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REVIEW ARTICLE

Impact of betaine as a feed additive on livestock performance, carcass characteristics and meat quality- a review

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Abstract: Betaine (trimethylglycine) is a nontoxic methylamine compound contains the amino acid glycine with three chemically reactive methyl groups. This review gives an overview of the roles of betaine as a feed additive on the performance, carcass, meat quality in livestock production. Biological functions of betaine are defined as an osmolyte, methyl donor, and carcass modifier. As an osmolyte, betaine regulates the cellular hydration status and alleviates osmotic stress. As a methyl donor, betaine plays an important role in methylation reactions. Therefore, betaine may partly replace other methyl donors such as choline and methionine in the diet. Betaine is also supposed to play a significant role in lipid metabolism and has lipotropic effects also participating in the protein synthesis. A review of the results of this study suggests that betaine supplementation was effective to improve the average daily gain significantly, increased feed consumption and improved efficiency of food utilization of ruminants and monogastric animals. Betaine has been characterized as a carcass modifier by increasing the lean carcass percentage and decrease fat percentage by reducing lipid deposition. In conclusion, this study implies that dietary betaine supplementation was efficacious on growth performance and carcass characteristics of livestock.

Key words: Betaine, Livestock, Meat quality, Carcass characteristics

1. Introduction

Many studies on betaine have been conducted since Cadogan et al. (1993) showed a 14.8% decrease in backfat thickness in finishing pigs fed 1,250 mg/kg dietary betaine. Betaine has various functions as a feed additive in livestock; methyl donor and osmoregulation (Eklund et al., 2005).

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Betaine via osmoregulation roles could protect the cells from osmotic stressors by increasing the water retention of the muscles tissues which save more energy in intestinal tissue for cellular proliferation, nutrient absorption and secretion of digestive enzymes (Esteve-Garcia and Mack 2000; Siljander-Rasi et al. 2003; Eklund et al. 2005). In addition, betaine chemical structure (C5H11NO2) contains three methyl groups which participate in transmethylation reactions (Eklund et al., 2005). Betaine is involved in the synthesis of methylated compounds choline such as carnitine and reducing the requirement for other methyl donors such as and creatine (Zhan et al., 2006; Eklund et al., 2005). Consequently, betaine is used as a carcass modifier to increase the lean percent and decrease the fat percent. Moreover, McDevitt et al. (2000) showed higher levels of the methionine and cysteine by the additive betaine which is necessary for a protein synthesis. The objective of this paper is to make an overview from several studies to evaluate betaine as a feed additive.

1. Effect of betaine on water consumption.

Few studies had been conducted to measure the effect of betaine on water consumption. For example, Hall (2014) showed that betaine (114 mg/kg of body weight) decreased (P<0.05) the water intake in Holstein cows subjected to thermal stress, but slightly increased water intake at the natural temperature. Moreover, Schrama *et al*. (2003) found that dietary betaine (1.29 g/kg of feed) decreased the water consumption by 20% in barrows compared with the control group. In broiler chicks, Zulkifli *et al*. (2004) found that soluble betaine (50 g/l) decreased (P<0.05) the total water consumption compared with control group, but betaine supplementation in the diet (100 g/kg) slightly decreased the water intake compared with control.

However, DiGiacomo *et al*. (2016) showed that dietary betaine (2 or 4 g/day) did not affect the water intake in Merino ewes. Moreover, in male broiler chickens, McDevitt *et al*. (2000) showed that water intake was similar in chicks fed on betaine diet (0.5 g/kg) or control diet. Similar results were observed in Pekin ducks (El-Badry *et al*., 2015) and broiler chicks (Honarbakhsh *et al*., 2007; Mostashari-Mohases *et al*., 2017).

2. Effect of betaine on feed consumption.

Several studies investigated the impact of betaine on feed intake. Many studies clarified that betaine could improve feed intake. For example, in grazing steers, Bock *et al*. (2004) concluded that 20 gram of betaine per head per day increased (P<0.05) feed intake compared with the control group. Similar results were observed in pigs (Suster *et al*., 2004; Yu *et al*., 2004; Wang and Huang, 2011; Dong *et al*., 2012; MA *et al*., 2012; Cabezón *et al*., 2016a) and rabbits (Hassan *et al*., 2011).

In contrast, few studies reported that betaine decreased the average daily feed intake. For example, Lawrence *et al*. (2002) showed that betaine (1.25 g/kg of diet) decreased (P<0.05) the average daily feed intake in barrows and gilts. Moreover, Martins *et al*. (2010) indicated that betaine (1 g/kg of diet) significantly (P<0.05) decreased the daily feed intake in Alentejano pigs.

On the other hand, many studies reported that betaine did not affect feed intake. Such as, in lambs, Fernández *et al*. (2000) found that betaine (2 g/kg of diet) did not influence feed intake. In addition, in ewes, Nezamidoust *et al*. (2014) indicated that betaine (5 g/kg of diet) did not affect the dry matter intake. Likewise, in both barrows and gilts, Siljander-Rasi *et al*. (2003) found that the dietary intake was not influenced by different levels of dietary betaine (250, 500 or 1000 mg/kg of diet). Moreover, in barrows, Schrama *et al*. (2003) showed that dietary betaine (1.29 g/kg of feed) did not influence the average daily feed intake. In addition, in gilts, Wray-Cahen *et al*. (2004) showed that dietary betaine supplementation with 1.25 or 5 g/kg of diet did not influence average daily feed intake at 80% of ad libitum energy intake. Likewise, many other studies showed that dietary betaine did not affect feed intake in pigs (Feng *et al*., 2006; Huang *et al*., 2007, 2008; Martins *et al*., 2012; Albuquerque *et* *al*., 2017).

3. Effect of betaine on average daily gain.

Several studies found that dietary betaine could increase the average daily gain. For example, Wang *et al*. (1998) showed that dietary betaine (1750 mg/kg of diet) increased average daily gain by 13.32% (P<0.01) compared with the control group. In addition, comparable results have been reported dietary betaine increased daily gain in pigs (Yang *et al*., 2009; Wang and Huang, 2011; Zhiguo *et al*., 2011; Dong *et al*., 2012; MA *et al*., 2012) and rabbits (Hassan *et al*., 2011).

However, several studies reported that the average daily gain was not affected by dietary betaine. Such as, in lambs Fernández *et al*. (1998) showed that dietary betaine (0.2 g/kg of diet) did not affect the body weight gain. In addition, Fernández *et al*. (2000) found that dietary betaine (2 g/kg of diet) did not affect the average daily gain of male lambs. Moreover, in cattle, Löest *et al*. (2002) found that the average daily gain was not influenced by 10.5 or 21 g/day of feed grade betaine. Similarly, in pigs, Cadogan *et al*. (1993) showed that betaine did not affect the average daily gain in finishing pigs fed diets supplemented with 1250 mg betaine/kg. Moreover, dietary betaine did not affect average daily gain of pigs (Nakev *et al*., 2009; Martins *et al*., 2010, 2012; Lothong *et al*., 2016; Albuquerque *et al*., 2017).

4. Effect of betaine on respiration rate.

DiGiacomo *et al*. (2016) showed that 2 g/day of supplemental betaine significantly (P<0.01) decreased the respiration rate compared with sheep supplemented with 0 or 4 g/day betaine. In addition, DiGiacomo (2011) showed that dietary betaine (35 g/day) decreased the respiration rate in cows exposed to heat stress. Moreover, Hall (2014) showed that betaine supplementation (57 mg/kg of body weight) decreased (P<0.01) the respiration rate in Holstein cows subjected to thermal stress but did not affect the respiration rate at the natural temperature. In addition, Hassan *et al*. (2011) reported that dietary betaine decreased (P<0.05) the respiration rate in rabbits offered dietary betaine.

In contrast, Mendoza *et al*. (2017) showed that dietary betaine (1.5 g/kg of diet) increased (P<0.05) respiration rate of pigs compared with the 0 mg betaine group . However, Zhang *et al*. (2014) showed that dietary betaine (10, 15 and 20 g/day) did not affect the respiration rate of dairy cows .In addition, Cabezon *et al*. (2017) found that dietary betaine at 2.2 g/kg of diet did not affect the respiration rate of sows.

5. Effect of betaine on rectal temperature.

It has been reported that supplemental betaine (2 g/day) significantly (P<0.01) decreased the rectal temperature compared with sheep supplemented with 0 or 4 g/day betaine (DiGiacomo *et al*., 2016). In addition, Cabezon *et al*., (2017) found that dietary betaine at 2.2 g/kg of diet decreased (P<0.05) the rectal temperature in sows. Moreover, Mendoza *et al*. (2017) showed that dietary betaine at 1 g/kg of diet decreased (P<0.05) the rectal temperature of heat-stressed pigs, but did not affect the rectal temperature of pigs under normal temperature. Likewise, dietary betaine decreased (P<0.05) the rectal temperature in rabbits offered dietary betaine (Hassan *et al*., 2011).

However, DiGiacomo (2011) showed that dietary betaine (35 g/day) increased the rectal temperature in cows exposed to heat stress. In addition, Hall (2014) showed that betaine (57 mg/kg of body weight) increased (P<0.01) the rectal temperature in Holstein cows subjected to thermal stress but did not affect the rectal temperature at the natural temperature .Moreover, Hashemi *et al*. (2007) showed that dietary betaine at 1.5 g/kg of diet significantly (P<0.05) increased body temperature of broiler chicks at 32 days of age.

In contrast, Zhang *et al*. (2014) found that dietary betaine (10, 15 and 20 g/day) did not affect the rectal temperature of dairy cows. In addition, Cabezón *et al*. (2016b) showed that the rectal temperature was not affected in boars fed diets with different concentration of betaine 0, 6.3, and 12.6 g/kg). Similar results were observed in the broiler (Zulkifli *et al*., 2004) and hens (Gudev *et al*., 2011).

6. Effect of betaine on carcass characteristics.

6.1. *Carcass weight.*

Several studies found that betaine could enhance the carcass weight. For instance, in both barrows and gilts, Siljander-Rasi *et al*. (2003) found that dietary betaine (250, 500 or 1000 mg/kg of diet) significantly (P<0.01) increased the carcass weight but did not influence slaughter loss proportion. In addition, Hassan *et al*. (2011) found that the hot carcass weights of rabbits were significantly (P<0.05) increased with the increasing levels of betaine.

In contrast, in steers Löest *et al*. (2002) found that betaine did not affect the hot carcass weights. In addition, Fernández-Fígares *et al*. (2002) showed that dietary betaine (1.25, 2.5, or 5 g/kg of diet) offered to feed-restricted barrows did not affect the empty body and the carcass weights.

6.2. *Organs weight.*

Some studies found that betaine could affect some internal organs. For example, Fernández-Fígares *et al*. (2002) showed that dietary betaine (1.25, 2.5, or 5 g/kg of diet) offered to feed-restricted barrows tended to reduce viscera weight and small intestine weight. However, the weights of the large intestine, stomach, bladder, spleen, liver, kidney, and heart were not affected by dietary betaine. In another study in rabbits, Hassan *et al*. (2011) found that the kidney weights were significantly (P<0.05) increased with the increasing betaine levels. However, the weights of the heart, liver, and lung were not affected by dietary betaine.

On the contrary, many studies found that betaine did not affect internal organs. For example, in pigs Matthews *et al*. (1998) found that the weights of the liver, heart, and kidney were not affected by 1.25 g betaine /kg of diets. In addition, in pigs Fernández-Fígares *et al*. (2008) showed that the liver weight was not affected by dietary betaine at 5 g/kg of diet. Moreover, Martins *et al*. (2010) found that betaine (0.1% of diet) did not affect the weight of fresh livers, belly, gallbladders and their contents in pigs.

6.3. *Dressing percentage.*

The dressing percentage improved as a result of betaine supplementation according to several studies. For example, in gilts, Matthews *et al*. (1998) reported that dietary betaine (1.25 g/kg of diet) elevated (P<0.05) the dressing percentage. Similar results were observed in pigs (Zheng *et al*., 2001; Wang and Huang, 2011) and rabbits (Hassan *et al*., 2011).

On the other hand, many studies showed that betaine did not affect the dressing percentage. For example, Fernández *et al*. (2000) found that dietary betaine (2 g/kg of diet) did not affect the dressing percentage of lambs. In addition, Overland *et al*. (1999) showed that betaine (10 g/kg of diet) did not affect the dressing percentage of pigs. Moreover, many studies showed similar results in pigs (Yu *et al*., 2004; Huang *et al*., 2006; Nakev *et al*., 2009).

6.4. Carcass fat content.

Many studies on the effect of betaine have been conducted on carcass fat weight. In sheep, Fernández *et al*. (1998) showed that dietary betaine decreased the subcutaneous fat of lamb carcass by 11%, suggesting that betaine inhibits the accumulation of extramuscular fat. Cadogan *et al*. (1993) showed a 14.8% decrease in backfat thickness in finishing pigs fed 1250 mg/kg dietary betaine. Furthermore, in pigs, Wang *et al*. (2000) found that betaine (1 g/kg of diet) reduced (P<0.01) the dissected fat by 18.27% compared with the control group. In addition, in pigs, Ma *et al*. (2000) found that betaine reduced fat ratio and mean backfat by 16.62% (P<0.01) and 16.19% (P<0.05), respectively, compared with control groups. In addition, Huang *et al*. (2006) found that dietary betaine (1.25 g/kg of diet) offered to barrows and gilts decreased carcass fat percentage and average backfat thickness by 13.07% (P<0.01) and 10.30% (P<0.05), respectively compared with control group. Similarly, dietary betaine decreased carcass fat percentage and average backfat thickness in pigs (Yu *et al*., 2004; Huang *et al*., 2008, 2009; Zhiguo *et al*., 2011; Lothong *et al*., 2016). In addition, betaine decreased backfat thickness in pigs (Feng, 1996; Fernández-Fígares *et al*., 2002 and Wang and Huang, 2011).

In contrast, in pigs dietary betaine supplementation did not affect the carcass fat ratio (Overland *et al*., 1999; Nakev *et al*., 2009) or backfat thicknesses (Siljander-Rasi *et al*., 2003) Moreover, in finisher boars, Suster *et al*. (2004) found that dietary betaine at 1.5 g/kg of diet did not affect carcass fat content or backfat thickness. In addition, dietary betaine (1 g/kg of diet) did not affect perirenal fat, backfat weight and average backfat thickness in Alentejano pigs (Martins *et al*., 2010, 2012; Albuquerque *et al*., 2017).

6.5. Carcass lean content.

Many studies showed the potential of dietary betaine to enhance the lean carcass percentage. For example, Yu *et al*. (2001) found that dietary betaine increased (P<0.05) the dissected lean of the carcass by 4.08%, 7.15%, and 3.31% in weanling, growing and finishing pigs, respectively. In addition, in both barrows and gilts, Huang *et al*. (2006) found that dietary betaine (1.25 g/kg of diet) significantly (P<0.01) increased carcass lean by 5.19% compared with control group. Furthermore, in Jinhua barrows, Zhiguo *et al*. (2011) showed that the dietary betaine (1.25 and 2.5 g/kg of diet) increased (P<0.05) the carcass lean by 8.43% and 9.51%, respectively, in respect to control group. Likewise, the carcass lean percentages were increased in pigs offered betaine (Ma *et al*., 2000; Zheng *et al*., 2001; Fernández-Fígares *et al*., 2002; Yu *et al*., 2004; Huang *et al*., 2008, 2009; Wang and Huang, 2011).

In contrast, some studies found dietary betaine did not affect the lean carcass percentage in pigs (Matthews *et al*., 1998; Overland *et al*., 1999; Siljander-Rasi *et al*., 2003).

7. Effect of betaine on meat quality.

Dietary betaine did not affect water holding capacity according to many studies. For example, Yu *et al*. (2004) showed that dietary betaine (1.5 g/kg of diet) did not affect the water holding capacity of longissimus dorsi muscle. In addition, in barrows, Feng *et al*. (2006) found that betaine (1250 mg/kg of diet) did not affect muscle water holding capacity. Moreover, Madeira *et al*. (2015) showed that betaine supplementation (3.3 g/kg of diet) did not affect cooking loss in pigs. Likewise, Yang *et al*. (2009) found that the betaine (0.2, 0.4

and 0.6% of diet) did not affect the cooking loss of loin muscle in pigs.

In addition, many studies revealed that dietary betaine did not affect the meat pH. For example, Yu *et al*. (2004) showed that dietary betaine (1.5 g/kg of diet) did not affect the pH value of longissimus dorsi muscle in pigs. Moreover, Feng *et al*. (2006) found that the pH value was not affected in finishing barrows offered diets supplemented with 1250 mg betaine/kg. Likewise, Yang *et al*. (2009) found that the betaine (0.2, 0.4 and 0.6% of diet) did not affect the pH value of loin and ham in pigs. Similarly, Martins *et al*. (2012) found that dietary betaine (1 g/kg of diet) did not affect the pH of Alentejano pigs' carcass muscles.

Conclusion

Dietary betaine showed enhancment effects on livetock due its properites as an osmoyte and as a methyl donor. Therefore, better average daily gain and feed intake were observed when betaine was used in the animal rations. In addition, intersting data were collected from other studies suggested that betaine can play roles in the carcass and meat quality of animals. These suggestions are based on the role of betaine in protein and energy metabolism. In addition, betaine as an osmolyte could help against the environmental stressors. Almost of studies about betaine were concentrated on monogastric animals specialy pigs and few research about ruminants. There is still further research needed about the affect of betaine and the mode of action in ruminants.

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