**Effect of Broussonetia papyrifera L. (paper mulberry) on growth performance, carcase traits, meat quality and immune performance in Hu ram lambs**

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**ABSTRACT**

This study was carried out in an attempt to evaluate the impact of *Broussonetia papyrifera* as a roughage substitute at different levels on carcase traits, growth performance, meat quality and immune performance in Hu ram lambs. Sixty Hu rams (5 months of age, 26.70 ± 2.14 kg body weight) were randomly divided into four groups. The treatments comprised *B. papyrifera* supplementation at levels of 0% (G0), 30% (G30), 60% (G60) and 100% (G100) of roughage feed. The results suggested that diet supplemented with *B. papyrifera* (G100 group) caused a higher average weight gain (AWG) and average daily gain (ADG) than those of G0 group. The highest carcase weight was observed in the G60 group. The chemical and physical properties of the *longissimus dorsi* muscle of Hu rams showed no significant differences (*p* > 0.05). For fatty acid, the G60 group had significantly lower content of saturated fatty acids (SFAs), higher contents of monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs) and higher PUFA/SFA ratio than other groups (*p* < 0.05). In terms of the immune response, G60 and G100 groups significantly showed a significant rise in the immunoglobulins (IgG, IgA and IgM) (*p* < 0.05). This study indicated multiple beneficial effects of the inclusion of *B. papyrifera* (60% of the roughage feed) on the growth performance, carcase traits, meat quality and immune response in Hu rams. It could be used as a high-quality unconventional feedstuff for rams.

**HIGHLIGHTS**

- The addition of *Broussonetia papyrifera* to the diet resulted in a significant improvement in the average weight gain (AWG) and average daily gain (ADG) of Hu rams.
- Adding appropriate proportion of *B. papyrifera* in diets positively modulates fatty acid percentage in the *longissimus dorsi* muscle, and also increases immunoglobulins (IgG, IgA and IgM) in blood.
- *Broussonetia papyrifera* could be used as a high-quality unconventional feedstuff for rams and has a positive effect on their growth performance, meat quality and immune performance.

**Introduction**

With the increasing demand for animal production in the contemporary world as well as the inadequate quality of conventional forage and scarcity of crude protein-feedstuffs in many developing countries, including China, there is an increasing demand for sufficient and nutritious forage (Liu and Wang 2008; Li et al. 2017). For sustainable intensification of ruminant industries, it is imperative to explore the potential of high-quality unconventional feedstuff resources.

*Broussonetia papyrifera* L. (paper mulberry), an important plant native to eastern Asia, is used in many applications such as in papermaking, bark-cloth making, medicine and livestock breeding and has proved to be an ecologically, economically and medicinally important plant (Zhai et al. 2012; Sakamoto and Okada 2013; Peng et al. 2019). Chinese scientists have discovered and cultivated a new hybrid of *B. papyrifera* species with a high crude protein content (Shen and Peng 2017). The stems and leaves of this plant contain crude protein content up to 18–22%, which is similar to that of alfalfa (20%) (Peng et al. 2019). This species of *B. papyrifera* has been identified to contain more than 40 flavonoids and terpenes that...
The current work aims at determining the influence of *B. papyrifera* supplementation at 0%, 30%, 60% and 100% of roughage feed. Moreover, these factors have proven that this hybrid *B. papyrifera* species is a potential source of superior quality feed that can replace protein ingredients in ruminant production, and thus, contribute to resolve the feedstuff deficiency.

The current work aims at determining the influence of *B. papyrifera* on growth performance, meat quality, carcase traits, blood characteristics and immune performance in Hu rams.

### Materials and methods

#### Experimental design and treatments

A total of 60 Hu rams of around five-month of age, with average initial body weight (IBW) of 26.70 ± 2.14 kg, were randomly divided into four treatment groups comprising 15 animals each, and 5 rams were raised in a same pen. The treatments involved *B. papyrifera* (hay) supplementation at 0%, 30%, 60% and 100% of roughage feed (Table 1). *Broussonetia papyrifera* consisted of (mean values, g/kg DM): 317.50 of dry matter, 194.7 of crude protein, 78.56 of crude fat, 116.96 of crude fibre, 136.1 of crude ash and 5.8 of phosphorus. All diets were kept at a concentrate roughage ratio of 60:40, and diet nutrients were formulated to meet the NRC requirements.

### Table 1. Ingredient and chemical composition of incubation substrate (DM basis; g/kg).

| Ingredients       | G0   | G30  | G60  | G100 |
|-------------------|------|------|------|------|
| Ingredients       |      |      |      |      |
| Corn              | 390  | 390  | 390  | 390  |
| Wheat bran        | 30   | 30   | 30   | 30   |
| Soybean meal      | 140  | 140  | 140  | 140  |
| Peanut vine       | 400  | 280  | 160  | 0    |
| Paper mulberry    | 0    | 120  | 240  | 400  |
| 4% Premix         | 40   | 40   | 40   | 40   |
| Diet composition  |      |      |      |      |
| Crude protein     | 125.10| 126.25| 129.85| 134.00|
| Neutral detergent fibre | 494.26| 507.27| 513.56| 535.83|
| Crude fat         | 135.05| 135.46| 132.53| 127.11|

The treatments involved *B. papyrifera* (hay) supplementation at 0%, 30%, 60% and 100% of roughage feed.

For the analysis of fatty acids, lipids were extracted according to the method defined by Folch et al. (1957). Fatty acids composition analyses were carried out with a gas chromatograph (GC–MS; Shimadzu QP 2010 Ultra, Kyoto, Japan) equipped with a 100 m × 0.25 nm ID × 0.2 µm fused silica capillary column. Helium was used as the carrier gas. The temperature was set at 100°C for 5 min, then it was increased at a rate of 4°C/min to 240°C, and was maintained at 240°C for 30 min. Individual fatty acid peaks were identified by comparing the retention times with those for authentic FAME standards run under the same operating conditions. The results are expressed as the percentage of the total identified fatty acids.

For hydrolysed amino acid analysis, the sample was weighed into a glass bottle and 6 mol/L of HCl was added. After filling nitrogen, the mixture was...
hydrolysed at 110 °C for 22–24 h. Subsequently, the hydrolysate was transferred to a 50 mL volumetric flask and diluted to calibration tail with ultrapure water. The amino acid analyser (LA-8080 system: Hitachi Inc., Tokyo, Japan) was employed for the hydrolysed amino acid analysis.

Before slaughter, samples of blood were drawn from the jugular vein of individual rams into a 5 mL heparinised collection tubes. Samples were centrifuged for 15 min at 3000 g at 4 °C. For further analysis, the supernatant was separated. An automatic biochemistry analyser (IDEXX Catalyst One chemistry analyser) was used to estimate the lysozyme, catalase (CAT), total antioxidant capacity (T-AOC), total superoxide dismutase (T-SOD), malondialdehyde (MDA), high-density lipoprotein (HDL), total cholesterol (T-CHOL), low-density lipoprotein (HDL), blood urea N (BUN), albumin (ALB), total protein (TP), globulin (GLB), glucose (GLU) and alkaline phosphatase (ALP). Immunoglobulin G (IgG), Immunoglobulin A (IgA) and immunoglobulin M (IgM) were estimated using their respective ELISA test kit (Nanjing Jiancheng Technology Co., Ltd, Nanjing, China).

**Statistical analysis**

Analysis of all obtained data was made using a one-way analysis of variance. Differences among means were determined using Duncan’s new multiple tests for all the four treatments. All the statistical analysis was conducted using SPSS version 22.0 software (SPSS Inc., Chicago, IL).

**Results**

**Growth performance and carcase traits**

Table 2 shows growth performance, including IBW, FBW, DMI, AWG and ADG. There were no significant differences in DMI among all groups (p > .05). While IBW and FBW were found to be unaffected by *B. papyrifera* (p > .05), a significant increase in AWG and ADG was seen with *B. papyrifera* supplementation at levels of 30% and 60% (G30 and G60 groups) (p < .05). G60 treatment group showed a significant higher carcase weight than G100 group (p < .05). There were no significant differences in ADG among the other groups (p > .05).

Diet supplemented with *B. papyrifera* resulted in a significant improvement in the lion-eye area of rams (p < .05). A significant increase in live body weight was seen with *B. papyrifera* supplementation at levels of 30% and 60% (G30 and G60 groups) (p < .05). G60 treatment group showed a significant higher carcase weight than G100 group (p < .05), while no difference was observed between the other treatment groups (p > .05). The dressing percentage was found to be unaffected by *B. papyrifera* (p > .05) (Table 2).

**Meat quality**

Table 3 shows the chemical-physical properties of *longissimus dorsi* muscle in Hu rams receiving diets supplemented with different levels of *B. papyrifera* (0%, 30%, 60% and 100%). No significant differences were observed between all treatment groups in terms of pH-0 h, ph-24 h, moisture, crude protein, intramuscular fat percentage, crude ash, water loss rate, shear force value and L*, a*, b* values of the *longissimus dorsi* muscle (p > .05).

No differences in Asp, Thr, Ser, Glu, Ala, Val, Met, Phe, Arg and Pro contents in *longissimus dorsi* muscle were found in this study when *B. papyrifera* was added (p > .05). However, there was a significant reduction of the Gly, Ile, Leu and His values in the G60 treatment group (p < .05). Except for Leu, G0 and G60 groups were not significantly different (p > .05) (Table 4).

Table 5 elaborates on the fatty acid compositions of *longissimus dorsi* muscle. Among the saturated fatty...
### Table 3. Effect of B. papyrifera on chemical-physical properties of Hu rams meat.

| Item                        | G0         | G30        | G60         | G100        | p-Value |
|-----------------------------|------------|------------|-------------|-------------|---------|
| **Conventional components analysis** |            |            |             |             |         |
| pH-0 h                      | 5.26 ± 0.09 | 5.39 ± 0.16 | 5.31 ± 0.19 | 5.26 ± 0.08 | NS      |
| pH-24 h                     | 4.93 ± 0.06 | 5.08 ± 0.16 | 4.99 ± 0.18 | 4.90 ± 0.12 | NS      |
| pH-48 h                     | 4.55 ± 0.04 | 4.73 ± 0.05 | 4.54 ± 0.03 | 4.49 ± 0.02 | *       |
| Moisture, %                 | 73.81 ± 0.60 | 73.09 ± 1.27 | 74.12 ± 0.98 | 73.47 ± 1.16 | NS      |
| Crude protein, %            | 22.21 ± 0.72 | 25.74 ± 0.29 | 30.69 ± 0.22 | 27.25 ± 0.46 | NS      |
| Intramuscular fat, %        | 2.85 ± 0.15  | 3.04 ± 0.16  | 2.76 ± 0.13  | 2.80 ± 0.11  | NS      |
| Crude ash, %                | 1.18 ± 0.07  | 1.19 ± 0.04  | 1.16 ± 0.09  | 1.21 ± 0.04  | NS      |
| **Chemical-physical properties analysis** |            |            |             |             |         |
| Water loss rate, %          | 62.78 ± 2.68 | 63.12 ± 5.41 | 62.12 ± 2.33 | 63.89 ± 3.54 | NS      |
| Shear force value, kg/cm²   | 3.03 ± 0.16  | 3.12 ± 0.25  | 3.16 ± 0.31  | 3.09 ± 0.25  | NS      |
| L* value                    | 30.21 ± 2.77 | 27.39 ± 1.16 | 29.39 ± 1.24 | 29.49 ± 1.21 | NS      |
| a* value                    | 14.31 ± 0.89 | 14.58 ± 0.73 | 15.41 ± 0.87 | 14.44 ± 0.41 | NS      |
| b* value                    | 5.58 ± 0.60  | 5.75 ± 0.42  | 6.13 ± 0.13  | 6.89 ± 0.58  | NS      |

*NS* means no significant difference (*p* > 0.05); **means significant difference (*p* < 0.05).

The treatments comprised *B. papyrifera* supplementation at levels of 0% (G0), 30% (G30), 60% (G60) and 100% (G100) of roughage feed.

### Table 4. Effect of *B. papyrifera* on amino acid composition in the longissimus dorsi muscle of Hu rams.

| Item   | G0         | G30        | G60         | G100        | p-Value |
|--------|------------|------------|-------------|-------------|---------|
| Asp    | 1.91 ± 0.15 | 1.97 ± 0.06 | 1.81 ± 0.21 | 1.94 ± 0.05 | NS      |
| Thr    | 0.94 ± 0.06 | 0.97 ± 0.04 | 0.88 ± 0.05 | 0.95 ± 0.03 | NS      |
| Ser    | 0.92 ± 0.06 | 0.95 ± 0.03 | 0.86 ± 0.09 | 0.91 ± 0.03 | NS      |
| Gly    | 3.13 ± 0.24 | 3.21 ± 0.17 | 2.85 ± 0.07 | 3.10 ± 0.11 | NS      |
| Ala    | 1.18 ± 0.08 | 1.20 ± 0.04 | 1.09 ± 0.13 | 1.18 ± 0.04 | NS      |
| Val    | 0.81 ± 0.07 | 0.87 ± 0.05 | 0.76 ± 0.07 | 0.84 ± 0.05 | NS      |
| Met    | 0.34 ± 0.04 | 0.34 ± 0.06 | 0.31 ± 0.06 | 0.34 ± 0.04 | NS      |
| Ile    | 0.67 ± 0.05 | 0.70 ± 0.04 | 0.60 ± 0.08 | 0.71 ± 0.03 | *       |
| Leu    | 1.54 ± 0.11 | 1.58 ± 0.07 | 1.40 ± 0.19 | 1.58 ± 0.02 | *       |
| Tyr    | 0.65 ± 0.05 | 0.68 ± 0.04 | 0.58 ± 0.10 | 0.78 ± 0.08 | *       |
| Phe    | 0.87 ± 0.06 | 0.90 ± 0.04 | 0.82 ± 0.12 | 0.89 ± 0.02 | NS      |
| Lys    | 1.77 ± 0.12 | 1.81 ± 0.08 | 1.61 ± 0.22 | 1.78 ± 0.05 | *       |
| His    | 0.59 ± 0.04 | 0.63 ± 0.03 | 0.55 ± 0.08 | 0.63 ± 0.01 | *       |
| Arg    | 1.29 ± 0.13 | 1.27 ± 0.06 | 1.36 ± 0.12 | 1.24 ± 0.03 | NS      |
| Pro    | 2.66 ± 0.27 | 2.74 ± 0.12 | 2.52 ± 0.24 | 2.64 ± 0.14 | NS      |

*NS* means no significant difference (*p* > 0.05); ** means significant difference (*p* < 0.05).

The treatments comprised *B. papyrifera* supplementation at levels of 0% (G0), 30% (G30), 60% (G60) and 100% (G100) of roughage feed.

Acids (SFAs) that were significantly influenced by the treatment G60, there were decreased levels of C14:0, C16:0 and C18:0 (*p* < 0.01). Among the monounsaturated fatty acids (MUFAs), we observed increased levels of C15:1 and C17:1 in G60 group (*p* < 0.01). The levels of C16:1 (cis-9) and C18:1 (cis-9) were significantly reduced in the G60 and G100 groups (*p* < 0.01). Among the polyunsaturated fatty acids (PUFAs), the levels of C18:2 (n-6) and C20:4 (n-6) were significantly increased in G60 group (*p* < 0.01). The content of total SFA was significantly reduced in G60 group, however, the content of MUFA and PUFA were significantly increased in G60 group. The PUFA:SFA ratio also was significantly higher in G60 group (*p* < 0.01) (Table 5).

### Blood characteristics and immune performance

No differences were observed in lysozyme, CAT, MDA, T-SOD, T-CHO, TP or ALB among four treatment groups (*p* > 0.05). From the immune response, IgG, IgA and IgM of G60 and G100 groups were found to be higher than that of G0 and G30 groups (*p* < 0.05), except for IgM, there was no significant difference between G30 and G100 (p > 0.05). T-AOC was significant greater for the G100 group compared with G0 and G30 groups (*p* < 0.05), besides, no difference was observed between the other three treatment groups (*p* > 0.05). G30 and G60 groups showed significantly higher HDL and LDL contents compared with G100 group (p < 0.05), and there was no significant difference between G0 and G100 groups (p > 0.05). For GLU content, the G60 and G100 groups showed significantly higher value than other two groups (p < 0.05). Inclusion of *B. papyrifera* significantly increased BUN, ALP, IL-2, IL-6, IL-1β, TNF-α and IFN-γ of Hu rams (p < 0.05) (Table 6).

### Discussion

In this work, a diet supplemented with *B. papyrifera* resulted in a significant improvement in the growth performance of Hu rams. The outcome of our investigation indicated that AWG and ADG of Hu rams manifested a significant increase (p < 0.05) as the content of *B. papyrifera* supplementation reached 100% of roughage feed. This is an indication that supplementation of *B. papyrifera* to diet is a beneficial way to accelerate the growth performance of Hu rams. This might be attributed to the low fibre and high protein content of *B. papyrifera* (Peng et al. 2019). The lower fibre content and higher protein content might cause higher protein and energy digestibility of diet, which may subsequently have increased the provision of energy for the animal. Furthermore, the loin eye area measurement in *B. papyrifera* groups were significantly higher than the control group, indicating...
supplementation of *B. papyrifera* to diet is benefit to muscular development.

The fatty acid concentration and composition of meat is an important aspect of meat quality from consumer perception as well as public health (Yousefi et al. 2012), they correlated with the development and/or prevention of non-communicable chronic diseases in humans. The vast majority of fatty acids in the *longissimus dorsi* muscle of sheep are in general regarded as C16 and C18 (Yakan and Unal 2010) and consist of stearic acid, palmitic acid, and oleic acid (Park and Washington 1993; Wood et al. 2008), followed by linoleic acid. Similar results were found in our present study. In our study, we found that the G60 group had lower content of SFA, higher contents of MUFA and PUFA, and higher PUFA/SFA ratio, which indicated that adding appropriate proportion of *B. papyrifera* in diets positively modulate fatty acid percentage. Previous studies have shown that SFA raise LDL-cholesterol levels, which could increase the risk of developing cardiovascular, however, MUFA and PUFA lowers it (Wood and Enser 2017). Many authorities have recommended that the contributions of SFA to dietary energy intake should be reduced (Wood and Enser 2017). Our dramatic effects on fatty acid concentration might be due to the different rumen microbial activities. All the changes of fatty acid content are related to the manipulation of rumen fermentation patterns (Wood and Enser 1997). Unlike monogastric animals, the meat fatty acid composition in ruminants can be altered by the dietary changes and action of rumen microorganisms. From our results, we found

| Item                  | G0       | G30      | G60      | G100     | p Value   |
|-----------------------|----------|----------|----------|----------|-----------|
| Lysozyme, ug/mL       | 1.68 ± 0.12 | 1.59 ± 0.32 | 1.78 ± 0.45 | 1.74 ± 0.24 | NS        |
| T-AOC, U/mL           | 11.04 ± 1.22 | 10.78 ± 0.63 | 13.25 ± 0.67 | 16.42 ± 0.93 | **        |
| CAT, U/mL             | 5.32 ± 0.56 | 5.12 ± 0.15 | 5.49 ± 0.54 | 5.45 ± 0.12 | NS        |
| MDA, mmol/mL          | 1.33 ± 0.12 | 0.76 ± 0.02 | 0.54 ± 0.08 | 0.54 ± 0.06 | NS        |
| T-SOD, U/mL           | 14.99 ± 1.24 | 14.78 ± 1.58 | 15.12 ± 2.17 | 14.99 ± 2.54 | NS        |
| TG, mmol/L            | 0.21 ± 0.01 | 0.20 ± 0.01 | 0.46 ± 0.02 | 0.26 ± 0.01 | NS        |
| T-CHO, mmol/L         | 1.76 ± 0.02 | 1.71 ± 0.05 | 1.87 ± 0.08 | 1.37 ± 0.02 | NS        |
| HDL, mmol/L           | 0.93 ± 0.02 | 0.98 ± 0.03 | 1.00 ± 0.01 | 0.81 ± 0.02 | NS        |
| LDL, mmol/L           | 0.46 ± 0.01 | 0.53 ± 0.01 | 0.58 ± 0.03 | 0.39 ± 0.02 | NS        |
| BUN, mmol/L           | 5.83 ± 0.23 | 6.83 ± 1.01 | 7.33 ± 0.45 | 7.85 ± 0.21 | NS        |
| TP, g/L               | 63.08 ± 6.54 | 58.18 ± 2.88 | 62.23 ± 4.32 | 58.28 ± 4.21 | NS        |
| ALB, g/L              | 39.02 ± 2.35 | 36.91 ± 3.54 | 36.41 ± 1.28 | 37.45 ± 2.11 | NS        |
| GLU, mmol/L           | 4.55 ± 0.12 | 5.62 ± 0.10 | 7.50 ± 0.32 | 6.80 ± 0.22 | **        |
| ALP, u/L              | 372.67 ± 15.21 | 554.88 ± 21.87 | 497.40 ± 18.99 | 649.00 ± 25.65 | **        |
| IgA, ug/ml            | 29.69 ± 1.12 | 29.42 ± 0.56 | 43.04 ± 2.12 | 34.40 ± 1.26 | **        |
| IgG, ug/ml            | 46.53 ± 1.56 | 45.26 ± 2.01 | 58.56 ± 2.15 | 55.74 ± 1.02 | **        |
| IgM, ug/ml            | 40.14 ± 2.43 | 42.30 ± 1.24 | 53.47 ± 0.98 | 44.46 ± 1.58 | **        |

**NS** means no significant difference (*p* > 0.05); **"** means significant difference (*p* < 0.05); "**" means extremely significant difference (*p* < 0.01).
that a high proportion of *B. papyrifera* negatively modulate fatty acid percentage. This might be due to the high tannin and lignin contents in *B. papyrifera*, which are not conducive to the rumen microbial fermentation. Previous studies have shown that high anti-nutrient factors (such as tannin and lignin, etc.) concentrations are always associated with poor rumen function (Mcsweeney et al. 2001).

In many countries around the world, the objectionable cooking smell and the flavour of the cooked meat directly affect consumer acceptance of mutton (Wong et al. 1975). Previous studies have shown that the key flavouring agents responsible for mutton flavour are short-chain fatty acids and stearic acid (Caporaso et al. 1977). For both taste panels, the odour and flavour of mutton were found to correlate positively with the concentration of stearic acid (Sanudo et al. 2000). In this study, short-chain fatty acid was not detected in all groups and stearic acid concentration was not affected by *B. papyrifera*, which demonstrates that no flavour changes resulted in mutton from being fed on the *B. papyrifera*.

An integrated index of nutrient supply in relation to the utilisation of nutrients of animal is represented by the blood metabolites (Si et al. 2018). This study suggests that diets supplemented with *B. papyrifera* could potentially induce positive effects on serum biochemical parameters in Hu rams. BUN and GLU concentrations are commonly regarded as key indicators for the status of protein and carbohydrate metabolism in animals which are relevant for growth performance (Zhou et al. 2015; Liu et al. 2018), BUN is categorised as the in vivo protein degradation product (Zhou et al. 2015), whereas serum GLU level is the most commonly used indicator in animals indicating their ability to supply energy (Wang et al. 2011). Besides ALP is the enzyme contributing to the absorption of Ca and P and protein synthesis (Wang et al. 2011). In this investigation, BUN, ALP, and GLU levels were significantly improved by *B. papyrifera* supplementation in the diet. These positive effects in serum parameters can in part explain the improvement observed in growth performance.

The immune system is complex, controlling a group of cells with an integrated function that is essential to the maintenance of health (Si et al. 2018). IgA, IgG and IgM are key components of the humoral immunity in animals, which could protect the extravascular compartment against microorganisms and pathogenic viruses (Kong et al. 2007). In this study, rams in G60 and G100 groups had a considerably higher IgA, IgG and IgM values compared to those in the G0 group, which might due to the phenolic compounds and flavonoids in the bark and leaves of *B. papyrifera*, which apparently are the main components responsible for the antioxidant activity (Du et al. 2008; Kai et al. 2015). Previous studies have shown that plant flavonoids are a predominant class of plant secondary metabolites with immunity-boosting activities (Middleton 1998; Proestos et al. 2006; Zhao et al. 2011), they can extend the activity of vitamin C, act as antioxidants, and may, therefore, enhance immune functions (Acamovic and Brooker 2005). Si et al. (2018) also observed an increase in IgA, IgG and IgM in the serum of dairy cows with the addition of *B. papyrifera* silage (Si et al. 2018). Furthermore, the increased activity of T-AOC in the serum with *B. papyrifera* addition also indicated that *B. papyrifera* enhanced the antioxidant status of Hu rams.

**Conclusions**

*Broussonetia papyrifera* supplementation at levels of 60% to the diet resulted in a significant improvement in the concentration of MUFA and PUFA in the longissimus dorsi muscle as well as IgG, IgA and IgM in blood. It can, therefore, be concluded that *B. papyrifera* could be used as a high-quality unconventional feedstuff for rams and adding appropriate proportion of *B. papyrifera* in diets has a positive effect on their growth performance, meat quality, and immune performance. The investigation regarding the mechanism of effects of *B. papyrifera* upon growth and immune function of rams needs to be taken up in the future.

**Ethical approval**

All the experiments performed in this study were reviewed and duly passed by the Jiangxi Academy of Sciences Animal Care and Use Committee.

**Disclosure statement**

The authors declare that they have no financial and personal relationships with other people or organisations that can inappropriately influence this work.

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