0, ENC15, ENC20, ENC25 = basal diet supplemented with natural extract of chestnut wood (ENC) at 0, 0.15, 0.20, and 0.25%, respectively.

substances (**TBARS**) evaluation was performed according to the iron-induced TBARS procedure described by Huang and Miller (1993). The iron-induced TBARS assay was performed at 0, 30, 60, and 120 min of incubation with $FeSO_4 \cdot 7H_2O$ (final concentration, 1 m*M* Fe^{+3}) as the oxidative agent, and absorbance was read at 532 nm. Liquid malonaldehyde bis(diethyl acetal) (**MDA**; Aldrich Chemical Co. Ltd., Dorset, United Kingdom) was used as the standard to determine the linear standard response and recovery. The TBARS values are expressed as milligrams of MDA per kilogram of fresh meat.

After removing the gastrointestinal contents, the carcasses of 4 chicks per group, randomly chosen from 2 pens, were ground and analyzed for body N content to assess N balance according to the methodology proposed by the European Commission (2002).

After emptying all the pens, the litter from each pen was collected separately, weighed, and analyzed for pH, DM, total N (AOAC 2000, method 955.04), and NH_4^+-N content (AOAC 2000, method 920.03).

Analyses for DM (methods 934.01 and 950.46), CP (methods 988.05 and 928.08), EE (methods 920.39 and 991.36), crude fiber (method 962.09), and ash (methods 942.05 and 920.153) for feed, droppings, and meat were performed according to AOAC (2000) procedures.

Statistical Analysis

Results are presented as mean values ± SEM. All the data obtained were statistically analyzed by one-way ANOVA (SPSS, 1999). Treatments were compared with the control group by Dunnett's *t*-test (2-way), and the effect of ENC inclusion was evaluated by polynomial contrasts (SPSS, 1999).

RESULTS

Apparent Digestibility

Apparent digestibility of OM, ADCP, and ADEE showed no polynomial response with the inclusion of ENC, and ADOM, CP, and EE were not affected by ENC supplementation. Digestibility average values were 83.34, 73.43, and 89.23 for ADOM, ADCP, and ADEE, respectively.

The droppings produced by birds in the control group had a lower ($P < 0.05$) percentage of DM (21.33 ± 4.71%) than the mean for the ENC groups (22.98 ± 4.90). No differences in the protein content of droppings were observed among the groups, and the values ranged from 34.98 to 37.22%.

Growth Performance

Experiment 2 lasted 42 d, from 14 to 56 d of age. No mortality was experienced and chicks showed good health status. Figure 1 shows the growth performance, DFI, ADG, and FCR of broiler chicks.

Addition of ENC had a positive effect on weight, with ENC25 inducing significantly higher weights than ENC0

Table 2. Growth performances of broiler chicks fed with different levels of natural extract of chestnut wood (ENC) from 14 to 56 d of age (mean ± SEM)

Item[2]	Diet[1]				Effect[2]
	ENC0	ENC15	ENC20	ENC25	
Pens[4] (n)	3	3	3	3	
Initial BW (g)	263.70 ± 0.86	266.60 ± 9.15	274.61 ± 5.41	272.65 ± 8.37	
Final BW (g)	2,967.11 ± 29.67	3,024.65 ± 34.22	3,144.70* ± 23.78	2,881.46 ± 62.00	Q
ADG (g/d)	64.22 ± 0.69	65.58 ± 1.02	68.28* ± 0.44	62.40 ± 1.31	Q
DFI (g/d)	128.91 ± 0.80	134.92* ± 1.23	132.28* ± 0.44	128.96 ± 0.23	L, Q, C
FCR	2.02 ± 0.03	2.09 ± 0.04	1.96 ± 0.04	2.10 ± 0.04	
PER	2.49 ± 0.04	2.43 ± 0.04	2.58 ± 0.05	2.42 ± 0.04	

[1]ENC0, ENC15, ENC20, ENC25 = basal diet supplemented with ENC at 0, 0.15, 0.20, and 0.25%, respectively.

[2]ADG = average daily gain; DFI = daily feed intake; FCR = feed conversion ratio; PER = protein efficiency ratio (grams of weight gain per gram of protein intake, as-fed basis).

[3]L = linear effect of dietary inclusion of ENC (ENC0 vs. mean of ENC15, ENC20, ENC25; $P < 0.05$); Q = quadratic effect of ENC level ($P < 0.01$); C = cubic effect of ENC level ($P < 0.05$).

[4]Values are means of 3 replicate pens. Each pen had 17 birds.

*Indicates a difference when each treatment was compared with the control (Dunnett's *t*-test, $P < 0.05$).

in the first 4 wk of the trial. During this period, growth was directly proportional to the concentration of ENC. On d 56, the ENC20 group showed a significantly higher weight than the control group. In the first 3 wk, DFI was significantly higher in the treated groups than in the control group (ENC0). The effect of ENC then became less evident, and DFI in ENC0 was similar to those in ENC15 and ENC20, with some oscillations. At the end of the trial, DFI was significantly higher in ENC20 and lower in ENC25 than in ENC0.

Similarly, ENC, especially ENC20 and ENC25, favorably influenced ADG in the first 2 wk of the trial, whereas the effect of ENC25 on ADG was drastically reversed in the last 2 wk. The FCR showed high oscillations: the effects were significant from d 14 to 35, with different contrast significances, whereas from d 42 to 49, only ENC25 showed an unfavorable rate because of the reduction in ADG.

Referring to the whole period of experiment 2, as summarized in Table 2, ENC20 had a significantly positive influence on final BW, which showed a quadratic ($P < 0.01$) response with increasing level of ENC. Daily feed intake was greater with ENC than without ENC and showed a quadratic ($P < 0.01$) and a cubic ($P < 0.05$) response with increasing level of ENC. Daily feed intakes with ENC15 and ENC20 were significantly higher than with ENC0. Average daily gain also showed a quadratic ($P < 0.01$) response with increasing level of ENC; a difference was shown only for ENC20 compared with ENC0. No differences were observed for FCR and PER.

Body Composition and Meat Quality

At slaughtering, no gross anatomic-pathological lesions were observed on the organs. The main parameters measured showed no significant differences among ENC0, ENC15, ENC20, and ENC25. The average value for carcass weight was 2,205.40 g, dressing percentage was 73.42, thigh percentage of carcass was 24.43, and breast percentage of carcass was 30.30. Mean length of the duodenum was 1,675.72 mm and the cecal lengths were 216.87 mm (left) and 210.00 mm (right). No differences ($P > 0.05$) were observed in the hepatosomatic index (**HSI**; liver weight/BW × 100) among the 4 groups (1.62 ± 0.03, 1.48 ± 0.11, 1.42 ± 0.07, 1.49 ± 0.06); nevertheless, the HSI of birds fed ENC0 was slightly higher ($P < 0.10$) than those of the treated groups, regardless of the ENC level.

No significant differences were found in the proximate composition of thigh and breast meat, which fell in the standard range of poultry meat composition. These results showed that ENC inclusion had no influence on chicken meat quality.

As regards oxidative meat stability, the results observed on breast muscle for different diets at different time points did not show significant differences and ranged from 0.28 to 19.24 mg of MDA/kg (ENC0), from 0.24 to 20.84 mg of MDA/kg (ENC15), from 0.29 to 19.25 mg of MDA/kg (ENC20), and from 0.32 to 20.54 mg of MDA/kg (ENC25) from time 0 to 120 min, respectively.

Manure Characteristics and N Balance

Table 3 summarizes data concerning manure characteristics. In experiment 2, with 17 kg of litter per pen at the beginning, there was no difference among groups in the final quantity of manure as DM. No statistical difference was observed for DM and ash percentage of litter. It must be pointed out that the ENC0 diet had a total N percentage in manure higher than those of ENC15 and ENC20, whereas ENC25 showed an intermediate value, with no difference from ENC0. Inclusion of ENC significantly ($P < 0.05$) reduced the total N percentage in manure, which showed a quadratic ($P < 0.01$) response with increasing level of ENC. No statistical significance was evident for NH_4^+-N. The pH value was constant in all the treatments.

To assess the N balance, a N content in initial BW equal to 3% was assumed, as indicated by the European Commission (2002), whereas N content in final BW was measured analytically and resulted in 3.3%. The N balance was calculated for each diet as the difference from

Table 3 Characteristics of litters at the end of experiment 2 (mean ± SEM)

Item	Diet[1]				Effect[2]
	ENC0	ENC15	ENC20	ENC25	
Pens (n)	3	3	3	3	
Litter (kg, as DM)	31.79 ± 2.61	31.10 ± 0.53	31.56 ± 0.74	31.77 ± 1.55	
DM (%)	50.57 ± 5.79	52.53 ± 1.27	49.57 ± 2.03	45.23 ± 2.62	
Ash (%)	15.07 ± 0.55	15.50 ± 0.80	14.77 ± 0.32	14.83 ± 0.57	
Total N (%)	4.03 ± 0.07	3.17* ± 0.12	2.90* ± 0.25	3.73 ± 0.07	L, Q
NH_4^+-N (% of total N)	85.23 ± 1.99	89.10 ± 2.39	89.07 ± 1.48	83.00 ± 1.37	
pH	8.63 ± 0.03	8.70 ± 0.06	8.63 ± 0.03	8.63 ± 0.03	

[1]ENC0, ENC15, ENC20, ENC25 = basal diet supplemented with natural extract of chestnut wood (ENC) at 0, 0.15, 0.20, and 0.25%, respectively.

[2]L = liner effect of dietary inclusion of ENC (ENC0 vs. mean of ENC15, ENC20, ENC25; $P < 0.05$); Q = quadratic effect of ENC level ($P < 0.01$ and $P < 0.05$, respectively).

*Indicates a difference when each treatment is compared with the control (Dunnett's *t*-test, $P < 0.05$).

N intake and N contained in the body at the end of the trial (European Commission, 2002). The proportion of N retention per chick ranged from 54.79 to 58.56%, without any difference compared with ENC0.

DISCUSSION

Many papers have been devoted to the effects of tannin on bird feeding. Tannins have been considered harmful for many years owing to their negative effect on nutrient digestibility, N retention, and productive traits (Chang and Fuller, 1964; Gualtieri and Rapaccini, 1990; Smulikowska et al., 2001). Nowadays, because of the ever-increasing knowledge on the chemical composition and biological activity of tannins, opinions are changing, and these compounds are no longer classified as antinutritional. In fact, their effects have been shown to differ among bird species and to depend on time and dose exposure, as well as chemical structure (Mueller-Harvey, 2006). A great deal of research on poultry nutrition has focused on the utilization of different feed grains rich in tannins, such as sorghum (Diao and Qi, 1999; Cherian et al., 2002; Mandal et al., 2006) and fava beans (Brufau et al., 1998), yet little work has been carried out on tannin-containing substances such as feed additives (Karunakaran and Kadirvel, 2001; Marzo et al., 2002). However, some products derived from sweet chestnut (*Castanea sativa*) wood, which is commonly distributed in Europe, have been approved as feed additives in different countries. Silvafeed ENC is one of these products registered in Italy.

In this study, inclusion of up to 25 g of ENC/kg of diet had no significant influence on the chicks' apparent digestibility and the CP content in droppings. Results of CP digestibility differ from those obtained by Brufau et al. (1998) in Leghorn chicks. They observed a reduction in digestibility when the level of condensed tannins contained in different cultivars of fava beans increased. Regarding the chemical characteristics of droppings, Singleton (1981) observed that protein content increased because of protein-tannin complexes; nevertheless, because the protein level did not differ among groups in our study, we can only suppose that ENC formed few protein-tannin complexes, if any. There are 2 possible reasons for the lack of protein-tannin complexes: first, ENC from *Castanea* spp. is higher in hydrolyzable tannins than in condensed tannins (Bhat et al., 1998); second, one of the main ingredients is castalagin, which is characterized by a low K_{ow} value (0.1) and is less toxic than tannins with a high K_{ow} value (Mueller-Harvey, 2006). However, the increases in DM of droppings in the treated groups confirmed the astringent property of tannin, as reported by Karunakaran and Kadirvel (2001). Those authors pointed out that the advantage of dietary administration of sweet chestnut tannins mainly concerned dropping consistency, which was firmer in treated groups.

In our study, growth performance generally fell in the standard range of Cobb 500 broilers (Lacy, 2001). The ENC seemed to play a more favorable role in the younger broiler than in older broilers. The ENC could modify the stability of the gastrointestinal microflora, improving competitive exclusion similarly to other plant extracts (de Lange, 2005). After studying the different trends of gut and cecal microflora, Knarreborg et al. (2002) and Lu et al. (2003) indicated that, starting from 7 d of age, *C. perfringens* showed a continuous increase in the gut of poultry and represented a high percentage of microflora. Bearing this in mind, we can argue that ENC may limit in vivo development of some unfavorable bacteria, improving the health of the bird and consequently stimulating growth performance.

It was evident from observing the trend ADG that the addition of ENC enhanced the growth of broilers from d 14 to 35 of age, whereas from d 42 to 56 the effect decreased, becoming significantly negative for ENC25. This result is strictly related to DFI, which were lower in ENC25 than in ENC0 in the 2 last weeks. These differences might be due to a combined effect of dose and exposure time. Because ENC15 and ENC20 showed no negative effects, it is feasible to think that the suitable dose of ENC might range from 15 to 20 g/kg of diet. Inclusion of more than 20 g/kg of ENC led to undesirable effects. Our result is in contrast to that reported by Karunakaran and Kadirvel (2001), who observed a reduction in live weight gain and feed efficiency with a lower level of ENC addition (10 g/kg). Overall, in experiment 2, ENC20 showed better performance than ENC0. The negative effect of tannin seemed to be evident in ENC25, where all the measured parameters were the lowest. This might be due to the significant reduction in DFI observed in the last 2 wk (see Figure 1). The reduction in DFI, and consequently weight gain, was not compensated for by the intake and weight gain observed in the initial weeks of the experiment. The initial advantage obtained by the ENC25 was lost before the end of the experiment. The ENC20 diet had favorable but insignificant values for FCR compared with other groups (3.0 to 6.6%). These FCR were better than those observed by Diao and Qi (1999), which ranged from 2.20 to 2.24 for broilers at 8 wk age, and were slightly higher than those reported by de Lange (2005) and those referred to by the European Commission (2002), where the chicks had lower final BW (1.8 kg). No significant difference was evident for PER. This evidence does not confirm the observations by Marzo et al. (2002), who reported that tannic acid (25 g/kg of diet) strongly reduced PER.

The slaughtering data showed no significant differences among the parameters examined. Data concerning morphological features showed no differences among groups. However, a slightly significant effect ($P < 0.10$) was observed for HSI. Regardless of the inclusion level, the ENC-fed groups had a lower HSI than the control groups. The liver reduction attributable to a tannin-containing diet was also noticed by Marzo et al. (2002) in chicks and by Marzoni et al. (2005) in pheasants. Severe damage was reported for the kidneys, intestinal wall, and other internal organs when doses higher than 30 g/kg of tannic acid were administrated to chicks (Singleton, 1981). Lack of gross lesions at slaughtering, as well as lack of differences in intestinal length, and similar CP contents in feces in all groups indicated that the toxicity of ENC was low or absent. The lack of organ modification is in agreement with the results observed by Brufau et al. (1998) when feeding chicks a cultivar of *Vicia faba.*

Meat composition was not affected by ENC intake, and the proximate composition was in the normal range for broiler meat. The same quantity of EE in meat of different groups indicated that the energy metabolism had not been affected. The oxidative stability of meat had not been affected by ENC intake. Regarding the antioxidant properties of tannins, the effect on the mechanism of lipid superoxide of plasma cholesterol oxidation (Chung et al., 1998) is known in humans, whereas little information is available on lipid oxidative stability in poultry. Cherian et al. (2002) fed broilers different cultivars of sorghum and observed that the stability varied in relation to the different cultivars used. Our data give no evidence of an improvement in oxidative stability, which can vary in relation to the quantity of muscle fat. Neither the carcass quality nor the chemical composition of the leg and breast were influenced by inclusion of ENC, which implies that the product could safely be included in poultry diets.

Safeguarding the environment is currently one of the major issues. Intensive animal or poultry farming is considered one of the most important polluting activities. We evaluated some of the chemical characteristics of manure in pens. Total N in the litter appeared statistically higher in the control group than in the ENC inclusion groups. The percentage of NH_4^+-N in total N did not appear to be significantly modified. Even though poultry produce uric acid as major excreta (Groot Koerkamp, 1994), these preliminary results seem to show a higher volatilization of N as ammonia in ENC15 and ENC20 than in ENC0. These results are not in agreement with the observation of Śliwiński et al. (2004), who reported a reduction in N losses from the manure of ruminants fed a chestnut extract. From this point of view, more specific research on the emission of ammonia from poultry litter should be carried out. At the level of N balance, no significant difference was observed, and the N content of whole chicks fell into the range indicated by the European Commission (2002). The proportion of N retention was in agreement with the values observed by Romer and Abel (1999).

In conclusion, the use of ENC did not influence the digestibility, carcass quality, or N balance. The use of up to 0.20% ENC had a positive influence on growth performance, especially in young birds. Further research is needed to understand the mechanism of ENC in the gastrointestinal tract as well as the possible effect of manure storage to clarify whether chestnut tannins can reduce or increase N volatilization.

Study of the nutritional effects of tannins is complicated because of their great structural diversity, and this difficulty has led to considerable confusion in the literature when determining their benefits or toxicity (Mueller-Harvey, 2006). Our study adds to the trend that considers tannins as compounds that need to be studied individually because their origin, chemical structure, and biological properties are greatly diverse.

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