

## Effects of Urea Phosphate Supplementation on Growth Performance, Carcass Traits, and Meat Quality in Lambs (Postprint)

**Authors:** Zhang Fan, Shoukun Ji, Zhang Naifeng, Jiang Chenggang, Si Bingwen, Tu Yan, Qiyu Diao, Wang Liwen, Ding Jian

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### Abstract

This study aimed to investigate the effects of urea phosphate supplementation on growth performance, slaughter performance, and meat quality of lambs, and to evaluate the safe dosage of urea phosphate in mutton sheep production. Eighty Dorper × Han crossbred F1 male lambs with an average body weight of  $(25.86 \pm 1.06)$  kg were randomly allocated into 5 groups with 8 replicates per group and 2 lambs per replicate. In diets with a forage ratio of 1 : 1, urea phosphate replaced part of the soybean meal-based feed at levels of 0 (control), 0.5%, 2%, 4%, and control group (4.21 kg/cm<sup>2</sup>) (P < 0.05). These results indicate that urea phosphate can be utilized as a nitrogen and phosphorus additive in mutton sheep diets. When urea phosphate supplementation level in lamb feed was 1%, lambs achieved optimal growth and slaughter performance; when the urea phosphate replacement ratio reached 4%, it significantly reduced average daily gain and carcass weight, and increased muscle lightness value; when the urea phosphate replacement ratio was 2%, it represented an effective and safe level, exerting no significant effects on lamb growth performance, slaughter performance, or meat quality except for muscle yellowness value. Therefore, a 1% urea phosphate supplementation level in feed enables lambs to achieve optimal growth performance.

### Full Text

#### Effects of Urea Phosphate Supplemental Level on Growth Performance, Slaughter Performance and Meat Quality of Lambs

ZHANG Fan<sup>1</sup>, JI Shoukun<sup>1</sup>, ZHANG Naifeng<sup>1</sup>, JIANG Chenggang<sup>1</sup>, WANG Liwen<sup>2</sup>, DING Jian<sup>2</sup>, SI Bingwen<sup>1</sup>, TU Yan<sup>1</sup>, DIAO Qiyu<sup>1\*</sup>

(1. Key Laboratory of Feed Biotechnology of the Ministry of Agriculture, Feed Research Institute, Chinese Academy of Agricultural Sciences, Beijing 100081, China; 2. Station of Animal and Veterinary of the Ministry of Agriculture, Beijing 100026, China)

**Abstract:** This experiment aimed to investigate the effects of urea phosphate supplemental level on growth performance, slaughter performance and meat quality of lambs, and to evaluate the safe dosage of urea phosphate for use in lamb production. Eighty  $F_1$  Dorper $\times$ thin-tailed Han crossbred male lambs with an average body weight of  $(25.86\pm 1.06)$  kg were randomly divided into 5 groups with 8 replicates per group and 2 lambs per replicate (P<0.05). In conclusion, urea phosphate can be used as a nitrogen and phosphorus additive in lamb diets. A 1% supplemental level yields optimal growth and slaughter performance. At 4% supplementation, average daily gain and carcass weight are significantly reduced while muscle brightness increases. At 2% supplementation, urea phosphate represents an effective and safe level that does not significantly affect growth performance, slaughter performance or meat quality except for muscle yellowness. Therefore, a 1% supplemental level of urea phosphate in feed enables lambs to achieve optimal growth performance.

**Keywords:** urea phosphate; lamb; average daily gain; slaughter rate; meat quality

**CLC number:** S816.7; S826

## Introduction

With the rapid development of China's livestock industry, soybean, as an important protein feed resource, has become heavily dependent on imports. According to customs data, China's total soybean imports reached 71.4 million tons in 2014, setting a new historical record, while domestic soybean production was only 11.5 million tons that same year, creating obstacles for the sustainable development of China's animal husbandry. Therefore, finding alternative protein feed resources to replace soybeans represents an important measure to alleviate this situation. Urea phosphate is a feed additive that can simultaneously provide non-protein nitrogen (NPN) and phosphorus. Ruminants can utilize urea phosphate to synthesize microbial protein, which is then converted into animal products. Currently, the most commonly used NPN source in ruminants is urea, but practical production faces numerous problems including bitter taste, poor palatability, inconvenient usage, limited feeding amounts, and rapid ammonia release that can easily cause urea poisoning. Urea phosphate is a ruminant feed additive that provides both nitrogen and phosphorus with slower ammonia release than urea, making it a novel and safe NPN source. In animal husbandry, urea phosphate is not only a Class I additive legally recognized in European Community feed regulations but also a ruminant-specific nutritional additive and phosphorus supplement recommended by the Food and Agriculture Organization (FAO). Research on urea phosphate in China began in the mid-to-late 1980s. A beef cattle fattening trial conducted in Zhoukou, Henan using

urea phosphate produced by Guizhou Tiande Feed Additive Factory found that adding 50 g urea phosphate per head increased average daily gain to 1,213 g/d, representing a 380 g/d increase compared with the control group. An acute toxicity test conducted by the Yunnan Chemical Research Institute on 50 Kunming mice aged 18-23 days found that the median lethal dose of urea phosphate was  $(3.9 \pm 0.67)$  g/kg BW, classifying it as a low-toxicity substance according to food additive acute toxicity classification standards. Zhang et al. reported that urea phosphate supplementation had no significant effect on calcium and phosphorus content in the longissimus dorsi muscle of lambs. Mutton is characterized by high nutritional value and low cholesterol content. With improving living standards, mutton consumption is increasing rapidly, particularly demand for lamb meat. Growing health consciousness has heightened consumer attention to meat quality, which is typically evaluated using meat color, pH, drip loss and other indicators. Urea phosphate represents an effective, safe and low-toxicity NPN feed additive for ruminants, but few studies have reported its effects on lamb growth performance, slaughter performance and meat quality—factors that directly affect producer economic benefits and consumer acceptance and preference. This study investigated the effects of different urea phosphate supplemental levels on growth performance, slaughter performance and meat quality indicators including meat color, pH, shear force and drip loss of fattening lambs, providing reference for urea phosphate utilization in lamb fattening.

## Materials and Methods

### 1.1 Experimental Time and Location

The experiment was conducted from April 8 to June 20, 2014 at Tongying Sheep Farm in Daxing District, Beijing. The adaptation period lasted 12 days and the experimental period lasted 60 days, for a total duration of 72 days.

### 1.2 Experimental Design

A single-factor randomized block design was employed. Eighty healthy F<sub>1</sub> Dorper × thin-tailed Han crossbred male lambs aged 3 months with an average body weight of  $(25.86 \pm 1.06)$  kg were randomly divided into 5 groups according to body weight, with 8 replicates per group and 2 lambs per replicate (16 lambs per treatment). The control group was fed a concentrate without urea phosphate, while experimental groups were fed concentrates in which 1%, 2%, 4% and 8% urea phosphate partially replaced soybean meal and other ingredients. Lambs were fed twice daily (08:00 and 20:00). Daily feed allowance was adjusted based on the previous day's intake, with forage fed first followed by concentrate. The concentrate-to-forage ratio was maintained at 1:1 throughout the experimental period, with ad libitum access to feed. The actual urea phosphate intake levels in each group were 0 (control), 0.5%, 1%, 2% and 4%. Lambs were housed in a completely confined system with 2 lambs per pen, free access to water, and conventional lighting, temperature and immunization programs.

### 1.3 Experimental Diets

The nutrient levels of experimental diets were formulated according to NRC (2007). The concentrate was a powdered feed prepared by Beijing Zhongnongxing Feed Technology Co., Ltd., and the forage was soybean straw. Diets were formulated to maintain consistent nutrient levels except for phosphorus according to experimental requirements. The concentrate composition and nutrient levels are shown in Table 1. Nutrient levels were determined according to “Feed Analysis and Feed Quality Detection Technology.”

### 1.4 Experimental Materials

Urea phosphate used in the experiment was colorless transparent prismatic crystals provided by Sinochem Yunlong Company, containing 16% NPN and 17% phosphorus.

### 1.5 Measurements

**1.5.1 Growth Performance** Lamb body weight was measured before morning feeding on days 1 (beginning of adaptation), 13, 43 and 73 to calculate average daily gain (ADG) during the adaptation period (0-12 d), first month of experimental period (13-42 d), second month of experimental period (43-72 d) and entire experimental period.

**1.5.2 Slaughter Performance** At the end of the experiment, lambs were fasted for 12 h (with free access to water) before measuring live weight. Six lambs were randomly selected from each group for slaughter by jugular exsanguination. After removal of head, blood, tail, skin, hooves and viscera, carcass weight was measured and slaughter rate was calculated.

Slaughter rate (%) = (carcass weight / live weight before slaughter) × 100.

**1.5.3 Meat Quality Determination** After slaughter, the longissimus dorsi muscle from the same location was selected from each carcass for meat quality analysis. Measurements were conducted as follows: (1) Meat color: Three longissimus dorsi muscle samples from the last thoracic vertebra were collected 1-2 h post-slaughter for color measurement using a TCP2 automatic colorimeter to determine redness (*a*), *yellowness* (*b*) and lightness ( $L^*$ ) values. Each sample was measured three times and the average was used as the final value. (2) pH measurement: Three longissimus dorsi samples were collected 45 min post-slaughter and pH was measured using a Testo 205 pH meter. Three points were measured on each sample and the average was used as the final value. (3) Shear force measurement: Three mutton samples measuring 6 cm × 3 cm × 3 cm were cut along the muscle fiber direction, heated in a sealed bag in an 80°C water bath for 30 min, then stored overnight at 4°C. After removal, meat columns were cut along the fiber direction using a 1.27 cm diameter corer, and shear force was measured using a TMS-PRO texture analyzer. Each sample

was measured three times and the average was used as the final value. (4) Drip loss measurement: Three longissimus dorsi samples measuring 5 cm × 3 cm × 2 cm were weighed for initial weight (W1), then hung with wire in disposable plastic cups without contacting the cup walls, and stored at 4°C. After 24 h, samples were removed, surface moisture was absorbed with paper towels, and final weight (W2) was measured. The calculation formula was:

$$\text{Drip loss (\%)} = [(W1 - W2) / W1] \times 100.$$

### 1.6 Data Processing

Experimental data were initially processed using Excel 2013, then subjected to one-way ANOVA using SPSS 20.0 statistical software. Data were expressed as means ± standard deviation (means±SD). Differences were considered significant at P<0.05 and highly significant at P<0.01.

## Results

### 2.1 Effects of Dietary Urea Phosphate Supplemental Level on Lamb Growth Performance

As shown in Table 2 , the 4% group exhibited significantly lower ADG during the adaptation period, first month, second month and entire experimental period compared with other groups (P<0.01), while no significant differences were observed among other groups (P>0.05). The 1% group achieved the highest ADG at each stage. Compared with the control group, all supplemented groups except the 4% group showed ADG values close to or higher than the control group.

### 2.2 Effects of Dietary Urea Phosphate Supplemental Level on Lamb Slaughter Performance

As shown in Table 3 , the 4% group had significantly lower live weight before slaughter and carcass weight compared with other groups (P<0.01), while no significant differences were observed among other experimental groups and the control group (P>0.05). Urea phosphate supplementation had no significant effect on slaughter rate (P>0.05), though the 2% group showed lower slaughter rate than the control group, and the 1% group achieved the highest slaughter rate.

#### 2.3.1 Lamb Meat Color

As shown in Table 4 , urea phosphate supplementation significantly affected lamb meat color (P<0.05). For redness values, the 2% group was significantly higher than the 4% group (P<0.05), with no significant differences among other groups (P>0.05), though all supplemented groups showed higher redness values than the control group. The 2% group exhibited significantly higher yellowness than other groups (P<0.05). The 4% group showed significantly higher lightness

than other groups ( $P < 0.05$ ), with no significant differences among other groups ( $P > 0.05$ ).

### 2.3.2 Lamb pH, Shear Force and Drip Loss

As shown in Table 5, urea phosphate supplementation had no significant effect on pH or drip loss ( $P > 0.05$ ), though there was a trend toward increased drip loss with supplementation ( $0.05 < P < 0.10$ ). Regarding shear force, the 4% group was significantly lower than the 0.5%, 1% and 2% groups ( $P < 0.05$ ), while the 1% group was significantly higher than the control group ( $P < 0.05$ ).

## Discussion

### 3.1 Effects of Dietary Urea Phosphate Supplemental Level on Lamb Growth Performance

Average daily gain during different periods directly reflects the effectiveness of urea phosphate as an NPN feed source for lamb fattening. In this experiment, only the 4% group showed significantly lower ADG at all stages compared with other groups, while ADG values at other supplementation levels showed no significant differences from the control group. This indicates that urea phosphate supplementation up to 2% can maintain normal lamb growth. The 1% group achieved the highest ADG at each stage, with ADG during the experimental period 13.40 g/d higher than the control group, suggesting that 1% supplementation is more conducive to lamb growth. Urea phosphate has strong acidity, with a pH of 1.89 for a 1% solution. When supplementation exceeds ruminant tolerance, it can easily cause rumen acidosis. The substantially lower ADG in the 4% group, with some lambs showing negative growth, likely resulted from acidosis at this supplementation level, which restricted feed intake, reduced digestive and metabolic function, and consequently impaired growth. Wang et al. studied the effects of urea supplementation on growth performance of Dorper × thin-tailed Han crossbred lambs and found that ADG at 0.5% and 1.5% supplementation levels showed no significant differences from the control group, though values were lower than the control, indicating that urea supplementation can restrict lamb growth to some extent. In this experiment, urea phosphate supplementation groups except the 4% group showed trends toward improved ADG. Puga et al. demonstrated that slow ammonia release in the rumen helps improve feed intake and rumination performance, thereby increasing ADG. The superior effects of urea phosphate observed in this experiment compared with urea feeding effects reported by Wang et al. may be related to the slow ammonia release of urea phosphate in the rumen.

### 3.2 Effects of Dietary Urea Phosphate Supplemental Level on Lamb Slaughter Performance

Average daily gain directly affects live weight before slaughter and carcass weight. The 4% group, which showed significantly lower ADG at all stages, consequently

had significantly lower live weight before slaughter and carcass weight. Slaughter rate is an important indicator for evaluating animal growth and slaughter performance. In this experiment, no significant differences in slaughter rate were observed among groups, though the 1% group showed higher slaughter rate than the control group. Combined with live weight before slaughter and carcass weight, these results indicate that urea phosphate as an NPN source can improve slaughter performance at appropriate supplementation levels. Supplementation up to 2% is safe and effective for lamb production, with optimal slaughter performance achieved at 1% supplementation.

### 3.3.1 Lamb Meat Color

Meat color is a critical indicator for consumer purchase decisions and determines meat acceptability. Consumers evaluate meat quality primarily through visual assessment of color, with bright red and glossy appearance being the ideal. Meat color depends on myoglobin and hemoglobin in muscle, with the former accounting for 80-90% of meat pigments under adequate bleeding conditions. Myoglobin appears purplish-red, but becomes bright red when combined with oxygen to form oxymyoglobin. Higher redness values indicate better meat color and freshness, while higher yellowness indicates poorer color, and higher lightness indicates better gloss. In this experiment, no significant differences in redness values were observed compared with the control group, though there was a trend toward improved redness. Only the 2% group showed significantly higher yellowness than the control group, while the 4% group exhibited significantly higher lightness. Since optimal growth and slaughter performance was achieved at 1% supplementation, this level is appropriate and improved muscle redness, enhancing bright red coloration. Although the 2% supplementation level resulted in significantly higher yellowness, it showed no significant differences in redness or lightness compared with the control group while maintaining good growth and slaughter performance. Therefore, this supplementation level can also be considered appropriate.

### 3.3.2 Lamb pH, Shear Force and Drip Loss

pH is an important indicator for meat quality assessment and reflects post-slaughter muscle glycogenolysis rate. pH directly affects meat color, tenderness, cooking loss and preservation, significantly influencing meat quality. Rapid pH decline or glycogen depletion can increase shear force, reduce tenderness and result in pale, soft and exudative (PSE) meat, while insufficient glycogen degradation with pH >6.5 produces dark, firm and dry (DFD) meat. Normal lamb pH at 45 min post-slaughter ranges from 6.0-6.5, with high pH meat having lower odor and flavor characteristics that decrease further as pH increases. In this experiment, all groups had pH values within the normal range with no significant differences among groups. Except for the 0.5% group, all supplemented groups had lower pH than the control group, indicating that urea phosphate supplementation does not affect ideal odor and flavor and may even provide

slight improvement. Wang et al. reported that urea supplementation had no significant effect on lamb pH, with all groups within the normal range. Wang et al. also found that urea supplementation at 0.25-0.75% had no significant effect on leg muscle pH in rabbits. These results are consistent with our findings on urea phosphate effects on lamb pH. Since both urea phosphate and urea are NPN feed additives utilized through similar pathways in ruminants, they produce similar effects.

Muscle tenderness is an important sensory characteristic reflecting resistance to tooth pressure, difficulty in biting or chewing, and muscle flexibility perceived by the tongue. Shear force is closely related to tenderness and can be used to measure it, with higher shear force indicating poorer tenderness. Shear force reflects myofibril, connective tissue and fat content in muscle to some extent. In this experiment, the 1% group showed significantly higher shear force than the control group, while other groups showed no significant differences. However, all supplemented groups except the 4% group had higher shear force than the control group, indicating that urea phosphate can increase muscle shear force. Xia reported shear force values of  $(8.69 \pm 1.14) \text{ kg/cm}^2$  for 6-month-old Dorper  $\times$  thin-tailed Han crossbred lambs using halal slaughter methods. Our experiment with 6-month-old lambs of the same breed showed lower shear force values, also lower than those reported by Wang et al., indicating that urea phosphate supplementation can maintain lamb tenderness. Zhong et al. found that pork shear force increased with slaughter weight. The final average body weights in our experiment were 42.34, 42.57, 43.59, 42.45 and 28.38 kg for the control, 0.5%, 1%, 2% and 4% groups, respectively. The lower shear force in the 4% group may be related to suppressed growth at this supplementation level, which reduced muscle shear force. Although 4% supplementation improved muscle tenderness, it was detrimental to lamb growth.

Drip loss reflects muscle protein water-holding capacity and affects meat juiciness, serving as an important indicator of liquid release from the muscle protein system under gravity without external force. The lost liquid contains substantial water-soluble and sarcoplasmic proteins, so high drip loss not only reduces meat quality and causes economic losses but also decreases nutritional value. Water-holding capacity directly affects meat flavor, color, texture and tenderness, representing important economic value, with lower drip loss indicating better meat quality. In this experiment, no significant differences in drip loss were observed between supplemented groups and the control group, though all supplemented groups showed higher drip loss than the control group, indicating that urea phosphate supplementation can increase lamb drip loss. This may be because dietary urea phosphate increased blood ammonia concentration, thereby increasing muscle ammonia content and affecting water-holding capacity.

## Conclusion

Urea phosphate supplementation at 1% enables lambs to achieve optimal growth and slaughter performance. At 2% supplementation, urea phosphate does not significantly affect lamb growth performance, slaughter performance or meat quality except for significantly increasing muscle lightness value. At 4% supplementation, urea phosphate significantly reduces average daily gain and carcass weight while increasing muscle redness and lightness values.

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