

## Review

# Effect of metabolic modifiers on meat quantity and quality

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Accepted 17 April, 2012

The inadequacy of food supply due to the population growth together with urbanization, drive a significant demand for animal sources. Consequently, a number of technologies have been developed and are being used commercially to enhance profitability of animal production and to improve their quality. The objective of this paper is to review recent studies on the effects of metabolic modifiers on quantity and quality of meat and their contribution in sustaining food security and improving quality of life. Metabolic modifiers such as  $\beta$ -agonists, anabolic implants, somatotropin, immunocastration, vitamin E, conjugated linoleic acid (CLA) and trace elements have been utilized by different agribusiness to improve meat production and enhance meat quality. These compounds supplement to the animals with feed, as an injection or implant to enhance the rate of gain, the feed utilization efficiency, carcass percentage, shelf-life of meat, improve meat's nutrient content and/or meat palatability. On the other hand, some metabolic modifiers are either not approved or banned from use due to negative health effects to the consumer. There is a consistent research report for the approved technologies enhancing protein synthesis and muscle deposition, while decreasing fat synthesis and deposition, when they are applied in the recommended dosage. Therefore, we believe that utilizing available technologies and methodologies in reference to the mentioned materials will help in improving meat quality and thereby increase productivity of the livestock resource and hence, improve food security.

**Key words:** Meat yield, food security, beef, lamb, pork.

## INTRODUCTION

Food security can be achieved with a strategic development plan which is people centered, environmentally sound, participatory, capable of building local and national capacity for self-reliance. These are the basic characteristics of sustainable human and environmental development. In this regard, there was an increase of food availability with the growth of human population for the last three to four decades. However, there are still more than 900 million malnourished people in the world (FAO, 2010). This can be explained in terms of food shortage, improper distribution, low purchasing

ability or the poor and low nutritional content of the available food that is affordable by poor people. Alongside crops, livestock play an important role in food security as a source of food (protein and energy source), skin, fiber, manure, dispensable capital and providing socio-cultural stability to farmers of developing or under developed nations. Similar to cereal groups, meat and meat products provide both omega-3 ( $n-3$ ) and omega-6 ( $n-6$ ) polyunsaturated fatty acids and is also, a major provider of monounsaturated fatty acids (Wood et al., 2008).

Despite the many positive attributes of meat and meat products, they contain a high proportion of fat enriched with saturated fatty acids (Muchenje et al., 2009; Barton et al., 2007; Scollan et al., 2006), which is usually associated with cardiovascular diseases and also

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considered as unpopular constituents of meat in many parts of the world (Wood et al., 2008). These factors have led the attention of researchers into the development of technologies that can control the proportion of lean and fat muscle deposition in meat animals, such as metabolic modifiers. So, the objective of this paper is to review recent studies on the effects of metabolic modifiers on quality of meat.

## METABOLIC MODIFIERS

Metabolic modifiers are compounds that can be supplemented with feed, injected, or implanted to the animals in order to enhance the rate of gain, the feed utilization efficiency, increase the carcass percentage, extend the shelf-life of meat, improve meat's nutrient content and/or improve meat palatability (Dikeman, 2007). There are documented adverse effects of these compounds on human health; such as, food poisoning associated with the residues in liver, cardiovascular and central nervous diseases (Pulce et al., 1991; Martinez-Navarro, 1990). But, in general, these metabolic modifiers increase protein synthesis and decrease fat synthesis and deposition (Dunshea et al., 2005). Due to these technological advancements, producers, processors and consumers are benefited, as the efficiency of production and processing is improved. Simultaneously, consumers are getting lean meat as of their demand. This review emphasizes on those modifiers that are, or likely will be approved for use in different species in different countries. These include  $\beta$ -agonists, anabolic implants, somatotropin, immunocastration, conjugated linoleic acid (CLA), Vitamin E and the trace elements.

### $\beta$ -agonists

$\beta$ -agonists are analogues of a natural group of compounds called catecholamines and are the recent approaches to improve the meat quality and yield in livestock industry (Strydom et al., 2009; Mohammadi et al., 2006). They tend to decrease the synthesis and storage of fat (lipogenesis) while increasing the mobilization and hydrolysis of fat (lipolysis) (Dunshea et al., 2005). Ractopamine hydrochloride for pigs (Paylean<sup>®</sup>), cattle (Optalex<sup>®</sup>) and zilpaterol hydrochloride (Zilmax<sup>®</sup>) for cattle are the only approved  $\beta$ -agonists (Claus et al., 2010; Strydom et al., 2009; Dikeman, 2007). On the other hand, the use of  $\beta$ -agonists as growth promoters in meat production is banned in the EU indicating that their residues may have intoxication effect for consumers (Danyi et al., 2007).

$\beta$ -agonists are generally used for both ruminants and non-ruminants, but the later is less sensitive to  $\beta$ -agonists in fat mobilization (Dunshea et al., 2005).

$\beta$ -agonists protect the protein from degradation to a higher extent in ruminants than in pigs. In the case of ruminants, they bind to receptors found on adipocyte membrane and muscle to activate the intracellular signaling molecules (Mersmann, 1998). Moreover, the molecules especially cyclic adenosine monophosphate (cAMP) exerts its action on cellular metabolism thereby increase protein synthesis and fat degradation and decrease protein degradation.

A study on the effects of supplementing ractopamine at 300 mg steer<sup>-1</sup> d<sup>-1</sup> for a period of 33 days reduced the feed intake, while it increased the gain/feed ratio, and improving dressing percentage and carcass weight (Avendano-Reyes et al., 2006). Inclusion of ractopamine hydrochloride (Paylean<sup>®</sup>) to pigs diet at dosages of 5.0 and 9.9 mg/kg of feed for 30 to 50 days before the slaughter has improved the rate of growth, feed utilization efficiency, dressing percentage and carcass composition (Dikeman, 2007).

Daily supplementation of zilpaterol to lambs in the rate of 0.15, 0.20 or 0.25 mg/kg of LW for 32 days before slaughter increased gain efficiency, daily gain and total gain by 15.8, 16 and 17%, respectively (Estrada-Angulo et al., 2008). Similar work was done by Plascencia et al. (2008) and Avendano-Reyes et al. (2006) in feedlot cattle and found enhanced daily gain, carcass yield and dressing percentage by feeding zilpaterol at a rate of 60 mg/day. Zilpaterol has also a positive effect in increasing hot carcass weight and longissimus muscle area when supplemented to cattle (Avendano-Reyes et al., 2006 and Mohammadi et al., 2006). Mohammadi et al. (2006) indicated that zilpaterol supplementation has a positive effect on growth performance, dressing percentage and carcass fat in lambs in a manner comparable to that of cattle. Zilpaterol (Zilmax<sup>®</sup>) supplementation for a duration of 20 to 40 days decreased meat tenderness (Claus et al., 2010; Holmer et al., 2009; Strydom et al., 2007; Avendano-Reyes et al., 2006). However, this effect can be minimized by adequate postmortem aging and effective electrical stimulation (Dikeman, 2007).

Claus et al. (2010) reported the work of Robles-Estrada et al. (2009) who evaluated different pre-slaughter withdrawal periods (3, 6 or 12 days) of zilpaterol hydrochloride (Zilmax<sup>®</sup>) and it is indicated that 3 day withdrawal period enhanced average daily gain, gain to feed ratio, dressing percent and hot carcass weight, while 6 and 12 days withdrawal periods negatively affected lean meat yield. This result exclusively indicates that a 3 day withdrawal period is optimum for the mentioned benefits.

Avendano-Reyes et al. (2006) compared the effects of ractopamine (Optalex<sup>®</sup>) and zilpaterol (Zilmax<sup>®</sup>) and reported that shear values were similar among steers supplemented zilpaterol and ractopamine. However, these authors indicated that ractopamine reduced feed intake of steers and showed slightly more fat thickness than steers fed zilpaterol. Strydom et al. (2009) also

reported the advantage of zilpaterol over ractopamine in growth performance and carcass yield.

Though only Ractopamine and Zilpaterol are approved so far, there are also many other  $\beta$ -agonists that have been proved to have positive effects in livestock industries (Dunshea et al., 2005). Strydom et al. (2009) reported that clenbuterol can improve tenderness better than both ractopamine and zilpaterol on different muscles but has adaptation problems for animals. To study effects of various  $\beta$ -agonists on meat quality, Dunshea et al. (2005) collected pork quality data with different doses and breeds of pigs. The result indicates that the effect of cimaterol is more pronounced than the other  $\beta$ -agonists by reducing intramuscular fat and enhancing drip loss and shear force. However, in the same work,  $\beta$ -agonist treatments reduced redness ( $a^*$ ) and yellowness ( $b^*$ ) of the meat that might render lower level of acceptance by consumers.

### Anabolic implants

Anabolic implants are growth promoting implants that are inserted into the body of an animal through different methods. They are categorized as estrogenic, androgenic, or both estrogenic and androgenic (Scanga et al., 1998). Estrogenic and androgenic implants have been used widely on cattle for more than 50 years to enhance growth of animal and profitability of the livestock industry (Dunshea et al., 2005). There are many estrogenic and androgenic compounds that are approved either alone or in combination including naturally occurring steroids such as progesterone and testosterone, 17-oestradiol and their synthetic counterparts like trenbolone acetate, melengestrol acetate and zeranol (Dunshea et al., 2005; Freyberger et al., 2007; Moon et al., 2009; Sissom et al., 2007; Walker et al., 2006). Both estrogenic and androgenic implants are reported to improve growth performance and feed utilization efficiency of animals (Ahmadkhaniha et al., 2009; Chung and Johnson, 2008; Muchenje et al., 2009). Besides, steroid hormones have been found to enhance meat quality (Ahmadkhaniha et al., 2009). Choi et al. (2010) mentioned that meat quality grades are positively correlated with the concentrations of estrone (one of the three estrogens) and 17 $\alpha$ -estradiol in *longissimus dorsi* muscle. Yarrow et al. (2010) stated that trenbolone (a synthetic analog of testosterone) binds to androgen receptors about three times the affinity of testosterone and induces growth of bone and skeletal muscles and also, decrease adiposity in many mammals. It is also noted that these compound alter the action of endogenous growth factors by influencing glucocorticoid's action.

Dikeman (2007) reported that using a combination of androgenic and estrogenic implants is more advantageous than using either of them alone. In

general, anabolic implants are more effective to ruminants, in improving meat quality and quantity parameters, than non-ruminants such as pigs (Dunshea et al., 2005). Steroid hormone expression levels and concentrations of androgen and estrogen receptor  $\alpha$ -genes were compared in longissimus dorsi muscles of bulls and steers; and steers showed lower concentrations of testosterone than bulls (Choi et al., 2010). Since estrogens and androgens have fat and protein anabolic properties, they determine the distribution and development of muscle and fatty tissues (Ahmadkhaniha et al., 2009). Androgens mostly have genomic effects on bone, muscle and sexual development of male and it takes a long time for new protein synthesis (Yarrow et al., 2010). Endogenous steroids are always available in the tissues of animal and it is difficult to determine in meat.

### Somatotropin

Somatotropin is a naturally occurring protein hormone produced by the anterior pituitary gland and secreted into the circulation and plays an important role in coordinating the metabolism of protein, lipid and minerals in mammals. There are also genetically- engineered somatotropins which have been approved for use in swine (porcin Somatotropin) and ruminant (bovine and ovine Somatotropin) in different countries (Dikeman, 2007). These hormones are delivered to the animal in the form of injection usually once to trice a week. Injecting porcin somatotropin to pig reduced the lipid accretion rate by 82% while the protein accretion rate was enhanced by about 74%. Daily injection of 6 mg porcin somatotropin during early gestation of sows (from day 10 to 27) showed a negative effect on meat quality of the offspring (Kuhn et al., 2004). However, treatment of finisher pigs with 150  $\mu$ g porcin somatotropin per kg of live weight, enhanced daily gain by 20% (Beerman, 1994; cited in Dikeman). Dunshea et al. (2005) reported that porcin somatotropin has advantage on growth performance, feed conversion efficiency and protein deposition in pigs. These authors conducted a meta-analysis of literature and concluded that porcin somatotropin increased shear force by 9% and decreased intramuscular fat and drip loss by 12 and 9%, respectively.

Therefore, there is a decrease in tenderness according to consumer preferences. Exogenous bovine somatotropin (bST) and ovine somatotropin (oST) can also be applied in growing sheep (Dikeman, 2007) and goat (Kouakou et al., 2005). As there is no effective anabolic steroid implant use in sheep, an implant release form of oST seems to be appropriate in the sheep industry (Dikeman, 2007). The author summarized the effect of Somatotropin in improving growth rate and carcass percentage, in decreasing marbling and tenderness and its neutral to slightly negative effect on firmness and color.

## Immunocastration

Castration is a common activity in animal production to improve growth performance, to avoid unwanted reproduction, to reduce aggressiveness of the animal and to control undesirable taste of meat from matured animal by reducing testosterone hormone. After the non-castrated male animals have reached puberty, substances like skatole and androstenone pheromone accumulate in their fatty tissue and results the taint. Taint is the offensive taste or odor derived from matured and non-castrated male meat producing animals (Bonneau, 1992; Dunshea et al., 2005). Castration in livestock can be performed by surgically removing the testicles or by chemical treatment or by using burdizzo, which blocks the spermatid cords. However, pain and stress resulting from surgical castration (without anaesthesia) may lead to economic crisis in swine production and even not appreciated by animal welfare (Prunier et al., 2006; Thun and Gajewski, 2006).

Immunocastration is a temporary suppression of male reproductive system by vaccination against gonadotrophin releasing hormone (GnRH) and it is becoming a better alternative to surgical castration. Immunizing boars with synthetic GnRH and protein results in the production of antibodies against GnRH. The antibodies produced could block the hypothalamus–pituitary–gonad axis, with suppression of testicular function which finally results in the decrease of male steroid hormone synthesis (Jaros et al., 2005; Zamaratskaia et al., 2008). This immunization against GnRH result in decreased size of testicle as well as reduced levels of androstenone (Evans, 2006; Jaros et al., 2005). In recent study, Gispert et al. (2010) revealed a distinct difference in testicular size between immunocastrated and whole male pigs when visualized outside the scrotum. Vaccine of immunocastration is found to be effective in suppressing skatole (99%) and androstenone (100%) (Dunshea et al., 2005).

Furnols et al. (2008, 2009) stated that the effectiveness of immunocastration in controlling boar taint is demonstrated by sensory analysis with panel tests and consumer survey. Dunshea et al. (2005) cited the work of D'Souza et al. (1999) indicating that tenderness, flavor, and overall acceptability of pork were better from immunocastrates, compared with pork from whole male and similar to females. Gispert et al. (2010) also evaluated quality and quantity of pork from immunocastrates, females and boars. The result showed that surgically castrated males and immunocastrated males were fatter than female and non-castrated male in the loin area. In addition, the authors mentioned that intramuscular fat of immunocastrated male was slightly more than surgically castrated male, female and whole male.

Furnols et al. (2008) evaluated consumer acceptability of pork among non-castrated male, female, surgically

castrated and immunocastrated male. The acceptability of consumer was similar for pork from female, surgically castrated and immunocastrated male. Whereas, pork from non-castrated male was least accepted than the other and it resulted in dissatisfied consumer scores. Finally, Dunshea et al. (2005), Dikeman (2007), Furnols et al. (2008) and Gispert et al. (2010) argued that from the point of view of practicability and meat quality, immunocastration can replace surgical castration. They also added that, Immunocastration can produce pork that is accepted by the consumers and indistinguishable from females or surgically castrated pork. Thus, from different literatures, it is possible to conclude that immunocastration is practicable, welfare-friendly and effective in preventing boar taint without affecting quality and acceptability of the meat. Immunocastration is also reported to be a good alternative to physical castration in ruminants (Ulker et al., 2002; Bonneau and Enright, 1995; Gökdal et al., 2010; Ribeiro et al., 2004). Ulker et al. (2002) examined the effect of immunocastration in Ram lambs and indicated its positive effect on carcass quality with no influence on growth rate and dressing percentage. In recent study, Gökdal et al. (2010) also reported the success of immunocastration in Ram lambs. These authors observed better feed conversion efficiency than controls and a non-significance difference of carcass percentage, intramuscular fat and color of the meat. Ribeiro et al. (2004) conducted an experiment on castrated, immunocastrated and intact bulls and showed that body weight and average daily gain was lower for castrated and immunized bulls than the intact. According to these authors, there was no significant difference in carcass percentage, flavor, juiciness, thawing and cooking loss among the group. However, there was an advantage in color and tenderness of the meat and it is concluded that immunocastration can replace castration with a similar production of carcass traits.

## Conjugated linoleic acid (CLA)

CLA is commonly found in ruminant products such as beef, lamb and dairy products and arises directly from biohydrogenation of dietary linoleic acid and alpha-linolenic acid (Collomb et al., 2006). It is a mixture of geometric and positional isomers of linoleic acid with conjugated double bonds located at positions 7,9-, 8,10-, 9,11-, 10,12- or 11, and 13- on the carbon chain (Dunshea et al., 2005; De la Torre et al., 2006). CLAs have numerous biological effects on animals and humans. Corino et al. (2007) mentioned that CLA modulate utilization and storage of nutrient, growth of cell and metabolism of lipid. As Scollan et al. (2006) stated, *trans* vaccenic acid (*trans*-11, 18:1) is the precursor for tissue synthesis of beneficial CLA in both humans and animals. The anti-cancer role and the reduction of fatty streak formation in the aorta are the proposed human

health benefits from consuming CLA (Dikeman, 2007).

Animal products are criticized for their high content of saturated fatty acids, being damaging to health and it is indicated that modifying the diet of the animal can enhance the content of unsaturated fatty acid in animal products (meat, milk and eggs) (Woods and Fearon, 2009). In the same document it is mentioned that large proportion of unsaturated fatty acid in dairy cows' ration may influence the activity of rumen, decrease concentrations of protein and fat and affecting milk yield negatively. Though animal products (meat and milk) are the primary sources of CLA in human nutrition, the proportion of CLA in meat is by far below daily recommendation for health benefits which is about 3500 mg d<sup>-1</sup> (Dikeman, 2007). The range of CLA in meat is from 35 to 134 mg 100 g<sup>-1</sup> of fresh muscle and the value for beef is even lower than this figure (Scollan et al., 2006).

There are opportunities to enhance the content of health promoting fatty acids in animal's origins with a certain value addition of the product. Animal feed is one of the most important factors in determining meat quality parameters (Carrasco et al., 2009; Joy et al., 2008). Givens and Gibbs (2006), in a detailed review of the role of meat as a source of *n*-3 PUFA in human diet, mentioned that it is possible to enrich the content of beneficiary fatty acids in meat by improving the animal diet. Forage portion of animal diet is reported to be a source of unsaturated fatty acid and ruminants that consume fresh pasture will have a better proportion of unsaturated fatty acid in their product including meat (Dewhurst et al., 2006; Chilliard et al., 2007; Lourenco et al., 2008). Scollan et al. (2006) noted that feed is the major route to improve the proportion of beneficial fatty acids in beef. Warren et al. (2003) has compared forage and concentrate on the composition of fatty acid in beef and showed that the amount of unsaturated fatty acids of beef from grass fed cattle was superior to concentrate fed cattle. Lorenzen et al. (2007) also found CLA content to be higher in cooked muscles from cattle fed on pasture than those fed a feedlot diet.

CLA supplementation of pigs reported to increase muscle mass production by reducing carcass fat (Dikeman, 2007; Dunshea et al., 2005). The amount of reduction in back fat is directly related to the initial back fat depth, which means the more initial back fat the more reduction. In a review of the literature, Dunshea et al. (2005) summarized back fat reduction of 6%, and an increase in marbling score and intramuscular fat by about 11 and 7%, respectively in response to dietary CLA supplementation. However, this author reported that consumer perception of juiciness was reduced by 12%. Dikeman (2007) says feeding CLA or sunflower oil to pigs decreased feed intake and enhanced feed utilization efficiency while there was no effect on growth performance, drip loss, shear force, color and meat palatability trait. Corino et al. (2007) found that addition of

CLA isomers to rabbit diet improved the content of lipid and fatty acid composition and decreased oxidation of meat.

## Vitamin E

Vitamin E commonly known as tocopherol is a lipid soluble vitamin occurring naturally in different forms:  $\alpha$ ,  $\beta$ ,  $\gamma$ , and  $\delta$  tocopherols (Niculita et al., 2007). Dietary vitamin E supplementation in meat animals consistently reduces oxidation in meat and meat products (Dunshea et al., 2005; Boler et al., 2009; Dikeman, 2007; Guo et al., 2006; Cusack et al., 2009). Meat is stored in a fresh manner for only a short duration due to the oxidation of the pigment to a brown color and causes a considerable crisis in the meat industry (Dunshea et al., 2005). The supplementation of vitamin E improves the color of meat and can extend shelf-life of pork, beef and lamb (Dikeman, 2007; Dunshea et al., 2005). These authors reported that supplementing vitamin E to cattle and pig diets showed an advantage in color display life of meat. It was also reported that drip losses after refrigeration and after thawing frozen meat was reduced when animals were supplemented with vitamin E (Asghar et al., 1991).

Oxidation of lipid is usually measured with thiobarbituric acid reactive substances (TBARS). TBARS indicates the degree of off-flavors and rancidity. In order to get all the advantages of vitamin E, Dunshea et al. (2005) indicated a dose of 40 to 700 mg of natural vitamin E. However, in recent a study, Boler et al. (2009) indicated that there was no additional improvements by supplementing pigs more than a level of 40 mg/kg feed showing that 40 mg/kg might be the optimum value. The later authors supplemented five levels of a natural vitamin E and one level of synthetic vitamin E and compared with pigs fed 10 mg/kg natural vitamin E. The concentration of vitamin E in adipose tissue was about 143% more for pigs fed 40 mg/kg natural vitamin E than the pigs with 10 mg/kg natural vitamin E diet. Other reports also suggest that a 40, 100 and 200 mg/kg natural vitamin E, and 200 mg/kg synthetic vitamin E incorporation in the diet resulted higher concentration of vitamin E in the adipose tissue with decreased oxidation and drip loss, and improved color (Boler et al., 2009; Guo et al., 2006; Dunshea et al., 2005). Supplementing vitamin E has no known negative effect on feed intake, feed efficiency, dressing percentage or meat yield and overall performance of animals (Dikeman, 2007). However, economic advantage of applying vitamin E need to be assessed as it is expensive.

## Selenium, betaine, chromium and magnesium

Selenium, in the form of selenocysteine, is the central structural component for many specific enzymes and as

a result it is an essential trace element for both humans and animals (Vignola et al., 2009). Selenium deficiency is usually associated with cellular and heart disease of human and foods with good selenium content are considered as a functional food (Dunshea et al., 2005). Organic selenium, in the form of selenomethionine is the predominant selenium species in forage crops and cereals. Sodium selenite is another commercial selenium source used as an ingredient in animal feed (Vignola et al., 2009).

Zhan et al. (2007) described that treatment of both sodium selenite and selenomethionine can improve the content of selenium in muscle, serum, pancreas, liver and kidney tissue. Selenomethionine is more effective than sodium selenite in depositing selenium in tissues, increasing the antioxidant status, minimizing the drip losses and stabilizing the meat color. Juniper et al. (2006) reported that organic and inorganic selenium supplements in the diets of growing lambs for a period of 112 days has no effect on growth rates and feed intake. Antioxidant status and concentrations of C18:1 *trans*-11 in plasma and C18:2 *trans*-10, *cis*-12 in liver improved with selenium supplementation (Yu et al., 2008). Vignola et al. (2009) fed diets supplemented from different selenium sources at different levels and concluded that selenium supplementation can significantly improve selenium levels of muscle in lambs. Betaine, present in most organisms, is a naturally occurring tertiary amine, acting as either an organic osmoprotectant or as a methyl donor, playing a role in metabolism of lipid (Eklund et al., 2005). Huang et al. (2006) evaluated the effect of dietary betaine supplementation of finishing pigs and showed that lean percentage, average daily gain and *longissimus* muscle area were enhanced by about 5, 6 and 18%, respectively, but the fat percentage and back fat thickness reduced by about 13 and 10%, respectively. The feed intake and feed conversion ratio were not affected. The expression level of mRNA and the potential enzyme activity of fatty acid synthases are significantly correlated (Huang et al., 2008). Hormone-sensitive lipase activity is enhanced by supplementing with betaine, which resulted in a 24% reduction of fatty acid synthesis activity. Betaine has been found to have effect on growth factors and different hormones in pigs and inhibit the synthesis of fat by decreasing the lipogenic enzymes activities. On the other hand, the increasing activities of hormone-sensitive lipase stimulate fat degradation. The combination effects of all these activities enable betaine to reduce the mass of adipose tissue and improve carcass characteristics.

Chromium is an essential trace element for normal metabolism (Dikeman, 2007). Stahlhut et al. (2006) determined the effects of dietary chromium status on glucose metabolism in beef cows; and chromium supplementation decreased concentrations of plasma glucose. Supplementing high levels of chromium to pigs enhance muscle percentage, reduce back fat and had no effect on tenderness or sensory traits. Dunshea et al.

(2005) also reported that feeding chromium is a good option to reduce fat deposition and it is widely used in swine production.

Other element is magnesium. Tang et al. (2009) reported that supplementation of magnesium aspartate enhanced concentration of serum magnesium, mRNA level of  $\mu$ -calpain in muscle and reduced concentration of serum cortisol. The paper also suggested that supplemental magnesium aspartate improved color of pork and decline shear force while there was no effect on pH and drip loss of pork.

## CONCLUSION

A number of technologies have been developed and are being commercially used to improve profitability of animal production and to improve the quality of their product. Producers, processors and consumers are benefited due to these technological advancements. The use of metabolic modifiers in farm animals has a significant competitive advantage of improving quality and quantity of meat. In general, they increase protein synthesis and decrease fat synthesis and deposition and in recommend dosage, result in enhancement of shear force by 5 to 10%. As a result, some modifiers received regulatory approval for use in livestock in different part of the world while many others are not approved in different countries. Thus, well organized and routine control is required to monitor the illegal presence of these residues and to assure quality and safety of meat.

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