Growth, carcase characteristics, meat quality, nutrient digestibility and immune function of broilers fed with enzymatically treated or raw dandelion (Taraxacum mongolicum Hand.-Mazz.)

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ABSTRACT

This study aims at evaluating the effects of enzymatically treated or raw dandelion (Taraxacum mongolicum Hand.-Mazz.) on growth performance, carcase characteristics, meat quality, apparent nutrient digestibility, and immunity of Arbor Acres broilers for 42 d. One hundred and twenty 1-day-old birds were randomly distributed into three treatments: basal diet (CON), basal diet plus 1 g/kg of raw dandelion (RD) and enzyme-treated dandelion (ED). The results shown that ED significantly decreased feed conversion ratio during the starter period (1–21 d). ED significantly increased apparent nutrient digestibility of ether extract and organic matter (OM) (1–21 d) as well as crude protein (22–42 d). RD significantly increased the OM nutrient digestibility (1–21 d). ED groups had significantly higher breast muscle rate, lower drip loss and water-holding capacity (WHC) in breast muscle, and lower cooking loss in leg muscle. RD significantly decreased breast muscle WHC. The serum immunoglobulin (Ig) A and IgG (d 21 and 42) as well as IgM (d 21) levels were observed higher in response to ED supplementation. RD treatment showed significantly higher serum IgA level at d 21. Additionally, dietary ED supplementation resulted in higher serum interleukin 10 (d 21) and interferon-γ (d 42) contents. In conclusion, ED displayed superior effects on improving feed conversion ratio, carcase characteristics, meat quality, apparent nutrient digestibility, and immune function of broilers.

HIGHLIGHTS

- Enzymatically treated (ED) and raw dandelion (RD) were evaluated in broiler chicken.
- ED improved feed conversion ratio and breast muscle rate.
- ED and RD enhanced meat quality, nutrient digestibility and immune function.
- ED had more beneficial effects than RD.

Introduction

In recent decades, poultry meat has become one of the most important animal protein sources due to its low price (Kleyn and Ciacciariello 2021). Modern intensive poultry production system has achieved phenomenal gains in efficiency; however, the presence of stressful conditions in the system reduces immune function and growth performance and facilitates the spread of diseases (Ghanima et al. 2020). Antibiotic growth promoters (AGP) have been used to solve these questions for a long time. However, the application of AGP in feed for poultry and livestock animals has been completely banned in China from July 1, 2020, due to the risk of antimicrobial resistance and antibiotic residues (Zhao, Yang et al. 2021). Hence, finding AGP-free solutions suitable for intensive poultry production system is urgent.

In recent year, the positive effects of Chinese herbs on the performance, apparent nutrient digestibility, and immunity of broilers have been widely reported (Kuralkar and Kuralkar 2021). Dandelion (Taraxacum mongolicum Hand.-Mazz.) is a perennial herb belonged to the Asteraceae family and has been used in...
traditional and modern herbal medicinal systems of China (Escudero et al. 2003). Dandelion exhibits remarkable biological properties including antimicrobial, antioxidant, and immunostimulatory effects (González-Castejón et al. 2012), due to the presence of a wide variety of bioactive components including polysaccharides, phenolics and flavonoids (Qian et al. 2014; Qureshi et al. 2017). Accumulated evidence suggests that dandelion increased antioxidant enzyme activities in liver of rats (Gulfraz et al. 2014), regulated the immune system of broilers (Lee et al. 2012) and improved performance, carcase characteristics and meat quality of growing-finishing pigs (Samolińska et al. 2019). However, some researchers have reported that although dandelion contains multiple bioactive components, the cell wall matrix restricts the utilization of these natural functional components by the host (Krakowska-Sieprawaska et al. 2020). Thus, enzymatically treated procedure has been emerged to degrade cell wall matrix of herbs and enhance the release of bioactive components (Puri et al. 2012). A recent study conducted by Wan et al. (2016a) demonstrated that enzymatically treated A. annua leaves have more profound influences on growth of broilers. Song et al. (2018) also confirmed that dietary inclusion of enzymatically treated A. annua exhibited beneficial effects on the growth, digestive enzyme, and immune status of broilers under heat stress.

In our previous study, we treated dandelion with pectinase and found that the extractability of polysaccharides was increased (Zhao, Liu et al. 2021). Thus, we hypothesise that dietary supplementation of enzymatically treated dandelion than raw dandelion may lead to better performance and immune status of broilers. So, the purpose of this study was to compare the effects of enzymatically treated and raw dandelion on growth, carcase characteristics, meat quality, apparent nutrient digestibility, and immunity function of broilers.

Materials and methods

Preparation of enzymatically treated dandelion

The dandelion was purchased from Bozhou zhenshan-yuan traditional Chinese medicine Sales Co., Ltd (Anhui Province, China). Wheat bran was purchased from Bayannur Hengfeng Dagong food company limited. The preparation of enzymatically treated dandelion was conducted in accordance with previous study in the laboratory (Zhao, Liu et al. 2021). Briefly, whole dandelion was dried and milled to pass through a mesh 20 sieve. Wheat bran was pulverised to pass a mesh 60 sieve. Basal substrates were prepared by mixing dandelion and wheat bran at the ratio of 9:1 (w/w). Then, basal substrates were divided into 2 lots. One lot was raw dandelion, and the other lot was treated by pectinase (Beijing Solarbio Technology Co., Ltd, Beijing, China). Basal substrate was adjusted to 50% moisture with distilled water, incubated with 1500 U/g pectinase, then packaged in multi-layer polythene bags. The hydrolysis conditions were 60 °C and 12 h. After that, basal substrate was dried at 45 °C for 48 h to obtain enzymatically treated dandelion. The total polysaccharide content of RD and ED was determined by the phenol-sulfuric acid method, for which glucose was used as a standard (Huang et al. 2019). The total polyphenols content was estimated by the Folin-Ciocalteu colorimetric method using gallic acid as a standard (Hu et al. 2009). The total polyphenols and polysaccharides contents of RD and ED were 21.30 to 25.72 mg/g and 127.34 to 218.93 mg/g, respectively.

Animals, experimental design, and management

The animal trial was approved by Inner Mongolia Agricultural University Institutional Animal Care and Use Committee (No. 2020065). A total of 120 1-day-old Arbour Acres male broiler chickens with similar body weights (45.96 ± 3.55 g) were purchased from a local hatchery, and randomly divided into 3 groups with 5 replications of 8 birds each. Three dietary treatments were supplied as follows: basal diet (CON); basal diet plus 1 g/kg of raw dandelion (RD) and enzyme-treated dandelion (ED). The dosage of dandelion supplementation was applied based on the results of our previous research (Mao et al. 2021). The basal diets (Table 1) were in mash form and formulated to meet the nutrients recommendations of Chinese Feeding Standard of Chicken (NY/T 332004) for starter period (d 1–21) and finisher period (d 22–42).

The birds were reared in stainless-steel wire cages (100 × 60 × 50 cm) and allowed free access to water and feed. The house temperature was set at 35 °C for 1 week, then gradually reduced by 2–3 °C per week to a 25 °C until the end of the trial. The lighting schedule was set as 24 h of lighting on d 1, and 23 h of lighting: 1 h of darkness up to d 7, then for 16 h of lighting: 8 h of darkness until d 42. All birds were inoculated with Newcastle disease infectious bronchitis vaccine at d 7 and infectious bursal disease vaccine at d 21.

Growth performances

Body weight (BW) of each bird and feed consumption of each replicate were measured at d 21 and d 42.
The average daily gain (ADG), average daily feed intake (ADFI) and feed conversion ratio (FCR) were calculated.

Carcass characteristics and meat quality

At d 42, one bird was randomly selected from each replicate, duly weighed, euthanized by electrical stunning and then immediately bled. The carcasses were plucked, eviscerated, and weighed. Then the weight of breast muscle (pectoralis major and pectoralis minor), leg muscle (thigh and drumstick) and abdominal fat were determined (Al-Sagan et al. 2020). The pH value and drip loss were measured as previously described method (Zhang et al. 2021). Cooking loss and shear force were detected according to the description of Alghirani et al. (2021), and water loss rate was measured by Farouk et al. (2004).

Apparent nutrient digestibility

The excreta of each replicate were collected daily during d 19-21 and 40-42. Clean excreta were pooled within each replicate, thoroughly mixed, dried in a hot air oven at 65 °C and ground to pass through 0.5 mm sieve. According to the methods of AOAC (1995), dry matter (method 934.01), crude protein (method 954.01), ash (method 930.05), ether extract (method 954.02), calcium (method 927.02), and phosphorus (method 984.27) of feed and excreta samples were determined. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined in mixed diets and faecal samples according to the sequential procedures of Van Soest et al. (1991) using an Ankom 200 Fibre Analyser unit (ANKOM Technology Corporation, Macedon, NY, USA).

Acid insoluble ash (AIA) as internal marker was measured according to Siriwan et al. (1993), and nutrient apparent total tract digestibility was calculated as:

\[
\text{Digestibility} = \frac{100 - \left(\frac{\% \text{ AIA in feed}}{\% \text{ AIA in excreta}}\right) \times \frac{\% \text{ nutrient in excreta}}{\% \text{ nutrient in feed}}}{100}
\]

Serum immune indices

At 21 d and 42 d, blood samples were obtained from five birds/treatment for serum immune indices analysis. Blood samples (5-10 mL) were collected by the jugular vein puncture and then serum was separated by centrifugation at 3000 g at 4 °C for 10 min. The serum antibodies [immunoglobulin G (IgG), immunoglobulin A (IgA), immunoglobulin M (IgM)] and cytokines [interleukin-1β (IL-1β), interleukin-8 (IL-8), tumour necrosis factor-α (TNF-α), interleukin-10 (IL-10), interferon-γ (IFN-γ)] contents were analysed according to the instructions of the commercial kits purchased from Jiangsu Mei Biao Biological Technology Co., Ltd. (Jiangsu, China).

Statistical analysis

Data were analysed with one-way ANOVA and Duncan’s multiple comparison tests and showed as the means and SEM. Each replicate was considered as the experimental unit. Significance was considered at \( p < 0.05 \).

Results

Growth performance

As shown in Table 2, there was no difference on 1 d BW, 21 d BW, 42 d BW, ADG and ADFI among three treatment groups during the starter, finisher and whole period \( (p > 0.05) \). Compared to CON, the FCR during starter period was decreased \( (p < 0.05) \) by feeding ED. However, the FCR during other periods did not differ among treatment group \( (p > 0.05) \).
Table 3. Effect of enzyme-treated and raw dandelion on carcase characteristics of broilers.

| Items            | Treatments 1 | SEM | p-Value |
|------------------|--------------|-----|---------|
| Slaughter rate, %| CON 91.28    | RD 91.47 | ED 90.91 | 0.860 | 0.609 |
| Eviscerated rate, % | 81.32 | 81.18 | 81.24 | 0.899 | 0.969 |
| Breast muscle rate, % | 27.70b | 27.61ab | 28.86a | 0.968 | 0.041 |
| Leg muscle rate, % | 18.39 | 19.65 | 19.39 | 1.232 | 0.101 |
| Abdominal fat rate, % | 1.92 | 1.77 | 1.77 | 0.030 | 0.729 |

abValues with different letter superscripts mean significant difference (p < 0.05).
1Treatments included basal diet (CON) and basal diets plus 1 g/kg of raw dandelion (RD) and enzyme-treated dandelion (ED).

Discussion
Due to the presence of abundant bioactive components, dandelion has been used as feed additive in monogastric animal production (Qureshi et al. 2017). However, it has been revealed that the cell wall matrix restricts the dissolution of bioactive components and is therefore unfavourable for the utilisation of herbs by the host (Puri et al. 2012). It is well known that cell wall of herbs is mainly composed of cellulose and pectin crosslinking glycans and proteins, and pectinase could break down the pectin and pectic compounds and destroy the cytoderm (Zhai et al. 2018). Therefore,
dandelion in this study was treated with pectinase to improve the release of bioactive components. The total polyphenols and polysaccharides contents of dandelion was increased from 21.30 and 127.34 mg/g to 25.72 and 218.93 mg/g, respectively. In line with our study, Wan et al. (2016b) demonstrated that enzymatic treatment improved the total phenolic and flavonoid contents of A. annua leaves.

Several studies have confirmed that dietary dandelion supplementation promoted the growth performance of broilers (Galib et al. 2010). Qureshi et al. (2015) founded that the average BW and FCR of broilers was enhanced by feeding with dandelion leaves. However, the effects of dandelion on growth performance of broilers seemed to be inconsistent among studies. Oh et al. (2007) reported no differences in final BW, weight gain, feed intake, and FCR of broilers fed with dandelion. In the current study, broilers fed diet added RD or ED had similar ADG and FCR, indicating that the enzyme in the diet could improve the release of bioactive components. The dandelion in this study was treated with pectinase to improve the release of bioactive components. The total polyphenols and polysaccharides contents of dandelion was increased from 21.30 and 127.34 mg/g to 25.72 and 218.93 mg/g, respectively. In line with the above results, Wan et al. (2016b) demonstrated that enzymatic treatment improved the total phenolic and flavonoid contents of A. annua leaves.

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digestibility to provide nutrient in optimal position (Poohgasemi et al. 2018).

The pH value, colour, water holding capacity (drip loss, water loss rate and cooking loss), and shear force were widely used to evaluate the sensory characteristics of meat quality (Castellini et al. 2002). The pH value of breast and leg muscle reported in this study is comparable to previously reported values in broilers (Alvarado et al. 2007) and was unaffected by dietary supplementation. As a consequence of the similar pH value, the colour of breast and leg muscle was not altered by the dietary treatments (Bahadori et al. 2017; Moyo et al. 2020). It is suggested that stressful conditions or strenuous muscle activity of broilers were absent in current study (Schaefer et al. 2001; Salwani et al. 2016). The similarity among treatments in the pH value and colour of breast and leg muscle, is in agreement with the results of other authors (Cho et al. 2014; Ding et al. 2020). Likewise, Yan et al. (2011) reported that the longissimus lumborum muscle of colour and pH of finishing pigs were not affected by the dietary addition of dandelion extract powder. In this study, addition of RD reduced the water loss rate in breast muscle of broilers. Additionally, the drip loss and water loss rate of breast muscle as well as cooking loss of leg muscle in ED group was decreased. Our observations are in line with previous studies where dietary supplementation with herb and its extracts could improve water holding capacity of broilers (Aziza et al. 2010; Zhang et al. 2015, 2018). Moreover, Wan et al. (2016b) discovered that the water holding capacity of breast and thigh muscle in broilers were increased by feeding enzymatically treated A. annua, and further confirmed the positive correlation between the antioxidant capacity and quality of meat (Aziza et al. 2010; Zhang et al. 2015). Therefore, we speculated that the superior effects of ED in improvement of water holding capacity in broilers might be due to the increased polyphenols level, which exhibited strong antioxidative activity (Patel et al. 2010). Shear force is one of the crucial meat quality traits affected by strain, sex, age, diet, as well as the environment (Abdulla et al. 2017). The results of this study found that neither RD nor ED impacted the shear force of breast or leg meat in broilers, and the reason needs to be further studied.

In current study, the apparent OM digestibility during the starter period was increased by RD supplementation. As expected, our data shown that ED exhibited superior beneficial effects on the nutrient digestibility with higher apparent OM and EE digestibility during the starter period and higher apparent CP digestibility during the finisher period was observed. This may be attributed to higher total polyphenols and polysaccharides contents of ED. The beneficial effects of herb and its extracts on the nutrient digestibility of broilers have been well dementated (Malekzadeh et al. 2018; Sun et al. 2020). According to Qureshi et al. (2016a) and Song et al. (2018), this could be explained by the improvement of intestinal morphology and digestive enzyme activities caused by dietary herbs supplementation. Furthermore, some authors have observed that herbs could modify intestinal microbiota by inhibiting pathogenic microorganism growth and promoting probiotic microorganism growth, as a result, enhanced the nutrient digestibility (Guo et al. 2004; Giannenas et al. 2018).

Herb and its extracts have been shown to benefit immune function of broilers (Kuralkar and Kuralkar 2021; Long et al. 2021). IgM, IgG, and IgA are the main immunoglobulins, which played key roles in immune functions of poultry (Herich, 2017). In this study, RD supplementation increased serum IgA (d 21) and IgG (d 42) levels of broilers. In addition, the immune responses were more pronounced in the ED group, with enhanced contents of IgA and IgM (d 21 and 42) as well as IgG (d 21). Similar results were reported by Song et al. (2018), who demonstrated that dietary enzymatically treated A. annua supplementation increased the intestinal secretory immunoglobulin A and IgG contents of broilers. It has been shown that polyphenols and polysaccharides in herbs could strengthen the phagocytic function of macrophages, elevate the lymphocyte transformation and promote antibody formation (Han et al. 2003; Lv et al. 2018). In this sense, the superior effects of ED on humoral immune response of broilers may be related to the higher contents of these bioactive substance. The immune response is controlled by a complex interplay among various cytokines (Choi and Lillegaard 2000). Therefore, the cytokine contents in serum were measured in this test, and the results shown that ED supplementation increased serum IL-10 content at 21 d and IFN-γ content at 42 d. It has been revealed that IL-10 and IFN-γ could initiate cell-mediated immune responses (Park et al. 2008; Nagata and Nishiyama 2021). All these results imply that dietary supplementation with ED could enhance the IL-10 and IFN-γ levels, and then stimulate the antibody production. Furthermore, the enhanced immune function of broilers in this study may be the main contributors for the improvement in growth performance by ED.
Conclusions
In conclusion, broilers fed with ED rather than RD showed decreased FCR, improved breast muscle rate and meat water holding capacity, enhanced apparent OM, EE and CP digestibility, and increased serum Ig, IL-10 and IFN-γ contents. Therefore, ED would be more effective than RD in improving feed conversion rate, and carcase characteristics, meat quality, nutrient digestibility, and immune function of broilers.

Ethical approval
The study was conducted according to the institutional guidelines for the care and use of laboratory animals in China (The State Science and Technology Commission of China, 1988) and approved by the Institutional Animal Care and Use Committee of Inner Mongolia Agricultural University (protocol number 2020065).

Software and data repository resources
None of the data were deposited in an official repository.

Disclosure statement
The authors certify that there is no potential conflict of interest to disclose.

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