The replacement value of betaine for DL-methionine and Choline in broiler diets

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Key information

- In practical broiler diets adequately supplemented with methyl groups via choline, there is enough evidence to support that betaine has no sparing effect of methionine

For some years it has been suggested that betaine could replace, or partially replace, methionine in practical broiler diets without losing performance. The reason behind this suggestion is the close interrelationship between the roles of methionine, choline, and betaine in the homocysteine remethylation cycle, which provides methyl groups to the organism.

Relationship between methionine, choline, and betaine

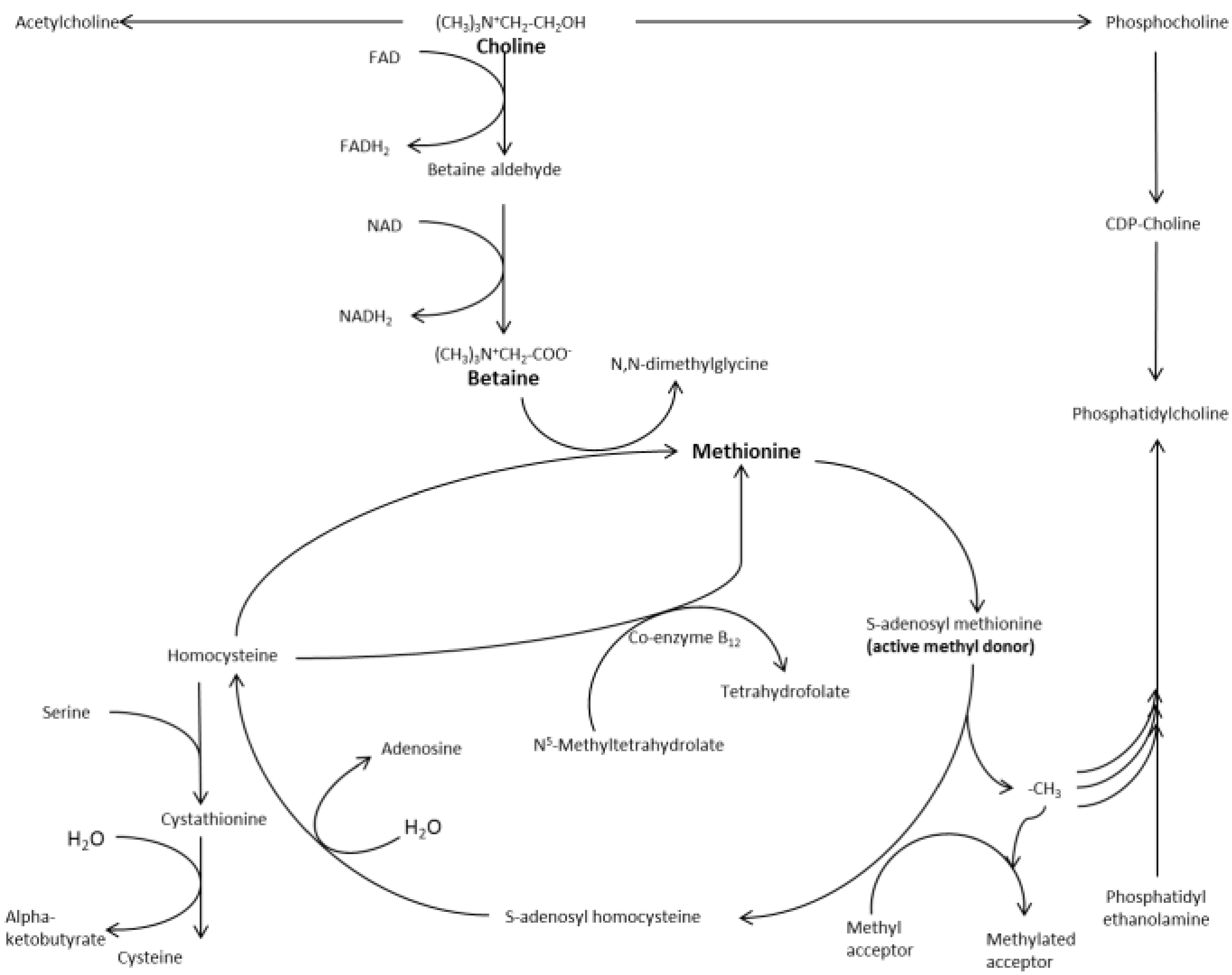
There is a close and complex relationship between methionine, choline, and betaine metabolism (Figure 1). Methionine is utilized in the organism as a building block for protein synthesis. It is, also, the precursor of cysteine and forms S-adenosyl methionine, which acts as a major donor of methyl groups. Though methyl groups are used to synthesize different compounds, their major destiny is to combine with phosphatidylethanolamine to form phosphatidylcholine, the major component of cell membranes.

Choline provided in the diet can also be used to form phosphatidylcholine for the same purpose, and, at the same time, choline is the only available precursor for the synthesis of the neurotransmitter Acetylcholine.

Betaine can be obtained from the oxidation of choline or can be directly fed to the bird. It takes part in the homocysteine remethylation cycle, turning homocysteine (HCY) into methionine which in turn is transformed into S-adenosyl methionine, the active methyl donor compound.

Each molecule of betaine, coming from either choline oxidation or from feed, can methylate two molecules of homocysteine to recycle two molecules of methionine through two different metabolic pathways. Methionine can be recycled from HCY by the betaine-homocysteine methyltransferase (BHMT) or methionine synthase (MT). Both pathways need methyl groups provided by betaine itself or by N,N-dimethylglycine, a by-product of the action of BHMT. Methyl groups from N,Ndimethylglicine are used to form N^5-methyltetrahydrofolate, which in turn will donate its methyl group to form methionine from HCY.

Figure 1. Metaboilc pathway of Choline, betaine, and methionine.



As a consequence, phosphatidylcholine can be synthesized from methyl groups coming from feed grade betaine, instead of feed grade choline. In this way, feed grade betaine can spare the choline necessary to take part in the remethylation process of the homocysteine cycle but cannot replace the choline necessary to form acetylcholine. Dilger et al., (2007) reported that 50% of the choline requirement in broilers could be replaced by betaine.

The replacement value of betaine for DL-methionine has been studied extensively. Since betaine plays a key role in the homocysteine cycle, it has been proposed that betaine could spare dietary methionine. By studying the metabolic pathways of these three molecules, it is clear how betaine can spare the choline needed to take part in the homocysteine cycle and to synthesize phosphatidylcholine. At the same time, since methionine is part of the cycle and is recycled every time the process takes place, there is no chance for betaine to spare this essential amino acid. Betaine recycles methionine but does not replace methionine at any time in the metabolic pathway.

Extensive research on the replacement value of betaine for DL-methionine supports the fact that betaine cannot spare methionine in practical broiler diets.

Betaine cannot replace methionine

In order to explore the possible methionine sparing effect of betaine, Rostagno and Pack (1996) fed broiler chicks a basal diet deficient in methionine (Total Met:0.31%, total Met + Cys: 0.63%) with different levels of methionine and betaine. Results showed that betaine inclusion did not improve either body weight gain (BWG) or feed efficiency compared to broilers fed adequate levels of DL-methionine (Table 1).

Table 1. Male Broiler performance and breast meat yield of birds fed different levels of methionine and betaine (1-40 days). Adapted from Rostagno and Pack, (1996).

Treatment	DL-methionine %	Betaine %	Weight gain g	Feed efficiency	Breast meat %
1	0	0	1378[d]	2.205[a]	15.0[d]
2	0	0.05	1438[d]	2.143[a]	15.7[d]
3	0	0.10	1393[d]	2.173[a]	15.5[d]
4	0.06	0	1710[c]	1.983[b]	17.3[bc]
5	0.06	0.05	1688[c]	1.979[b]	16.9[c]
6	0.06	0.10	1743[c]	1.992[b]	18.0[b]
7	0.12	0	1959[b]	1.845[c]	19.6[a]
8	0.18	0	2078[a]	1.787[c]	19.9[a]
SEM			8.2	0.0082	0.033
Probability			<0.05	<0.05	<0.05

Schutte et al., (1997) conducted a similar trial to study the potential of betaine to replace DL-methionine as a methyl group donor. To do this, researchers used two different basal diets, one based on typical dutch ingredients (corn, tapioca, wheat) and the other diet based on corn and soy bean meal. Both diets were TSAA (total sulfur amino acid) deficient and were supplemented with increasing levels of DL-methionine or betaine. Betaine addition to either basal diet produced no improvement in performance; however, DL-methionine addition increased both body weight gain and breast meat yield while reducing feed efficiency. (Table 2).

Table 2. Male Broiler performance and breast meat yield of birds fed different levels of methionine and betaine (1-38 days). Adapted from Schutte et al.,(1997).

Treatment	DL-methionine %	Betaine %	Weight gain g	Feed efficiency	Breast meat %
Dutch diet					
1	0	0	2.046[a]	1.723[a]	14.00[a]
2	0.05	0	2.235[b]	1.638[c]	15.52[c]
3	0.1	0	2.312[c]	1.584[d]	x
4	0	0.04	2.071[a]	1.686[b]	14.64[b]
5	0.05	0.04	2.239[b]	1.641[c]	15.79[c]
6	0.1	0.04	2.325[c]	1.592[d]	x
Corn-soy bean diet					
7	0	0	2.085[a]	1.562[de]	13.91[a]
8	0.5	0	2.314[c]	1.503[f]	15.41[c]
9	0.1	0	2.357[c]	1.479[fg]	x
10	0	0.04	2.112[a]	1.544[e]	14.42[ab]
11	0.05	0.04	2.32[c]	1.501[f]	15.97[c]
12	0.1	0.04	2.356[c]	1.463[g]	x
SEM			23.8	0.0109	0.214
			Probability		
Basal diet (BD)			<0.01	<0.01	0.70
Methionine			<0.01	<0.01	<0.01
Betaine			0.37	0.10	<0.01
BD x methionine			0.38	0.09	0.54
BD x betaine			0.90	0.80	0.78
Methionine x betaine			0.78	0.15	0.59
BD x methionine x betaine			0.96	0.39	0.51

Further trials using sulfur amino acid deficient basal diets have been conducted repeatedly, removing any doubt about the replacement value of betaine for methionine. McDevitt et al., (2000) obtained similar results when feeding male broilers for 42 days with graded levels of betaine and DL-methionine (Table 3).

Table 3. Male Broiler performance and breast meat of birds fed different levels of methionine and betaine (7-21 and 21-42 days). Adapted from McDevitt et al., (2000).

Treatment		**7-21 d Weight gain g**	**7-21 d Feed efficiency**	**21-42 d Weight gain g**	**21-42 d Feed efficiency**	**Breast meat g**
DL-methionine %	**Betaine %**					
0	0	695[a]	1.83[a]	1916[a]	2.31[a]	213[a]
0	0.05	673[a]	1.8[a]	1837[a]	2.35[a]	204[a]
0.06	0	809[b]	1.64[b]	2347[b]	2.07[b]	310[b]
0.06	0.05	826[b]	1.6[b]	2376[b]	2.11[b]	340[c]
0.12	0	863[c]	1.57[b]	2501[b]	2.09[b]	366[d]
0.12	0.05	846[bc]	1.59[b]	2432[b]	2.14[b]	376[d]
SEM		10.5	0.038	26.3	0.051	7.25
Probability		<0.05	<0.05	<0.05	<0.05	<0.05

Comparable responses were reported by Esteve Garcia and Mack (2000), Swain and Johri (2000), Baghei et al. (2009). Waldroup et al., (2006) fed male broilers with diets using industry standards and reducing methionine gradually to study a possible sparing effect of choline or betaine. Neither choline nor betaine supplementation could be shown to spare methionine in this trial..

Some researchers have observed sparing of methionine by betaine. Zhan et al., (2006) fed a TSAA deficient diet (Total methionine 0.29% and TSAA 0.63%) to male broilers from 22 to 42 days of age and reported an improvement in performance when 0.1% methionine was supplemented and a similar improvement with 0.05% inclusion of betaine to the basal. The reason for this result could be that methionine supplementation was not enough to reach recommended levels of both methionine and TSAA. Rostagno's (Rostagno et al 2011) recommendation for the period from 22 to 33 days is 0.486% total methionine and 0.91% TSAA.

In a series of experiments conducted by Emmert and his collaborators (Emmert et al., 1996; Pillai et al., 2006a, Pillai et al., 2006b) studied how different levels of methionine, choline, and betaine affected the expression of enzymes involved in the remethylation cycle of homocysteine. They found that a methionine deficient diet or an excess of betaine and choline increased the expression of betaine-homocysteine methyltransferase (BHMT) and methionine synthase (MT) in broilers. Betaine addition to methionine deficient diets, however, did not improve performance to the levels achieved with adequate levels of methionine; although, when choline or betaine were added to extremely methionine deficient diets some improvement could be observed (Pillai et al., 2006a, Pillai et al., 2006b). Saunderson and Mackinlay (1990) reported similar results in performance and enzyme expression when a marginally methionine deficient diet was compared to a highly methionine deficient diet supplemented with choline.

When trials of this kind are conducted, a diet deficient in TSAA is usually used as a basal treatment and supplemented with different levels of methionine, choline or betaine. It has been demonstrated that varying levels of these additives alter the activity of enzymes that take part in homocysteine remethylation pathway. This change in enzyme activity could lead to a performance improvement from choline and betaine addition to diets highly deficient in TSAA. It is, therefore, necessary to always include a positive control treatment containing recommended levels of TSAA in the experimental design so the genetic potential of the bird can be expressed as well.

Conclusion

Numerous trials confirm that betaine has no methionine sparing effect when the diet is adequately supplemented with methyl donors. Methionine is part of the homocysteine remethylation cycle and is constantly recycled through a methylation process while betaine, coming either from feed or from choline oxidation, is the methyl group donor. Betaine cannot spare methionine since it plays a different role in the same metabolic pathway.

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