# Amino Acids

## Livestock

## Identification

**Chemical Names:**
See the attached list for the names of protein amino acids.
Chemical names for methionine: 2-amino-4-methylthiobutyric acid; α-amino-γ-methylmercaptobutyric acid.

**Other Names:**
The model used to illustrate amino acids in livestock is methionine. Among the other names for methionine are DL-methionine, D-methionine, L-methionine, Met, Acimethin. See the attached table of other amino acids commonly used in food processing.

**CAS Numbers:**
59-51-8 (DL-methionine)
63-68-3 (L-methionine)
348-67-4 (D-methionine)

**Other Codes:**
International Feed Names (IFN):
DL-methionine: 5-03-86
DL-methionine hydroxy analog calcium: 5-03-87
DL-methionine hydroxy analog: 5-30-281

## Recommendation

| Synthetic / Non-Synthetic: | National List: | Suggested Annotation: |
|---|---|---|
| *Synthetic (consensus--see Condensed Reviewer Comments for a discussion of synthetic v. non-synthetic amino acids)* | *prohibited (2-1)* | *None. [See Condensed Reviewer Comments and Conclusions for reviewer response and possible annotations if the NOSB votes to add any or all amino acids to the recommended National List.]* |

## Characterization

**Composition:**
Amino acids have an amino group ($NH_2$) adjacent to a carboxyl (COOH) group on a carbon. The model amino acid for livestock production is methionine. The formula for methionine is $H_2NCH_3SCH_2CH_2COOH$.

**Properties:**
L-Methionine: Colorless or white lustrous plates, or a white crystalline powder. Has a slight, characteristic odor. Soluble in water, alkali solutions, and mineral acids. Slightly soluble in alcohol, insoluble in ether. MP 280-282°C. It is assymetric, forming both an L- and a D- enantiomer.

**How Made:**
Methionine may be isolated from naturally occurring sources, produced from genetically engineered organisms, or entirely synthesized by a wide number of processes. While methionine has been produced by fermentation in laboratory conditions, racemic mixtures of D- and L- methionine (DL-Methionine) are usually produced entirely by chemical methods (Araki and Ozeki, 1991). Methionine can be produced from the reaction of acrolein with methyl mercaptan in the presence of a catalyst (Fong, et al., 1981). Another method uses propylene, hydrogen sulfide, methane, and ammonia to make the intermediates acrolein, methylthiol, and hydrocyanic acid (DeGussa). The Strecker synthesis can be used with α-methylthiopropionaldehyde as the aldehyde (Fong, et al., 1981). A recently patented process reacts 3-methylmercaptopropionaldehyde, ammonia, hydrogen cyanide, and carbon dioxide in the presence of water in three reaction steps (Geiger et al., 1998). Other methods are discussed in the Crops Amino Acid TAP review.

**Specific Uses:**
The primary use of isolated amino acids in livestock production are as a feed supplement. For optimum health and performance the animal's diet must contain adequate quantities of all nutrients needed, including amino acids. The essential amino acid furthest below the level needed to build protein is known as the limiting amino acid. A shortage of the limiting amino acid will constrain animal growth, reduce feed efficiency, and in extreme cases cause a nutritional deficiency. Supplementation with isolated amino acids increases feed conversion efficiency, thus lowering feed costs per unit of weight gain or production (Pond, Church, and Pond, 1995). Methionine is often the first or second limiting amino acid in most diets, and so is most representative of amino acids fed as a nutritional supplement (Buttery and D'Mello, 1994).

Amino acids are also used in livestock health care. Methionine is used as a urine acidifier because excretion of its sulfate anion lowers urine pH. Its sulfate anion may also displace phosphate from magnesium-ammonium-phosphate hexahydrate (struvite, double phosphate, or triple phosphate if calcium is also present) crystals and uroliths, which form best at a pH above 6.4-6.6. As a result of these effects methionine is used to assist in dissolving and/or preventing uroliths, kidney stones, bladder stones or urologic syndromes thought to be caused by struvite uroliths or crystals (Lewis, Morris, and Hand, 1987). Methionine is also used to assist in the treatment and/or prevention of hepatic lipidosis because of its need for body fat mobilization and transport.

Other amino acids may be used for therapeutic purposes as well. This includes a number of non-essential protein amino acids, as well as non-protein amino acids. For example, glutamine is used in the management of enteritis because it is protective and promotes repair of injured intestines (Tremel, et al, 1994).

**Action:**
Amino acids form protein. Between 8 and 14 cannot be synthesized by animals and therefore must be consumed in feeding. These are considered essential (or semi-essential) for animal nutrition. Others may be produced by the animal or by organisms in the animal's gastrointestinal tract in adequate amounts. The National Academy of Sciences and most other sources on animal nutrition list arginine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine as essential (National Research Council, various years). Animals convert dietary protein into tissue protein through digestive processes. Proteins are metabolized by animals through two phases: catabolism (degradation) and anabolism (synthesis).

**Combinations:**
Amino acids are combined in feed rations of grains, beans, oilseeds, and other meals with antioxidants, vitamins, minerals, antibiotics, and hormones (Pond, Church, and Pond, 1995).

## Status

### OFPA
Amino acids do not appear on the list of synthetics that may be allowed (7 USC 6517(b)(1)(C)(i). The NOSB may want to discuss whether or not the administration of synthetic amino acids in the absence of any symptoms of illness would be considered a growth or production promoter and therefore categorically prohibited in livestock production for such purposes (7 USC 6509(c)(3)).

### Regulatory
Regulated as a nutrient / dietary supplement by FDA (21 CFR 582.5475). The Association of American Feed Control Officials (AAFCO) set the standard of identity for DL-methionine as containing a minimum of 99% racemic 2-amino-4-methylthiobutyric acid (AAFCO, 1998). The AAFCO model regulation states that “the term Methionine Supplement may be used in the ingredient list on a feed tag to indicate the addition of DL-Methionine.” (AAFCO, 1998.)

### Status among Certifiers
A number of private certifiers prohibit the use of amino acids. Various state and private certifiers either explicitly or implicitly allow the use of essential amino acids. Their status among US certifiers remains unresolved awaiting a recommendation by the NOSB and final determination by the NOP.

**Historic Use**
Crystalline amino acids were generally not used as feed supplements in organic livestock production until very recently. Most current use in organic production appears to be as a supplement for laying hen feed rations.

**International**
The Codex guidelines do not address livestock materials at this point (Joint FAO/WHO Standards Programme. 1999). Amino acids are prohibited for use in feed by IFOAM (IFOAM, 1998). The European Standards do not include amino acids among permitted feedstuffs (European Union, 1999). Canadian standards allow essential amino acids, but explicitly prohibit ones from genetically engineered sources and state that the material may have some additional requirements. Operators are instructed to consult with their certification body for approval (Canadian General Standards Board, 1999).

## OFPA 2119(m) Criteria

(1) The potential of such substances for detrimental chemical interactions with other materials used in organic farming systems.

The primary chemical interaction is the dietary intake by animals. While many of the interactions may be regarded as beneficial, excess methionine in a diet may cause deficiencies in other amino acids and induce toxicity (D'Mello, 1994). Methionine, while often one of the most limiting amino acids, is also one that readily goes to toxic excess. Small excesses of methionine can be deleterious (Buttery and D'Mello, 1994). Excess supplemental methionine can actually depress growth and development at levels of 40 g/kg (Baker, 1989). Growth depressions resulting from excess supplemental amino acids include lesions in tissues and organs (D'Mello, 1994).

(2) The toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.

While it is nutritionally essential, methionine excesses are far more toxic to poultry than similar excesses of tryptophan, lysine, and threonine (National Research Council, 1994). Force feeding methionine to excess can result in death to chicks (National Research Council, 1994).

A dosage of 2 g / mature cat / day (20 to 30 g / kg dry diet) for 20 days induces anorexia, ataxia, cyanosis, methemoglobinemia and Heinz body formation resulting in hemolytic anemia (Maede, 1985). Rat studies of methionine is significantly toxic in excess (Regina, et al., 1993). High levels of methionine were found to be toxic to hepatic cells and liver function of the rat models. The results of this study indicated that the biochemical reason for the extreme sensitivity of mammals to excess dietary methionine is thought to be due to the accumulation of toxic catabolites, most notably, S-adenosylmethione, resulting in liver dysfunction. L-methionine has an acute $LD_{50}$ of 4,328 mg/kg (rat) (NIEHS, 1999b). NIEHS carcinogenicity and teratogenicity are not available, but reports positive mutagenicity (NIEHS, 1999b).

Methionine is stable in crystalline form at standard temperature and pressure.

(3) The probability of environmental contamination during manufacture, use, misuse or disposal of such substance.

Synthetic production of DL-methionine involves a number of toxic source chemicals and intermediates. Each of the several manufacturing processes used to produce DL-methionine were rated as either "moderately heavy" to "extreme" (Fong, et al., 1981). Newer processes have not replaced many of the feedstocks. Several of the feedstocks are likely to result in ruptured storage tanks, leaking chemicals, and releases into the environment. The methionine production process is listed by EPA as a hazardous air pollutant (40 CFR 63.184).

Methyl mercaptan can react with water, steam, or acids to produce flammable and toxic vapors (Sax, 1984). The EPA rates methyl mercaptan fires as highly hazardous and can cause death by respiratory paralysis (EPA, 1987). Acrolein has a toxicity rating of 5 (on a scale of 1 to 6 with 6 being most toxic) (Gosselin, 1984) and it is also an aquatic herbicide (Meister, 1999). The acrolein process involves several steps that render it synthetic as well (1994). Acrolein itself is an extreme irritant.

Hydrogen cyanide is produced by further processing of methane and ammonia. Hydrogen cyanide is a gas that is highly toxic. Hydrogen cyanide has a toxicity rating of 6 and is one of the fastest acting poisons known to man (Gosselin, 1984). Exposure causes paralysis, unconsciousness, convulsions, and respiratory arrest. Death usually results from exposure at 300 ppm concentrations for a few minutes (Clayton and Clayton, 1982). Manufacture of hydrogen cyanide is a significant source of atmospheric release of cyanide (Midwest Research Institute, 1993). Ammonia is a corrosive agent. Methane is a central nervous system depressant (Gosselin, 1984).

(4) The effect of the substance on human health.

Methionine is essential in small amounts in the human diet, and is sold over-the-counter as a dietary supplement. The L- form of methionine is used extensively in human medicine for a variety of therapeutic purposes including pH and electrolyte balancing, parenteral nutrition, pharmaceutical adjuvant, and other applications. It is in fact one of the top 800 drugs in human medicine (Mosby, 1997). Methionine may cause nausea, vomiting, dizziness, and irritability and should be used with caution in patients with severe liver disease (Reynolds, 1996).

The D- form of methionine is not well utilized by humans (Lewis and Baker, 1995). Individuals may have allergic reactions to the D- isomers or a racemic mixture of DL-methionine. While a number of amino acids are considered GRAS for human consumption and as feed supplements, DL-methionine is not (see 21 CFR 172, 21 CFR 184, and 21 CFR 570.35). DL-methionine is unique among amino acids cleared for food use in that it is the only one listed that explicitly says it is not for use in infant feed formulas (21 CFR 173.320). When heated to decomposition, methionine emits dangerous and highly toxic fumes (NIEHS, 1999).

(5) The effects of the substance on biological and chemical interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including the salt index and solubility of the soil), crops and livestock.

Although methionine is nutritionally essential for all mammals, it can be significantly toxic according to rat studies (Regina, 1992). In pigs, excess methionine can actually suppress weight gain (Baker, 1989). The rate of methionine depletion from tissue pools is high, therefore the potential for methionine wastage is high if supplementation of intact protein diets with pure sources in a once-a-day feeding regimen is employed. On the other hand, pure sources of amino acids are more bioavailable than intact-protein sources (Baker, 1989).

Amino acid requirements may be affected by environmental temperature extremes, basically because of the effect on feed intake, but amino acid supplementation will only affect weight gain if it improves feed intake. Methionine may range from first to third-limiting amino acid depending on the species, stage of production, and type of diet being supplemented (Baker, 1989).

For ruminants, the factors affecting the benefit of amino acid supplementation become even more complex due to the fact that 70% of bovine protein synthesis is a result of microbial conversion. Moreover, unprotected forms of methionine, such as DL-methionine, will be degraded in the rumen although it may still have a positive effect on enhancing microbial synthesis. Nonetheless, research continues on ways to protect DL-methionine such as with coatings of synthetic plastics or zinc methioninate complexes. Whenever certain factors change--species, age, environmental conditions, level of performance, energy content of the feed, vitamin dosing--the amino acid requirements of the animal change as well (Degussa, no date).

Intensive animal production leads to the inefficient utilization of nitrogen in feed and hence its waste in animal excreta. Supplementation with amino acids, especially synthetic ones which are absorbed more rapidly, may counteract this loss. However, amino acid losses from the rumen in dairy cattle may indicate that this benefit is more likely to be seen in pigs and poultry (Tamminga and Verstegen, 1992). Nonetheless, livestock management modifications such as more efficient use of animal excreta, i.e. manure, or less intensive animal production could also counteract this problem.

Managing the nitrogen cycle is seen as a challenge to livestock producers (Tamminga and Verstegen, 1992; Tamminga, 1992; Morse, no date). Poultry layer operations are experiencing increased costs and regulations for manure management (Sloan, et al., 1995). Supplementation with amino acids may allow dietary protein and excretory nitrogen levels to be reduced with a minimum reduction in egg output (Summers, 1993; Sloan et al., 1995). Amino acid supplementation is not the only means identified to reduce nitrogen pollution from animal manure. Other potential solutions include lower animal densities; more frequent rotations; better manure storage, handling, and application techniques; use of enzymes; improved processing of the feed; and selection of more appropriate land and locations to graze and shelter animals (Archer and Nicholson, 1992; Tamminga, 1992; Tamminga and Verstegen, 1992; Bedford, 1995).

(6) The alternatives to using the substance in terms of practices or other available materials.

The production factors cited as reasons to supplement limiting amino acids may be addressed by changes in animal and land management practices, novel feed sources, and better feed handling. Methionine is also found in naturally occurring proteins. Alternatives include improved pasture management, a balanced supplemental ration composed of organic grains, legumes, and oilseed meals. Feed sources with high percentages of methionine are bloodmeal, fish meal, corn gluten meal and sunflower seed meal. In ruminants, sources of mineral sulfur such as gypsum and epsom salts can be coverted to methionine (National Research Council, 1989). Natural sources of essential amino acids and appropriate feed regimens exist to assure adequately balanced rations. DL-methionine is one of the few amino acids not able to be produced economically by fermentation (Areki and Ozeki, 1991). It seems unlikely that a non-synthetic, non-GMO source of isolated L-methionine will be commercially available at a cost competitive with organic feed.

It appears to the investigator, and to two of the three reviewers that all essential amino acids are available in organically grown feed in quantities sufficient to ensure a balanced diet. This is true of methionine as much as any other amino acid. Methionine is seldom considered limiting in ruminants given the ability of the rumen to metabolize other forms of sulfur into methionine and other sulfur amino acids (National Research Council, 1989; van Soest, 1982). While certain amino acids may be able to enhance production, it remains to be proven that basic animal nutritional needs are not met by organic sources or that health-threatening amino acid deficiencies will result from the withholding of synthetic amino acids. The National Academy of Sciences reports that "[t]he greatest disagreement concerning amino acid requirements for broilers centers on the sulfur amino acids, methionine and cystine" (National Research Council, 1994). Some poultry nutrition researchers consider the claim that methionine is the first limiting amino acid to be unsubstantiated and in need of further investigation (Fisher, 1994). Even chicks that are marginally deficient in methionine will show little difference in weight gain from those fed on an adequate diet (Buttery and Boorman, 1976). Cystine and cysteine compliment methionine in that a certain amount of methionine will be converted into those other sulfur amino acids if necessary. In many cases, methionine requirements are overestimated because assays do not accurately reflect the amounts of cystine and cysteine precursors in practical diets (Baker, 1989).

Other cases have shown significantly higher weights and faster gains from amino acid (lys+met) supplementation (Slominski et al, 1999). Also, the digestibility of practical ingredients, such as corn and soybeans, appears to be on the order of 85% or more (National Research Council, 1994).
Rice and casein offer potential novel available sources of methionine (Lewis and Bayley, 1995). Yeast protein has long been known as a rich protein source relatively high in methionine+cystine (Erbersdobler, 1973; National Research Council, 1994), as well as phosphorous and B-complex vitamins (Morrison, 1951). Other potential sources of available methionine for poultry appear to be sunflower meal and canola meal (Waibel et al., 1998). Optimally balancing these nutrients may be challenging to feed processors and livestock producers.

The NOSB may also want to discuss and consider the role of animal protein in the diets of poultry. Hens on good pasture have no need for protein supplements of animal origin (Morrison, 1951). Pasture quality will vary according to field conditions and the season. However, free range poultry on well managed pasture are able to supplement their diets with insects, annelids, and fresh green forage (Smith and Daniel, 1982). Temporarily confined poultry can be fed practical organic corn / soybean ration. Depending on how other parts of the standards evolve and market conditions, novel organic products can be developed as supplements. Among the potential alternative sources include organic dairy products such as casein, organic meat by-products, and--assuming organic fish standards--organic fish meal (National Research Council, 1982 and 1994).

Macroorganisms commonly found in healthy pasture soils cannot be discounted as a source of nutrient cycling in free-range poultry systems. Given the natural feeding habits of poultry and other birds, the use of earthworms is a logical source of protein in chicken feed (Fisher, 1988). Earthworm populations of pasture depends on a number of factors (Curry, 1998). The amino acid content of earthworms will vary depending on species and food source. However, earthworms have been found to accumulate and concentrate methionine found in the ecosystem in proportions greater than for other amino acids (Pokarzhevskii, et al., 1997). As a feed supplement, earthworms have been found to equal or surpass fish meal and meat meal as an animal protein source for poultry (Harwood and Sabine, 1978; Taboga, 1980; Mekada et al., 1979; and Jin-you et al., 1982 all cited in Edwards, 1998).

Earthworms can play a role in moderating nitrogen losses as well (Blair, et al., 1997). Enzyme treatment of feedstuffs can improve amino acid availability and also reduce nitrogen pollution (Tamminga and Verstegen, 1992), as can changes in stocking density, rotations, and manure handling.

The therapeutic uses of different amino acids also have a number of alternatives. Given that most of the treatments are to treat nutritional disorders, alternative programs of prevention and treatment will often be based on better diet. Uroliths appear to be more common in carnivorous companion animals such as dogs and cats than in herbivorous / more omnivorous farm animals. They tend to be related to acid-base balance in the rations and excessive calcium and / or magnesium relative to other cations in the diet. Ammonium chloride is another synthetic substance commonly used to acidify urine, but sodium chloride (common salt) may be used to treat urinary tract calculi in sheep (Aiello, 1998). Hepatic lipidosis is a condition of excessive fat in the liver commonly associated with caged birds and is related to the fact that wild diets are much lower in fat than seed diets fed to captive species (Aiello, 1998). A diet that has less fat and living conditions that allow birds to exercise more appears to be a practical, viable alternative. Enteritis is a disease frequently observed in poultry that do not have access to the soil and green growing plants (Titus, 1942). Well managed pasture would prevent this cause of the disease.

(7) Its compatibility with a system of sustainable agriculture.

The feeding of isolated amino acids produced by the use of non-renewable fossil fuels and toxic chemicals is not compatible with a system of sustainable agriculture. Synthetic amino acids increase animal production by lowering feeding costs, overcoming nutritional and stress related diseases associated with confinement, and reducing manure output. While this is not by itself unsustainable, amino acids thus facilitate high-input concentrated confinement animal production seen as antithetical to sustainable agriculture. Most importantly synthetic amino acids discourage the integration of a whole-systems approach to cycling nutrients, particularly nitrogen, as part of an integrated crop-livestock production system.

Increased efficiency of protein conversion reduces the amount of nitrogen excreted (Summers, 1993; deLange, 1993). The cycling of nutrients from animals is part of an integrated farming system, and the environmental effects of manure management requires looking at the big picture (Archer and Nicholson, 1992). What is viewed as a liability in confinement animal systems--nitrogen production--is seen in cropping systems as a limiting factor resource. Reduction of nitrogen pollution may require improved range or pasture management, and with that either more frequent rotations or lower stocking rates.

# Discussion

## *Condensed Reviewer Comments*

None have a direct commercial or financial interest in enzymes in general or bromelain in particular. Reviewer 1 is a consultant in animal nutrition; reviewer 2 is a veterinarian and pharmacology researcher; reviewer 3 is a professor of food science.

Reviewer 1
I agree with what is proposed but think it should be expanded to indicate that methionine or an amino acid can be added in amounts necessary so that the diet meets the animal's nutritional requirements. When a produced substance is identical chemically to that which occurs naturally I think that produced should be considered non-synthetic. I believe this is the case for methionine, as well as other amino acids. Therefore I believe they should be considered non-synthetic. Their production however, may not be compatible with organic purposes and standards.

I believe their use to meet the animals nutritional requirements for optimum health and performance should be allowed, if they are obtained from organic feedstuffs or in a manner compatible with organic status. As such I disagree with what is stated in this section after OFPA that amino acids "may be considered prohibited as a growth or production promoter and therefore prohibited in livestock production for such purposes".

Based on medical (versus nutritional) uses, as indicated previously for methionine, and those for the non-essential amino acid glutamine for conditions in which enteritis is present, I would add the following to this section. . . . 'While amino acids have a number of functional uses in animal production their primary purposes are to enhance production with a lower costing diet, or with some amino acids to assist in the management of certain diseases (e.g. urolithiasis, hepatic lipidosis and those in which enteritis may be present).'

. . . 1) I think an artificially produced substance identical chemically to that which occurs naturally should be considered non-synthetic. This does not imply that all means of its production are acceptable and therefore that the substance is acceptable and can be used, but that it is indistinguishable from that occurring naturally, and 2) methionine, or any amino acid or nutrient, whose addition to the diet enhances growth would do so only if it helped correct a nutritional deficiency for that particular animal or situation. In addition an amino acid is not a synthetic growth promoter; it is a nutrient whose addition to the diet promotes growth only if it were deficient in that diet. Amino acid supplementation would enhance growth when a growth promoter was used only if the growth promoter stimulated growth in excess of what the diet provides without its addition, i.e. the growth promoter increased the animal's requirement for that nutrient in excess of what was in the diet. . . This . . . should relate to all amino acids, essential or non-essential (e.g. glutamine).

[In reference to the statement] "Suitable uncontaminated pasture and exposure to sunlight can provide all the protein and vitamins laying hens require (Morrison, 1951)."
Comment: This depends on the pasture forage type and season but generally it is not true. Certainly many pastures and during many seasons do not provide the 15% protein, 0.53% methionine plus cysteine, 0.5% lysine, 2.85 Mcal/kg, 2.75% calcium or 0.6% phosphorus required for laying hens or the 20% protein, 0.75% methionine plus cysteine, 1.1% lysine or 2.9-3.2 Mcal/kg needed for growth (NRC).

Rice groats, sunflower seed meal and fish meals are particularly high in the sulfur containing amino acids, methionine plus cysteine (5.85, 4.7 and 4.7% of their protein, respectively), followed by rice, casein, skim milk, whey, cottonseed meal and rape or canola seed meal (3.7 to 3.9% for all) (NRC, Nutrient Requirements of Dogs, Table 8, 1985), as compared to requirements of 3.5 to 3.7% for poultry, 2.8% for swine, 2.4% for dogs, 3.6 to 4.2% for cats and none specified for ruminants or horses (NRC and AAFCO).

Optimally balancing these nutrients may be challenging to feed processors and livestock producers. The NOSB may also want to discuss and consider the role of animal protein in the diets of poultry, although animal tissues contain less methionine plus cysteine than needed (2.8 to 3.3% of their protein versus 3.5 to 3.8% needed in their diet). Hens on good growing pasture containing some legumes may not need more protein (Morrison, 1951), but may need more methionine plus cysteine, since both grass and legume forage contain less than that needed (2.0 to 3.1% of their protein versus 3.5 to 3.8% needed). Organic fish meal (assuming organic fish standards), organic dairy products, as well as slaughter by-products from organic meat may offer potential sources to balance amino acids in a practical corn / soybean meal ration (which contain 2.0% in corn and 2.8% in soybean meal of their protein as methionine plus cysteine).

<Note regarding Reviewer 1
In a phone coversation following the review, Reviewer 1 said that he did not know of any naturally occurring source of the racemic mixture of DL-methionine. Such as specific mixture would be synthetic in his opinion. However, he believes in general that source or manufacturing process is not relevant to determining whether or not a substance is synthetic or non-synthetic. He acknowledged that amino acids could be synthesized outside of biological processes, but as long as they were chemically indistinguishable from those isolated from natural sources, they were 'non-synthetic' regardless of the source. >

Reviewer 2
This is a synthetic substance in that its commercial manufacture involves not only chemical extraction but reaction and conversion as well. While organic farming is based on certain principles, it is also an art and shouldn't be overly restrictive as far as individual practices that a particular farmer may want to utilize as long as they do not conflict with those principles. Substituting a synthetic essential nutrient source for naturally derived ones seems to be such a conflict. Therefore, methionine should only be allowed as long as it is from organically produced sources and does not contain any toxic contaminants as a result of the chemical processing which renders it synthetic. Furthermore, the protocol and reasons for its use should be noted in the farm plan along with steps taken to eliminate reliance on amino acid supplementation.

Reviewer 3
Methionine is one of the sulfur containing amino acids used as a feed supplement to balance nitrogen metabolism and enhance weight gain. The L and D forms of amino acids may not have the same physiological characteristics and effects (DeGussa, no date). For methionine, its chemical synthesis results in a racemic mixture of 50% D and 50% L forms. Additionally according to Degussa the D form (non-biologically active) can be converted to the L form (i.e. biologically active) via an amino acid oxidase enzyme system by oxidative deamination and subsequent transamination reactions in organisms. This reference does not state for what animals this may occur. If it does occur in all animals as the paper suggests on page 14, is 100% of the D form converted to the L form? This is not clear. The D form of lysine can not be converted to the L form in animals and therefore can not be utilized. I feel this is important because all synthetic methionine is in a racemic mixture and little is known concerning the projected benefit based on the stoichiometry of the coupled deamidiation- transamination reaction invivo.

From the literature, several studies have shown that feed rations can be engineered to enhance animal nutrition and subsequent weight gain and performance (Waibel, et al., 1998). In a review paper by Baker (1989), he describes a transition by animal nutritionists to formulate diets on an amino acid rather than a protein basis. Overall, there seem to be more questions than scientifically proven facts regarding the over all use, level, effects of environment, species, gender and other variables to accurately predict the positive benefit of amino acid supplementation.

From the studies and information presented to date, DL methionine is clearly synthetic. . . . [A] well-balanced animal feed ration coupled with well-managed organic pasture preclude the need or necessity to supplement animal feed. I also feel that the addition of synthetic DL racemic mixtures of any amino acid is not compatible with organic agriculture. Additional research should be conducted to evaluate the potentially positive effects of amino acid supplementation on agro ecosystem issues of water and air pollution. However, this is a complex issue and it is difficult to extrapolate the effects of one of many variables (i.e., synthetic amino acids). Additionally, I agree with the reference (Morrison, 1951) that suitable uncontaminated pasture and exposure to sunlight can provide all the protein and vitamins laying hens require. I concur with the discussion section of the NOSB materials database.

In the quest for more rapid weight gain over shorter times conventional farming has sought to increase animal weight gains and overall productivity by optimizing each nutrient to create a synthetic formulation to reduce overall economic issues. Therefore I feel this approach (synthetic amino acid feed supplementation) is simply not compatible with sustainable agriculture. In summary, I do not recommend that synthetic methionine in all its forms be added to the National list of Allowed Non-organic Ingredients for Animal Feed Stuffs.

## *Conclusion*

Farm animal diets formulated based on amino acid content rather than protein content is a relatively recent phenomenon. Animal nutritionists have been making the transition over only the past 20 years (Baker, 1989). Amino acids are essential for animal nutrition and do not need to be derived from non-organic or synthetic sources (Morrison, 1951). Synthetic amino acids used as feed supplements have many parallels to synthetic nitrogen sources for plant foods. Animal nutrition studies have embarked on a reductionist paradigm that does not take into account the ecology of the animals and their interaction with other components of the entire farming system. Even those who conduct the research in such systems acknowledge the limitations of the ability of model feed rations to capture the complexity of animal nutrition (see, for example, Buttery and D'Mello, 1994).

By substituting a non-renewable synthetic input for organically grown crops as a source for nutrition, synthetic amino acids would thus reduce the amount of acreage planted to organic feed and forage crops. Farmers who seek organic certification have less of an incentive to provide clean, fresh pasture as a primary source of animal nutrition if they have available synthetic amino acids. Use of dietary manipulation to reduce nitrogen excretion is an artifact of high-input confinement systems divorced from a holistic farming system. Isolated amino acids should not be allowed to substitute for organically grown grains, well managed pasture systems, and sound programs for manure management.

Experts disagree on the need and efficiciencies of supplementation. While there is need for a great deal more research and there are limitations to extrapolating across species, the debate between the nutritional value of pure or intact food remains unsettled. A recent study of 46 supplements for the quality of their antioxidants composition demonstrated that natural intact food sources were better (Tufts, 1999).

In summary, to be certified as organic, the Technical Advisory Panel recommends that livestock obtain their amino acids from protein sources that meet organic standards. Such a conclusion and recommendation appears outside the scope of the National List, and requires no action on the part of the NOSB. The NOSB may want to consider amending the livestock feed standards to explicitly make it clear that proteins and amino acid sources fed to organic livestock must be produced and processed according to certified organic standards.

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