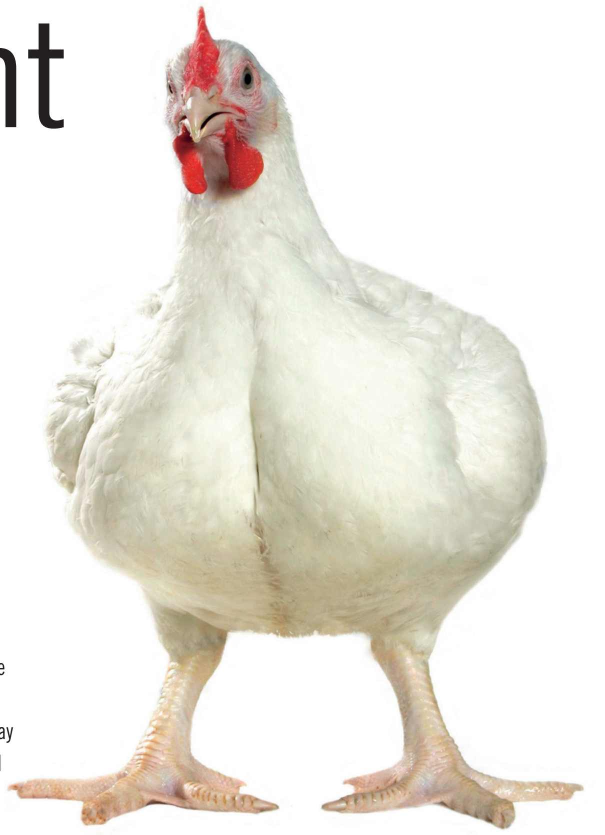
Betaine hydrochloride: An essential nutrient in broiler diets



Betaine is a known functional nutrient in broiler nutrition, which was in the past mainly used as betaine anhydrous extracted from sugar beets. Nowadays, it is also available as betaine hydrochloride from synthetic production.

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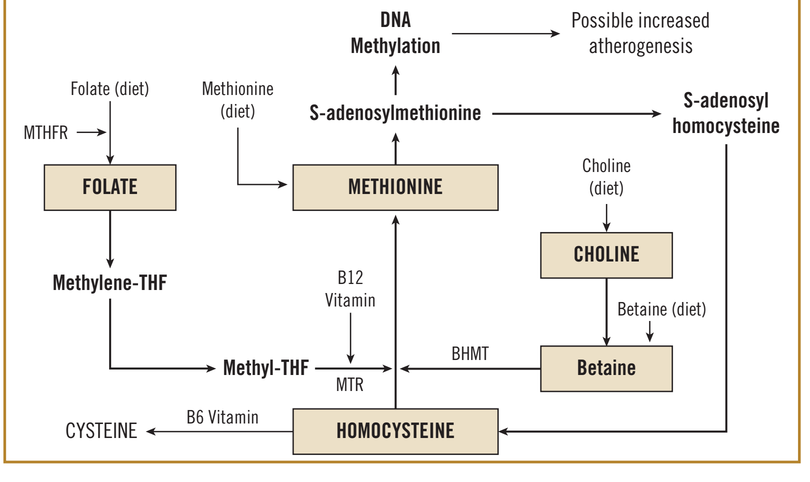
Latest research highlights that nutritional properties of naturally derived and synthetic products are equal, unveiling a cheaper, non-hygroscopic as well as non-seasonal (available all year) source of betaine for the feed industry. However, special care should be taken that the free-flowing properties of betaine hydrochloride are always ensured, since hygroscopicity may limit application in feed factories. With a strong focus on the crystallisation process and correct application of a free flowing carrier, a non-hygroscopic betaine hydrochloride can be produced.

Including betaine hydrochloride in broiler diets can replace choline and methionine and may provide nutritionists a new tool to compose an optimal diet.

Betaine is absorbed via the duodenum. Human studies showed rapid absorption and distribution, with a peak increase in serum 1–2 h post food intake.

Figure 1 - Transmethylation reactions; dietary choline, betaine and methionine can be interchanged for this purpose.



Betaine is absorbed in the gastrointestinal tract (GIT); whereas up to 3/4 of it could remain at GIT intracellular level. Intracellular accumulation takes place via active (Na^+ or Cl^-) and passive (Na^+) transport systems.

Betaine is eliminated by metabolism, not excretion, and catabolised via a series of enzyme reactions (transmethylation) that occur in the mitochondria of liver and kidney cells. The principal physiologic role of betaine is to act as an osmolyte and as methyl donor (transmethylation). As an osmolyte (dipolar zwitterion characteristics), betaine increases intracellular water retention and therefore protects intracellular enzymes against osmotic induced inactivation. As a methyl donor, betaine participates in the methionine cycle (mainly in the liver) and can be further used in transmethylation reactions for synthesis of essential substances like carnitine and creatine (*Figure 1*).

Betaine had shown to also accumulate in other internal organs (gut, liver, kidney and heart) to protect them and enhance performance in human athletes.

Biological equivalence

Betaine is a zwitterion metabolite also known as trimethylglycine. It was first discovered in sugar beets and it is also present in other plants, animals and seafood. However, sugar beets contain exceptionally high levels of betaine which accumulate in condensed soluble (≈ 116,000 mg/kg). Nowadays, betaine is also available in several purified forms (anhydrous, monophosphate and hydrochloride betaine). Some questions were raised if osmoregulatory properties of betaine hydrochloride were similar to those of betaine anhydrous. To study this question, an in vitro trial was setup to mimic gastric passage. De Krimpe (University of Ghent, 2010; unpublished) evaluated the biological equivalence of different betaine sources. The products were dissolved in a solution of water and hydrochloride with pH 2.3 (gastric conditions) and then analysed. Results showed that irrespective of the ionic form and production method (natural extraction vs. chemical synthesis) different sources of betaine gave the same analytical results (same m/z retention time pairs); therefore no difference in biological activity or osmoregulatory function should be expected. As after gastric passage both molecules are identical, no differences between betaine hydrochloride and betaine anhydrous as an effective feed additive could reasonably be expected.

Table 1 - Summary of peer-reviewed results of dietary betaine on performance parameters and slaughter characteristics in poultry (adapted from Ratriyanto et al., 2009).

Betaine (%)	Trait	Effect	Carcass	Effect	Reference	Year
0.05-0.15	ADG FCR	↑ ↓	Breast yield Fat %	↑ ↓	Virtanen & Rosi	1995
0.08	ADG FCR	↑ ↓	Breast yield	↑	Virtanen & Rosi	1995
0.15	ADG FCR	↑ ↓			Augustine et al	1997
0.10-0.50	ADG FCR	↑ ↓			Matthews et al	1997
0.10 0.15	ADG FCR	↑ ↓			Teeter et al	1999
0.10	ADG FCR	↑ ↓			Waldenstedt et al	1999
0.05			Carcass yield	↑	Esteve-Garcia & Mack	2000
0.08	ADG	↑			Matthews & Southern	2000
0.10	ADG	↑	Dressing%	↑	Waldroup & Fritts	2005
0.10	ADG	↑			Farooqi et al	2005
0.04-0.07	ADG FCR	↑ ↓	Crcass yield Muscle protein yield	↑ ↑	Attia et al	2005
0.07-0.14	ADG FCR	↑	Abdominal fat	↓	Hassan et al	2005
0.05-0.10			Breast yield	↑	Pirompud et al	2005
0.10	FCR	↓	Breast yield	↑	Waldroup et al	2006
0.05	ADG FCR	↑ ↓	Breast yield Abdominal fat	↑ ↓	Zhan et al	2006
0.05-0.10	ADG FCR	↑ ↓			El-Husseiny et al	2007
0.08	ADG FCR	↑ ↓			Honarbakhsh et al	2007
0.10			Breast yield	↑	Remus	2001
0.09	ADG	↑	Breast yield Abdominal fat	↑ ↓	Noll et al	2002
0.5	ADG FCR	↑ ↓	Breast yield Abdominal fat	↑ ↓	Wang et al	2004
0.04-0.08	Egg count	↑			Lu & Zou	2006
0.03-0.12	Egg weight	↑			Park et al	2006

All results in above trials were significant at P<0.05. Other authors could not show significant differences: (Zulkifie et al., (2004); Pillai et al., (2006))

yellow = broilers, orange = turkeys, green = meat ducks, pink = layers

Use in poultry production

Results of nutrient digestibility, animal performance, metabolism and improvement in carcass leanness are reviewed and reported by Elklund et al., (2005) and Ratriyanto et al., (2009), see *Table 1*. These peer reviewed papers illustrate the benefits of betaine as a feed additive for improving animal performance and slaughter characteristics. Studies included in these two reviews were indeed conducted with a particular scientific thought and animal responses were the result of one of the betaine's modes of action (methyl donor or osmolyte) which are both influenced by the concentration of other methyl donors in the diet and the presence of either an osmotic or metabolic stress.

Methyl donor

Dietary supplementation of betaine may reduce the requirement of other methyl donors such as methionine and choline. However this theoretical application must be subjected to considerable analysis before practical implementation. This sparing effect has been thoroughly investigated in poultry and to a lesser extent in pigs. Pesti et al. (1979) showed that the dietary addition of betaine and methionine can replace each other in broiler chicks. Florou-Paneri et al. (1997) showed that between 30 and 80%

Conclusions

Betaine has been used in broiler nutrition for many years. Scientific proof has been provided to show that betaine improves production performance, to replace other methylgroup donors; to assist birds during heat stress and to improve slaughter characteristics. Many of these published articles were not clear on the source of betaine used (natural or synthetic), and concern was raised if the synthetic form would be as effective in osmoregulation as the natural equivalent from sugar beet extraction. The presented data clearly shows that if a proper crystalline betaine hydrochloride is used, its molecular structure is similar after gastric passage as betaine anhydrous. Care should be taken that the product has good free flowing properties and is non-hygroscopic.

Practical application trials with birds fed betaine during heat stress clearly showed the expected improvement and therewith the mode of action of betaine hydrochloride as an osmoprotectant. Different strategies to replace choline and methionine were evaluated and may give tools to nutritionists to define the optimal strategy to include betaine in the diet. In the past many nutritionists evaluated betaine as a feed additive. With a new form of betaine (betaine hydrochloride), the year around availability has increased, since its production is independent to sugar beet production. Secondly, as the cost price is generally lower than that of betaine anhydrous, the applications of betaine in broiler nutrition may be reconsidered.

Table 2 - Trial results of Excential Beta-key on production performance, slaughter yields and economical evaluation.

Excential Beta-Key treatments	T1	T2	T3	T4
Performance				
Final body weight (kg)	2.11	2.16	2.12	2.15
FCR	1.92	1.83	1.89	1.85
Economical evaluation (US$)				
Average feed cost/kg	0.368	0.370	0.367	0.368
Average feed intake (kg)	4.04	3.96	4.07	3.98
Total feedings costs/bird	1.487	1,466	1,492	1,464
Chick cost/bird	0.56	0.56	0.56	0.56
Medication/vaccination/bird	0.05	0.05	0.05	0.05
Administrative (US$/bird)	0.11	0.11	0.11	0.11
Total production costs/bird	**2.207**	**2.186**	**2.212**	**2.184**
Average live body weight (kg)	2.11	2.16	2.13	2.15
Average dressing %	74.82	77.60	75.99	77.57
Average dressing weight (kg)	1.577	1.679	1.616	1.671
Production cost per kg liveweight	1.05	1.01	1.04	1.01
Production cost per kg dressed weight	1.40	1.30	1.37	1.31

T1 (control)
T2 (500 g Beta Key/t
T3 (Beta Key 500 g/t by replacing 750 g choline chloride & 200 g methionine
T4 (Beta Key 1,000 g/t by replacing 1,000 g choline chloride & 300 g methionine
Purities: Excential Beta-Key: min. 71%; CholineChloride 75%;
DL-Methionine 98%

of the supplemental methionine can be substituted by betaine without negative effects on performance. A more conservative replacement approach was evaluated in popular magazines by Lensing and Van der Klis (2007) and Cresswell (2010). Both experiments studied the bio-equivalency between betaine and choline/methionine in broilers diets; whereas choline was fully replaced and methionine decreased by 25-30% of daily requirements. Within this range of replacement no differences in broilers performance were observed.

In line with the results found by Cresswell, feeding strategies were tested to get more insight into application strategies. This trial was performed at IPME Pune, India by Dr. Rama Rao (2011, unpublished) and showed improved performance and carcass yield for all treatments. Two thousand Cobb broiler birds were divided over four treatments with two replicates each. The control diets were typical corn-soy diets containing 2,000 ppm, 1,500 ppm and 1,500 ppm added CholineChloride (75%) and 0.61%, 0.58% and 0.45% total methionine for respectively starter, grower and finisher diets.

- Best economical results (*Table 2*) were achieved with on top addition of betaine (Treatment 2). An investment of $0.002/kg feed resulted in 7% savings in production costs of dressed weight. Replacement of certain levels of choline and methionine showed good economical results.
- Treatment 3 (strong replacement of choline and methionine) shows that with lower feeding costs, a small improvement in production can be achieved.
- Treatment 4 (careful replacement of choline and methionine) is a safe strategy with equal costs of the diet, but a good return on investment. Premix companies, compound feed manufacturers and integrated companies may have different commercial interests that each may desire their own strategy.

Osmoprotective properties

The regulation of cellular hydration state, and therefore cell volume, is important for maintenance of cell function and several metabolic pathways (i.e.: protein turnover, amino acid carbohydrate, etc). Cells try to adapt to external osmotic stress by accumulating inorganic ions (Na^+, K^+, Cl^-) and organic osmolytes (methylated amines and certain amino acids). However, the increase in intracellular concentrations of inorganic ions is limited due their destabilising effect on protein structure and enzyme function; on the other hand organic osmolytes can reach high intracellular concentrations without disturbing cellular functions. Betaine is considered the most effective organic osmolyte. It accumulates in GIT cells regulating water flux across the intestinal epithelium. Betaine also had shown to inhibit cellular apoptosis and to reduce energy expenditure for GIT cells. A 5% reduction in energy requirements for maintenance (ENm) of the GIT cells in pigs fed betaine was found.

Several scientific publications showed the proof of principle that betaine anhydrate can be used to overcome heat stress. Attia et al., (2009) showed that the impact of severe heat stress could partially be overcome by adding betaine to the diet in slow growing broilers. Adding 1 kg/t betaine to the diet improved weight gain and feed conversion compared to negative control treatment. More importantly, rectal temperature decreased (43.2°C versus 41.9°C) compared to negative control. Panting, a mechanism of heavily breathing to lose heat via evaporation, was also reduced (78.3 versus 63.9 breaths/minute). Hassan et al., (2011) showed a clear dose-response effect when betaine was added in 250, 500, 750 or 1000 g/t feed to the diet in rabbits kept under severe heat stress conditions. Haldar et al., (Bangkok, 2011) presented a study under more practical conditions showing that under (milder) heat stress conditions (31°C, ±85% relative humidity) in conventional broilers, the same effects can be expected. More importantly, he showed that these results could be obtained using betaine hydrochloride and thereby gave practical proof that betaine hydrochloride has similar osmoregulatory properties as an anhydrous source. AAF

References are available upon request from the AllAboutFeed desk