Effects of cassava foliage on feed digestion, meat quality, and antioxidative status of geese

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ABSTRACT As the by-product of cassava, cassava foliage (CF) has been widely used in livestock feed. However, little information is available on its utilization for geese. In this study, we aimed to investigate the effects of CF on the feed digestion, meat quality, and antioxidative status of geese. A total of 108 male Hainan indigenous geese (28-days-old) with similar body weight were randomly and evenly divided into 3 groups, and the geese were fed for 42 D on either the control diet (CON) consisting of ground maize, soybean meal, and wheat bran, or the experimental diet composed of ground maize, soybean meal, and wheat bran supplemented with 5% (CF1) or 10% (CF2) CF. Dietary nutrient digestibility, physicochemical properties, amino acid and fatty acid composition of meat, and antioxidative status of geese were evaluated. The results showed that supplementation of CF in goose diets enhanced the feed digestion and affected the meat quality. In addition, supplementation of CF had beneficial effects on the regulation of amino acid and fatty acid profiles in muscle tissues. Moreover, such supplementation had no significant effect on antioxidative status. Taken together, goose diet containing 5% CF was recommended based on feed efficiency and meat quality.

Key words: cassava foliage, geese, meat quality, amino acid, fatty acid, antioxidant activity

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INTRODUCTION

As an herbivorous waterfowl, geese have significantly bigger and powerful gizzard, which can generategreatest forces to break down the high-fiber roughage. Because of their excellent roughage utilization and adaptability, geese can consume large amounts of forage and agricultural byproducts. Numerous studies on the roughage utilization in goose production have shown that the moderate supplementation of roughage can improve the growth performance, gastrointestinal tract (**GIT**) development, nutrient digestibility, meat quality, and microbial diversity (Wang et al., 2010, 2014b; Jin et al., 2014; Liu and Zhou, 2013; He et al., 2015; Li et al., 2017). Moreover, roughage is a good source of bioactive compounds, which is the primary lipid-soluble antioxidant in biological systems. Natural antioxidants can increase the oxidative stability of animals (Liu et al., 2013), while little information has been reported on the contribution of roughage intake to the oxidative stability of geese.

Cassava is a major food crop grown in tropical areas, which is the most important root crop that constitutes staple food for millions of people in tropical and subtropical countries worldwide (Wang et al., 2014a). In addition, cassava is also widely used as bio-energy, biomaterials, and animal feeds (Anyanwu et al., 2015). Cassava foliage (**CF**) is known as an agricultural by-product with high protein content, gross energy, and mineral elements, and it can be used as animal feed. CF has been widely used in livestock production as dietary for goats, sheep, and pigs, showing positive effects on their growth performance and carcass characteristics (Fasae et al., 2011; Hue et al., 2012; Nguyen et al., 2012; Régnier et al., 2013). From the feed resource perspective, little information is available regarding the utilization of CF for poultry. CF can improve the nutriment digestion of chickens and ducks, facilitating digestive organ development (Borin et al., 2006). Our previous study on geese has found that CF can improve the growth performance, GIT development, and affect the microbial diversity of gut, while it has no effect on blood parameters and is harmless to health (Li et al., 2016, 2017, 2019). However, its effects on feed digestion, meat quality, and antioxidative status of geese remain largely unexplored. Therefore, we aimed to investigate the effects of CF as a dietary supplement on feed digestion, meat quality, and antioxidative status of geese.

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Table 1. Ingredient and nutrient composition of the experimental diets.

Items	CON	CF1	CF2
Ingredient (%)			
Corn	62	58.5	50.3
Soybean meal	22	21	20
Wheat bran	9	7.5	7
Cassava foliage		5	10
Vegetable Oil	0.5	1.5	4
Fish meal			3
Limestone powder	2	2	1.5
Calcium hydrogen phosphate	0.2	0.2	
DL-Met	0.3	0.3	0.2
Premix compound[a]	4	4	4
Total	100	100	100
Nutrient composition			
Metabolisable energy, ME (MJ/kg)[b]	11.27	11.3	11.34
Crude protein, CP (%)[c]	16.48	16.53	16.47
Crude fiber (%)[c]	3.04	5.01	6.93
Neutral detergent fiber, NDF (%)[c]	24.52	29.39	34.86
Acid detergent fiber, ADF (%)[c]	14.35	18.13	22.17
Calcium, Ca (%)[c]	0.8	0.8	0.8
Phosphorus, P (%)[c]	0.5	0.5	0.5
Lysine, Lys (%)[d]	0.8	0.8	0.8
Methionine, Met (%)[d]	0.45	0.45	0.45

[a]The premix provided the following per kilogram of diet: VA, 15,000,000 IU; VD, 5,000,000 IU; VE, 50,000 mg; VK, 150 mg; VB_1, 60 mg; VB_2, 600 mg; VB_6, 100 mg; VB_{12}, 1 mg; nicotinic acid, 3 g; pantothenic acid, 900 mg; folic acid, 50 mg; biotin, 4 mg; Choline, 35 mg; Fe, 90 mg; Cu, 10 mmg; Zn, 100 mg; Mn, 130 mg; Se, 0.3 mg; I, 1.5 mg; and Co, 0.5 mg.
[b]The values are calculated from ingredient AME values for chickens.
[c]Analyzed values.
[d]Calculated values.

Table 2. Chemical composition of CF (DM base).

Chemical composition			
CP (%)	22.68	Crude fiber (%)	27.26
EE (%)	5.79	Crude ash (%)	8.48
NDF (%)	28.89	Ca (%)[b]	0.92
ADF (%)	25.02	P (%)	0.36
AA composition (g/100 g of protein)			
Thr	0.81	Arg	0.97
Val	0.99	Asp	1.76
Met	0.08	Glu	2.17
Ile	0.81	Ser	0.78
Leu	1.59	Gly	0.93
Phe	0.99	Ala	1.10
Lys	1.06	Tyr	0.56
His	0.42	Pro	0.84
Fatty acid composition (g/100 g of the total FA)			
C16:0	29.52		
C16:1	4.38		
C18:0	0.12		
C18:1	3.55		
C18:2	20.61		

DM: dry matter, CP: crude protein, EE: ether extract, Ca: Calcium, P: Phosphorus, NDF: Neutral detergent fiber, ADF: Acid detergent fiber, AAs: amino acids.

MATERIALS AND METHODS

Experimental Diets and Animal Management

The animal-related protocols were approved by the Animal Care and Use Committee of Chinese Academy of Tropical Agricultural Sciences (**CATAS**), and animal experiments were performed at Tropical Animal Research Center of CATAS in 2014. All surgeries were carried out according to recommendations proposed by the European Commission to minimize the suffering of animals.

A total of 3 sets of diets were used in this trail, and Tables 1 and 2 summarize the diets and CF compositions. The control diet (**CON**) was composed of ground maize, soybean meal, and wheat bran, and the experimental diet consisted of ground maize, soybean meal, and wheat bran supplemented with 5% CF (**CF1**) or 10% CF (**CF2**). All diets were formulated to meet or exceed the recommendations for geese and adjusted based on the research requirement of some nutrients for tropical Chinese indigenous geese. The diets were offered to animals ad libitum, and water was available throughout the trial.

A total of 108 male Hainan indigenous geese (28-days-old) with similar BW were purchased from a breeding farm at CATAS (Danzhou, China), where they were raised under normal conditions. These birds were distributed into 18 pens of 4 m × 6 m with 6 birds per pen, lined up in 3 rows, and reared in a room (the building was closed, with windows and catwalk) at approximately 25°C without heating system under natural daylight. Each treatment had 6 replicates.

Sample Collection

The daily feed supply for geese of each pen was recorded to calculate the feed intake, which was determined by electronic crane scales (Jinghua Instruments, Shanghai, China) to the nearest 0.1 g. The dry matter (**DM**) of feed samples was determined after drying samples to a constant weight at 105°C.

A total of 18 geese were used for the digestion trail, 1 goose per pen (with BW closest to the mean weight per pen) was chosen, and the geese were placed in individual metabolic cages. The test consisted of a 3-day adaption, a 1-day fasting, and a 3-day collection period of total feces to determine the apparent digestibility of feed nutrients from days 64 to 70. Fecal samples were weighed and mixed with 10% sulfuric acid solution to prevent nitrogen, as ammonia, from escaping, and then the samples were stored at −20°C. Fecal samples of each pen from the 3-day collection period were pooled. In addition, fresh feces was subsampled and dried at 105°C to determine the DM content. Before the laboratory analyses, all feed and fecal samples were dried at 65°C for 48 h and ground to pass through a 1-mm screen for analysis of chemical composition.

After fasting for 12 h at age of 70-days-old, all birds were individually weighed, and 2 birds per pen (with BW closest to the mean weight per pen) were chosen and sacrificed. The samples of breast meat (m pectoralis major) and liver were immediately collected. The breast meat taken from the left side was divided into 2 parts, the forepart was used to analyze parameters of meat quality, and the hind part and liver samples were immediately frozen in liquid nitrogen and stored at −80°C for analyses of chemical composition, amino acid (**AA**), fatty acid, and antioxidant indicator.

Sample Analysis

Approximately 100 g of each diet and feces collected from each batch were mixed and then stored at −20°C for chemical analyses. Contents of crude protein (**CP**), crude fiber ether extract (**EE**), crude ash, calcium (**Ca**), and phosphorus (**P**) were determined according to the guidelines of Association of Official Analytical Chemists (AOAC, 1990). Contents of neutral detergent fiber (**NDF**) and acid detergent fiber (**ADF**) were measured as previously described (Van Soest et al., 1991). Heat-stable amylase and sodium sulfite were used for NDF measurement, and the results were expressed in the absence of residual ash.

The DM, CP, and EE of breast meat were determined as previously described. The AA profiles were assessed according to a previously established method (Gilka et al., 1989). The fatty acid concentrations were determined as fatty acid methyl ester derivatives in a PerkinElmer gas chromatographer (GC-2010) using a previously described method (O'Fallon et al., 2007). After a 24-h aging period, the pH value of meat samples was determined by directly inserting a probe into muscle with a pH meter (Testo 205, Testo AG, Lenzkirch, Germany). The shear force of meat (m pectoralis major) samples was analyzed using a texture analyzer (TMS-Pro, Food Technology Corp., Sterling, VA). A Minolta color-meter (model CR410, Minolta Camera Co., Ltd., Osaka, Japan) was used to measure the meat color parameters, including lightness (L*), redness (a*), and yellowness (b*), where L*, a*, and b* were marked on the inside of the muscle from the sternum bone side. There were 6 repeats for physicochemical property indexes.

The oxidant product of lipid, antioxidative status, and protein content of liver tissue were determined by measuring malondialdehyde (**MDA**) concentrations, total antioxidant activity (**T-AOC**), the activities of glutathione peroxidase (**GSH-Px**), catalase (**CAT**) and superoxide dismutase (**SOD**) in liver tissue using commercial kits (Jiancheng Biology Co., Nanjing, China) according to the manufacturer's instructions.

Statistical Analysis

The experiment was completely randomized. All data were subjected to one-way analysis of variance using the general linear models of SAS software (SAS Institute, 1996). For feed digestion, pen means served as the experimental unit. For meat quality and antioxidative status, individual birds were considered as the experimental units. Differences between treatments were tested, and $P < 0.05$ was considered as statistically significant.

Table 3. Effects of CF supplementation on the apparent digestibility of nutrients in geese.

	CON	CF1	CF2	*SEM*	*P*-value
DM, %	80.11[b]	89.78[a]	88.67[a]	3.11	0.013
CP, %	57.20[b]	63.68[a]	62.53[a]	2.03	0.009
EE, %	74.34	80.32	77.36	1.76	0.203
Ca, %	31.41	32.97	32.45	0.47	0.124
P, %	46.16	45.51	43.91	0.68	0.119
NDF, %	35.75[b]	41.28[a]	40.20[a]	1.72	0.020
ADF, %	28.47	30.71	29.00	0.69	0.257

Means within a row with different letters are different ($P < 0.05$). DM: dry matter, CP: crude protein, EE: ether extract, Ca: Calcium, P: Phosphorus, NDF: Neutral detergent fiber, ADF: Acid detergent fiber. SEM: standard error of means.

Table 4. Effects of CF supplementation on physicochemical proporties of geese.

	CON	CF1	CF2	*SEM*	*P*-value
DM, %	31.00	31.35	30.11	0.38	0.541
CP, %	20.68	22.15	21.08	0.45	0.447
EE, %	2.98	2.81	2.87	0.05	0.359
pH at 24 h postmortem	5.94[a]	5.48[b]	5.53[b]	0.15	0.030
Shear force, N	29.27[a]	22.73[b]	23.03[b]	2.17	0.015
L*	45.86[b]	51.42[a]	49.75[a]	1.68	0.018
a*	14.69	14.77	14.23	0.17	0.462
b*	3.21	3.19	3.08	0.04	0.112

Means within a row with different letters are different ($P < 0.05$). DM: dry matter; CP: crude protein; EE: ether extract; L*: lightness; a*: redness; b*: yellowness. SEM: standard error of means.

RESULTS

Diet Digestibility

Table 3 shows the apparent digestibility of dietary nutrients. Diet digestion in geese was affected by the dietary supplementation of CF. There were significant differences ($P < 0.05$) in the apparent digestibility of feed DM, CP, and NDF between the CF diet groups (CF1, CF2) and the control diet group (CON). However, there were no significant differences ($P > 0.05$) in the apparent digestibility of feed EE, Ca, P, and ADF between the CF diet groups (CF1, CF2) and the control diet group (CON). Moreover, a lower numerical digestibility of DM, CP, EE, Ca, NDF, and ADF was found in the control diet group (CON), whereas no significant difference ($P > 0.05$) in the apparent digestibility was found between CF1 and CF2 groups.

Meat Quality

Table 4 lists the parameters of physicochemical properties for different treatments. There was no difference ($P > 0.05$) in the proportions of DM, CP, and EE across the treatments. The pH and shear force of breast muscle were greater ($P < 0.05$) in the control diet group (CON) compared with the CF diet groups (CF1, CF2), while the L* was decreased ($P < 0.05$) in the control

Table 5. Effects of CF supplementation on main breast fatty acid profile (% of total fatty acids) of geese.

	CON	CF1	CF2	*SEM*	*P*-value
C16:0	27.77	27.75	26.33	0.49	0.569
C16:1	3.58[b]	4.32[a]	4.31[a]	0.25	0.268
C18:0	6.72	7.44	7.38	0.23	0.217
C18:1	49.85	51.42	49.79	0.54	0.331
C18:2	10.69[b]	11.37[a]	11.21[a]	0.21	0.037

Means within a row with different letters are different ($P < 0.05$). SEM: standard error of means.

Table 6. Effects of CF supplementation on breast meat AA profile of geese (% of protein).

	CON	CF1	CF2	*SEM*	*P*-value
Thr	0.63[b]	0.78[a]	0.74[a]	0.05	0.007
Val	0.79	0.82	0.79	0.01	0.436
Met	0.33	0.40	0.39	0.02	0.354
Ile	0.74	0.78	0.75	0.01	0.149
Leu	1.40	1.47	1.45	0.02	0.251
Phe	0.78[b]	0.88[a]	0.90[a]	0.04	0.013
Lys	1.20[b]	1.31[a]	1.21[b]	0.04	0.022
His	0.36	0.40	0.38	0.01	0.348
Arg	0.95[b]	1.05[a]	0.97[b]	0.03	0.019
Total EAA	7.18[b]	7.89[a]	7.58[a]	0.21	0.015
Asp	1.39	1.45	1.36	0.03	0.677
Glu	2.40[b]	2.54[a]	2.41[b]	0.05	0.025
Ser	0.61	0.64	0.61	0.01	0.308
Gly	0.72	0.75	0.71	0.01	0.109
Ala	1.11[b]	1.18[a]	1.13[b]	0.02	0.021
Tyr	0.69[b]	0.75[a]	0.77[a]	0.02	0.014
Pro	1.33	1.39	1.27	0.04	0.169
Total NEAA	8.25[b]	8.70[a]	8.26[b]	0.15	0.031
Total AA	15.55[b]	16.58[a]	15.84[a]	0.31	0.020
EAA: NEAA	0.87[b]	0.91[a]	0.92[a]	0.02	0.045

Means within a row with different letters are different ($P < 0.05$). AAs: amino acids, EAAs: essential and semi-essential amino acids, NEAAs: non-essential amino acids. SEM: standard error of means.

diet group (CON). Meanwhile, there was no difference ($P > 0.05$) in the a* and b* across the treatments.

Table 5 presents the fatty acid composition of goose meat. The proportions of palmitoleic acid (C16:1) and linoleic acid (C18:2) of breast muscle were lower ($P < 0.05$) in the control diet group (CON) compared with the CF diet groups (CF1, CF2). Meanwhile, there was no difference ($P > 0.05$) in the proportions of palmitic acid (C16:0), stearic acid (C18:0), and oleic acid (C18:1) across the treatments.

Table 6 presents the AA composition of goose meat. The levels of individual threonine, phenylalanine, lysine, arginine, glutamate, alanine, and tyrosine of breast muscle were lower ($P < 0.05$) in the control diet group (CON) compared with the CF diet groups (CF1, CF2). However, the concentrations of valine, methionine, isoleucine, leucine, histidine, aspartic acid, serine, glycine, and proline of breast muscle were not affected by supplementation of CF. In addition, the contents of total EAA, total NEAA and total AA as well as the ratio of EAA to NEAA were lower ($P < 0.05$) in the control diet group (CON).

Table 7. Effects of CF supplementation on antioxidative status of geese.

	CON	CF1	CF2	*SEM*	*P*-value
T-AOC, U/mg	1.85	1.72	1.79	0.04	0.377
MDA, nmol/mg	37.57	36.83	37.25	0.22	0.249
SOD, U/mg	93.52	94.23	94.78	0.37	0.281
GSH-Px, U/mg	123.20	127.81	128.44	1.68	0.496
CAT, U/mg	108.57	110.36	110.18	0.58	0.303

Means within a row with different letters are different ($P < 0.05$). MDA: malondialdehyde, T-AOC: total antioxidant activity, GSH-Px: glutathione peroxidase, CAT: catalase, SOD: superoxide dismutase. SEM: standard error of means.

Antioxidative Status

Table 7 presents the results of antioxidative status of the goose liver. The concentrations of T-AOC and MDA were similar between the control diet group (CON) and the CF diet groups (CF1, CF2). Meanwhile, there was no statistically significant difference ($P > 0.05$) in the activities of antioxidants, including CAT, GSH-Px, and SOD, across the 3 groups.

DISCUSSION

In the present study, the digestibility of DM, CP, and NDF was higher in the CF diet groups (CF1, CF2) compared with the control diet group (CON). Borin et al. (2006) have reported a lower total tract apparent digestibility in chickens and ducks, which are fed the diet supplemented with CF. Compared with chickens and ducks, geese possess a more developed digestive system, which might lead to this discrepancy. Geese digested and utilized the fiber component in roughage, which could improve the nutrient digestibility. Similar findings in nutrient digestibility have been reported with supplementation of rice hull, whole corn, wood shavings, whole wheat, coarse insoluble fiber, barley, or oat (Vetési et al., 2000; Hetland et al., 2003; Svihus et al., 2004; Amerah et al., 2009; Lu et al., 2011; Yang et al., 2016). The results of the these studies can probably be explained by the larger and more developed gizzard sizes in birds fed the high-fiber diet, which might enhance the grinding of feed, leading to increased exposure of nutrients to digestive juice and improved nutrient digestion (Wang et al., 2014b; He et al., 2015). These studies support our findings, and it appeared that CF in goose diets had beneficial effects on the nutrient digestibility.

As an important index of meat quality, the pH value is one of the influence factors impacting the shelf life. In the present study, the pH of breast meat was greater ($P < 0.05$) in the control diet group (CON) compared with the CF diet groups (CF1, CF2). Similar results have been also observed by Liu et al. (2013) in geese and Castellini et al. (2002) and Mourão et al. (2008) in broiler chickens.

This finding could be probably attributed to that forage intake improved the level of carbohydrates and therefore reduced metabolism of glycogen, which could maintain the acid-base balance in animal metabolism (Castellini et al., 2002; Foulkes and Cohen, 2010). Color is another important sensory attribute affecting consumer's purchasing decisions of meat. In the present study, the L* value in the CF-fed birds was greater ($P < 0.05$) than that in the control birds. We showed that roughage intake increased L* value and reduced the ultimate pH of geese or broilers, which was consistent with previous studies (Castellini et al., 2002; Liu et al., 2013). It could be explain by that shrinkage of the contractile fibers caused by a lower pH reduces the water-binding ability and increases the light scattering (Warriss, 2000). Shear force is an index for evaluating tenderness of meat, and the meat with lower shear force is tenderer. In the present study, the shear force in the control geese was greater ($P < 0.05$) than that in the CF-fed birds. In contrast, Liu and Zhou (2013) has observed that pasture intake has no effect on shear force of geese. Discrepancy in these results might be related to the composition and consumption of roughage.

The nutritional value of meat is most affected by its fatty acid and AA compositions. Meat is an important source of protein (Purchas et al., 2014), and previous studies have rarely reported the concentrations of AAs in goose meat. The meat of the geese in this study exceeded most of the human dietary requirements for AAs, as listed in the World Health Organization's report (WHO, 2007), indicating that goose meat could be a valuable source of AAs. Heo et al. (2015) have reported the AA composition of duck meat, which contains the most abundant AAs similar with goose meat in the present study. In contrast, Kokoszyński et al. (2017) have observed that the threonine and valine contents in duck meat are higher than those in goose meat in this study. Moreover, other studies (In-Chul et al., 2005; Straková et al., 2006) have shown the AA composition of chicken meat, which is obviously different from ducks and geese, and such discrepancy could be attributed to the different species. Furthermore, we found significant differences in the levels of AAs among treatments in this study. Similarly, a number of studies have shown that the AA composition of meat is affected by diet (Dimov et al., 2012; Kokoszyński et al., 2017; Chai et al., 2018).

The fatty acids and their ratios are key factors in determining the nutritional value of meat and its ability to integrate as part of a healthy diet (Cabrera and Saadoun, 2014). Goose meat is regarded as relatively safe for consumers, as it contains a greater proportion of PUFA compared with chickens and ducks (Heo et al., 2015; Tavaniello et al., 2018). The proportions of main fatty acids in goose meat in this experiment were similar to those found in other studies (Liu et al., 2013). In general, goose meat was characterized by a high proportion of oleic acid, followed by palmitic acid and stearic acid. Numerous studies have shown that the fatty acid profile of animal fat can be manipulated through feeding strategies (Hoffman et al., 2007; Ponte et al., 2008; Chai et al., 2018). Similarly, supplementation of CF had a significant effect on the fatty acid content of goose meat. The underlying mechanism could be attributed to the exogenous fatty acid from forage, which was in the esterified form of structural lipids, including galactolipids. Meanwhile, the digestive system of geese might be able to digest structural lipids or galactolipids. However, it is necessary to clarify the effect and underlying mechanisms that regulate fatty acid profile of goose meat in further investigations.

Forage is a good source of bioactive compounds, which is the primary lipid-soluble antioxidant in biological systems. Diets enriched with natural antioxidants can increase the oxidative stability of animals (Maraschiello et al., 1999; Liu et al., 2009). In our study, we observed a tendency of increased antioxidative status with the increase of CF content in diets. Likewise, Liu and Zhou (2013) have also observed that pasture intake can prevent lipid peroxidation in geese. Conversely, Castellini et al. (2002) have reported that broilers with access to a grass paddock show decreased antioxidative status compared with those housed in an indoor pen. The discrepancies between their results and our current study might be attributed to differences in digestive ability, since geese could consume more forage than broilers, and the bioactive compounds in forage can prevent lipid peroxidation.

CONCLUSIONS

Supplementation of CF in goose diets enhanced the feed digestion and influenced the meat quality. In addition, such supplementation had the beneficial effects on the regulation of AA and fatty acid profiles in muscle tissues. Moreover, CF had no significant effect on antioxidative status. Collectively, goose diet containing 5% CF was recommended based on feed efficiency and meat quality.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest.

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