UREA IN POULTRY NUTRITION
– REVIEW –

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Summary

A chronological account of the prospect and problems of utilization of urea in poultry diets is presented. Urea has long been considered as toxic to poultry but recent research, although limited, has yielded controversial results. The main problem appears to be due to the fact that whether or not response to urea is dependent on environment (germ free versus conventional). Although caecum is found to be the major site of ammonia production from urea, the so called nutritional benefit derived by chicken fed urea is probably limited to its utilization for the synthesis of nonessential amino acids in the protein depleted chicken, but not in the protein adequate chicken. More research is needed to monitor production characteristics of birds fed urea and investigate its toxic effect, if any, in some greater detail before recommending this nonprotein nitrogenous substance for inclusion in the poultry diets.
(**Key Words** : Urea, NPN, N, Nutrition, Diets, Ceca, Urinary Urea)

Introduction

Urea, the diamide of carbonic acid having a molecular formula of H_2NCONH_2 and formula weight of 60.06 is the principal end product of nitrogen metabolism in mammals and in most fishes. It is a white granular compound containing 46% nitrogen. In addition to its presence in urine, blood and bile, other body fluids also contain urea. The compound was first discovered by H. M. Rouelle in 1773, by alcoholic extraction of the solid residue from evaporated urine, an alkaline nitrogenous substance which on bacterial fermentation yielded carbonic acid and ammonia. Later in 1798, urea nitrate was prepared by Antoine F. Fourcry and Louis N. Vanquline from urine. The isolation of urea from the same source was first accomplished by Joseph L. Proust in 1821. Friedrich Wohlen discovered the artificial formation of urea from ammonia and cyanic acid. Historically, urea was the first organic compound to synthesize from inorganic ingredients. The principal reaction in the synthesis of urea involves the combination of NH_3 and CO_2 in first step to form ammonium carbamate and in a second step, dehydrating the ammonium carbamate to yield urea :

1. $NH_3 + CO_2 \longrightarrow NH_2COONH_4$
2. $NH_2COONH_4 \longrightarrow NH_2CONH_2 + H_2O$

It is also prepared commercially from the partial hydrolysis of cyanide :

$$H_2NCN + H_2O \longrightarrow H_2CONH_2$$

Although scientists are considering urea to feed different types of animals particularly ruminants, little is known about its effects on different species of poultry particularly with regard to its influence on production characteristics. To author's knowledge, no attempt was made in the past to review the exsisting information available in the literature. The present review is therefore prepared by consolidating and updating information relating to urea nutrition in poultry.

Urea as a source of nitrogen in animal diets

Urea is being considered for feeding ruminant animals as a non-protein nitrogenous (NPN) substance. Fingerling and coworkers (Maynard et al., 1985) made studies with calves and produced clear evidence from nitrogen balance that urea can be utilized to supply a part of protein needs

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for growth. Rose et al. (1949) were the first to show that NPN could be utilized by the rat by feeding a diet containing all essential amino acids supplemented with ammonium salts and glycine. L-glutamic acid and ammonium acetate were utilized under this condition. Results of many workers repeatedly indicated that the protein requirements of animals particularly herbivores could be met in part by such NPN compounds as urea, asparagine and even ammonium salts. These findings were frequently explained on the basis that the microorganisms play an active role to convert these simple compounds into protein which was later digested and thus served the body (Maynard et al., 1985). Feeding of urea is in practice for ruminant animals since these results were established.

Urea as a source of nitrogen in poultry diets

Scarcity of protein feed ingredients particularly of animal origin and a sharp rise in the prices of commonly used animal protein ingredients are the problems of supplying nitrogen to poultry particularly in the South-East Asia. To solve the problem, the use of unconventional feedstuffs is gaining momentum. Urea, a NPN substance is still a unconventional item in poultry feeding unlike ruminant animals. Many of the early workers (Ackerson et al. 1940; Jones and Combs, 1953) did not support the inclusion of urea in the poultry diets because of its toxic effects. Although urea has long been recognized as toxic to poultry, considerable evidence (Karasawa, 1989a, 1989b, Karasawa and Maeda, 1994) have been developed in the recent years in favour of the fact that chickens are able to derive nutritional benefit from this NPN compound.

Urea in chick nutrition

Reports with regard to role of dietary urea and other NPN substances in chick nutrition are conflicting. Sullivan and Bird (1937) were able to show that nitrogen from urea and diammonium citrate (DAC) could be utilized by chicks when fed in diets in which methionine and glycine were replaced by their hydroxy analogues. Ackerson et al. (1940) fed growing chicks a ration in which 13 percent protein nitrogen was supplied by urea ($N \times 6.25$) and found no beneficial effects. In agreement with this result, Jones and Combs (1953) reported that urea nitrogen as well as DAC and diabasic ammonium phosphate (DAP) could not be utilized by the young chicks whereas Featherston et al. (1962) and Shannon et al. (1970) reported that urea and DAC were effective sources of nitrogen for chicks, a result which indicated that nitrogen from non-protein sources could be utilized. Baker and Molitoris (1974) showed that urea supplementation stimulated growth even in the presence of high dietary content of chlorotetracycline. Sibbald and Hamilton (1975) fed urea to broiler and observed that birds given urea drank more water than did controls had wet droppings that smelt strongly of ammonia. In another experiment, layers and broilers received from 14 to 35 days old an identical ration containing 3, 6, 9, 12 or 15 percent urea. Mortality was confined to the layer type chicks. This was 2 percent for birds which received 6 percent or 12 percent urea and 6 percent for those which received 15 percent urea. Weight gain for both strains decreased linearly and correlation coefficients were -0.915 for layer-type chicks and -0.950 for broilers. That the germ free chicks did not benefit from urea supplementation whereas conventional birds showed improved feed conversion efficiency and significantly better growth were reported by Okumura et al. (1976). On the other hand, Prieto et al. (1978) obtained no practical advantage by adding urea to diet of crossbred (Cornish $\times$ White Rock) fattening chickens. Bruckental and Nitsan (1981) observed that urea nitrogen was better utilized for growth when the diets were supplemented with methionine. There was significant correlation between these variables in chickens given protein at 292 g/kg. The study made by Kobasyshi et al. (1981) led them to conclude that dietary urea decreases the biological value of protein for increased excretion of uric acid.

Urea in the nutrition of layers

Vander Meluen (1943) showed that urea had no protein substituting effect in the diet of laying hens. The feeding of 3 percent protein equivalent from urea in a 15.75 percent protein ration did not improve egg production or egg size suggesting that urea is not a good source of available nitrogen (Chavez et al., 1966). Young et al. (1965) and Young and Manoukas (1968) obtained positive but inconsistent response in egg production with non-protein nitrogen but Akintunde et al. (1968) found no improvement. An interesting result with regard to urea in layer diet was reported by Davis and Martindale (1973). They found 2 percent increase in egg production and improved feed conversion efficiency when included in an amount equivalent to 1.7 percent protein when the ration contained a total of 16 percent CP. Kazemi and Balloun (1973) found no effect on Haugh Units and shell thickness by feeding urea and DAC to layers. Filev et al. (1974) observed that neither source of NPN (urea and DAC) was good as proteins, DAC was better utilized than urea. They also found no significant effects on egg fertility or hatchability when replacement of fish meal in the ration by 2 percent urea was carried out. A study with turkey layer indicated that egg production and hatchability were unaltered when 2 percent fish meal was replaced by urea (Abdel-Rahman and EL-Abbady, 1975). Colostomized hens were given ^{15}N in dietary urea by Gruhn et al. (1986). Incoporating of ^{15}N into the essential amino acids in the white and yolk of eggs was very low; 0.18% of the applied ^{15}N was detected in 9 essential amino acids in egg white and 0.12% in those in egg yolk. For the 6 nonessential amino acids analysed 0.5% of ^{15}N was detected in egg white and 0.81% in egg yolk.

Fate of dietary urea

Bell and Bird (1966) reported that cecal ammonia concentration is relatively high in the domestic fowl compared with other parts of the intestine. Stutz and Metrokotsas (1972) did not find urease activity in ceca while Barnes and Impey (1974) observed there microbial activities suggesting that cecum of the chicken is the most active site in the digestive tract for ammonia production by microflora. Stocki et al. (1974) was of the opinion that a complete urea cycle occurs in the liver of chickens but the enzyme levels (carbamylphosphatesynthetase (CPS I and II), omithycarbamyltranferase (OCT) and arginase) are very low in comparison with ox, pig and rat. Okumura et al. (1976) stated that the gut microorganisms are responsible for the growth promoting effect of urea, presumably through release of NH_3 by bacterial urease and its consequence incorporation into amino acids. Kagan and Balloun (1976) reported that blood urea N was increased by dietary urea. Older birds weighed significantly less when the diet contained urea. Kobayashi and Itoh (1985) found that urease and caprylohydroxanic acid (CHA) both at 100 mg/kg and urea at 2% of the diet cost lower urinary acid excretion than did urease added alone to the 2 % of the diet, CHA considerably inhibited whereas jack bean urease significantly increased ureolytic activity in the digestive tract. For birds fed on protein diets, feed conversions tended to increase with increasing dietary urea but weight gain and feed intake were not affected. PER and NPR decreased and N balance and urinary N excretion increased. BV and NPU tended to be high in chickens given diets with 0.5% urea. Koh et al. (1985) obtained increased protein efficiency ratio (PER) and net protein ratio (NPR) with an increasing amount of urea in the diet. Digestibility of N decreased with the increasing dietary urea, but biological value (BV) and net protein utilization (NPU) tended to be high in birds given 1.5% urea. Karasawa (1989a) fed a low protein diet plus urea to chicken and proposed the following mechanism for urea utilization "dietary urea is rapidly absorbed intact from the upper intestine, appears in circulating blood and is excreted in urine. Next, urinary urea reaches the ceca through retrograde peristalsis, and is hydrolyzed there to ammonia and is easily absorbed from the ceca and is finally utilized for the synthesis of non-essential amino acids in the liver". This mechanism was further supported by Karasawa et al. (1993a). It has been stated that urease activity in cecal contents of the digestive tract accounts for 99% of the total urease activity (Stutz and Metrokotsas, 1972). In agreement with this, Karasawa (1989b) demonstrated that urolysis by the microflora in the ceca can contribute appreciably to ammonia production in the ceca of the chicken. This ammonia is utilized for the synthesis of non essential amino acids and ultimately becomes available for protein synthesis in chicken. Karasawa et al. (1993b) concluded that increased protein intake and the feeding of urea were able to induce ammoniagenesis from urea and uric acid in the caeca of the fowl. Karasawa et al. (1994) confirmed that the caecum is the major site of ammonia production from urea but indicated the possibility that liver and kidney activites might play a significant role in the utilization of dietary urea which is rapidly absorbed intact from the upper intestine of chicken. Karasawa and Maeda (1994) studied the nitrogen nutrition of the chicken fed on a moderate protein diet or a low protein diet plus urea. They concluded that the caeca play a useful role in nitrogen economy of the protein-depleted chicken but not in the protein-adequate chicken and that dietary urea degradation in the caeca occurs from 3 h after feeding.

Discussion

It is well established that dietary urea is well utilized in ruminant animals by virtue of microorganisms present in the rumen while the situation is quite different in case of poultry because of differences in anatomy and physiology of the digestive system. Available information in the literatures indicate that it is still controversial whether or not urea could be well utilized in chicken or other species of poultry. It is clear that the studies that have been made so far yielded conflicting results in this regard. At least part of this problem has resulted from the fact that whether or not the experimental birds were maintained in a germ free environment although the influence of environment is not clearly understood. The report of Okumura et al. (1976) clearly indicated that only the conventional birds showed better results from urea feeding. The most of the remaining workers failed to report whether they carried out their experimentation in conventional environment although there is reason to belief that most of them probably did so. But the recent evidence with regard to utilization of urea N for the synthesis of non-essential amino acids (Karasawa 1989a; 1989b) may not solve the issue since these reports contain no information with regard to growth and production performance of birds fed urea.

Karasawa's reports (1989a; 1989b) showed the metabolic pathway of dietary urea and the role of cecal microflora in releasing NH_3 for ultimate utilization of this NH_3 for the synthesis of nonessential amino acids. Unfortunately, nothing is available as to whether cecal microflora can utilize urea N for their own body protein synthesis (as like as rumen microorganism of the ruminants) which can be utilized by the host animal. It is true that most of the researchers did not investigate the production characteristics of brolier and layer-type chicken by feeding urea N to chicken. As a result, information available in this regard is scanty.

One cannot consider urea for feeding poultry until and unless the biochemical and physiological events following its ingestion show a positive influence on production variables and/ or make the diet economic without causing any harmful effects. In addition, the quality of meat and eggs of birds fed urea should be evaluated before any recommendation about urea is made.

Future work

Thus future research with feeding urea to poultry should include the following. It is necessary to determine the influence of environment on feeding urea and whether the feeding effect is related to environment and if so, how ? So, more research should be conducted in germ free and conventional environment. Secondly, detailed study should be undertaken to know the effects of urea on the production charecteristics of brolier chicken (i.e. weight gain, feed consumption, feed conversion, liveability etc.) and that on layers (egg production, egg weight, feed conversion, live ability, egg quality etc.). Finally, in addition to determining protein substituting effects, toxic effect, if any, should be carefully investigated in some greater detail in order to remove controversies available in the literatures.

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