Effects of grape residue supplementation in diet on Liangfeng chicken growth performance, nutrient metabolism and blood biochemistry

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ABSTRACT
Grape residue prepared from red wine has been reported as an effective antioxidant against chemical-induced toxicity and to attenuate oxidative stress. This experiment was conducted to investigate the effects of grape residue supplement in diet on growth performance, nutrient digestion, blood biochemical and antioxidant parameters of chicken. A total of 180, 30-day-old healthy Liangfeng chicken with paired body weight were randomly allocated into 6 groups with 5 replicates per group and 6 chickens per replicate. Control group (group I) was fed with a basal diet, while other groups were further supplemented with grape residue at 0.5% (group II), 1% (group III), 2% (group IV), 4% (group V) and 8% (group VI) respectively. All the diets were regulated in equal formula protein, metabolic energy, methionine and lysine content basic. After 49 days of the experiment, data showed that dietary supplementation with grape residue improved the growth performance of Liangfeng chicken and significantly enhanced the antioxidant capacity, and the supplementation at the level of 4% was recommended.

1. Introduction
Oxidative stress, attributing to high temperature of environment, transportation and nutrient limitation, exists widely in livestock and poultry production system (Shi et al. 2020). In recent years, different ways to reduce oxidative stress exposure have attracted increasing attention in the field of livestock and poultry production due to its detrimental influence on health and growth (Siervo et al. 2014). Ronique et al. (2020) reported that high temperature during summer was an important inducer of oxidative stress in poultry, obviously reducing feed intake and production performance of chickens. Imbalanced pro-oxidant and endogenous antioxidant mechanisms in tissues are caused by reactive oxygen species engaged in the generation of oxidative stress (Cadenas and Davies 2000; Kohen and Nyska 2002). Increasing oxidative stress occurring in the body activates a pile of oxidative free radicals accumulating in the tissue or slows down the scavenging rate, which pose a considerable threat to organism (Sa et al. 2018). Therefore, the production performance and growth status of livestock and poultry will be adversely disturbed. Previous studies have highlighted the impact of oxidative stress during the breeding process, which inhibited feed conversion rate and production performance of animals. Thus, research focusing on investigating anti-oxidative stress feed additives with safety and efficacy could be the potential strategy to promote the healthy development of livestock and poultry (Wu and Prior 2008).

Grape residue, a by-product derived from the red wine industry, is a promising alternative feed resource for its rich polyphenols components, which could exert an effective antioxidant effect (Xia et al. 2010; Cottart et al. 2014). The supplementation of grape residue in diet also possesses antioxidant properties, resulting in the reduction of MDA in the skeletal muscle of mutton sheep and the increase of SOD and GPX4 (Zhao et al. 2017). In addition, the inclusion of grape seed polyphenols in sows during late pregnancy and lactation period can obviously increase the contents of GSH-Px and SOD in serum and advance the antioxidant capacity of the organism (Wang et al. 2019). Given that high temperature is closely involved in the negative production of chickens and even the development of functional feed from grape residue, but the current researches proposed so far have not further documented the antioxidant ability of grape residue in chickens under high temperature conditions. To be noted, the research works on grape residue have concentrated restrictively on antioxidant properties while systematic research on growth, nutrient metabolism and blood biochemical indexes were constrained. For this reason, the aim of this study was to investigate the effects of grape residue on performance, nutrient digestion, serum biochemical indices and plasma antioxidant function of chickens. The present study provides a fundamental basis for functional research and development of grape residue as antioxidant and application of efficient utilization technology.

2. Materials and methods
2.1. Test materials
The grape residue used in this experiment was collected from Feed Engineering and Technology Research Center of Ningxia University, and diet analysis was shown in Table 1.
2.2. Experimental animals and feeding management

A total of 180, 30-day-old Liangfeng chicken with paired body weight were randomly divided into 6 groups with 5 replicates per group, and 6 chickens per replicate (the first 30 days of brooding were carried out at the farm). Double cages were used throughout the process, and each experimental chicken tied with foot tags was reared in a single cage. During the experiment, each replicate was fed separately, and all chickens had free access to feed and drinking water.

2.3. Experimental design and experimental diets

According to the previous relative studies and production practice, the suitable addition proportion of grape residue in diet was usually between 2% and 4%, on the basis of which we took these two adding levels as the middle and established different adding gradients covering them and further explored the impact of grape residue on the body on a large scale. The experimental basal diet was formulated in China’s ‘Chicken Raising Standards’ (NY/T33-2004) and fed to the control group, while experimental groups were fed with the basic composition supplemented with grape residue at 0.5% (II group), 1% (III group), 2% (IV group), 4% (V group) and 8% (group VI) individually. All diets were isoenergetic and isonitrogenous. The formal trial period was 49 days. The contains of protein, metabolizable energy, methionine and lysine were basically equal in all dietary formulas between different groups. The composition and nutrient levels of the basal diets are shown in Table 2.

2.4. Sample collection and analytical determination

2.4.1. Performance

All chickens were weighed per replicate on the last day of the experiment, and feed intake was also calculated. Meanwhile, the following parameters were measured, including average body weight (ABW), average daily gain (ADG), average daily feed intake (ADFI), and feed-to-gain ratio (F/G) of broilers during the experiment.

2.4.2. Nutrient metabolism

Faecal collection was conducted to carry out metabolic tests in the last week of the experiment. Feed intake and faecal sample weight were accurately recorded in the unit of repetition, and feed samples of each experimental group were collected during the same period. Feathers and other sundry objects were picked out of the daily collected faeces (daily on a repetitive basis, 10% concentrated sulfuric acid was sprayed). Appropriate fresh faecal samples were collected into sample bags, weighed and recorded for dry matter determine and further treatment. The fecal samples were dried and crushed through a 40-mesh sieve and reserved at room temperature for further test. The dry matter (DM), gross energy (GE), crude protein (CP) and ether extract (EE) of the diets and faeces were collected. The calculation formula was nutrient metabolism (％) = [(nutrient intake – nutrient output)/nutrient intake] *100.

2.4.3. Serum biochemical indices

At the end of the feeding experiment, 2 chickens with similar body weight and health were randomly selected from each replicate of 6 groups, a total of 60 broilers were tested, and blood samples were collected from subwing vein. Blood was collected and centrifuged at 3000r/min for 15 min after 3 h standing, then serum samples were obtained and stored at −20°C. Then serum was processed at Ningxia Dijia medical inspection centre for further determination, and serum biochemical indices included aspartate aminotransferase (AST), fasting blood glucose (GLU), white balls than (A/G), total protein (TP), total cholesterol (TC), serum uric acid (UA), serum triglyceride (TG), serum globulin (GLB), serum alkaline phosphatase (ALP), serum albumin (ALB).

Table 2. Diet composition and nutrient level (%).

| Ingredients   | I   | II  | III | IV  | V   | VI  |
|---------------|-----|-----|-----|-----|-----|-----|
| Corn          | 63.39 | 62.75 | 62.35 | 61.3 | 59.02 | 54.33 |
| Soybean oil   | 1.92  | 2.1  | 2.15 | 2.45 | 2.92 | 4.02  |
| Corn protein  | 1.6  | 1.63 | 1.75 | 1.76 | 2.02 | 2.18  |
| Rapeseed meal | 6.32  | 6.35 | 6.18 | 6.43 | 6.5 | 6.52  |
| Cottonseed meal | 5.85  | 5.75 | 5.64 | 5.3 | 4.6  | 4  |
| Soybean meal  | 17  | 17 | 17 | 17 | 17 | 17 |
| CaHPO4        | 1.6  | 1.6 | 1.6 | 1.6 | 1.6 | 1.6  |
| Limestone     | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7  |
| NaCl          | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2  |
| Met           | 0.1 | 0.1 | 0.1 | 0.1 | 0.12 | 0.13 |
| Lys           | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 | 0.32 |
| Premix<sup>a</sup> | 1 | 1 | 1 | 1 | 1 | 1 |
| Grape residue | 0 | 0.5 | 1 | 2 | 4 | 8  |
| Total         | 100 | 100 | 100 | 100 | 100 | 100 |

2. Notes: DM: dry matter; CP: crude protein; EE: ether extract; CF: crude fiber; Ca: calcium; P: phosphorus; ME: metabolism energy; Asp: Asparagine; Thr: Threonine; Ser: Serine; Glu: glutamic acid; Gly: Glycine; Ala: Alanine; Cys: Cysteine; Val: Valine; Met: Methionine; Ile: Isoleucine; Leu: Leucine; Tyr: tyrosine; Phe: Phenylalanine; Lys: lysine; His: Histidine; Arg: Arginine; Pro: Proline.

Table 1. Nutrient content of grape residue (air-dry basis) %.

| Items (MJ/kg) | DM | CP | EE | CF | Ash | Ca | P | ME | Asp | Thr | Ser | Glu | Gly |
|---------------|----|----|----|----|-----|----|---|----|-----|-----|-----|-----|-----|
| 63.39         | 95.6| 12.12| 8.22| 30.64| 7.43| 0.44| 0.31| 6.83| 0.69| 0.38| 0.44| 1.16| 0.56|
| 62.75         | Al| Cys | Val | Met | Ile | Leu | Tyr | Phe | Lys | His | Arg | Pro | Lys |
| 62.35         | 0.41| 0.09| 0.36| 0.03| 0.33| 0.66| 0.51| 0.66| 0.43| 0.37| 0.82| 0.53| 0.57|
| 61.3          |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 59.02         |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 54.33         |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 0.76          |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 0.75          |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 0.7            |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 0.68          |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 0.72          |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 0.71          |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 0.7           |     |     |     |     |     |     |     |     |     |     |     |     |     |
| 0.55          |     |     |     |     |     |     |     |     |     |     |     |     |     |

<sup>a</sup>Premix is provided per kg of diet: Vitamin A 160,000 IU, Vitamin D3 80,000 IU, Vitamin B1 43 mg, Vitamin E 540 mg, Vitamin K3 47.5 mg, Vitamin B2 136 mg, Vitamin B6 65 mg, Choline chloride 2734 mg, Pantothenic acid 309 mg, Copper 0.62 g, Iron 9.5 g, zinc 3.0 g, manganese 3.5 g, selenium 10.0 mg, chlorine 48 mg.
<sup>b</sup>The nutrient composition of each raw material is the measured value.
2.4.4. Plasma antioxidant indices

In order to assess the ability against oxidation with antioxidant indices, part of the collected blood samples was placed in EDTA anticoagulant tubes and centrifuged at 3000 r/min for 10 min after 30 min standing at room temperature. Then, the plasma was prepared and stored at −20°C for the determination of plasma antioxidant indices including malondialdehyde (MDA), catalase (CAT), glutathione peroxidase (GSH-Px), total antioxidant capacity (T-AOC), and superoxide dismutase (SOD), all of which were detected by trial boxes selected from Jiangsu Jingmei Biological Technology Co., Ltd.

2.5. Statistical analysis

Data were processed by Excel 2019, one-way ANOVA was performed by SPSS 25.0 software with ANOVA program, and Duncan’s method was used for multiple comparisons. P < .05 was considered a significant difference, and the results were expressed as ‘mean ± standard deviation’.

3. Results

3.1. Performance

As indicated in Table 3, the average daily feed intake of experimental chickens ranged from 123.48 to 130.19 g, and there was no significant difference among all groups (P > .05). Compared to the control group (40.15 g/d), the chicken treated with grape residues had a significantly higher average daily gain (P < .01). After treatment for 7 weeks, the average daily gain was numerically the highest (48.72 g/d) in 2% grape residues-treated chicken. The ratio of feed to gain in the control group was 3.27, while experimental groups receiving different concentrations of grape residues presented a lower ratio (P < .01), particularly, the addition amount in 4% was found the lowest to 2.70.

3.2. Nutrient metabolism

Fresh faecal samples were collected and the nutrient metabolism was calculated to investigate the effect of grape residues. As observed in Table 4, the dry matter metabolism of each group ranged from 60.11% to 63.60% reaching no statistical significance among the groups (P > .05). Also, the energy metabolism between 65.70% and 69.97%, accompanied by the fat metabolism between 86.40% and 88.43%, showed no significant difference among all groups (P > .05). Additionally, protein metabolism rate was within 51.89% and 59.79%, and 4% grape residues strikingly stimulated the protein digestibility compared to that in other groups (P < .05), but there experienced no significant difference between control and II, III, IV experimental groups (P > .05).

3.3. Serum biochemical indices

Metabolic parameters of chicken among different groups were illustrated in Table 5. The fasting plasma glucose concentration from supplemented groups was greatly lower than that in control group (P < .01), but no significant difference was observed among supplemented groups (P > .05). Group VI adding 8% of grape residue in the diet promoted the content of amino acids transferase in comparison with other groups (P < .01; 264.7 U/L), simultaneously, inhibited serum uric acid concentration at 149.00 μmol/L, which was significantly lower than that in group II and controls (P < .01). No differences were shown in serum concentrations of TP, TC, GLB, ALP, TG, ALB and A/G of broilers among all groups (P > .05).

3.4. Plasma antioxidant capacity

As shown in Table 6, chicken receiving grape residues from Group III, IV, V and VI significantly decreased plasma malondialdehyde content considerably compared with those receiving a standard diet (P < .01). In contrast, catalase content was accumulated gradually in grape residues-treated chicken, climbing to the top as 38.69 U/ml in 4% concentration (P < .01). Likewise, the elevation in glutathione peroxidase was associated with a higher concentration of grape residues compared to the controls (P < .05). Importantly, total antioxidant activity was stimulated in chicken supplemented with higher grape residues than that of the control and II group (P < .05). No significant differences in the values of superoxide dismutase were observed among groups (P > .05).

4. Discussion

4.1. Growth performance

Productive performance index is considered as a crucial index to measure the growth and nutritional status of animals. In this experiment, additional grape residue in the diet of broilers witnessed a remarkable elevation in the average daily gain and a significant decline in the ratio of feed to gain, importantly, the concentration of 4% presented the optimal result, in agreement with the previous description of Abu Hafsa and Ibrahim (2018). The research by Fawzia et al. (2014) adding 1.0% grape seeds also shared the similar tendency with our results. These results indicated the predominant presence of grape residue in body performance and promoting growth as the phenolic compounds in grape seeds played the pivotal roles in antioxidant activity, attenuating intestinal peristalsis and increasing the residence time of feed in the intestinal tract which protect the intestinal tract from oxidative damage (Ismail et al. 2003; Kermauner and Laurenčič 2008). However, when the polyphenols in grape seeds reached excessive inclusion, the production performance of broilers was diminished (Hughes et al. 2005; Chamarro et al. 2013; Abu Hafsa and Ibrahim 2018), mainly manifested as poor palatability of feed, thereby reducing the feed intake of broilers with inferior production performance (Yang et al. 2016). Our study made comparisons between the experimental group and controls, showing that adding a higher amount of grapes residue did not produce an adverse effect on the production performance of broilers and poultry production performance. The difference might result from the selection of chicken species, as Liang Feng chickens were used in this study and their resistance to feeding ability showed superior to other varieties of
4.2. Nutrient metabolism

Nutrient metabolism was an important indicator to estimate the ability of ingestion and absorption of an animal for some feed resources and diets (Zhou et al. 2011). In this experiment, there experienced no adverse effects on the nutrient metabolism of chickens with the addition of grape dregs, including dry matter, energy and fat metabolism. Notably, 4% grape dregs supplemented accelerated the protein metabolism compared to that of the control group, which was consistent with the results of Brenes et al.’s study on ileal protein metabolism in broilers (2010). The underlying mechanism might be that active substances contained in 4% grape dregs revealed the optimal function. On the contrary, inhibiting effects on the digestion of nutrients, including the decrease of protein metabolism, were found with the polyphenols content in the grape residue (Ortiz et al. 1993), which was in contrast to our current experiment probably due to the different experimental environment and broiler hybrids. In addition, with the shortage of research on the nutrient metabolism of grape residue in poultry, more research on grape residue need to conduct further.

4.3. Serum biochemical indices

The changes in serum biochemical indices were proposed as the indicator to reflect the substance metabolism in animal body and the health status of animals (Cozzi et al. 2011; Brscic et al. 2015; Grelet et al. 2018). TP, ALB, GLB and A/G in serum enjoyed an essential position on protein metabolism and immune function in the body, along with TP also a reflection of protein deposition in the animals and GLB participating in immune regulation (Li 2012; Li et al. 2019). In addition, ALB is synthesized in the liver and plays an indispensable role in maintaining normal osmotic pressure of blood and transporting metabolites in the body. UA is the final product of purine metabolism in the body and is excreted by the kidneys along with urine, which is indirectly applied to reflect the utilization of protein in birds and can also be used as an indicator of animal kidney function (Wang et al. 2013). In this present study, TP, ALB, GLB and A/G were not significantly different among experimental groups. Protein synthesis and sedimentary demonstrated no improvement in the experimental diet of chicken, but interestingly, supplementation with grape residue to a greater extent in 8% induced decreased concentration of serum UA than other treatment group and control group. The results also showed that adding grape residue in diet could facilitate the utilization rate of body protein and enhance kidney metabolism.

Table 3. Effects of grape residue on the performance of Liangfeng chicken.

| Items   | Groups   |
|---------|----------|
|         | I       | II       | III      | IV       | V        | VI       |
| IBW (g) | 730.55 ± 22.20 | 725.40 ± 35.48 | 713.96 ± 16.95 | 723.00 ± 29.49 | 730.00 ± 37.54 | 720.37 ± 20.42 |
| FBW (g) | 2620.87 ± 144.56a | 2987.60 ± 117.85a | 2981.58 ± 60.04a | 3110.92 ± 97.11a | 3062.26 ± 30.63a | 3033.98 ± 130.98a |
| ADFI (g/d) | 123.48 ± 5.84 | 125.53 ± 4.03 | 126.89 ± 2.30 | 128.53 ± 11.04 | 130.19 ± 2.64 | 125.72 ± 6.31 |
| ADG (g/d) | 40.15 ± 4.13 | 46.17 ± 2.68 | 46.38 ± 1.18 | 48.72 ± 1.83 | 47.61 ± 0.54 | 47.13 ± 2.73 |
| F/G     | 3.27 ± 0.24 | 2.72 ± 0.12 | 2.74 ± 0.12 | 2.72 ± 0.08 | 2.70 ± 0.02 | 2.73 ± 0.09 |
| GLU (mmol/L) | 13.38 ± 1.04 | 12.42 ± 1.06 | 12.21 ± 1.09 | 11.73 ± 0.59 | 11.65 ± 0.53 | 11.47 ± 0.90 |
| TG (mmol/L) | 0.32 ± 0.03 | 0.32 ± 0.06 | 0.30 ± 0.03 | 0.30 ± 0.02 | 0.29 ± 0.03 | 0.29 ± 0.02 |

Note: Different superscripts within a row indicate a significant difference. IBW: initial body weight; FBW: final body weigh; ABW: average body weight; ADG: average daily gain; ADFI: average daily feed intake; F/G: feed to gain ratio.

Table 4. Effects of different levels of grape residue on nutrient digestion of Liangfeng chicken.

| Items   | Groups   |
|---------|----------|
|         | I       | II       | III      | IV       | V        | VI       |
| DMM%    | 60.11 ± 2.61 | 61.08 ± 2.32 | 61.53 ± 2.75 | 61.84 ± 2.05 | 63.10 ± 4.46 | 63.60 ± 3.58 |
| GEM%    | 65.70 ± 3.33 | 66.79 ± 1.89 | 66.45 ± 3.14 | 67.96 ± 1.00 | 69.97 ± 1.34 | 67.31 ± 3.11 |
| CPM%    | 52.34 ± 2.78 | 51.89 ± 0.54 | 53.82 ± 3.85 | 53.39 ± 3.55 | 59.79 ± 4.55 | 57.82 ± 3.92 |
| EEM%    | 86.40 ± 3.18 | 86.48 ± 3.23 | 85.31 ± 1.48 | 86.87 ± 1.67 | 88.43 ± 0.97 | 88.01 ± 2.04 |

Note: DMM: dry matter metabolic rate; GEM: gross energy metabolic rate; CPM: crude protein metabolic rate; EEM: ether extract metabolic rate.

Table 5. Effects of grape residue on serum biochemical indices of Liangfeng chicken.

| Items     | Groups   |
|-----------|----------|
|           | I       | II       | III      | IV       | V        | VI       |
| AST (U/L) | 215.44 ± 27.45 | 220.4 ± 18.7 | 225.3 ± 29.2 | 231.5 ± 19.7 | 233.00 ± 20.18 | 264.7 ± 32.89 |
| GLU (mmol/L) | 13.38 ± 1.04 | 12.42 ± 1.06 | 12.21 ± 1.09 | 11.73 ± 0.59 | 11.65 ± 0.53 | 11.47 ± 0.90 |
| A/G       | 0.51 ± 0.08 | 0.53 ± 0.09 | 0.51 ± 0.07 | 0.54 ± 0.07 | 0.52 ± 0.11 | 0.53 ± 0.07 |
| TP/g/L    | 36.67 ± 1.01 | 35.92 ± 2.5 | 35.87 ± 1.05 | 34.4 ± 1.36 | 35.08 ± 1.83 | 35.22 ± 1.00 |
| UA (μmol/L) | 200.17 ± 29.04 | 197.50 ± 30.22 | 182.33 ± 29.67 | 172.67 ± 12.10 | 166.88 ± 29.43 | 149.00 ± 22.63 |
| TC (mmol/L) | 2.57 ± 0.13 | 2.54 ± 0.14 | 2.51 ± 0.12 | 2.52 ± 0.16 | 2.74 ± 0.13 | 2.74 ± 0.06 |
| GLB (g/L) | 24.08 ± 0.72 | 24.03 ± 3.02 | 23.55 ± 0.92 | 23.42 ± 2.66 | 23.68 ± 1.39 | 22.21 ± 1.31 |
| ALB (g/L) | 12.84 ± 0.74 | 12.75 ± 0.40 | 12.72 ± 0.57 | 12.25 ± 0.41 | 12.7 ± 0.10 | 12.64 ± 0.34 |
| ALP (mmol/L) | 834.80 ± 70.30 | 850.00 ± 49.67 | 854.25 ± 211.12 | 895.14 ± 211.05 | 866.71 ± 236.84 | 847.80 ± 95.39 |

Note: AST: alanine aminotransferase; GLU: glucose; A/G: albumin/globulin; TP: total protein; UA: uric acid; TC: total cholesterol; GLB: globulin; ALB: albumin; ALP: alkaline phosphatase; TG: triglyceride.
Enlarged serum TC and TG are the hallmarks at the onset of aberrant fat metabolism in the body. Studies found that the addition of grape seeds could partly improve the metabolism of fat in the body. Del Bas et al. (2005) found that grape seed proanthocyanidins could significantly reduce the content of serum triglycerides, and adding to rats with high-fat diet could significantly reduce some genes expression involved in fat synthesis in their liver and improve fat metabolism as evidenced by Quesada et al. (2009). Rui et al. (2010) found that proanthocyanidins supplementation in diet could reduce the contents of plasma TC and TG from golden Syrian hamsters, and adding grape seed extract to diet of laying hens could reduce the cholesterol content in egg yolk (Long 2018). However, in the present work, dietary supplementation of grape residue exerted no significant effects on serum TC and TG contents in fat metabolism of these trial chickens, which may be related to the different experimental animals selected for study, and the specific reasons need further study and analysis.

As the main energy source for poultry metabolism (Jia et al. 2019), blood glucose concentration was found a dramatic drop in grape residue-treated chicken, which was consistent with the description by many studies that grape seed proanthocyanidin could decrease blood glucose (Ardevol et al. 2015), further indicating that the addition of grape residue might enhance the ability of broilers to regulate glucose metabolism. AST is known as an important index in liver function assessment. The permeability of liver cells enhanced to release a large amount of AST into the blood increases in responses to the impaired liver (Zhang et al. 2015). In this experiment, when adding 8% grape dreg, AST content was significantly higher than that of other groups. Therefore, it can be inferred that excessive addition of grape dreg may cause certain adverse effects on liver function of broilers, and further study is urgently needed to verify the results. ALP, mainly secreted by osteoblasts and liver, correlates with bone metabolism, calcium and phosphorus metabolism (Yuan et al. 2011). High activity of ALP has been described to accelerate salt deposition, bone formation and metabolism, thereby promoting the growth and development of animals. In this study, there was no significant difference in the content of ALP compared with the control group, indicating that the increase in the average daily gain of broilers in this study was not achieved through the improvement of this metabolic pathway, and the specific reasons need to be further analyzed.

## 4.4. Plasma antioxidant capacity

Antioxidant is short for antioxidant free radical, which is a physiological phenomenon to delay the gradual degeneration of the functions of various organs of animals, and serves as a critical protector for the animal body health (Jia et al. 2019). Antioxidants in grape residue have been extensively identified, including a variety of polyphenols such as flavonols and anthocyanins (Caillet et al. 2006). Previous reports have shown that grape polyphenols could scavenge free radicals, terminate oxidation reaction (Brenes et al. 2010; Viveros et al. 2011; Yang et al. 2016; Abu Hafsa and Ibrahim 2018), and advance the antioxidant capacity of grape seeds about 20–50 times higher than vitamin E and vitamin C (Shi et al. 2003). MDA is the secondary metabolite of lipid oxidation, typically reflecting the extent of lipid peroxidation in the body and the degree of cell damage indirectly (Yun et al. 2002; Wei et al. 2005). Our study suggested that adding different levels of grape residue to the diet reduced MDA content, indicating that grape dregs could regulate lipid oxidation in the body and thus improve the antioxidant capacity of the body. CAT could remove hydrogen peroxide in the body due to the decomposition of hydrogen peroxide, protecting cells free from the toxicity of hydrogen peroxide (Zhang et al. 2020). GSH-Px and SOD are also two kinds of antioxidant enzymes in the body, which played an antioxidant role in removing oxygen free radicals and thus (Zhong et al. 2020). Another enzyme named T-AOC is a comprehensive index reflecting the free radical scavenging ability of the body. The higher its value in the normal range, the stronger the antioxidant ability of the body (Tian et al. 2020; Cong et al. 2021). In concordance with the results of Bremes, Iqbal and other previous reports, it was found the addition of grape residue could significantly increase the contents of CAT, GSH-Px and T-AOC, stimulating the ability to scavenge free radicals, and improve the body’s antioxidant capacity (Viveros et al. 2011; Iqbal et al. 2015). However, it has been found that the addition of these natural antioxidants to broiler diets was limited by the low availability of polyphenols (Viveros et al. 2011; Iqbal et al. 2015; Abu Hafsa and Ibrahim 2018), and the optimal antioxidant effect could be obtained by adding 4% grape residue. Combined with the performance data of broilers, it was speculated that grape residue could improve the performance of broilers by advancing the antioxidant capacity of the body.

## 5. Conclusions

In this present study, the supplementation of grape residue in diet of Liangfeng chicken significantly ameliorated their health and growth performance, so did improve nutrient digestion, health status and antioxidant activity alike. Metabolic ability tended to present an improvement in experiment groups. Further, we recommended a level of 4% for supplementation from intergroup analysis and comparison.
Disclosure statement
No potential conflict of interest was reported by the author(s).

Funding
This work was supported by Ningxia Key Research and Development Project [grant number 2019BBF02016, 2019BBF02001].

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