.

Methionine Task Force

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December 13, 2007

National Organic Standards Board
c/o Robert Pooler, Agricultural Marketing Specialist
National Organic Program
1400 Independence Avenue SW
Room 4008 South Building
Washington, DC 20250-0200

Dear NOP Staff and NOSB Chair,

Attached you will find a petition from the Methionine Task Force (MTF) for continued use of Synthetic Methionine (MET) in organic poultry feed. **Our petition is to remove the annotation date of October 1, 2008 for Synthetic Methionine (MET)**

The Task Force membership represents the majority of organic broiler and laying hen operations in the United States. This group represents a cross section of long time organic producers, many of whom are considered pioneers within the organic industry.

As a group, we are extremely concerned about the end of the current annotation to use Synthetic Methionine in October 2008. We have spent considerable resources (time and money) on funding research into an array of alternatives to Synthetic Methionine. The results of this research are discussed in detail in the petition. Our intent in this process is to be as open and transparent as possible and give you the information you need to appropriately consider this matter.

The MTF members are united in the belief that MET can eventually be eliminated from organic production. However, with less than one year before the current annotation expires, several things are apparent:

1. The US organic poultry industry is not currently able to eliminate MET from organic poultry rations
2. Although the MTF has identified several viable alternatives to MET, none of them are currently commercially available
3. The ongoing cycle of annotations and petitions every three years has become problematic for the NOSB, the NOP, and organic poultry farmers

The MTF has now put in place a mechanism to fund a significant body of research on MET alternatives. The Task Force will continue to actively support the development of an array of the most viable alternatives in the hopes that a satisfactory alternative can be developed on a commercial scale as quickly as possible.

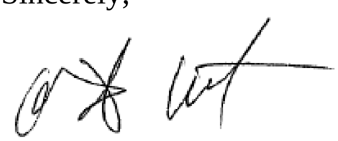
To date our energy and activity has focused on finding viable alternatives. However, given the pace of development of these alternatives, and the looming deadline of October 2008, we feel that we must now take the step of submitting this petition. At this point in time, the petition is necessary to allow us to continue to make progress on eliminating MET, without compromising the existence of the organic poultry industry itself.

Because of these time constraints, you will find that much of the background information on the petition is unchanged from the prior petition in 2005. However the justification statement has been re-written to reflect our current research and a discussion of the viable alternatives.

We again want to emphasize the importance of this issue to our industry. In addition to our MTF members, which are principally chicken farmers, we want to speak for other organic poultry producers (turkey, duck, goose, game bird, and ratite). We have all worked long and hard to raise our animals humanely and in accordance with organic principles. Over the years, we have developed a significant network of production to meet ever growing consumer demand. Given the current state of the alternatives, all of this will be lost without an allowance for synthetic MET.

We will continue to update you on our research results and provide supplementary information to this petition as it becomes available. We thank you very much for your consideration of this topic, albeit on a very short timeline.

Sincerely,



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Petition for Amending the National List of the USDA's National Organic Program

DL- Methionine, ML-Methionine Hydroxy analog, and DL-Methionine-hydroxy analog calcium-for use only in organic poultry production

A Synthesized Essential Amino Acid

Submitted December 17, 2007 by:
Dave Martinelli, on behalf of the Methionine Task Force
(Please refer to the first attachment to this petition for a list of Task Force representatives.)

Introduction:

The Methionine Task Force requests that 7 CFR §205.603(d)(1) be amended, by removing the reference/annotation date of "October 8, 2008", and therefore submitting DL-Methionine to the standard process for sunset review of allowed substances on the National List.

Petitioners are required to provide the following information as applicable:

Category for inclusion on the National List:

- *This request is to remove the annotation date currently listed on synthetic methionine [MET] in Section 205.603 of the National List as a synthetic substances allowed for use in organic livestock production thereby submitting MET to the standard sunset process for review of materials on the National List.*

Common name:

- *The three names in the title of this document are the most widely used common names. They are however the common names associated with specific manufacturers. Throughout this petition the term "Methionine" will be used to refer to the natural form of the amino acid and the term MET will be used to refer to any synthetic analog.*

Chemical Structure:

- *The formula for Methionine is $H_2NCH_3SCH_2CH_2COOH$.*
  Other Chemical Structures;
  DL-Methionine   CH3-S-CH2-CH2-CH(NH2)-COOH
  Methionine Hydroxy Analog   CH3-S-CH2-CH2-CH(OH)-COOH

Manufacturers name, address and telephone number

- *There are three major manufacturers of MET world wide:*

Adisseo
3480 Preston Ridge Road, Suite 375. Alpharetta, GA 30005 Phone 678-339-1513

Degussa Feed Additives
1701 Barrett Lakes Blvd., Suite 340 Kennesaw, GA 30144 Phone 800-955-3114

Novus International, Inc.
530 Maryville Centre Drive St. Louis, MO 63141 888-906-6887

List of uses, rates and applications for crops and livestock uses, mode of action for handling uses:

- *Typically added to poultry feed rations at the following rates:*
  - *Laying Hens: 0.001% (1-3 lbs per ton of feed)*
  - *Broilers: 0.0025% (5 lbs per ton of feed)*
  - *Turkeys: 0.0025% (5 lbs per ton of feed)*

Sources and detailed description of manufacturing procedures:

The following text is taken from the May 21, 2001 Methionine Livestock TAP Review:

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 ⟨-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 1999 Crops Amino Acid TAP review. DL-methionine hydroxy analog calcium and DL-methionine hydroxy analog forms are considered to be alpha-keto acid analogues in which the amine group has been replaced by a hydroxy (OH) group. These forms are converted to the amino form in the bird by transamination in the liver, using non-essential amino acids such as glutamic acid (Cheeke 1999; Leeson 1991). These forms are produced by reacting hydrogen cyanide with an aldehyde that has been treated with a sulfite source to form a cyanohydrin. The aldehydes used are prepared from either hydrogen sulfide or an alkyl mercaptan with an aldeyhde such as acrolein and are then hydrolyzed using sulfuric or hydrochloric acid (USPO 1956).

Regulatory status with EPA, FDA or state authorities:

The following text is taken from the May 21, 2001 Methionine Livestock TAP Review:

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, 2001). 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, 2001). AAFCO also lists a feed definition for DL-Methionine hydroxy analogue calcium (min. 97% racemic 2-amino-4-methylthiobutyric acid, 21 CFR 582.5477) and DL-Methionine hdyroxy analogue, (min. 88% racemic 2-amino-4-methylthiobutyric acid, 21 CFR 582.5477).

Chemical Abstract Service (CAS) number or other product number, samples of labels:

The following text is taken from the May 21, 2001 Methionine Livestock TAP Review:

Chemical Names:
2-amino-4-methylthiobutyric acid and
〈-amino-©-methylmercaptobutyric acid

Other Names:
DL-methionine, D-methionine, L-methionine,
Met, Acimethin

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: 5-30-28

Physical properties of the substance and chemical mode of action: including environmental impacts, interactions with other materials, toxicity and persistence, effects on human health, effects of soil organisms, crops or livestock:

The following text is taken from the May 21, 2001 Methionine Livestock TAP.

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 280-82°C. It is assymetric, forming both an L- and a D- enantiomer. Methionine hydroxy analog (MHA) is available in liquid form.

Action:
Amino acids form protein. Of the 22 amino acids found in body proteins, the National Research Council lists 13 as essential in poultry diets, and these must be consumed in feed. These 13 are: arginine, glycine, histidine, isoleucine, leucine, lysine, methionine, cystine, phenylalanine, proline, threonine, tryptophan, and valine (NRC 1994). Five that are deemed critical in poultry rations are methionine, cystine, lysine, tryptophan, and arginine (North, 1990).

Animals convert dietary protein into tissue protein through digestive processes. Proteins are metabolized by animals through two phases: catabolism (degradation from body tissue to the free amino acid pool) and anabolism (synthesis into body tissue). Amino acids utilized as proteins are primary constituents of structural and protective tissues, including skin, feathers, bone, ligaments, as well as muscles and organs.

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). Methionine is a precursor in the diet to cystine, and the amount needed in the diet depends on the amount of cystine also present. Requirements for methionine are frequently cited in terms of methionine plus cystine, because methionine converts to cystine as needed.

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). Errors in feed formulation or excess supplemental methionine can actually depress growth and development at levels of 40 g/kg (4.0%) (Baker, 1989, NRC 1994). Excess methionine exacerbates deficiencies of vitamin B-6, which results in depressed growth and feed intake (Scherer, 2000). Growth depressions resulting from excess supplemental amino acids include lesions in tissues and organs (D'Mello, 1994). Methionine is "well established as being among the most toxic of all amino acids when fed at excess levels in a diet" (Edmonds and Baker, 1987 cited in Scherer, 2000).

(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). However, NRC acknowledges that such toxicities are unlikely in practical circumstances for poultry, in that an amino acid toxicity requires a particularly high level of an amino acid relative to all others. Supplemental levels fed to poultry are usually fed at lower levels, ranging from 0.3 - 0.5% of the diet. Susceptiblity of an animal to imbalances and excesses is influenced by the overall protein supply, and animals that are fed relatively high levels of protein are more tolerant (Buttery and D'Mello, 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 was 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. 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.
<u>Interactions and Imbalances</u>
Protein is required for body development in all growing birds, and layers also need a good proportion since eggs consist of 13-14% protein. Broilers also need high energy diets as they are commericially raised to grow rapidly to reach about 4.4 lbs in 8 week at a desired food conversion rate of 1.8 (consuming less than 8 lbs of feed total) (Sainsbury, 2000). This is a 50-55 fold increase inbody weight by 6 weeks after hatching, which leads to a high amino acid requirement to meet the need for active growth (NRC 1994). The dietary requirement for protein is actually a requirement for the amino acids contained in the dietary protein. Protein quality is related to the proper balance of essential amino acids in the diet. The presence of nonessential amino acids in the diet also reduces the necessity of synthesizing them from the essential amino acids (NRC 1994).

Amino acids in the body are constantly in flux between three states: stored in tissue, oxidized from tissue to free amino acids, and digested and excreted as uric acid. If some nonessential amino acids are low, they may be synthesized from others in the free amino acid pool, or degraded from those stored in tissue. Deficiencies or excesses of a particular amino acids can cause problems in availability of other amino acids (Buttery and D'Mello 1994; Baker 1989). Intact proteins (as in natural grains) are more slowly available in the digestive system, while pure sources of amino acids are more bioavailable than intact-protein sources (Baker, 1989). Excesses of some amino acids in an unbalanced source of crude protein can reduce feed intake and depress amino acid utilization (Pack, 1995). Depressed feed intake and growth at excess intake levels of protein has recently been attributed to insufficient supply of vitamin B-6 which is required to metabolize the sulfur amino acids (Scherer and Baker 2000).

The requirement for sulfur containing amino acids of methionine, cystine, and cysteine can be misjudged due to inaccurate accounting for the availability of cystine in the diet (NRC, 1994).

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 (NRC, 1994).

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 (Baker 1989; NRC 1994). Interactions between deficiencies of methionine and several vitamins and minerals have also been documented, and suggest that other dietary factors in addition to total protein have an effect on the efficency of amino acid utilization (Baker, D.H. et.al, 1999).

<u>Environmental Impact</u>

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 and no loss in weight gain in broilers (Summers, 1993; Sloan et al., 1995, Ferguson, et.al 1998). Excess ammonia build up in poultry houses can be a hazard to workers and birds if not properly ventilated (Ferguson, 1998).

Feeding systems that reduce levels of protein fed using amino acid supplementation are 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). Increased digestiblilty of protein in feeds suplemented with microbial phytase provided better availabilty of most of the amino acids other than lysine and methionine and allowed for reduced P and Ca levels in feed, a goal in reducing phosphorus overload from poultry manure (Sebastian 1997). Another study found that reduced crude protein and energy content were needed in enzyme supplemented broiler diets, although availability of individual amino acids were not improved equally and were still deemed to need balancing (Zanella, et al 1999).

One grower reported success with innovative housing design that allows twice daily cleanout of manure, combined with a commercial composting operation (La Flamme, 2001). Manure from organic operations has potential added value to organic crop farmers seeking to avoid manure from conventional operations. Some markets in the EU require that imported crops are documented to be grown free of "factory farm" manure, requiring additional verification from U.S. certifiers (McElroy, 2001).

<u>Impacts on Bird Health</u>

A number of reports cite a benefit of methionine supplementation on reduced immunologic stress (Klasing, 1988; Tsiagbe et al, 1986). Immunologic stress is considered to be a response to microbial challenges, in these experiments due to injections of E. coli and Salmonella and other pathogens. This causes decreased feed rates and lower rates of growth. Chicks that received deficient levels of methionine were more subject to an impaired immune response. These experiments seem to be more applicable to a high density confinement system or high density production system in terms of bird treatment, and may not be very relevant to an organic system approach.

A problem exacerbated by excess methionine is hepatic lipidosis, 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). This can be mangaged by a well balanced diet, and is reportedly not a problem in free range birds in organic systems (Krengel, 2001). 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.

Reduced feathering has been reportedly linked to lack of methionine and cystine (Elliott, no date). Many other factors are also involved, including deficiencies of other amino acids, vitamins, zinc, feather pecking in cage systems, and cannibalism (Elliot, NRC 1994). Increased protein level is correlated with reduced feather loss and cannibalism (Ambrosen, 1997).

(6) The alternatives to using the substance in terms of practices or other available materials.
Birds raised on pasture with access to insects and worms historically did not need supplementation (Morrison, 1951), and smaller scale pastured operations have success without the need for synthetic supplements (Salatin, 1993). 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). The two most limiting amino acids, methionine and lysine, are found in richest sources in proteins of animal origin. Common natural sources of these amino acids have traditionally been fish meal and meat meal, especially for starter chicks and broilers (Sainsbury, 2000). The USDA organic program final rules do not allow the use of meat meal as feed for poultry or mammals and may or may not allow fish or crab meal (7CFR 205).

Diets can be formulated without supplemented synthetic acids to meet the objective of adequate methionine percentages, but this usually requires an increase in crude protein level of the diet (Hadorn, 2000). Many studies have been done to identify a cost effective method of lowering protein content by supplementing with methionine and lysine. Often the control treatments are non-supplement grain based diets. A comparison study using supplemented and non-supplemented diets found that adequate dietary methionine can be attained, at a cost of higher intake of protein and less protein efficicy ratio (Emmert 2000). Another study fed a control diet using only corn and soy to satisfy amino acid levels compared to reduced protein supplemented with methionine and lysine, and these treatments were considered successful because performance was not lowered in 4-5 experiments (Harms, 1998).

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). As a natural feed supplement, NOSB should advise whether yeast is considered agricultural and required from organic sources or permitted as a natural substance. Other potential sources of available methionine for poultry appear to be sunflower meal and canola meal (Waibel et al., 1998). These natural sources are all currently of limited availability in organic forms. Alfalfa meal is reported to be a good additional protein source, though difficult to blend in commercial formulations. Optimally balancing these nutrients may be challenging to feed processors and livestock producers.

Feed sources with high percentages of methionine are bloodmeal, fish meal, crab meal, corn gluten meal, and sunflower seed meal (National Research Council, 1994). If fish meal were permitted, there is a lack of supply that does not contain ethoxyquin, a synthetic antioxidant not permitted under the final rules. A limited supply of fish meal preserved with natural tocophorols has gone mostly into the pet food market (Mattocks, 2001). Corn gluten and sunflower seed meal are not currently very available in organic form, and feed formulators and nutritionists have reported difficulty in meeting NRC requirements for methionine based on currently available organic plant protein sources (Mattocks, Morrisson, Simmons, 2001). One feed mill operator feels he can meet even broiler needs with a combination of crab meal (at 75 lbs/ton or 3.75%) and organic corn gluten (Martens, 2001). Crab meal is a by-product of crab processing and not treated with preservatives but has limitations due to salt content. Another certified feed mill produces layer and range broiler rations without synthetic amino acids based only on plant products, including corn, soy, barley, oats, wheat, field peas, and flaxmeal. These products are labeled at a minimum of 0.3% met and 0.6% lysine, but reportedly achieve good results (White 2001, VOG).

NRC requirements for amino acids and protein are designed to support maximimum growth and production. The recommended levels for methionine in poultry depend on species, stage, and level of feed consumption. For chickens, recommendations for layers range from 0.25% to 0.38% and for broilers 0.32 - 0.50%. NRC notes that maximum growth and production may not always ensure maximum economic returns when protein prices are high, and that if decreased performance can be tolerated, dietary concentrations of amino acids may be reduced somewhat to maximize economic returns (NRC, 1994). Methionine is known to have a direct effect on egg weight (size) and rate of lay, and is used by some producers to manipulate egg production to meet market needs, such as to increase egg size in younger birds, reduce it in older birds, or produce more eggs in off peak market periods (NRC 1994; Harms 1998; Simmons 2001). A reduction in rate of gain in broilers (longer time to finish) would be an outcome of lower than optimal methionine levels. Unless the diet contained other forms of sulfur containing amino acids (cystine or cysteine), problems with inadequate feathering might be encountered (Simmons, 2001).

Temporarily confined poultry can be fed a practical organic corn / soybean ration. Depending on market conditions and on how other parts of the standards evolve, novel organic products can be developed as supplements. Among the potential alternative sources include organic dairy products such as casein (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 in a 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; Toboga, 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. 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.

(7) Its compatibility with a system of sustainable agriculture.
In 1994 the NOSB recommended that feed and feed supplements be produced organically. When considering the review of feed additive vitamins and minerals, an NOSB statement of principles advised that non-synthetic viamins and mineral sources are preferable when available. The NOSB also advised that a farm plan should reflect attempts to decrease or eliminate use of feed additives when possible (NOSB, 1995).

A constraint to optimal production in modern organic systems that are not able to utilize pasture based systems appears to be adequate organic sources of the first limiting amino acid, methionine. The allowance of isolated amino acids facilitates the use of the lowest cost, non-diverse corn-soy ration. It is the basis of conventional confinement animal production systems which may be considered as antithetical to the principals of organic livestock production. The source and method of production of synthetic amino from non-renewable fossil fuels and toxic chemicals is also questionable in compatibility with system of sustainable agriculture.

The use of synthetic amino acids increases animal production by increased efficiency of protein conversion, which lowers feeding costs and reduces nitrogen content of the waste output. While this is not by itself unsustainable, 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. Allowance of synthetic sources of amino acids may discourage market development of organic plant sources, such as seed meals.

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

Safety information, including a MSDS (Material Safety Data Sheet) and report from National Institute of Environmental Health Studies (NIEHS):

A MSDS for DL Methionine is attached to this petition.   A search of the National Institute of Environmental Health Sciences (NEIHS) website for Methionine and DL Methionine yielded no Substance Reports.

Petition justification statement which states why the synthetic substance is necessary, alternatives that could be used, beneficial effects to the environment, etc:

Overview / History

In 2001, synthetic methionine [hereafter referred to as MET] was approved for use in organic poultry production for use until October 2005. Three Technical Advisory Panel reviews were conducted prior to this approval. In 2005, there was a petition to extend the deadline to October 2008. This petition was approved unanimously by both the Livestock Committee and the NOSB. This approval allowed for the continued use of MET since the US organic poultry industry has historically used MET.

For the past six years, organic poultry producers have worked to reformulate feed rations without MET. Although methionine is the primary limiting amino acid in poultry, the industry collectively believed that we would be able to reformulate organic feed without it. For example, in conventional poultry production, synthetic lysine (the second limiting amino acid for poultry) is routinely added to the diet. And yet, organic poultry producers have been able to successfully formulate feed without lysine. However, our methionine reformulation efforts have not been successful and the organic poultry industry still remains dependant upon synthetic MET as a supplement.

As will be discussed in more detail below, the 2001 TAP Review referenced a number of potential feed ingredients that could be used in lieu of synthetic MET. Unfortunately, while some of these alternatives have more methionine content than the typical ingredients in a poultry diet, none of the alternatives are particularly rich in methionine. Therefore, reformulation with these ingredients has not yet proved successful.

During this same time, university research has been conducted on alternative breeds to determine whether heritage or slower growing breeds would have a lower methionine demand than the widely used commercial breeds. However, Prof. Anne Fanatico's work at the University of Arkansas has demonstrated that heritage and slow growing breeds have the same methionine demand as commercial breeds.

At this point in time, neither the industry's feed reformulation efforts nor the breed research has resulted in viable alternative to the use of MET.

The Methionine Task Force [hereafter referred to as MTF], consists of US organic poultry producers, many of whom were raising chickens organically even prior to the national standards. The MTF has existed since the first MET petition was approved and has continuously conducted and sponsored research into alternatives to MET. The MTF has evaluated an array of alternatives to MET and in turn has solicited voluntary contributions from its members to fund research on these alternatives. The results of these efforts are discussed in this petition.

Why MET is Necessary

The primary benefit to MET use is animal health and welfare. As referenced in the TAP review from May 21, 2001:

> A number of reports cite a benefit of methionine supplementation on reduced immunologic stress (Klasing, 1988; Tsiagbe et al, 1986). Immunologic stress is considered to be a response to microbial challenges, in these experiments due to injections of E. coli and Salmonella and other pathogens. This causes decreased feed rates and lower rates of growth. Chicks that received deficient levels of methionine were more subject to an impaired immune response.

The TAP review goes on to postulate that the impaired immune response is a result of high density confinement, which if true, would not be as relevant in an organic system. However, the trials conducted by the MTF reflect lower growth rates when MET is reduced or eliminated, even in a less densely populated organic environment.

The TAP review also notes that "reduced feathering has been reportedly linked to lack of methionine and cystine (Elliott, no date)." The TAP reviewer appropriately notes that there may be other factors involved, including the deficiencies of other amino acids. Nonetheless, it needs to be restated that organic poultry producers have eliminated all other synthetic amino acids from the feed ration. Therefore, supplying sufficient balances of the other amino acids is continually challenging, and occasionally is not achieved. Consequently, the use of synthetic MET is even more critical in organic poultry production since one of the typical solutions (supplementation with other synthetic amino acids) is not available.

The traditional signs of methionine deficiency (feather picking, cannibalization, incomplete feather development, excessive mortality) have been well documented in scientific literature. All of these symptoms raise questions about animal health and welfare in the absence of methionine.

To help the MTF better understand the implications of attempting to raise chickens without MET, a number of ranch trials have been conducted. Additional trials are either underway or currently being designed for implementation in 2008.

A layer trial is underway at the University of Minnesota, sponsored by Organic Valley/CROPP Cooperative. This trial is evaluating the performance of a control group (standard organic diet) against a diet excluding MET, but using high methionine corn in the place of standard organic corn. The trial is not yet concluded, but preliminary results show good performance on both groups, suggesting that a diet with high methionine corn may be adequate to eliminate the use of MET. However, it will take a substantial amount of time to confirm these results, and if successful to implement growing high methionine corn on a commercial scale necessary to substitute for MET.

The Methionine Task Force has also sponsored several broiler farm trials in the past year.

The broiler trials consisted of 4 groups:

1. Standard organic diet (control group)
2. Standard diet, but without MET
3. Standard diet, excluding MET, but including Betaine*
4. Standard diet, excluding MET, but including Betaine and Corn Gluten Meal

**Betaine is an alkaloid commonly used in poultry diets. It is a methyl donor which spares methionine in the bird. It is currently approved for use in organic production.*

In all cases, the control groups performed the best, followed by group 4 (Betaine & Corn Gluten Meal). Field observers could readily pick out the non MET groups, particularly group 2. These birds were smaller and less developed. All of the non MET groups had unfavorable feed conversions and meat yields relative to the control group.

In the broiler trials, the traditional signs of a methionine deficiency were not seen in any of the groups without MET. Although these findings are encouraging, it needs to be pointed out that the trials consisted of small lots of birds raised in test housing. We recognize that most organic producers grow chickens in a commercial setting with a higher level of basic challenges (e.g. disease, rodents, housing quality). Chickens given low levels of methionine may perform acceptably in an ideal setting, but the same birds may exhibit the traditional signs of methionine deficiency in a commercial setting.

Health through good nutrition is the fundamental key to successful organic livestock production. Unlike conventional production, there is little recourse available to a producer once disease manifests. MET is considered a “Maintenance Nutrient” added to organic poultry rations only in amounts necessary to achieve the basic nutritional level necessary to maintain good health and avoid disease. In trial settings, with optimal housing, MET deficiencies may not have tipped the balance towards disease outbreaks and corresponding performance breakdowns. But MTF members are very concerned that on the practical scale of commercial poultry production, different results may be experienced. Additional trials on a larger scale will be attempted in 2008 to address this point.

The higher feed conversions seen in the “no methionine” trials have other implications. Higher feed conversions mean that more organic grains need to be produced and fed. From a whole systems perspective, this does not appear to be a prudent utilization of resources and our limited organic acreage.

Synthetic MET is a relatively modern material, only available to poultry producers since the early 1950’s. So the obvious question becomes, if methionine is so critical to bird health and welfare, how were chickens raised prior to the availability of MET? The answer has several elements:

- Prior to the inclusion of MET in the feed ration, diets were typically supplemented with meat and bone meal to add incremental methionine to the diet. Attached are sample rations from the 1940’s which indicate how farmers met the nutritional needs of the birds before the advent of synthetics. Under NOP standards, meat and bone meal are not acceptable feed ingredients for livestock.

- When going back to the pre-MET era, eggs and birds were typically much smaller. For example, prior to 1955, broilers averaged less than 3.3 lbs live weight. Flocks also experienced much higher levels of mortality and poorer feed conversion. A chart illustrating US Broiler Historical Bird Performance over time is attached for reference.
- We feel that raising undersized chickens, with higher mortality and higher feed conversions, is unacceptable from an animal welfare and good poultry husbandry perspective.

<u>Discussion of Alternatives</u>

The Methionine Task Force has commissioned a Literature Review to identify the methionine needs of poultry, summarize the organic livestock standards nationally and internationally, and discuss the viability of potential alternatives. This review as conducted by Dr. Bonny Burns-Whitmore at the California State Polytechnic University in Pomona, CA. A summary of this report is attached.

The TAP review identified several potential feed ration alternatives. One of the important findings in this Literature Review is that while all of these alternatives carry "more" methionine than the traditional Corn and Soybean Meal poultry diet, they do not carry "sufficient" methionine to meet the bird's methionine demand unless included at very high rates (resulting in other nutritional imbalances).

In addition, many of the alternatives cited in the TAP review are either not available in organic form, or are only available in organic form in a very small quantity (i.e. not commercially available). A Table entitled SUMMARY OF METHIONINE SOURCES is attached for reference.

<u>Status of Most Viable Alternatives</u>

1. Alternative Feed Ingredients

High Methionine Corn

As evidenced by the University of Minnesota / Organic Valley trials (ongoing), high methionine corn is one alternative feed ingredient with considerable promise. Much of the work to develop these hybrids has been done by Dr. Walter Goldstein of the Michael Fields Agricultural Institute.

Methionine levels with these hybrids are typically are two times the levels of standard organic corn. Per the ongoing University of Minnesota / Organic Valley trial, this level of methionine may be sufficient for laying hens. But with turkeys and broilers, even though corn is a large part of the organic poultry diet (60% or more), this higher level of methionine alone is not sufficient to eliminate the need to use synthetic MET.

Nonetheless, this alternative still looks promising in that:

- Although presently still in the Research and Development phase, high methionine corn could be ready on a commercial scale within five years.
- When used in conjunction with other feed ration additives (e.g. Betaine), this corn may eliminate the need to use MET.
- The Methionine Task Force has committed funding for seed trials going on now in Chile and Hawaii. These trials are enabling the Michael Fields Agricultural Institute to accelerate the rate of hybrid experimentation, expand the stock of seed supply, and increase the number of planted acres in the US in 2008.

The significant challenges encountered with this alternative thus far include:

- **Agronomic viability**
  Farmers continue to express concerns about higher moisture levels and poorer yields in the first round of hybrids. Balancing the poultry producers demand for high methionine with the organic farmers demand for high yields has proven difficult.
- **Time constraints**
  Significant research needs to be done in both corn production trials and poultry trials with new high methionine corn diets. Even with the multiple crop cycles offered by utilizing Chile and Hawaii, it will be years before the commercial viability of this alternative is tested and known.
- **Economic consequences**
  Significant capital is required to continue the research and bring high methionine corn to a commercial scale. In addition, farmers will need to be financially incented to grow high methionine corn, rather than standard organic corn hybrids. As a result, high methionine corn will need to carry a price premium over standard organic corn. The level of premium, and therefore the economic impact to the US organic poultry producers, is completely unknown.

Corn Gluten Meal

As referenced earlier, the best bird performance in the broiler trials resulted when corn gluten meal was included in the feed ration. In Dr. Bonny Burns-Whitmore's report, several feed producers indicate that organic corn gluten meal is available. ***However, no member of the Task Force has ever been able to source this product in organic form.*** As the MTF understands it, the problem is two fold:

- **Process**
  The corn gluten meal manufacturing process appears to be inherently in conflict with organic principles. Unless an alternative processing technology were to be used, the manufacturing process is unlikely to meet the organic criteria. For example, sulphurous acid is used in the fermentation and steeping process. The current production standards and technologies will have to change to resolve this issue.

- **Inputs**
  The current corn gluten plants are all “conventional” operations which do not segregate their input sources (organic vs. non-organic). The plants are large and require huge input volumes to maintain their productivity. No current plant in the US is appropriately sized or economically incented to segregate out organic inputs.

MTF members continue to hear that there may be some interest in developing organic processing materials (e.g. high fructose corn syrup) which in turn might lead to the production of organic corn gluten meal (as a by-product). The MTF members would be very interested in this product if developed, as a potential nutritional balancer for poultry rations.

Insect Meal

At the NOSB Meeting in November 2007, the MTF became aware of a company (Neptune Industries) that is working on a project to develop organic insect meal for the aquaculture producers. According to company literature, this product is high in methionine and offers great potential for the US organic poultry industry as well. Much information (protein percentage, methionine levels, availability, etc.) still needs to be gathered and flock trials will need to be performed. Nonetheless, this alternative offers potential as a long term solution.

2. Naturally Produced MET

The MTF is most intrigued by the development of methionine produced naturally through fermentation methods. To poultry producers, this represents the most effective and likely economically viable alternative. Unfortunately, to date the science in this area is contradictory. Dr. Billy Hargis from the University of Arkansas is on record with the MTF indicating that “…I am sorry that it does not look like the simple idea of selecting for high methionine content producing natural flora has a probability of success.”

Nonetheless, the MTF has initiated discussions with Dr. Steve Ricke, Food Safety Endowed Chair and Director of the Center for Food Safety, University of Arkansas. Dr. Ricke has committed to reviewing this possibility further with the intention of developing a method to produce methionine naturally.

In addition, the MTF continues to take inquiries from private firms who believe that development of this product is possible. The MTF envisions that it will continue to work with any and all parties on developing such a product.

3. Genetic Selection

At the time of the last petition in 2005, it was felt that part of the solution to eliminating MET from organic poultry production lay in finding suitable alternative or heritage breeds as well as commercial hatcheries willing to produce sufficient quantities for the organic market. This area of research was being pursued by Prof. Anne Fanatico at the University of Arkansas. Subsequently, this research has been completed, with the surprising finding that heritage and/or commercial slow growing breeds have the same methionine demand as the more widely used, faster growing commercial breeds.

Within the commercial breeds, however, there may be sufficient variability to select for those birds with lower methionine needs. For example, the broiler farm trails conducted to date by the MTF indicate that there is a wide range of performance within the "No Methionine" groups. Even without MET being added to the diet, some of the birds in these groups performed remarkably well—similar to the standard diet control groups. The wide range of performance variability suggests that even within the commercial breeds there is the potential to genetically select for birds that perform acceptably even with lower levels of methionine.

This selection process will take time and it is unknown what other unintended traits may manifest themselves. While genetic selection through selective breeding offers potential for broilers, no such results with layers have been observed. This is clearly a very long term solution requiring significant additional research before it could be considered truly viable.

Conclusion:

Methionine is the first limiting amino acid in poultry. Sufficient levels of methionine must be found in a poultry diet, balanced appropriately with the other feed ingredients. Without supplemental methionine and a nutritionally balanced diet, bird health and growth performance suffer.

Poultry growing has advanced tremendously in the last fifty years. Prior to the advent of synthetics, farmers supplemented the diet with ingredients that are not allowed in organic production (e.g. bone meal, meat meal, meat scraps). Chicken mortalities were higher and feed conversions poorer, indicating that overall raising standards and animal husbandry were well below current standards.

The MTF members are united in the belief that MET can eventually be eliminated from organic production.

However, with less than one year before the current annotation expires, several things are apparent:

1. The US organic poultry industry is not currently able to eliminate MET from organic poultry rations
2. Although the MTF has identified several viable alternatives to MET, none of them are currently commercially available
3. The ongoing cycle of annotations and petitions every three years has become problematic for the NOSB, the NOP, and organic poultry farmers

Consequently, we now petition for the removal of the date of October 1, 2008 from the listing of synthetic methionine [MET] in Section 205.603 of the National List as a synthetic substance allowed for use in organic livestock production as a feed additive for poultry, and submit MET to the standard sunset review process.

In this petition, we have gathered a significant amount of information in order to substantiate our case. We have presented it here as openly, honestly and transparently as possible in the hopes of stimulating an open, honest and transparent discussion among the NOSB, the NOP and the organic community. We look forward to this discussion and offer our further services in order to clarify, elaborate or in any other way assist the process.

Final Note: this petition focuses on chicken since the MTF members have the greatest expertise in chicken, but MET is currently allowed in all organic poultry production. Consideration needs to be given to the potential impact of MET to other organic poultry such as turkeys, ducks, geese, game birds, and ratites.

Commercial Confidential Information Statement - describing information that is considered to be confidential business or commercial information:

- *None of the information submitted in this report is considered confidential.*

LIST OF ATTACHMENTS AND STATUS

Current as of December 14, 2007

- **Methionine Task Force Members –***attached*
- **MSDS Sheet for DL Methionine –***attached*
- **Poultry Diets from the 1940's –***attached*
- **US Broiler Historical Bird Performance –***attached*
- **A Review of Recent Scientific Research of Methionine –** *attached*
- **Summary of Methionine Sources –***attached*

Methionine Task Force Members

Company Name	***Representatives***
Eberly Poultry	Bob Eberly
Kreamer Feed	Bob Schwartz, Steve Smelter
Heritage Poultry	Chris Pierce, Mel Gehman
Organic Valley / CROPP Cooperative	David Bruce, Jim Pierce
Chino Valley Ranchers	David Will, Steve Nichols
Free Bird Chicken / Hain Celestial	Joe DePippo, Hank Correll
Organics Unlimited	Ken Rice
Foster Farms	Sun Kim, Norm Ramos
Coleman Natural Foods	Dave Martinelli, Mike Leventini
Hidden Villa Ranch	Mike Sencer
Pete and Gerry's Organic Eggs	Jesse Laflamme
SonCrest Eggs	Randy Boone

Material Safety Data Sheet (MSDS) for DL Methionine

SIGMA-ALDRICH

Material Safety Data Sheet

Date Printed: 03/AUG/2005
Date Updated: 16/MAR/2004
Version 1.1
According to 91/155/EEC

1 - Product and Company Information

Product Name	DL-METHIONINE
Product Number	M9500
Company	Sigma-Aldrich Pty. Ltd. 12 Anella Avenue Castle Hill NSW 2154
Technical Phone #	+61 2 9841 0555 (1800 800 097)
Fax	+61 2 9841 0500 (1800 800 096)
Emergency Phone #	+44 8701906777 (1800 448 465)

2 - Composition/Information on Ingredients

Product Name	CAS #	EC no	Annex I Index Number
DL-METHIONINE	59-51-8	200-432-1	None

Formula	C5H11NO2S
Molecular Weight	149.21 AMU
Synonyms	Acimetion * alpha-Amino-gamma-methylmercaptobutyric acid * DL-2-Amino-4-(methylthio)butyric acid * Banthionine * Cynaron * Dyprin * Lactet * Lobamine * Meonine * Methilanin * (+-)-Methionine * DL-Methionine (9CI) * Metione * Mertionin * Neston * Racemethionine

3 - Hazards Identification

SPECIAL INDICATION OF HAZARDS TO HUMANS AND THE ENVIRONMENT
Not hazardous according to Directive 67/548/EEC.

4 - First Aid Measures

AFTER INHALATION
If inhaled, remove to fresh air. If breathing becomes difficult, call a physician.

AFTER SKIN CONTACT
In case of contact, immediately wash skin with soap and copious amounts of water.

AFTER EYE CONTACT
In case of contact with eyes, flush with copious amounts of water for at least 15 minutes. Assure adequate flushing by separating the eyelids with fingers. Call a physician.

AFTER INGESTION
If swallowed, wash out mouth with water provided person is conscious. Call a physician.

5 - Fire Fighting Measures

EXTINGUISHING MEDIA
Suitable: Water spray. Carbon dioxide, dry chemical powder, or appropriate foam.

SPECIAL RISKS
Specific Hazard(s): Emits toxic fumes under fire conditions.

SPECIAL PROTECTIVE EQUIPMENT FOR FIREFIGHTERS
Wear self-contained breathing apparatus and protective clothing to prevent contact with skin and eyes.

6 - Accidental Release Measures

PROCEDURE(S) OF PERSONAL PRECAUTION(S)
Exercise appropriate precautions to minimize direct contact with skin or eyes and prevent inhalation of dust.

METHODS FOR CLEANING UP
Sweep up, place in a bag and hold for waste disposal. Avoid raising dust. Ventilate area and wash spill site after material pickup is complete.

7 - Handling and Storage

HANDLING
Directions for Safe Handling: Avoid inhalation. Avoid contact with eyes, skin, and clothing. Avoid prolonged or repeated exposure.

STORAGE
Conditions of Storage: Keep tightly closed.

8 - Exposure Controls / Personal Protection

ENGINEERING CONTROLS
Safety shower and eye bath. Mechanical exhaust required.

GENERAL HYGIENE MEASURES
Wash thoroughly after handling.

PERSONAL PROTECTIVE EQUIPMENT
Respiratory Protection: Wear dust mask.
Hand Protection: Protective gloves.
Eye Protection: Chemical safety goggles.

9 - Physical and Chemical Properties

Appearance	Physical State: Solid Color: White Form: Powder

Property	Value	At Temperature or Pressure
pH	N/A	
BP/BP Range	186 °C	
MP/MP Range	280 °C	
Flash Point	N/A	
Flammability	N/A	
Autoignition Temp	N/A	

Oxidizing Properties	N/A
Explosive Properties	N/A
Explosion Limits	N/A
Vapor Pressure	N/A
SG/Density	1.34 g/cm3
Partition Coefficient	N/A
Viscosity	N/A
Vapor Density	N/A
Saturated Vapor Conc.	N/A
Evaporation Rate	N/A
Bulk Density	N/A
Decomposition Temp.	N/A
Solvent Content	N/A
Water Content	N/A
Surface Tension	N/A
Conductivity	N/A
Miscellaneous Data	N/A
Solubility	Solubility in Water:soluble

10 - Stability and Reactivity

STABILITY
Stable: Stable.
Materials to Avoid: Strong oxidizing agents.

HAZARDOUS DECOMPOSITION PRODUCTS
Hazardous Decomposition Products: Carbon monoxide, Carbon dioxide, Nitrogen oxides, Sulfur oxides.

HAZARDOUS POLYMERIZATION
Hazardous Polymerization: Will not occur

11 - Toxicological Information

RTECS NUMBER: PD0456000

SIGNS AND SYMPTOMS OF EXPOSURE
To the best of our knowledge, the chemical, physical, and toxicological properties have not been thoroughly investigated.

ROUTE OF EXPOSURE
Skin Contact: May cause skin irritation.
Skin Absorption: May be harmful if absorbed through the skin.
Eye Contact: May cause eye irritation.
Inhalation: May be harmful if inhaled. Material may be irritating to mucous membranes and upper respiratory tract.
Ingestion: May be harmful if swallowed.

CHRONIC EXPOSURE - REPRODUCTIVE HAZARD

Species: Rat Rat
Dose: 40 GM/KG 40 GM/KG
Route of Application: Oral Oral
Exposure Time: (1-20D PREG) (1-20D PREG)
Result: Effects on Fertility: Other measures of fertility Effects on Embryo or Fetus: Extra embryonic structures (e.g., placenta, umbilical cord). Effects on Embryo or Fetus: Fetotoxicity (except death, e.g., stunted fetus). Effects on Fertility: Other measures of fertility Effects on Embryo or Fetus: Extra embryonic structures (e.g., placenta, umbilical cord). Effects on Embryo or Fetus: Fetotoxicity (except death, e.g., stunted fetus).

12 - Ecological Information

No data available.

13 - Disposal Considerations

SUBSTANCE DISPOSAL

Contact a licensed professional waste disposal service to dispose of this material. Dissolve or mix the material with a combustible solvent and burn in a chemical incinerator equipped with an afterburner and scrubber. Observe all federal, state, and local environmental regulations.

14 - Transport Information

RID/ADR

Non-hazardous for road transport.

IMDG

Non-hazardous for sea transport.

IATA

Non-hazardous for air transport.

15 - Regulatory Information

Not hazardous according to Directive 67/548/EEC.

COUNTRY SPECIFIC INFORMATION

Germany

WGK: 1

16 - Other Information

WARRANTY

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Inc., shall not be held liable for any damage resulting from handling or from contact with the above product. See reverse side of invoice or packing slip for additional terms and conditions of sale.

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US Broiler Historical Growth Performance

Source: Poultry USA, Watt Publications, February 2002

Table 1. Average For All USA Broiler Chickens

Year	Average Live Weight	Feed Conversion	Mortality Percent	Age in Days
1925	2.2	4,7	18	112
1935	2.6	4,4	14	98
1945	3.1	4,0	10	84
1955	3.3	3,0	7	70
1965	3.5	2,4	6	63
1975	3.7	2,1	5	56
1985	4.2	2,0	5	49
1995	4.6	1,9	5	45
2005	5.4	1,9	5	45

Poultry Diets from the 1940’s

		Weaning to 50 lbs.	50 to 75 lbs.	75 to 125 lbs.	125 to 175 lbs.	Over 175 lbs.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
4.	Barley	79	86	92	99	99
	Tankage, meat scraps, or fish meal	8	6	3.5	..	..
	Linseed meal	13	8	3.5	..	..
	Bone meal	..	..	0.6	0.6	0.6
	Ground limestone	..	..	0.4	0.4	0.4
	Total	100	100	100	100	100
5.	Grain sorghum	78	83	91	95	96
	Tankage, meat scraps, or fish meal	8	6	4	..	..
	Soybean oil meal	14	11	5	4	3
	Bone meal	..	..	..	0.6	0.6
	Ground limestone	..	..	..	0.4	0.4
	Total	100	100	100	100	100

POULTRY*

Laying hens and laying pullets

In addition to the mash and scratch grain in these rations, oyster shell or another source of calcium should be available at all times in hoppers. Plenty of fresh water should also be furnished. Cod-liver oil or other suitable vitamin-rich fish oil should be added to the mash when the hens are confined. To insure an ample supply of manganese, 0.25 lb. of manganese sulfate should be added to each ton of mash.

A. Laying mashes with which an equal weight of grain is to be fed

1. Ground yellow corn, 20 lbs.; ground heavy oats, 12.5 lbs.; wheat bran, 20 lbs.; wheat flour middlings, 20 lbs.; dried skimmilk or buttermilk, 2.5 lbs.; meat scraps, 17.5 lbs.; alfalfa meal (low fiber), 5 lbs.; ground limestone or oyster shell flour, 2 lbs.; salt, 0.5 lb. Add 0.4 lb. vitamin A and D feeding oil when hens are not on range.

2. Ground yellow corn, 25 lbs.; ground oats, 10 lbs.; wheat standard middlings, 10 lbs.; soybean oil meal, 24 lbs.; peanut oil meal or other suitable plant-protein supplement, 5 lbs.; meat scraps, 4 lbs.; alfalfa meal, 9 lbs.; distillers' dried solubles, 2 lbs.; ground limestone, 5.5 lbs.; bone meal, 3.5 lbs.; salt, 1.6 lbs.; vitamin A and D feeding oil, 0.4 lb.

3. Ground barley, 30 lbs.; ground wheat, 12 lbs.; soybean oil meal, 20 lbs.; corn gluten meal or soybean oil meal, 7.5 lbs.; peanut oil meal or other suitable plant-protein supplement, 4 lbs.; meat scraps, 3.5 lbs.; dried whey, 2 lbs.; alfalfa meal, 10 lbs.; ground limestone, 5.5 lbs.; bone meal, 3.5 lbs.; salt, 1.6 lbs.; vitamin A and D feeding oil, 0.4 lb.

4. Ground grain sorghum, 30 lbs.; ground barley, 13 lbs.; soybean oil meal, 22.5 lbs.; peanut oil meal or other suitable plant-protein supplement, 7.5 lbs.; meat scraps, 4 lbs.; alfalfa meal, 10 lbs.; distillers' dried solubles, 2 lbs.; ground limestone, 5.5 lbs.; bone meal, 3.5 lbs.; salt, 1.6 lbs.; vitamin A and D feeding oil, 0.4 lb.

5. For hens on good pasture: ground yellow corn, 100 lbs.; ground oats, 100 lbs.; wheat bran, 100 lbs.; wheat middlings, 100 lbs.; meat scraps, 100 lbs.; salt, 5 lbs.

*Unless otherwise indicated, these rations are chiefly from: Titus, Hammond, Whitson, and Bird, U. S. Dept. Agr., Special Cir., Dec., 1946; Heuser, Feeding Poultry, 1946.

B. Grain mixtures to be fed with laying mash

Almost any mixture of grain that does not contain too large a proportion of oats is suitable. Popular combinations are:

1. Equal weights of yellow corn (cracked or whole) and wheat.
2. Yellow corn, 40 lbs.; wheat, 40 lbs.; oats, 20 lbs.
3. Grain sorghum, 30 to 50 lbs.; yellow corn, 25 to 40 lbs.; wheat, 20 lbs.

C. All-mash rations for laying hens and laying pullets

1. Ground yellow corn, 50.5 lbs.; wheat bran, 10 lbs.; wheat flour middlings, 20 lbs.; meat scraps, 7.5 lbs.; dried skimmilk, 2.5 lbs.; alfalfa meal, 5 lbs.; salt, 0.5 lb.; oyster shell meal or ground limestone, 3 lbs.; cod-liver oil, 1.0 lb.
2. Ground yellow corn, 42.5 lbs.; ground oats, 10 lbs.; wheat standard middlings, 15 lbs.; wheat bran, 5 lbs.; soybean oil meal, 12 lbs.; peanut oil meal or other suitable plant-protein supplement, 3 lbs.; meat scraps, 2 lbs.; alfalfa meal, 4 lbs.; ground limestone, 3 lbs.; bone meal, 2.5 lbs.; salt, 0.8 lb.; vitamin A and D feeding oil, 0.2 lb.
3. Ground barley, 30 lbs.; ground wheat, 36.5 lbs.; soybean oil meal, 12 lbs.; corn gluten meal or soybean oil meal, 4 lbs.; peanut oil meal or other suitable plant-protein supplement, 3 lbs.; meat scraps, 2 lbs.; alfalfa meal, 6 lbs.; ground limestone, 2.5 lbs.; bone meal, 3 lbs.; salt, 0.8 lb.; vitamin A and D feeding oil, 0.2 lb.
4. Ground grain sorghum, 40 lbs.; ground barley, 28 lbs.; soybean oil meal, 12.5 lbs.; peanut meal or other suitable plant-protein supplement, 5 lbs.; meat scraps, 2 lbs.; alfalfa meal, 6 lbs.; ground limestone, 2.5 lbs.; bone meal, 3 lbs.; salt, 0.8 lb.; vitamin A and D feeding oil, 0.2 lb.

D. Mashes for breeding hens

For hens producing eggs for hatching, the same sort of mashes are satisfactory, except that a mash to be fed with grain should contain at least 7 to 9 per cent of protein supplements of animal origin (including meat scraps, fish meal, and dried dairy by-products). Also, the content of riboflavin should be increased. (1409)

Chicks and growing chickens

A. All-mash chick starters

1. Ground yellow corn, 20 lbs.; ground wheat, 32 lbs.; soybean oil meal, 21 lbs.; other suitable plant-protein supplement, 10 lbs.; dried skimmilk or buttermilk, 5 lbs.; alfalfa meal, 7.7 lbs.; bone meal, 2 lbs.; ground limestone or oyster shell, 1.2 lbs.; salt, 1 lb.; vitamin A and D feeding oil, 0.1 lb.
2. Ground barley or grain sorghum, 42 lbs.; ground wheat, 10 lbs.; soybean oil meal, 21 lbs.; other suitable plant-protein supplement, 10 lbs.; meat scraps, 2.5 lbs.; dried whey, 5 lbs.; alfalfa meal, 6 lbs.; bone meal, 1.1 lbs.; ground limestone or oyster shell, 1.3 lbs.; salt, 1 lb.; vitamin A and D feeding oil, 0.1 lb.
3. Ground yellow corn, 42 lbs.; ground oats or wheat middlings, 10 lbs.; soybean oil meal, 24 lbs.; other suitable plant-protein supplement, 10 lbs.; fish meal, 2 lbs.; dried whey, 5 lbs.; distillers' dried solubles, 2.7 lbs.; bone meal, 2 lbs.; ground limestone or oyster shell, 1.2 lbs.; salt, 1 lb.; vitamin A and D feeding oil, 0.1 lb.
4. Ground wheat, 52 lbs.; soybean oil meal, 21 lbs.; other suitable plant-protein supplement, 10 lbs.; meat scraps, 3 lbs.; alfalfa meal, 8 lbs.; distillers' dried solubles, 2.6 lbs.; bone meal, 1 lb.; ground limestone or oyster shell, 1.3 lbs.; salt, 1 lb.; vitamin A and D feeding oil, 0.1 lb.

SUMMARY OF METHIONINE SOURCES

Alternative	Approx. Methionine %	Synthetic	Natural	Organic	Commercially Available	Other Comments
Dl Methionine	99.00	Yes				Included as 0.001-0.0025% of ration
Corn	0.18			Yes	Yes	*Currently in Poultry Ration*
Hi Methionine Corn	0.36			Yes	No	In R&D Phase
Soybean Meal	0.60			Yes	Yes	*Currently in Poultry Ration*
Sesame Meal	1.26			Yes	No	Deficient in Lysine
Sunflower Meal	0.72			Yes	No	Relatively Low Methionine
Canola Meal	0.75			Yes	No	Relatively Low Methionine
Alfalfa Meal	0.20			Yes	No	Very Low Methionine
Corn Gluten Meal	1.50		Yes			Not available in organic form
Flax Meal	0.50			Yes	No	Relatively Low Methionine
Blood Meal	1.00			No		Not allowed: Animal By Product
Insects	Unknown				No	Pilot project under development
Earthworm Meal	1.60				No	Not being produced
Crab Meal	0.50					Not available in organic form
Meat Meal	0.81					Not allowed: Animal By Product
Rice	0.22			Yes	No	Very Low Methionine
Casein	2.56			Yes	No	Ratio of methionine to cystine is poor
Milk Powder, Skim	0.79			Yes	Yes	Relatively Low Methionine
Potato Protein	1.60		Yes		No	Not available in organic form
Fish Meal	1.68		Yes	??		Not available in organic form, ratio of methionine to cystine is poor

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A REVIEW OF RECENT SCIENTIFIC RESEARCH OF METHIONINE

By

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Abstract

Organic poultry and eggs are a growing industry (Oberholtzer, Greene, Lopez, 2006). Consumer trends show a preference towards organic produce and organic livestock. In order to produce a strong foundation for organic marketing, consumer acceptance of organically produced foodstuffs, and good organic practices; organic agriculture needs to make science-based decisions. Therefore, it is important to evaluate all the studies, regulations, successful poultry operations, and good practices that are related to the removal of synthetic methionine in poultry feed.

Organic poultry producers are having some success with 100% organic production, however some organic grains and feedstuffs are grown in small quantities, some organic feedstuff supplies are limited, and the October 2008 deadline is approaching. New technologies and ongoing identification of adequate high methionine containing sources, or methionine sparing compounds is continuing.

Based on the scientific studies, researchers suggestions, and poultry professional's feedback, this Methionine Research Team has developed some suggestions for further research and applications. These suggestions are located at the end of the report in the *Suggestions For Further Research* portion of this report.

TABLE OF CONTENTS

Purpose
The purpose of this project is to provide the organic egg and broiler industry with a comprehensive, science-based literature research on the replacement of methionine in poultry feed.

Objectives
1. To gather information on methionine supplementation in feed, requirement and absorption of methionine in broilers and layers and the corresponding requirements for chicken egg production, interference factors and facilitators of methionine absorption in the chicken and turkey, and the effectiveness of alternative methionine-rich foods as potential replacements, and suggestions for further research; using scientific studies and literature from peer-reviewed journals, as well as industry-related sources.
2. To arrange this material into a format with headings (see above)
3. To provide an opportunity for a student assistant to learn how to organize and accomplish a literature review. (This opportunity would coincide with The Department of Human Nutrition and Food Science's Mission Statement that states: "Our mission statement in the Department of Human Nutrition and Food Science is to work in collaboration with industry, alumni, and community to provide quality education to students in order to prepare competent, ethical graduates for a variety of careers.")
4. To complete and present this literature review and present the white paper to the organic egg and broiler industry before September 10, 2007.

Scope of plan
- Determine requirements and absorption of methionine in broiler and layer chickens and turkeys
- Determine methionine requirements for chicken egg production
- Investigate interference factors and facilitators of methionine absorption in the chicken and turkey
- Using scientific and commercial/industry sources, determine the effectiveness of alternative methionine-rich foods as potential replacements
- Provide suggestions for further research using scientific studies and literature from peer-reviewed journals, as well as industry-related sources.
- To gather information on methionine supplementation in chicken and turkey feed
    - The USDA / National Organic Program regulations on the allowance for synthetic Methionine in Poultry- chickens and turkeys
        - Obtain the testimony presented to the National Organic Standards Board (NOSB) supporting the use of Methionine and the discussion of Methionine
- Discussion of European Union (EU) organic poultry production standards concerning the use of Methionine.
    - Specifically the EU standards
    - Use or allowance of Methionine
        - If not allowed, how producers raise chickens without Methionine

Methodology

Literature was collected from peer-reviewed (refereed) journals and text as well as from preliminary studies, authors, online sources, industry, personal communications, industry practices or minutes of meetings and government papers in regards to methionine (see objectives).

The paper format is in standard review format, complete with headings. A copy of all references and minutes of proceedings is supplied with the white paper, and is in alphabetical order of author. The NOSB and USDA papers and minutes are arranged by date, as are the EU and EEC regulations.

Scientific papers that used synthetic methionine in alternative feedstuffs may or may not be included in this review, depending on the significance of the results, whether or not it is in the scope of this grant, and/or the relevance to organic practices.

Summaries may be provided after some topic discussions to the reader as a non-scientific language summary of the implications, results, limitations and findings of the scientific or regulatory literature.

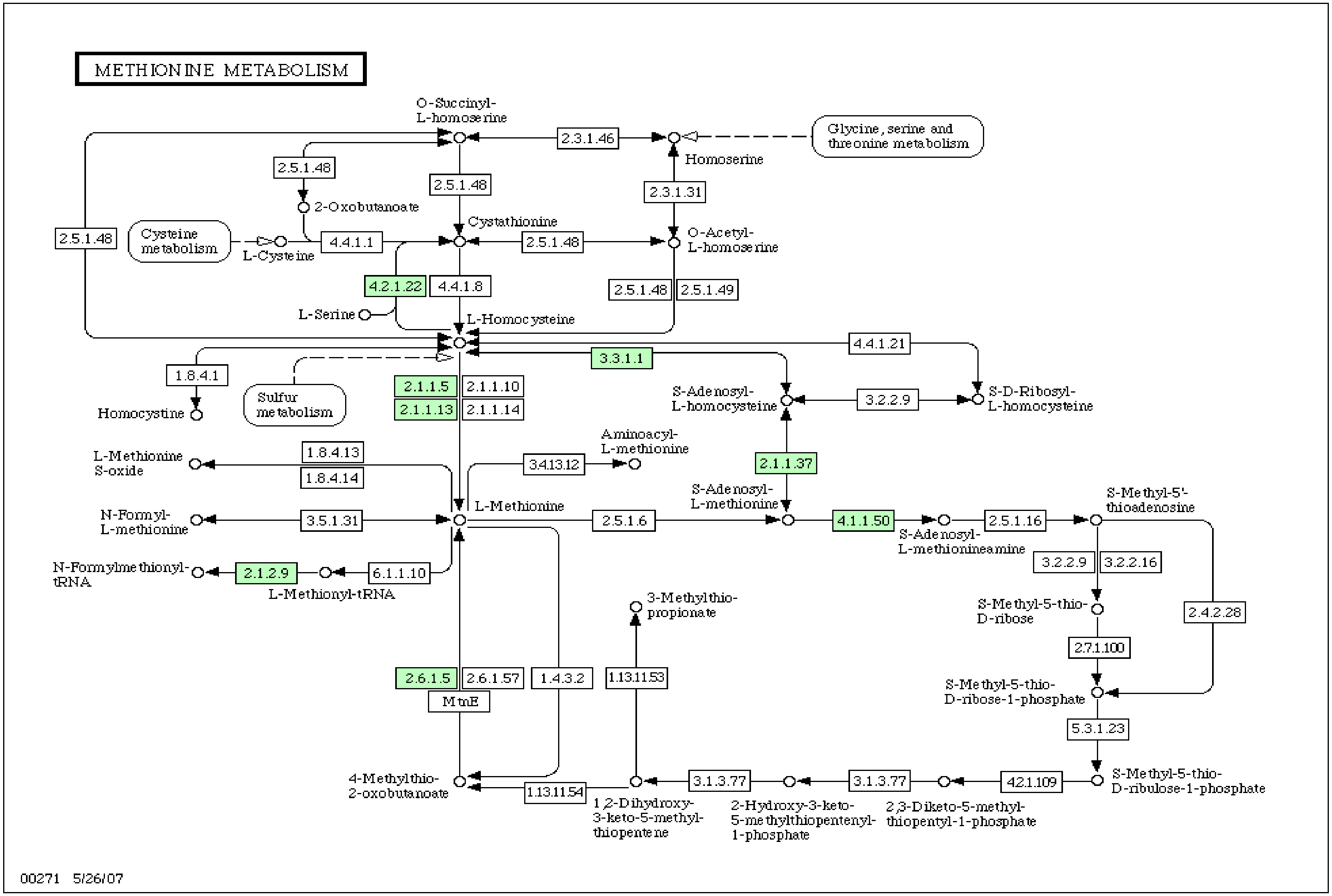
Introduction to Methionine

Methionine is a nutritionally essential (indispensable) amino acid for many animal diets, including those of poultry and humans. The term 'essential amino acid' means that it cannot be synthesized from other amino acids or that it is synthesized in amounts too small to maintain sufficient protein use in the body. Methionine is considered to be a polar neutral amino acid along with asparagine, cysteine, glutamine, serine and threonine. Because these amino acids' hydrogen bonds can interact with water, they are termed 'polar.' These polar neutral amino acids contain different functional groups. For example, cysteine and methionine contain sulfur (SAA), threonine and serine contain a hydroxyl group (OHAA), and asparagine and glutamine contain an extra amide group (NHAA).

The complex conversions of methionine and the inter-relationships to other amino acids and other dietary requirements are demonstrated in the figure on page 10.

Summary: Understanding the Metabolism of Methionine

It is important to understand all aspects of methionine metabolism and diagrams help provide a 'pathway' for determining certain factors that are involved in the process. Factors that aid in the metabolism of methionine may also hold keys as to 'sparing' (requiring less added methionine in the diet) or helping the process to become more efficient. We have investigated some of these inter-relationships in the *Alternative 'Helper' Sources of Methionine* heading of this report.



Methionine Metabolism

The numbers between the chemicals on the flowchart are enzymes. Source: KEGG Methionine Metabolism in *Gallus gallus* available online from: http://www.genome.ad.jp/dbget-bin/get_pathway?org_name=gga&mapno=00271

Sources of methionine

All animals utilize two sources of protein, ingested from the diet-exogenous proteins, and endogenous or recycled body proteins (Groff and Gropper, 2000).

Since amino acids (AAs) are the building blocks of protein, it follows that high protein foods contain the most amino acids, hence the most methionine and cysteine. Animal products such as meat, fish, dairy products (except butter), eggs and poultry are the highest sources. Some plants like soybean and quinoa (not really a grain or a legume) are also almost complete sources of protein. Most plant products such as grains, grain products, vegetables and most legumes contain protein but also contain limiting AAs. A limiting amino acid is the indispensable amino acid that is present in the lowest amount in a food. In order for an animal to form a protein, all amino acid amounts must be present in a certain ratio or amount. If one of the AAs essential for building a protein is absent, the protein may not be formed. Or, if the limiting amino acid is present in small quantities the protein will be formed in very small quantities instead of large quantities, resulting in a limited protein output leading to deficiencies. These limiting AAs are found in both grains and legumes, and each type of feed has different limiting amino acids. For example, the limiting amino acid in grains and grain products are lysine (polar), threonine (sometimes, not always limiting), and tryptophan (non-polar) (sometimes, not always limiting), while generally, methionine is the limiting amino acid in legumes. Some plants have been genetically modified (GMO) to have high levels of lysine, threonine and lysine, or in the case of legumes methionine in order to produce a higher or more complete protein. However, the more traditional approach uses the combination of certain grains high in methionine in combination with legumes high in lysine to make a complete protein (Groff and Gropper, 2000).

Endogenous proteins are those proteins that are recycled from digestive enzymes, glycoproteins, and mucosal cells in the animal. They are complete proteins and are broken down and reformed until eliminated or degraded (Groff and Gropper, 2000).

A combination of limiting and endogenous proteins can sustain an organism through short feeding periods with little to no problems. However, when the endogenous protein stores decrease during a feeding of low quality protein (proteins with limiting amino acids) this can result in catabolism of working proteins (muscle), leading to starvation and deficiencies.

Methionine can also be made synthetically. Two major forms, DL-methionine and DL-methionine hydroxyl analog do not occur in nature (NOSBTAP Review for the USDA NOP. 2001)

The 2 primary product forms of methionine activity commercially available for supplementation of methionine-deficient poultry diets are: DL-2-hydroxy-4-(methylthio) butanoic acid (HMTBA) in an 88% solution with 12% water, and dry DL-methionine (DLM), which is 99% powder. Both compounds provide L-methionine (L-Met) activity to avian and mammalian species alike, and they are chemically different in that HMTBA has a hydroxyl group at the asymmetric carbon, whereas DLM has an amino group. This chemical difference results in substantial differences in how and where the 2 materials are absorbed, metabolized, converted, and used to provide L-Met to the animal. (Kratzer & Littell, 2006; Dibner, 2003; Lobley et al., 2006; Wester et al., 2006).

Initial reports comparing the methionine activity of the 2 compounds in growing broilers indicated that the products provided similar quantities of methionine activity (Bird, 1952; Smith, 1966). However, subsequent comparisons conducted using purified diets under more extreme conditions of methionine deficiency reported lower growth rates and feed efficiency with HMTBA than with DLM (Katz and Baker, 1975). Another study refutes this. In male chickens supplemental sources of HMTBA and DLM perform relatively the same, but HMTBA produces a slightly greater growth response than DLM (Vazquez-Anon et al. 2006).

Dose response predictions of HMTBA and DLM

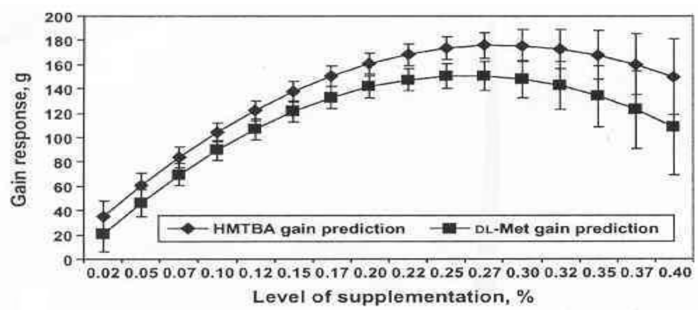


Figure 2. Comparison of the dose response predictions of 2-hydroxy-4-methylthio butanoic acid (HMTBA) and DL-methionine (DLM) gain models under the average conditions of the database. The dose response predictions from each Met source gain models were compared under the average conditions of the database. The values entered in the model for each independent variable were: age of bird at start of study = 6.7 d: age of bird at end of study = 31 d; gain of control = 799 g; basal Met = 0.28%; dietary Cys = 0.30%, dietary Lys = 1.17%, dietary energy = 3,135 kcal/kg; dietary CP = 19.90%; year of publication = 1989; liquid form of HMTBA; dry form of DLM; level of supplementation from 0.02 to 0.4%; mash diets; and absence of antibiotic and coccidiostat. No significant differences were observed between HMTBA and DLM gain predictions. However, as the dose response approached the peak response (0.22 to 0.25%), there was a trend ($P \leq 0.1$) for higher gains for HMTBA than DLM.

(Vasquez-Anon et al., 2006)

Hoehler et al., 2005 found in methionine and cysteine deficient diets in turkeys, the relative bioefficacy value of 68% for liquid MHA-FA relative to DLM is appropriate for young turkeys, and the relative effectiveness of MHA-FA is significantly lower than that of DLM in young turkeys.

Examples of high methionine containing feedstuffs, grains, and non-grains are also provided in this report under the headings: *Suggestions for further research in the US*, and in examples of methionine replacement diets provided under: *How producers raise poultry without methionine*.

Alternate 'Helper' Sources of Methionine

There are two major 'helpers' of methionine metabolism and methionine recycling - choline and betaine. When chickens receive a diet marginally deficient in methionine, supplementation with choline or betaine does not induce a return to the maximum growth rate (Simon, 1999). This indicates that choline and betaine are not a replacement for methionine, and may help to retain present stores of methionine.

Methionine is also a precursor for cysteine. In the chick, choline synthesis is extremely limited. Methionine does not replace choline in chicks or in turkeys for preventing perosis when the deficiency of choline is severe. Synthesis of choline in the chick may evidently take place from dimethylaminoethanol, which promotes growth and prevents perosis, but the total synthesis fails somewhere in the stages leading to this compound. In the presence of ample choline and cystine and a partial deficiency of methionine in the basal diet improved, but also limited growth rate. The evidence suggests that the methionine sparing actions of cystine and choline are additive (Almquist, 1946). At 0.31% cysteine is deficient in Cobb 500 broiler chicks. When given excess choline or betaine, it does not impact growth performance, but spares a small portion of methionine requirements (Pillai et al. 2006).

Choline
Choline is found in meats, nuts and eggs. The choline oxidase enzyme synthesizes betaine from choline (Almsquist, 1946; Kidd, et al. 1997). Choline has been found to prevent perosis in turkeys as long as it is above 850 mg/per pound of feed (Scott, 1949).

The choline requirement for 3 week old Arbor x Arbor broiler chicks should be set at 1300 mg/kg and the total sulfur amino acid content should be at 0.92% (Latta & Donaldson 1986).

Relationship of choline and betaine

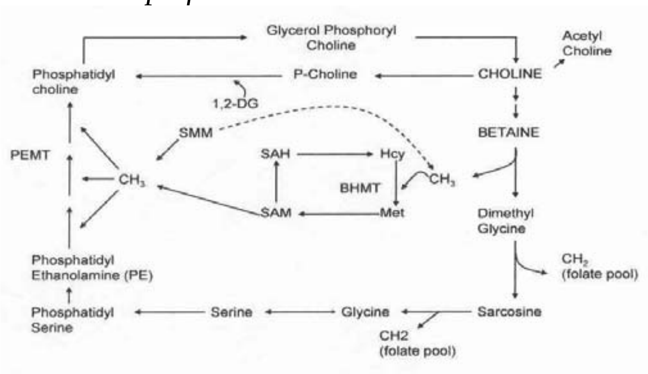


FIGURE 2 B Involvement of SMM in choline biosynthesis.

(Augspuraer et al., 2005)

In a methionine-deficient basal purified diet, added choline increased both weight gain and feed efficiency (Emmert, Garrow, Baker, 1996).

When the New Hampshire x Columbian Plymouth Rock male chick diet is deficient in choline or in both choline and methionine, synthetic methylmethionine addition produced a significant growth response. When chicks had an adequate choline diet, the addition of synthetic methylmethionine did not affect the growth of chicks. Additionally, excess S-methylmethionine doesn't eliminate the need for preformed choline (Augspuraer et al. 2005).

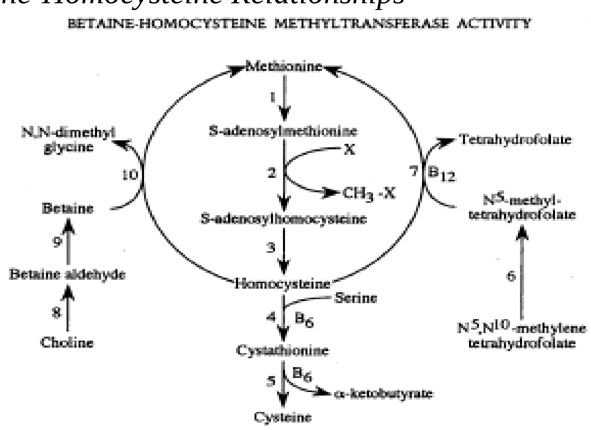
Turkeys
Miles, Ruiz, and Harms (1983) found that the addition of choline to the basal resulted in a significant 38.8g increase in growth. When the diet is deficient in methionine the poults responded to supplemental choline. This data indicate that the turkey poult can utilize choline and sulfate to spare a metabolic function portion of the sulfur amino acids.

The addition of 0.25% methionine resulted in significantly improved growth as compared with that obtained by adding supplemental choline and sulfate. The combination of either sulfate or choline individually or in combination did not improve growth when adequate methionine was present in the diet. This indicates that the turkey poult could utilize choline and sulfate to spare a portion of the metabolic function of the sulfur amino acids. The addition of the methionine resulted in significantly improvement in feed efficiency (Miles, Ruiz, and Harms 1983).

Betaine
Betaine is found in beets, broccoli, spinach, and in wine that uses beet sugar to increase alcohol content. Betaine is a methyl group donor to homocysteine that forms methionine, thus sparing methionine and choline, but is not a replacement for either in poultry diets. Betaine reduces carcass fat and aid in cell osmoregulation (Kidd, et al. 1997).

In male Ross broilers, there was no evidence that betaine spares DL-methionine as an essential amino acid supplement in broiler diets (Schutte et al., 1997). However, in Arbor Acres male broiler chicks, betaine spared methionine and was as effective as methionine in improving performance and carcass quality even when the diet was moderately deficient in methionine (Zhan et al. 2006).

Betaine-Homocysteine Relationships



(Emmert, Garrow, Baker, 1996; Pillai et al., 2006)

Excess dietary methionine cannot replace choline in the chick diet. Excess cystine in the diet may also effect the efficiency of homocysteine methylation to form methionine (Emmert, Barrow, Baker, 1996).

Organic and inorganic sulfur
In the Ruiz, Miles, Harms (1983) review, the authors discuss the addition of sulfur to poultry diets and some of the methionine sparing effects of supplementation. Sulfur addition to the poultry diet has a sparing action on the sulfur amino acids depending on the other constituents of the poult's diet.

Biological (organic) sulfur is present in several forms, taurine (found bonded to the bile acids as taurocholic acid), in muscles (creatine or as protein sulfur bonds), feathers, or major glycosaminoglycans/mucopolysaccharides (chondroitin sulfate, keratin sulphate, heparin sulphate, dermatan sulphate, and heparin). 0.50% inorganic sulfur supplementation can't replace cysteine or methionine for protein synthesis, but findings do show that inorganic sulphate can satisfy part of the total sulfur requirement in purified diets. Inadequate supplies of sulfur in the diet may be synthesized from the sulfur amino acids (Almquist, 1964). This is possibly one reason why the requirement results for the SAAs from different studies are widely variable. Corn and soybean meal diets don't show as much of a difference in growth as do the purified diets, nor do they require as much inorganic sulphate. The addition of 0.16% sodium sulfate was successful in stimulating growth (in conjunction with methionine supplementation) in one study and 0.20% resulted in a 14.5% growth (again with methionine addition) over the un-supplemented sulfur group. In another experiment addition of 0.06% sodium sulphate and low in methionine (0.08%) resulted in a growth of 5% over the basal diet only containing methionine. However in the purified diets, methionine can be adequate or deficient, but cystine must be deficient and more limiting than methionine in order to get a response from dietary sulfur supplementation. They suggest that further studies be done to understand the growth response of dietary sulphate and the interrelationship with sulfur amino acids, taurine and other metabolites. Additionally, in order for choline to spare a maximum amount of methionine, an adequate level of sulphate must be present in the diet. (Ruiz, Miles, Harms, 1983).

Taurine-an end product of SAA metabolism
Dietary taurine is a sulfur-containing end product of sulfur amino acid metabolism. Added dietary taurine can decrease egg weight without deleterious effects on egg production, egg mass, feed conversion or body weight (Yamazaki & Takemasa, 1998).

Homocysteine
Homocysteine (Hcy) can replace methionine only when there is a sufficient amount of choline present. This implies that choline and methionine are very closely interrelated. However, natural proteins contain very little homocysteine.

Biotin
Turkeys
Robblee and Clandinin (1970) noticed that a deficiency in pantothenic acid and biotin caused white barring in Bronze Poults and dermatitis. The dermatitis noted included encrustations at the beak angle and around the eyes as well as scaliness and cracking of the skin on the bottom of the feet. The results claimed that the addition of calcium pantothenate to the ration fed caused some alleviation of the symptoms of the disorder in later hatched poults. A combination of supplementary biotin, folic acid, and calcium pantothenate resulted in the

production of high quality poults essentially free of symptoms of the syndrome and showing low incidence of hock disorder.

The addition of biotin to the ration was effective in markedly reducing incidence and severity of the disorder but was not effective in eliminating it entirely. The addition of folic acid and calcium pantothenate to the ration, in the absence of biotin, was not effective in reducing incidence and severity of the syndrome: however, when folic acid and calcium pantothenate were included along with biotin, high quality poults were essentially free of the disorder were produced.

Folic acid and Vitamin B_{12}
Male broiler chick requirement for folic acid is interdependent on the concentrations of labile methyl group metabolism including B_{12}, methionine, cysteine, and choline. The folic acid requirement in a corn-soybean diet is 1.5 mg/kg. Folic acid deficiency can be produced in chicks given supplemental vitamin B_{12}, but no supplemental choline or methionine. Low levels of folic acid may limit methyl metabolism. The researchers conclude that methionine and choline requirements of starting chicks may be overestimated due to subclinical folic acid deficiencies in the requirement studies.

Summary of Alternative 'Helpers' of Methionine
Obviously these 'helpers' of methionine are interrelated. Availability of methyl group donors and substrates influence methionine requirements.

In humans (and rats), there are many genotypes (such as the MTHFR 677T, 677 CC or TT, 677C-->T, GNMT 1289 C->T), which can potentially influence dietary requirements of choline, folate, vitamin B12 and any of the transmethylation reactions of methionine (Abratte et al, 2007; Beagle et al. 2005, Guinotte et al., 2003; Hung et al., 2004). This is due to a genetic mutation causing increased requirements of certain key substances list above. It is entirely possible that the requirements for each of the 'helper' substances vary as much for poultry as it does for humans. Understanding the genetic requirements for different poultry strains may help to make informed decisions regarding supplementation of methionine, choline and betaine as well as determining adequate requirements for poultry. More research is needed.

Deficiencies of Methionine in Poultry and Supplementation of Methionine

Much research has shown that low intake of methionine in commercial layers is detrimental; the low intake of methionine, a methyl group donor, is reduced metabolism in animals, which affects protein synthesis for body growth and egg production in commercial layers (Pourreza and Smith, 1988). Research has shown that several parameters such as albumen solids (Shafer et al., 1998), egg performance (Keshavarz and Jackson, 1992; Harms and Russell, 1996a), egg size (Keshavarz and Jackson, 1992; Hsu et al., 1998), and body weight (BW) (Pourreza and Smith, 1988; Keshavarz and Jackson, 1992; Harms and Russell, 1996a & 1996b) are negatively affected by decreased dietary methionine content and inadequate methionine intake of the hen. Feeding commercial pullets with a low-methionine and low-lysine diet in the starter/grower phase reduced development of immature BW and delayed onset of production, negatively influencing the egg production during the first 6 weeks of lay (Halle, 2002)

The closer the amino acid composition of the diet matches the hen's requirement, the more efficient the protein of the diet is utilized. In commercial layers, supplementation of laying hen diets with methionine provides a means for increasing the efficiency of protein utilization (Sell and Johnson, 1974; Schutte and Van Weerden, 1978; Schutte et al., 1983, 1984). Low protein diets in both turkeys and chickens cause poor growth and pica in large white turkeys and a drop in egg production in 60-week old white leghorns (Ekperigin, Silva, and McCapes, 1982).

Methionine is the first limiting essential amino acid, and growing chickens consuming a low protein diet exhibit depressed plasma IGF-I levels, which return to normal on restoration of dietary protein (Lauterio & Scanes, 1988; Rosebrough et al., 1989; Rosebrough & McMurtry, 1993). The results during the 8- to 22-day growing period suggest that 0.4% dietary methionine is sufficient for optimum growth (Rosebrough et al., 1989)**.** However, the small but significant increase in feed intake by chicks fed 0.4% methionine as an indication that this level is still deficient, and chicks compensate for the deficiency by overeating**.** This increased feed intake does not cause an increase in weight gain because the added caloric intake is converted to body fat, which replaces body water (Carew and Hill, 1961). With a borderline methionine deficiency of 0.4%, feed intake is increased, but body protein synthesis is decreased, and the surplus calories are shunted into fat synthesis. These changes are not a consequence of alterations in energy utilization due to changes in the metabolized energy value of the diet or in the efficiency of energy processing (Carew and Hill, 1961). The overall result of these changes in feed intake and weight gain was that the ratio of weight gain to feed intake decreased significantly only with 0.3 and 0.2% methionine, and it was significantly worse with 0.2% methionine.

In free-range Danish hens, feather pecking and cannibalism is related to chicken genotype and dietary levels of methionine and cysteine. (Kjaer & Sorensen, 2001). Genotypes used were the ISA brown, New Hampshire, white leghorn and a New Hampshire x white leghorn. Mortality from cannibalism was highest in the ISA, while mortality from impaction (grass) occurred more in the New Hampshire. ISA also significantly exhibited more bouts of feather pecking than the other genotypes.

Additionally, fatty livers seem to be a common occurrence in chicks and other animals fed deficient levels of protein (Velu et al., 1971; Keagy et al., 1987). This is probably due to the inability of the liver to synthesize lipoprotein carriers due to protein deficiency. Consequently, a build-up of fat occurs in the liver.

In Chickens

Leclercq, 1983 showed that commercial birds given the methionine-deficient feed through the first 3 wk had reduced body weight. After processing, chilled carcasses from birds given the low-methionine regimen were observed to have increased proportions of abdominal fat. Inadequate methionine is known to accentuate abdominal fat in broilers. Methionine deficiency led to reduced proportions of breast fillets and tenders but increases occurred with wings and cage. Their experiment suggested that the NRC (1984) essential amino acid requirements for broilers could be no more than "estimates." Particularly lean birds are known to decrease their feed intake, which leads to reduced growth when the corresponding protein level is insufficient to support the increased rates of deposition (Leclercq, 1983; Whitehead, 1990). However, the reduction in fat that occurs in response to supplemental methionine becomes minimal once protein becomes excessive (Mendonca and Jensen, 1989).

Methionine deficiency increases the production or release of T3 (a growth-related hormone) into the blood or inhibits its normal removal compared with control chicks consuming the same amount of feed. This may operate through inhibited synthesis of a key protein involved in the metabolism or turnover of T3 due to lack of sufficient methionine for polypeptide synthesis. Based on the T3 data, it is certain that methionine deficiency alters normal thyroid hormone metabolism (Carew et al., 2003).

Supplementation of the basal diet with DL-methionine resulted in an improvement in laying performance in light-bodied laying strains fed on cornmeal-soybean meal diets. There were numerical increases in egg mass production for all increases in dietary methionine, but these were not significant in excess of 0.07% added DL-methionine providing 0.55% TSAA. At 52 weeks there were numerical improvements in feed conversion efficiency for all increases in dietary methionine. Similar effects were observed in previous studies, indicating also that at marginal deficiencies of methionine, birds clearly ate more feed in an attempt to meet their requirement, but reduced feed intake was observed during severe methionine deficiencies. (Schutte and Van Weerden, 1978; Schutte et al., 1983,& 1984). The exact reason for the decline in feed intake at low methionine concentrations is not known.

Slow-Growing versus Fast-Growing Chicken Methionine Requirements
There is very little research into the methionine requirements for slow-growing poultry. European researchers are under the impression that requirements may be lower in their stocks, but more research is needed to determine if some breeds require more or less levels of methionine. Preliminary reports (unpublished) regarding methionine requirements of slow-growing US chickens indicate that there are no significant differences in methionine requirements for the slow-growing as compared to the fast-growing chickens (Fanatico, personal communication, posters-abstract #W15, 2007 and abstract #W189).

Summary
The requirement for additional methionine will differ depending on the feed constituents. Some of the results seen in the *Methionine Requirement* portion of this paper suggest the requirement may even be different depending on the genetic makeup of the chicken, however this needs to be explored. Two unpublished US studies (Fanatico-personal communication, personal communication, posters-abstract #W15, 2007 and abstract #W189) showed that slow growing chickens require the same amount of methionine as fast growing chickens.

In Turkeys
The information regarding the relative methionine effectiveness in turkeys is scarce. Jessen (1973) determined that supplementation of methionine to low protein (12-16% protein) in large white turkey breeder hens will not improve the reproductive performance.

Jessen found that the methionine requirement for optimum performance of breeder hens is as low as 0.158% and no higher than 0.208%, and theotal sulfur amino acid requirement may be as low as 0.336% and no higher than 0.386% (Jessen, 1973).

Atkinson, Bradley and Krueger (1976) determined that in Beltsville small white turkey layers, the addition of lysine to the basal diet had no significant effect on the rate of egg production, feed consumption, feed efficiency, or egg weight. The diet was mostly ground sorghum (58%), soy (16%) and 5% alfalfa meal, poultry by-product meal and total protein was calculated at 18.3%. Methionine addition to the basal diet produced highly significant increases in rate of egg production varying from 7.73% to 9.73% over the basal fed turkey hens. Body weight loss was significantly greater when the ration was supplemented with methionine or a combination of lysine and methionine. Egg size was increased when the basal ration was supplemented with methionine or the combination of lysine and methionine.

Moran (1994) showed that the adverse response of different broiler strains to low methionine was more pronounced during the first 6 weeks in both strains however Steggles x Arbor responded much more during the 0-3 week period than the Ross x Arbor. He also found that low methionine increased fat proportions at week 6, but not at week 8. He believes that the fat deposition in the Ross x Arbor Acres helped to minimize repercussion of the inadequate methionine intake, most likely due to the dietary protein catabolism and subsequent fat deposition, as well as the increased uric-acid forming enzymes. This basically means that broiler strains that are lean (not exercised induced) would be less able to handle a methionine deficiency than those birds that have the propensity to fatten.

Analyses verified accurate feed production and DL-Met or liquid MHA-FA supplementation, and performance data were evaluated by analysis of variance including comparison of means and simultaneous exponential regression in order to estimate relative effectiveness of liquid MHA-FA compared to DL-Met from studies. According to regression analysis, liquid MHA-FA was only 66 and 44% as effective as DL-Met regarding weight gain and feed conversion, respectively. With respect to weight gain corresponding treatments showed very similar performance confirming that 100 units of liquid MHA-FA can be replaced by 65 units of DL-Met without affecting performance (Hoehler & Hooge, 2003).

Summary
There is less information regarding methionine about methionine in turkeys than in chickens. Indications are that methionine supplementation for low methionine diets improve performance. Methionine addition to very low protein turkey diets, does not improve reproduction. Broiler strains that are lean (not exercised induced) would be less able to handle a methionine deficiency than those birds that have the propensity to fatten. More research is needed on methionine supplementation in turkeys.

Excess methionine in poultry
DL methionine is regarded as the most toxic of all essential amino acids. Amino acids including methionine transport copper between various body compartments. Ekperigin and Vohra (1980) examined this in broiler chicks. The birds affected most seriously went into convulsive seizures when touched, picked up and dropped, or distracted by sudden loud

noises. Excess dietary methionine also induced changes in the concentration of copper and iron in various organs. The concentration of copper was decreased in plasma and increased in the liver and the brain.

Rapid incorporation of methionine into pancreatic acinar cells has been reported, and the damaging effects of excess methionine were probably due to the presence of unusually large quantities of methionine or its metabolite acting directly upon the acinar cells (Ekperigin and Vohra, 1980).

Methionine Requirements in Broiler and Layer Chickens, and Turkeys

Nutritional requirements of poultry are influenced by a number of factors (Avian Research Centre, SAC, AYR KA6 5HW. 2002.Review Nutritional Standards for Livestock, 2002). These factors include species and genetic factors, production and environmental (organic, free-range, barn, temperature, etc.) factors, and age effects. Thus requirements will be different for each species, depending on the factors the poultry is exposed to. Sometimes, inclusions of nutrients are based on economic or availability of specific feed factors. The genetic variance of commonly used poultry is mostly restricted to Ross, Cobb, Nicholas, BUT, Lohmann, Hubbard-ISA and some others (Avian Research Centre, SAC, AYR KA6 5HW. 2002.Review Nutritional Standards for Livestock, 2002).

Hens

Experimental studies

Cao et al estimated the requirement for methionine and TSAA to be 424 and 785 mg per hen-day, respectively, for an egg mass production of 54.3 g per hen-day. However, at an egg mass yield of 50.8 g per hen-day they estimated a requirement of 670 mg TSAA per hen-day of which 364 mg is methionine. Novacek and Carlson (1969), Fisher and Morris (1970), Jensen et al. (1974), and Sell and Johnson (1974) reported lower requirement figures for methionine of 300 to 320 mg per hen-day.

The recommendation of the Agricultural Research Council in 1975 for young pullets producing 50 g egg mass per hen-day was 350 mg available methionine of a total of 470 mg available sulfur amino acids (SAA) per hen-day. Calderon and Jenson (1990) reported methionine requirements of 381, 388, and 414 mg per hen-day for diets containing 13, 16, and 19% CP respectively at TSAA intakes varying between 659 and 773 mg per hen-day. Schutte et al. (1985) reported that the requirement for methionine and TSAA for high producing layers appeared to be 375 and 750 mg per hen-day, respectively.

In Hubbard Broiler Breeder Hens, a 3 kg bird producing 45g of egg output each day would need 793 mg lysine and 321 mg of methionine per day (Bowmaker & Gous, 1991).

Schutte and De Jong (1994) found that the TSAA requirement was higher for maximum efficiency of corn-soy feed than for obtaining maximum egg production. In an egg mass yield of 55g/hen/day the requirement for methionine was 440 mg through the laying period of 52 weeks.

The dietary methionine requirement for production of 1 g of egg content (albumen and yolk) is ~5.4 to 5.6 mg (Harms & Russell, 1996a & 1996b)

The NRC Requirements (1994)

The National Research Council (NRC) in 1984 recommended 350 mg methionine per hen-day provided that the diet supplies 600 mg TSAA per hen-day. The 1994 NRC states that the methionine intake recommended requirement is 300 mg/hen per day (NRC, 1994).

Table of Hen NRC Requirements

TABLE 2-1 Nutrient Requirements of Immature Leghorn-Type Chickens as Percentages or Units per Kilogram of Diet

		White-Egg-Laying Strains				Brown-Egg-Laying Strains			
Nutrient	Unit	0 to 6 Weeks; 450 g[a] 2,850[b]	6 to 12 Weeks; 980 g[a] 2,850[b]	12 to 18 Weeks; 1,375 g[a] 2,900[b]	18 Weeks to First Egg; 1,475 g[a] 2,900[b]	0 to 6 Weeks; 500 g[a] 2,800[b]	6 to 12 Weeks; 1,100 g[a] 2,800[b]	12 to 18 Weeks; 1,500 g[a] 2,850[b]	18 Weeks to First Egg; 1,600 g[a] 2,850[b]
Protein and amino acids									
Crude protein[c]	%	18.00	16.00	15.00	17.00	***17.00***	15.00	14.00	***16.00***
Arginine	%	1.00	0.83	0.67	0.75	***0.94***	***0.78***	***0.62***	***0.72***
Glycine + serine	%	0.70	0.58	***0.47***	***0.53***	***0.66***	***0.54***	***0.44***	***0.50***
Histidine	%	0.26	0.22	0.17	0.20	***0.25***	***0.21***	***0.16***	***0.18***
Isoleucine	%	0.60	0.50	0.40	0.45	***0.57***	***0.47***	***0.37***	***0.42***
Leucine	%	1.10	0.85	0.70	0.80	***1.00***	***0.80***	***0.65***	***0.75***
Lysine	%	0.85	0.60	0.45	0.52	***0.80***	***0.56***	***0.42***	***0.49***
Methionine	%	0.30	0.25	0.20	0.22	***0.28***	***0.23***	***0.19***	***0.21***
Methionine + cystine	%	0.62	0.52	0.42	0.47	***0.59***	***0.49***	***0.39***	***0.44***
Phenylalanine	%	0.54	0.45	0.36	0.40	***0.51***	***0.42***	***0.34***	***0.38***
Phenylalanine + tyrosine	%	1.00	0.83	0.67	0.75	***0.94***	***0.78***	***0.63***	***0.70***
Threonine	%	0.68	0.57	0.37	0.47	***0.64***	***0.53***	***0.35***	***0.44***
Tryptophan	%	0.17	0.14	0.11	0.12	***0.16***	***0.13***	***0.10***	***0.11***
Valine	%	0.62	0.52	0.41	0.46	***0.59***	***0.49***	***0.38***	***0.43***
Fat									
Linoleic acid	%	1.00	***1.00***	***1.00***	***1.00***	***1.00***	***1.00***	***1.00***	***1.00***
Macrominerals									
Calcium[d]	%	0.90	0.80	0.80	2.00	***0.90***	***0.80***	***0.80***	***1.80***
Nonphytate phosphorus	%	0.40	0.35	0.30	0.32	0.40	0.35	0.30	0.35
Potassium	%	***0.25***	***0.25***	***0.25***	***0.25***	***0.25***	***0.25***	***0.25***	***0.25***
Sodium	%	0.15	0.15	0.15	0.15	***0.15***	***0.15***	***0.15***	***0.15***
Chlorine	%	0.15	***0.12***	***0.12***	***0.15***	***0.12***	***0.11***	***0.11***	***0.11***
Magnesium	mg	600.0	***500.0***	***400.0***	***400.0***	***570.0***	***470.0***	***370.0***	***370.0***
Trace minerals									
Manganese	mg	60.0	***30.0***	***30.0***	***30.0***	***56.0***	***28.0***	***28.0***	***28.0***
Zinc	mg	40.0	***35.0***	***35.0***	***35.0***	***38.0***	***33.0***	***33.0***	***33.0***
Iron	mg	80.0	***60.0***	***60.0***	***60.0***	***75.0***	***56.0***	***56.0***	***56.0***
Copper	mg	***5.0***	***4.0***	***4.0***	***4.0***	***5.0***	***4.0***	***4.0***	***4.0***
Iodine	mg	0.35	***0.35***	***0.35***	***0.35***	***0.33***	***0.33***	***0.33***	***0.33***
Selenium	mg	0.15	***0.10***	***0.10***	***0.10***	***0.14***	***0.10***	***0.10***	***0.10***
Fat soluble vitamins									
A	IU	1,500.0	1,500.0	1,500.0	1,500.0	***1,420.0***	***1,420.0***	***1,420.0***	***1,420.0***
D_3	ICU	200.0	200.0	200.0	300.0	***190.0***	***190.0***	***190.0***	***280.0***
E	IU	***10.0***	***5.0***	***5.0***	***5.0***	***9.5***	***4.7***	***4.7***	***4.7***
K	mg	0.5	***0.5***	***0.5***	***0.5***	***0.47***	***0.47***	***0.47***	***0.47***
Water soluble vitamins									
Riboflavin	mg	3.6	1.8	1.8	2.2	***3.4***	***1.7***	***1.7***	***1.7***
Pantothenic acid	mg	***10.0***	***10.0***	***10.0***	***10.0***	***9.4***	***9.4***	***9.4***	***9.4***
Niacin	mg	27.0	11.0	11.0	11.0	***26.0***	***10.3***	***10.3***	***10.3***
B_{12}	mg	0.009	0.003	0.003	0.004	***0.009***	***0.003***	***0.003***	***0.003***
Choline	mg	1,300.0	900.0	500.0	500.0	***1,225.0***	***850.0***	***470.0***	***470.0***
Biotin	mg	***0.15***	***0.10***	***0.10***	***0.10***	***0.14***	***0.09***	***0.09***	***0.09***
Folic acid	mg	***0.55***	***0.25***	***0.25***	***0.25***	***0.52***	***0.23***	***0.23***	***0.23***
Thiamin	mg	***1.0***	***1.0***	***0.8***	***0.8***	***1.0***	***1.0***	***0.8***	***0.8***
Pyridoxine	mg	3.0	***3.0***	***3.0***	***3.0***	***2.8***	***2.8***	***2.8***	***2.8***

NOTE: Where experimental data are lacking, values typeset in bold italics represent an estimate based on values obtained for other ages or related species.

[a] Final body weight.

[b] These are typical dietary energy concentrations for diets based mainly on corn and soybean meal, expressed in kcal ME_n/kg diet.

[c] Chickens do not have a requirement for crude protein per se. There, however, should be sufficient crude protein to ensure an adequate nitrogen supply for synthesis of nonessential amino acids. Suggested requirements for crude protein are typical of those derived with corn-soybean meal diets, and levels can be reduced somewhat when synthetic amino acids are used.

[d] The calcium requirement may be increased when diets contain high levels of phytate phosphorus (Nelson, 1984).

Table of the body weight and feed consumption of immature Leghorn type chickens

TABLE 2-2 Body Weight and Feed Consumption of Immature Leghorn-Type Chickens

	White-Egg-Laying Strains		Brown-Egg-Laying Strains	
Age (weeks)	Body Weight[a] (g)	Feed Consumption (g/week)	Body Weight[a] (g)	Feed Consumption (g/week)
0	35	50	37	70
2	100	140	120	160
4	260	260	325	280
6	450	340	500	350
8	660	360	750	380
10	750	380	900	400
12	980	400	1,100	420
14	1,100	420	1,240	450
16	1,220	430	1,380	470
18	1,375	450	1,500	500
20	1,475	500	1,600	550

[a] Average genetic potential when feed is consumed on an ad libitum basis. Different commercial strains may show different growth rates and different final mature body weights.

The nutrient requirements of Leghorn-type laying hens per kilogram of diet

TABLE 2-3 Nutrient Requirements of Leghorn-Type Laying Hens as Percentages or Units per Kilogram of Diet (90 percent dry matter)

		Dietary Concentrations Required by White-Egg Layers at Different Feed Intakes			Amounts Required per Hen Daily (mg or IU)		
Nutrient	Unit	80[a,b]	100[a,b]	120[a,b]	White-Egg Breeders at 100 g of Feed per Hen Daily[b]	White-Egg Layers at 100 g of Feed per Hen Daily	Brown-Egg Layers at 110 g of Feed per Hen Daily[c]
Protein and amino acids							
Crude protein[d]	%	18.8	15.0	12.5	15,000	15,000	16,500
Arginine[e]	%	***0.88***	***0.70***	***0.58***	***700***	***700***	***770***
Histidine	%	***0.21***	***0.17***	***0.14***	***170***	***170***	***190***
Isoleucine	%	0.81	0.65	0.54	650	650	***715***
Leucine	%	***1.03***	***0.82***	***0.68***	***820***	***820***	***900***
Lysine	%	0.86	0.69	0.58	690	690	***760***
Methionine	%	0.38	0.30	0.25	300	300	***330***
Methionine + cystine	%	0.73	0.58	0.48	580	580	***645***
Phenylalanine	%	***0.59***	***0.47***	***0.39***	***470***	***470***	***520***
Phenylalanine + tyrosine	%	***1.04***	***0.83***	***0.69***	***830***	***830***	***910***
Threonine	%	***0.59***	***0.47***	***0.39***	***470***	***470***	***520***
Tryptophan	%	0.20	0.16	0.13	160	160	***175***
Valine	%	***0.88***	***0.70***	***0.58***	***700***	***700***	***770***
Fat							
Linoleic acid	%	1.25	1.0	0.83	1,000	1,000	***1,100***
Macrominerals							
Calcium[f]	%	4.06	3.25	2.71	3,250	3,250	3,600
Chloride	%	0.16	0.13	0.11	130	130	***145***
Magnesium	mg	625	500	420	50	50	***55***
Nonphytate phosphorus[g]	%	0.31	0.25	0.21	250	250	***275***
Potassium	%	0.19	0.15	0.13	150	150	***165***
Sodium	%	0.19	0.15	0.13	150	150	***165***
Trace minerals							
Copper	mg	?	?	?	?	?	?
Iodine	mg	0.044	0.035	0.029	0.010	0.004	***0.004***
Iron	mg	56	45	38	6.0	4.5	***5.0***
Manganese	mg	25	20	17	2.0	2.0	***2.2***
Selenium	mg	0.08	0.06	0.05	0.006	0.006	***0.006***
Zinc	mg	44	35	29	4.5	3.5	***3.9***
Fat soluble vitamins							
A	IU	3,750	3,000	2,500	300	300	***330***
D_3	IU	375	300	250	30	30	***33***
E	IU	***6***	***5***	***4***	***1.0***	0.5	***0.55***
K	mg	0.6	0.5	0.4	0.1	***0.05***	***0.055***
Water soluble vitamins							
B_{12}	mg	0.004	***0.004***	***0.004***	0.008	***0.0004***	***0.0004***
Biotin	mg	***0.13***	***0.10***	***0.08***	***0.01***	***0.01***	***0.011***
Choline	mg	1,310	1,050	875	105	105	***115***
Folacin	mg	0.31	0.25	0.21	0.035	0.025	***0.028***
Niacin	mg	12.5	10.0	8.3	1.0	1.0	***1.1***
Pantothenic acid	mg	2.5	2.0	1.7	0.7	0.20	***0.22***
Pyridoxine	mg	3.1	2.5	2.1	0.45	0.25	***0.28***
Riboflavin	mg	3.1	2.5	2.1	0.36	0.25	0.28
Thiamin	mg	0.88	0.70	0.60	0.07	***0.07***	***0.08***

NOTE: Where experimental data are lacking, values typeset in bold italics represent an estimate based on values obtained for other ages or related species.

[a] Grams feed intake per hen daily.

[b] Based on dietary ME_n concentrations of approximately 2,900 kcal/kg and an assumed rate of egg production of 90 percent (90 eggs per 100 hens daily).

[c] Italicized values are based on those from white-egg layers but were increased 10 percent because of larger body weight and possibly more egg mass per day.

[d] Laying hens do not have a requirement for crude protein per se. However, there should be sufficient crude protein to ensure an adequate supply of nonessential amino acids. Suggested requirements for crude protein are typical of those derived with corn-soybean meal diets, and levels can be reduced somewhat when synthetic amino acids are used.

[e] Italicized amino acid values for white-egg-laying chickens were estimated by using Model B (Hurwitz and Bornstein, 1973), assuming a body weight of 1,800 g and 47 g of egg mass per day.

[f] The requirement may be higher for maximum eggshell thickness.

[g] The requirement may be higher in very hot temperatures.

Estimates of metabolized energy required per hen/ day in relation to body weight and egg production

TABLE 2-4 Estimates of Metabolizable Energy Required per Hen per Day by Chickens in Relation to Body Weight and Egg Production (kcal)

Body Weight (kg)	Rate of Egg Production (%)					
	0	50	60	70	80	90
1.0	130	192	205	217	229	242
1.5	177	239	251	264	276	289
2.0	218	280	292	305	317	330
2.5	259	321	333	346	358	371
3.0	296	358	370	383	395	408

NOTE: A number of formulas have been suggested for prediction of the daily energy requirements of chickens. The formula used here was derived from that in *Effect of Environment on Nutrient Requirements of Domestic Animals* (National Research Council, 1981c):

$$ME \text{ per hen daily} = W^{0.75}(173 - 1.95T) + 5.5\,\Delta W + 2.07\,EE$$

where W = body weight (kg), T = ambient temperature (°C), ΔW = change in body weight (g/day), and EE = daily egg mass (g). Temperature of 22°C, egg weight of 60 g, and no change in body weight were used in calculations.

Broilers

Experimental Studies

Morris et al. 1992 found that in unsexed Ross 1 broiler chicks, methionine concentration should be no less than 0.025 the dietary crude protein concentration. Methionine is less well utilized in the presence of excess protein (Morris et al. 1992).

In male broiler chicks 0-14 days when total methionine was at 0.56%, arginine becomes the limiting amino acid. When given at 2.18%, arginine causes growth depression (Keshavarz & Fuller, 1971). This was substantiated in Chamruspollert et al., 2002 giving 35.2 g/kg arginine. Additionally this researcher found the arginine requirement was higher in Ross X Ross female broiler chicks when the diet contained more lysine. Growth depression was alleviated by 5.5 g/kg methionine (Chamruspollert et al., 2002).

In one study done with Ross x Ross slow feathering 0-3 week old chicks, the dietary methionine requirement is set at 0.5%, the cysteine requirement at 0.39% and the total sulfur amino acid requirement at 0.89%. For chicks from 3-6 weeks, the dietary methionine requirement is 0.46%, the cysteine requirement at 0.37% and the total sulfur amino acid requirement at 0.83% (Kalinowski et al. 2003a). In contrast, for the Ross x Ross Fast Feathering for 0-3 week old chicks, the dietary methionine requirement is set at 0.5%, the cysteine requirement at 0.44% and the total sulfur amino acid requirement at 0.94%. For chicks from 3-6 weeks, the dietary methionine requirement is 0.46%, the cysteine requirement at 0.42% and the total sulfur amino acid requirement at 0.88% (Kalinowski et al. 2003b).

High-unsaturated fat diets in Cockerel chicks of Ross 308 genotype, higher methionine (> than 0.5%) supplementation is needed to stimulate the synthesis of glutathione (an antioxidant) to decrease risk of peroxidation in chicks (Nemeth et al., 2004).

Table of the NRC Requirements for Broilers

TABLE 2-5 Typical Body Weights, Feed Requirements, and Energy Consumption of Broilers

Age (weeks)	Body Weight (g)		Weekly Feed Consumption (g)		Cumulative Feed Consumption (g)		Weekly Energy Consumption (kcal *ME*/bird)		Cumulative Energy Consumption (kcal *ME*/bird)	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
1	152	144	135	131	135	131	432	419	432	419
2	376	344	290	273	425	404	928	874	1,360	1,293
3	686	617	487	444	912	848	1,558	1,422	2,918	2,715
4	1,085	965	704	642	1,616	1,490	2,256	2,056	5,174	4,771
5	1,576	1,344	960	738	2,576	2,228	3,075	2,519	8,249	7,290
6	2,088	1,741	1,141	1,001	3,717	3,229	3,651	3,045	11,900	10,335
7	2,590	2,134	1,281	1,081	4,998	4,310	4,102	3,459	16,002	13,794
8	3,077	2,506	1,432	1,165	6,430	5,475	4,585	3,728	20,587	17,522
9	3,551	2,842	1,577	1,246	8,007	6,721	5,049	3,986	25,636	21,508

NOTE: Values are typical for broilers fed well-balanced diets providing 3,200 kcal *ME*/kg.

NRC Nutrient requirements of broilers per kilogram of diet

TABLE 2-6 Nutrient Requirements of Broilers as Percentages or Units per Kilogram of Diet (90 percent dry matter)

Nutrient	Unit	0 to 3 Weeks[a]; 3,200[b]	3 to 6 Weeks[a]; 3,200[b]	6 to 8 Weeks[a]; 3,200[b]
Protein and amino acids				
Crude protein[c]	%	23.00	20.00	18.00
Arginine	%	1.25	1.10	1.00
Glycine + serine	%	1.25	***1.14***	***0.97***
Histidine	%	0.35	***0.32***	***0.27***
Isoleucine	%	0.80	***0.73***	***0.62***
Leucine	%	1.20	***1.09***	***0.93***
Lysine	%	1.10	1.00	0.85
Methionine	%	0.50	0.38	0.32
Methionine + cystine	%	0.90	0.72	0.60
Phenylalanine	%	0.72	***0.65***	***0.56***
Phenylalanine + tyrosine	%	1.34	***1.22***	***1.04***
Proline	%	0.60	***0.55***	***0.46***
Threonine	%	0.80	0.74	0.68
Tryptophan	%	0.20	0.18	0.16
Valine	%	0.90	***0.82***	0.70
Fat				
Linoleic acid	%	1.00	1.00	1.00
Macrominerals				
Calcium[d]	%	1.00	0.90	0.80
Chlorine	%	0.20	0.15	0.12
Magnesium	mg	600	***600***	***600***
Nonphytate phosphorus	%	0.45	0.35	0.30
Potassium	%	0.30	0.30	0.30
Sodium	%	0.20	0.15	0.12
Trace minerals				
Copper	mg	8	***8***	***8***
Iodine	mg	***0.35***	0.35	0.35
Iron	mg	80	***80***	***80***
Manganese	mg	***60***	***60***	***60***
Selenium	mg	0.15	0.15	0.15
Zinc	mg	40	***40***	***40***
Fat soluble vitamins				
A	IU	***1,500***	***1,500***	***1,500***
D_3	ICU	200	200	200
E	IU	***10***	***10***	***10***
K	mg	0.50	0.50	0.50

NRC Nutrient requirements of broilers per kilogram of diet (continued)

Nutrient	Unit	0 to 3 Weeks[a]; 3,200[b]	3 to 6 Weeks[a]; 3,200[b]	6 to 8 Weeks[a]; 3,200[b]
Water soluble vitamins				
B_{12}	mg	0.01	***0.01***	***0.007***
Biotin	mg	0.15	0.15	***0.12***
Choline	mg	1,300	***1,000***	***750***
Folacin	mg	0.55	0.55	***0.50***
Niacin	mg	35	30	25
Pantothenic acid	mg	***10***	***10***	***10***
Pyridoxine	mg	3.5	3.5	***3.0***
Riboflavin	mg	3.6	3.6	3
Thiamin	mg	***1.80***	***1.80***	***1.80***

NOTE: Where experimental data are lacking, values typeset in bold italics represent an estimate based on values obtained for other ages or related species.

[a]The 0- to 3-, 3- to 6-, and 6- to 8-week intervals for nutrient requirements are based on chronology for which research data were available; however, these nutrient requirements are often implemented at younger age intervals or on a weight-of-feed consumed basis.

[b]These are typical dietary energy concentrations, expressed in kcal ME_n /kg diet. Different energy values may be appropriate depending on local ingredient prices and availability.

[c]Broiler chickens do not have a requirement for crude protein per se. There, however, should be sufficient crude protein to ensure an adequate nitrogen supply for synthesis of nonessential amino acids. Suggested requirements for crude protein are typical of those derived with corn-soybean meal diets, and levels can be reduced when synthetic amino acids are used.

[d]The calcium requirement may be increased when diets contain high levels of phytate phosphorus (Nelson, 1984).

Males grow faster and larger than females and so feed requirements may differ by gender. Sundrum shows the net requirements of methionine and cysteine by males in the fattening period in figure 3-3 (Sundrum et al, 2005).

Graph of net requirement of methionine and cysteine by male broilers in the fattening period

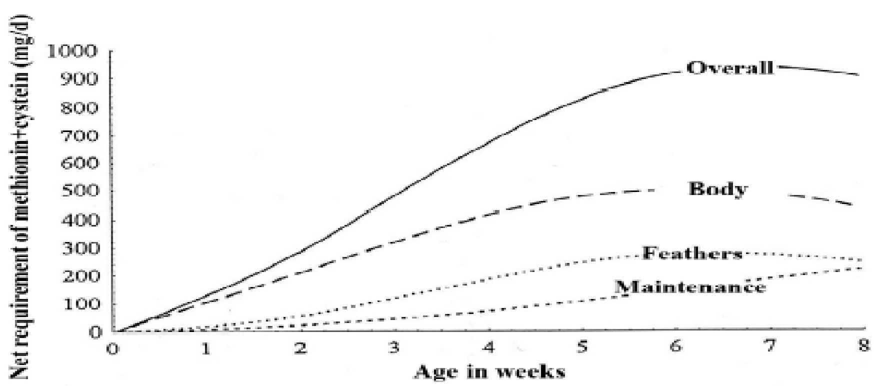


Fig. 3-3: Net requirement of methionine and cystine by male broilers in the fattening period (GfE, 1999).

The amino acid profile for broiler chicks vary between the recommendations from the Illinois Ideal Chick Protein (IICP, 1994) the Phone-Poulence Animal Nutrition (RPAN, 1993) and the National Research Council (NRC, 1994). Table 3-1 reflects these differences:

Table of differing requirements for IICP, RPAN, and NRC for broiler chicks

Tab. 3-1: Amino acids profile for broiler chicks

	IICP (1994) (digest. AS)	RPAN (1993) (total AS)	NRC (1994) (total AS)
Lysine	100	100	100
Methionine + Cystine	72	77	82
Methionine	36	47	46
Tryptophan	16	19	18

(Sundrum et al., 2005)

Turkeys
Experimental Studies

Warnick and Anderson's (1972) approach was that similar to that used by Dobson to define balanced amino acid proportions for chicks. That is, the level of each essential amino acid was adjusted in a basic diet until poult performance was reduced to about the same extent when 15% of any essential amino acid was removed. The amino acid levels found in the wall balanced diet were as follows: arginine 1.88, histindine 0.65; lysine 1.92, leucine 2.12, isoleucine 1.27, valine 1.42, phenylalanine and tyrosine 2.03, tryptophan 0.30, methionine and cystine 1.19, and threonine, 1.22 (all given as a percentage of the diet). The best performance was with a level of amino acids about 15% above the estimated minimum requirements (Warnick & Anderson, 1972).

A study determined the effects of adding methionine, lysine, and a fermentation residue to practical type diets containing 24, 27, and 30 % protein for young turkeys. Results showed that as dietary protein increased, the increases in body weight from added methionine became smaller. They also concluded that the total SAA requirement for turkeys might be in excess of 1.03% (Potter & Shelton, 1976).

Hurwitz et al.1983 determined that the total amino acid requirements vary with age. In their validation studies using Broad Breasted White Turkeys, they determined that methionine and cystine were first limiting amino acids in young turkeys. In turkeys over 16 weeks old, lysine became the limiting amino acid.

According to Boling and Firman (1996) Bronze poults require 0.5% methionine and 0.3% cysteine for a total of 0.8% SAA content of the diet (Kratzer et al., 1949). The Nicholas strain of Large White turkeys requires the total SAA to be 0.82% of the diet. Broad Breasted turkeys require 1.04% total SAA for the first 3 weeks of life (Warnick and Anderson).

Boling and Firman (1996) determined that the digestible SAA requirements for female turkeys during the starter period are 0.76% for optimum body weight gain and 0.75% for optimal: feed: gain at 3,171 kcal Me_n/kg. The basal diet without methionine added was found to be 0.50%, but calculated at 0.62%. Perhaps this value was lower than the recommended amount due to the added amount of lysine at 1.40%. Lehmann, Pack and Jeroch (1995) found that a level of lysine at 0.96% (3.0g/Mcal ME) was not sufficient to maximize weight gain in BUT Big 6 toms.

Waldroup, et al. (1997) determined that the NRC (1994) requirements were not adequate for both Nicholas (NIC) and British United (BUT) turkeys, and that about 5% higher level of amino acids were required to maximize breast yield. There were no differences between the requirements of the different strains of turkeys used in this experiment. Two experiments were conducted to determine the amino acids requirements for growing turkeys. The amino acid requirements for broilers increased as ambient temperatures increased from 12 to 27 C but declined as temperatures increased from 27 to 34 C. Female turkeys required a higher dietary protein content between 14 and 17 wk as environmental temperatures increased from 7 to 28C. Turkeys kept at over 27 C may require 105% of the suggested 1994 NRC requirement to provide maximum body weight gain, feed conversion and breast meat yield (Waldroup, Adams, Waldroup, 1997).

Some studies show that male British United B-6 turkeys, when exposed to ambient temperatures above their comfort level, do not respond to higher levels of methionine, lysine or threonine in the diet (Veldkamp et al.2000).

Moore, Baker and Firman (2004), determined the digestible sulfur amino acid requirement for Male British Turkeys of America from 6-12 weeks of age was between 0.50-0.82%. The SAA requirement for the 47-56 day growth period was 0.65 for body weight gain and 0.66% for feed conversion. The digestible requirements for the 67-78-day growth period were 0.56 for both the weight gain and feed conversion.

Growth rate, feed, and energy consumption of large type turkeys

TABLE 3-2 Growth Rate and Feed and Energy Consumption of Large-Type Turkeys

Age (weeks)	Body Weight (kg)		Feed Consumption per Week (kg)		Cumulative Feed Consumption (kg)		ME Consumption per Week (Mcal)	
	Male	Female	Male	Female	Male	Female	Male	Female
1	0.12	0.12	0.10	0.10	0.10	0.10	0.28	0.28
2	0.25	0.24	0.19	0.18	0.29	0.28	0.53	0.5
3	0.50	0.46	0.37	0.34	0.66	0.62	1.0	1.0
4	1.0	0.9	0.70	0.59	1.36	1.21	2.0	1.7
5	1.6	1.4	0.85	0.64	2.21	1.85	2.5	1.9
6	2.2	1.8	1.10	0.80	3.31	2.65	3.2	2.3
7	3.1	2.3	1.40	0.98	4.71	3.63	4.1	2.8
8	4.0	3.0	1.73	1.21	6.44	4.84	5.0	3.5
9	5.0	3.7	2.00	1.42	8.44	6.26	6.0	4.3
10	6.0	4.4	2.34	1.70	10.78	7.96	7.0	5.1
11	7.1	5.2	2.67	1.98	13.45	9.94	8.0	5.9
12	8.2	6.0	2.99	2.18	16.44	12.12	9.0	6.6
13	9.3	6.8	3.20	2.44	19.64	14.56	9.9	7.6
14	10.5	7.5	3.47	2.69	23.11	17.25	10.8	8.4
15	11.5	8.3	3.73	2.81	26.84	20.06	11.6	9.0
16	12.6	8.9	3.97	3.00	30.81	23.06	12.3	9.6
17	13.5	9.6	4.08	3.14	34.89	26.20	13.1	10.1
18	14.4	10.2	4.30	3.18	39.19	29.38	13.8	10.5
19	15.2	10.9	4.52	3.31	43.71	32.69	14.5	10.9
20	16.1	11.5	4.74	3.40	48.45	36.09	15.2	11.2
21	17.0	[a]	4.81	[a]	53.26	[a]	15.9	[a]
22	17.9	[a]	5.00	[a]	58.26	[a]	16.5	[a]
23	18.6	[a]	5.15	[a]	63.41	[a]	17.1	[a]
24	19.4	[a]	5.28	[a]	68.69	[a]	17.4	[a]

[a] No data given because females are usually not marketed after 20 weeks of age.

NRC requirements in turkeys per kilogram of diet (1994)

TABLE 3-1 Nutrient Requirements of Turkeys as Percentages or Units per Kilogram of Diet (90 percent dry matter)

		Growing Turkeys, Males and Females						Breeders	
Nutrient	Unit	0 to 4 Weeks[a]; 0 to 4 Weeks[b]; 2,800[c]	4 to 8 Weeks[a]; 4 to 8 Weeks[b]; 2,900[c]	8 to 12 Weeks[a]; 8 to 11 Weeks[b]; 3,000[c]	12 to 16 Weeks[a]; 11 to 14 Weeks[b]; 3,100[c]	16 to 20 Weeks[a]; 14 to 17 Weeks[b]; 3,200[c]	20 to 24 Weeks[a]; 17 to 20 Weeks[b]; 3,300[c]	Holding 2,900[c]	Laying Hens 2,900[c]
Protein and amino acids									
Protein[d]	%	28.0	26	22	19	16.5	14	12	14
Arginine	%	1.6	***1.4***	***1.1***	***0.9***	***0.75***	***0.6***	***0.5***	***0.6***
Glycine + serine	%	1.0	***0.9***	***0.8***	***0.7***	***0.6***	***0.5***	***0.4***	***0.5***
Histidine	%	0.58	***0.5***	***0.4***	***0.3***	***0.25***	***0.2***	***0.2***	***0.3***
Isoleucine	%	1.1	***1.0***	***0.8***	***0.6***	***0.5***	***0.45***	***0.4***	***0.5***
Leucine	%	1.9	***1.75***	***1.5***	***1.25***	***1.0***	***0.8***	***0.5***	***0.5***
Lysine	%	1.6	1.5	1.3	1.0	0.8	0.65	***0.5***	***0.6***
Methionine	%	0.55	0.45	0.4	0.35	0.25	***0.25***	***0.2***	***0.2***
Methionine + cystine	%	1.05	0.95	0.8	0.65	0.55	***0.45***	***0.4***	***0.4***
Phenylalanine	%	1.0	***0.9***	***0.8***	***0.7***	***0.6***	***0.5***	***0.4***	***0.55***
Phenylalanine + tyrosine	%	1.8	***1.6***	***1.2***	***1.0***	***0.9***	***0.9***	***0.8***	***1.0***
Threonine	%	1.0	***0.95***	***0.8***	***0.75***	***0.6***	***0.5***	***0.4***	***0.45***
Tryptophan	%	0.26	***0.24***	***0.2***	***0.18***	***0.15***	***0.13***	***0.1***	***0.13***
Valine	%	1.2	***1.1***	***0.9***	***0.8***	***0.7***	***0.6***	***0.5***	***0.58***
Fat									
Linoleic acid	%	1.0	***1.0***	***0.8***	***0.8***	***0.8***	***0.8***	***0.8***	***1.1***
Macrominerals									
Calcium[e]	%	1.2	1.0	0.85	0.75	0.65	0.55	0.5	2.25
Nonphytate phosphorus[f]	%	0.6	0.5	0.42	0.38	0.32	0.28	0.25	0.35
Potassium	%	0.7	***0.6***	***0.5***	***0.5***	***0.4***	***0.4***	***0.4***	***0.6***
Sodium	%	0.17	***0.15***	***0.12***	***0.12***	***0.12***	***0.12***	***0.12***	***0.12***
Chlorine	%	0.15	***0.14***	***0.14***	***0.12***	***0.12***	***0.12***	***0.12***	***0.12***
Magnesium	mg	500	***500***	***500***	***500***	***500***	***500***	***500***	***500***
Trace minerals									
Manganese	mg	60	***60***	***60***	***60***	***60***	***60***	***60***	***60***
Zinc	mg	70	***65***	***50***	***40***	***40***	***40***	***40***	***65***
Iron	mg	80	***60***	***60***	***60***	***50***	***50***	***50***	***60***
Copper	mg	8	***8***	***6***	***6***	***6***	***6***	***6***	***8***
Iodine	mg	0.4	***0.4***	***0.4***	***0.4***	***0.4***	***0.4***	***0.4***	***0.4***
Selenium	mg	0.2	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***	***0.2***
Fat soluble vitamins									
A	IU	5,000	5,000	***5,000***	***5,000***	***5,000***	***5,000***	***5,000***	***5,000***
D_3[g]	ICU	1,100	***1,100***	***1,100***	***1,100***	***1,100***	***1,100***	***1,100***	1,100
E	IU	12	***12***	***10***	***10***	***10***	***10***	***10***	25
K	mg	1.75	***1.5***	***1.0***	***0.75***	***0.75***	***0.50***	***0.5***	***1.0***
Water soluble vitamins									
B_{12}	mg	0.003	0.003	***0.003***	***0.003***	***0.003***	***0.003***	***0.003***	***0.003***
Biotin[h]	mg	0.25	0.2	***0.125***	***0.125***	***0.100***	***0.100***	***0.100***	***0.20***
Choline	mg	1,600	1,400	***1,100***	***1,100***	***950***	***800***	***800***	***1,000***
Folacin	mg	1.0	1.0	***0.8***	***0.8***	***0.7***	***0.7***	***0.7***	1.0
Niacin	mg	60.0	60.0	***50.0***	***50.0***	***40.0***	***40.0***	***40.0***	***40.0***
Pantothenic acid	mg	10.0	9.0	***9.0***	***9.0***	***9.0***	***9.0***	***9.0***	16.0
Pyridoxine	mg	4.5	4.5	***3.5***	***3.5***	***3.0***	***3.0***	***3.0***	***4.0***
Riboflavin	mg	4.0	3.6	***3.0***	***3.0***	***2.5***	***2.5***	***2.5***	***4.0***
Thiamin	mg	2.0	2.0	***2.0***	***2.0***	***2.0***	***2.0***	***2.0***	***2.0***

NOTE: Where experimental data are lacking, values typeset in bold italics represent estimates based on values obtained from other ages or relate species or from modeling experiments.

[a]The age intervals for nutrient requirements of males are based on actual chronology from previous research. Genetic improvements in body weight gain have led to an earlier implementation of these levels, at 0 to 3, 3 to 6, 6 to 9, 9 to 12, 12 to 15, and 15 to 18 weeks, respectively, by the industry at large.

[b]The age intervals for nutrient requirements of females are based on actual chronology from previous research. Genetic improvements in body weight gain have led to an earlier implementation of these levels, at 0 to 3, 3 to 6, 6 to 9, 9 to 12, 12 to 14, and 14 to 16 weeks, respectively, by the industry at large.

[c]These are approximate metabolizable energy (*ME*) values provided with typical corn-soybean-meal-based feeds, expressed in kcal ME_n/kg diet. Such energy, when accompanied by the nutrient levels suggested, is expected to provide near-maximum growth, particularly with pelleted feed.

[d]Turkeys do not have a requirement for crude protein per se. There, however, should be sufficient crude protein to ensure an adequate nitrogen supply for synthesis of nonessential amino acids. Suggested requirements for crude protein are typical of those derived with corn-soybean meal diets, and levels can be reduced when synthetic amino acids are used.

[e]The calcium requirement may be increased when diets contain high levels of phytate phosphorus (Nelson, 1984).

[f]Organic phosphorus is generally considered to be associated with phytin and of limited availability.

[g]These concentrations of vitamin D are considered satisfactory when the associated calcium and phosphorus levels are used.

[h]Requirement may increase with wheat-based diets.

Body weight and feed consumption of large-type turkeys during the holding and breeding periods

TABLE 3-3 Body Weights and Feed Consumption of Large-Type Turkeys during the Holding and Breeding Periods

	Females			Males	
Age (weeks)	Weight (kg)	Egg Production (%)	Feed per Turkey Daily (g)	Weight (kg)	Feed per Turkey Daily (g)
20	8.4	0	260	14.3	500
25	9.8	0	320	16.4	570
30	11.1	0[a]	310	19.1	630
35	11.1	68	280	20.7	620
40	10.8	64	280	21.8	570
45	10.5	58	280	22.5	550
50	10.5	52	290	23.2	560
55	10.5	45	290	23.9	570
60	10.6	38	290	24.5	580

NOTE: These values are based on experimental data involving "in-season" egg production (that is, November through July) of commercial stock. It is estimated that summer breeders would produce 70 to 90 percent as many eggs and consume 60 to 80 percent as much feed as in-season breeders.

[a]Light stimulation is begun at this point.

Protein Digestion & Methionine Absorption in broiler and layer chickens and turkeys

Amino acids differ in their specificity of transport systems. In the gut, these transport systems are commonly labeled either sodium dependent or sodium independent systems. The sodium dependent amino acid transport transports amino acids first by sodium binding to a carrier. The carrier then develops an affinity for the amino acid; then a sodium-amino acid co-transporter complex forms. This complex makes a conformational change that ultimately results in the delivery of the amino acid into the cytoplasm of the cell. At the end of this process, sodium is pumped out of the cell by the sodium/potassium ATPase. The carrier affinity (Km) is influenced by two major factors, the polar charge of the amino acid and the mass of the amino acid's functional groups. High mass amino acids (AAs) are the most affinitive, and essential AAs are absorbed faster than the non-essential ones. Methionine, isoleucine, leucine and valine are the most rapidly absorbed, whilst glutamate and aspartate are the most slowly absorbed. Phenylalanine and methionine utilize the PHE amino acid transport system, and threonine the 'B' (formerly the NBB) system (Groff & Gropper, 2000).

Absorption/Conversion/Metabolism of Methionine (Met) in Chickens

L-2-hydroxy-4-methylthiobutoanic acid (Synthetic)
In Hubbard x Hubbard, the uptake across the membrane is mediated entirely by saturable transport processes (Maenz & Englele-Schaan, 1996).

Met is transported by intermediate affinity systems (Maenz & Englele-Schaan, 1996).
In 18-21 day old Hubbard x Hubbard, Met is absorbed via a +H-dependent non-stereo specific transport system (Drew et al. 2003), and is Na^+ independent (Maenz & Englele-Schaan, 1996).

L-Met(L-Methionine)
In Hubbard x Hubbard, uptake across membrane is mediated entirely by saturable transport processes, and transported by high affinity systems (Maenz & Englele-Schaan, 1996).

In male 6-week old chicks, L-Met is transported in the apical membrane of the chicken jejunum by:
-Systems b $^{0,+}$- like and y^{+}m, shared with cationic amino acids (Soriano-Garcia et al., 1999)
-Systems L- and B-like, specific for neutral amino acids (Soriano-Garcia et al., 1999)

D-Met (D-Methionine)
In Hubbard x Hubbard, uptake is by low affinity systems (Maenz & Englele-Schaan, 1996), and transported by a single system B type transporter (Maenz & Englele-Schaan, 1996).

DL-Met (Synthetic)
In Hubbard x Hubbard, the overall rate of transport could be less than that of L-Met (Maenz & Englele-Schaan, 1996). Transport occurs by energy and Na-dependent and energy- and Na-independent pathways and diffusion (Maenz & Englele-Schaan, 1996).

L-Lysine
L-lysine supplementation results in upregulation of L-lysine transport via the b $^{0,+}$- like and y^{+}m systems (Soriano-Garcia et al., 1999)

Table of chicken transport systems involved in L-methionine and L-lysine transport

Table 1. ***Transport systems involved in L-methionine and L-lysine transport across apical membrane of chicken jejunum***

System	Na^+ Sensitivity	Specificity	NEM Sensitivity
y^+m	−/+	AA^+/AA^0	+
$b^{0,+}$	−	AA^0, AA^+, CssC	−
L	−	AA^0, BCH	−
B	+	AA^0, BCH	−

Functional properties of transport systems were previously characterized for L-methionine (12) and L-lysine (13, 14) transport in brush-border membrane vesicles (BBMV) from chicken jejunum. AA^+, cationic amino acids; AA^0, neutral amino acids; BCH, 2-aminobicyclo[2.2.1]-heptane-2-carboxylic acid; CssC, cystine; NEM, *N*-ethylmaleimide.

(Soriano-Garcia et al., 1999)

In male Ross (21-day old) chickens, methionine supplementation down regulates specific transport mechanisms of the small intestines involved in the apical L-Methionine transport (Martin-Venegas et al. 2006)

The intestine can convert 2-hydroxy-4-methylthiobutoanic acid to Met (Martin-Venegas et al. 2006). The conversion of 2-hydroxy-4-methylthiobutoanic acid to L Met involves two enzymatic steps: oxidation of the alpha carbon followed by transamination (Martin-Venegas et al. 2006). The first reaction in the conversion is a stereo specific oxidation involving different enzymes: paroxysmal L-2-hydroxy acid oxidase and mitochondrial D-2-hydroxy acid dehydrogenase, which catalyzes the oxidation of L-2-hydroxy-4-methylthiobutoanic acid and D-2-hydroxy-4-methylthiobutoanic acid, respectively, thereby yielding the corresponding alpha-retraced, 2-keto-(4-methylthio) botanic acid. The specific enzyme L-2-hydroxy acid oxidase has been found in chicken liver and kidney whereas D-2-hydroxy acid dehydrogenase has been detected in numerous tissues, including liver, kidney, skeletal muscle, intestine, pancreas, spleen, and brain.

After the formation of 2-keto-(4-methylthio) botanic acid, the second step is its conversion to L-Met by transamination, which is ubiquitous and does not constitute the limiting step in the complete conversion process of DL-2-hydroxy-4-methylthiobutoanic acid (Martin-Venegas et al. 2006). 2-hydroxy-4-methylthiobutoanic acid might be preferentially diverted to the trans-sulfuration pathway (Martin-Venegas et al. 2006)

The liver is an important site for metabolism of methionine (Met) in the Cobb 500 broiler (Pillai et al. 2006). Met is converted to homocysteine (HCY), which lies at the crossroads of sulfur amino acid (SAA) metabolism (Fig 1 picture below). Formation of Cys may occur if HCY proceeds through the irreversible transsulfuration pathway; alternatively, HCY may be converted back to Met after addition of a methyl group by folate-vitamin B12-dependent Met synthase (MS) or betaine (BET)-HYC methyltransferase (BHMT). The methyl group provided by BHMT is derived from BET, which is a product of choline oxidation (Pillai et al. 2006).

Figure of poultry liver metabolism of methionine

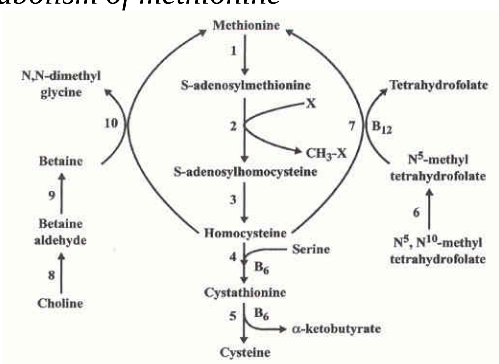


Figure 1. Metabolism of sulfur amino acids, choline, and betaine. Numerals indicate the following enzymes: 1) methionine adenosyltransferase, 2) various enzymes, 3) S-adenosylhomocysteine hydrolase, 4) cystathionine β-synthase, 5) cystathionine γ-lyase, 6) N^5,N^{10}-methylenetetrahydrofolate reductase, 7) methionine synthase, 8) choline dehydrogenase, 9) betaine aldehyde dehydrogenase, and 10) betaine-homocysteine methyltransferase.

(Pillai et al. 2006)

Transport of dietary Met through the basement (basolateral) membranes involves both diffusion and the sodium-potassium pump. Cysteine, methionine, alanine, and serine are transported using the ASC transport system along with all other 3 and four carbon amino acids (Groff & Gropper 2000).

Other substances that may increase/decrease absorption and transport of methionine

Chickens

In Male Ross chickens, L-methionine is transported in the jejunal brush border membrane vesicles through four transport systems, two of which are shared by cationic and neutral amino acid systems ($b^{0,+}$& y^{+}) and the neutral amino acid systems B and L. When these chickens were fed a diet high in saturated fat (60 g/kg lard), L-lysine and L-methionine transport was decreased, and when fed a diet high (60g/Kg) of n-3 polyunsaturated fatty acids (PUFA) in the form of linseed (flaxseed) oil, transport increased for both lysine and methionine in the B and L systems. The high saturated fat diet also decreased membrane passive permeability of L-lysine and L-methionine (Ferrer, et al. 2003).

Turkeys

There is no information regarding absorption and transport of methionine in turkeys, although the mechanism is most likely similar to chickens.

Methionine supplementation in chicken and turkey feed

Broiler Chickens

The growth increase and performance of present-day broilers is due to increased nutrients and genetic selection. Body weight development is important. Figure 3-2 shows that protein requirement for slow-growing chickens is less, and that live weight is too.

Graph of growth and age in laying hens, male and female broilers and Label Rouge

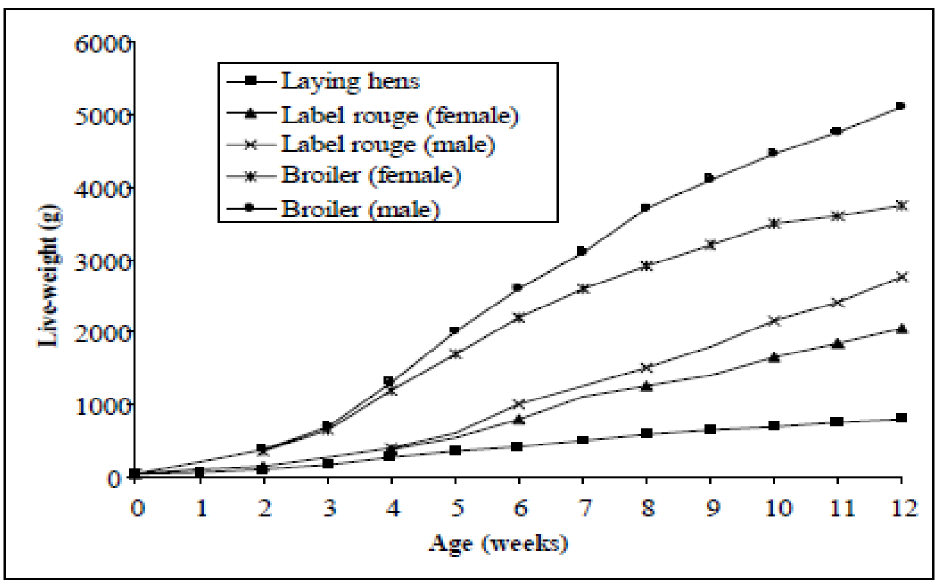


Fig. 3-2: Development of body weight in laying hens, male and female broilers and Label Rouge (EU-Report, 2000)

Laying Chickens
Many studies have been published on methionine additions to feedstuffs. Gross amino acid requirements are higher in brown-shelled eggs (about 10%) than for white-shelled egg, due to the higher live weight of the hens. Recommendations for the amino acid requirements in laying hens depend on body weight and are given in table 3-6 (Sundrum, Schneider, Richter, 2005).

Table of amino acid requirements in laying hens based on body weight

Tab. 3-6: Recommendations for the amino acid requirement in laying hens, depending on body weight

	Body weight					
	light	medium	light	medium	medium	heavy
Lys.	670	680	690	760	-	-
Met. + Cys.	580	595	580	645	595	615
Met.	330	335	300	330	335	350
Source	GFE, 1999		NRC, 1994		JEROCH, 2002	

At the present time, there are no systematically collected data published on amino acid supply in practice-based feedstuff analysis. The Methionine Replacement Taskforce has recently developed an organic feed-based grouping of high methionine containing feeds (Dr. Jacquie Jacobs, personal communication); it is attached to her communication, and is in the process of being published. This report will be discussed in the *Recommendations for Research* section of this paper.

The Surburban Rancher-an online publication of the Cooperative Extension of the University of California includes no methionine supplements, however suggests fish or meat meal or soybean meal 5 pounds per 100 lbs in a mix for starter and grower and 3 pounds per 100 lbs in a mix for layers (Ernst, Vohra, Beall, 1983).

Turkeys
According to the review done by Sundrum et al 2005, the growth of turkeys has increased markedly since 1972. The following table, 3-2 illustrates this:

Table of genetic development from 1972 to 1995 on turkey growth

Tab. 3-2: Effect of genetic development (1972 to 1995) on growth in turkeys

	1972	1981	1995
Varieties	Average varieties	Big 6	Big 6
Fattening period (weeks)	15	18	18
Live weight at slaughter (kg)	4.5	12.7	15.8
Average daily live weight gain (g)	42	101	125
Feed conversion 1:	2.83	2.76	2.66
Source	JEROCH, 1972	FRANKENPOHL, 2002	

The live weight differs between the sexes as well as by the genetic types of turkey.

Table of growth in female and male turkeys depending on type and fattening stage

Tab. 3-3: Live weight in male and female turkeys depending on type and fattening stage

Type	Fattening stage	♂ (kg)	♀ (kg)
Heavy	Age	20 - 25	10 – 12
	20 or 16 weeks	15 - 16	8 – 9
Medium weight	Age	10 - 12	6 – 7
	18 or 14 weeks	8 - 19	5 – 6
Light	Age	7 - 8	5 – 6
	14 or 12 weeks	6 - 7	4 – 5

Source: WEGNER, 1987

Table of requirements for amino acids in fattening turkeys

Tab. 3-4: Recommendations on amino acid supply in fattening turkeys

Age (weeks)	Crude protein (%)	Met (%)	Met + Cys (%)	Crude protein (%)	Met (%)	Met + Cys (%)
1 + 2	28	0.55	1.05	28	0.58	1.05
3 + 4				26	0.52	1.01
5 – 8	26	0.45	0.95	23	0.48	0.90
9 – 12	22	0.40	0.80	21	0.43	0.81
13 – 16	19	0.35	0.65	19	0.38	0.69
17 – 20	16.5	0.25	0.55	15	0.27	0.58
> 20	14	0.25	0.45	15	0.24	0.45
Source	NRC, 1994			JEROCH & DÄNICKE, 2002		

Effectiveness of alternative methionine-rich foods as potential replacements

Present use of non-methionine containing feeds in the US

Maine Organic Farmers and Growers Association organic specialist Eric Sideman has been a successful 100% organic small flock poultry farmer for 5 years using a whole wheat, organic whole oats, alfalfa meal, fishmeal and limestone and adds it to an organic corn-soy meal base feed (Sideman, personal communication, 2007). He also suggests using safflower or sesame as alternatives. From 1997 to 2002 Sideman served a term on the National Organic Standards Board, the advisory board to the USDA National Organic Program. His suggestion for poultry producers is to rebalance the 90% corn: 10% soy to 70%:30% corn to soybean. This increases the inefficiency in feed uptake, resulting in additional feed, longer growth time, and more manure. The original 90:10 ratio allows maximum feed efficiency, but the ration is low in methionine. As for the reason why the change has been met with resistance, Sideman believes that “It’s a cost issue, but they will never say it.”(Hungerford, 2005, The New Farm)

Anne Fanatico, a graduate student from the University of Arkansas resesarched slow and medium growing birds. She states that their methionine requirement is about the same as commercial birds, however, they are heartier birds-less prone to heart, leg and metabolic problems (Fanatico et al, 2005,& telephone communication, 2007). They cost more to raise, the yield is not comparable (it is lower than) conventional strains, and the food efficiency is not as good. These heritage breeds do not produce the meaty bird that is popular in the US"(Hungerford, 2005, The New Farm). She is presently finishing a study using medium growing birds that will be complete by Summer 2008 (Fanatico, personal communication, 2007).

Dr. Jacquie Jacobs from the University of Minnesota, presently on the Methionine Replacement taskforce stated in an e-mail communication that it is possible to get organic corn gluten meal and organic fishmeal in the US, but that it is difficult. Potato protein, used mostly in Europe by organic poultry producers would also be a potential high-methionine source, but it is not available organically. (Personal Communication-Dr. Jacquie Jacobs).

West Virginia-J Moritz et al., 2005
Moritz et al. (2005) looked at the ability of the commercial broiler to partially meet the amino acid requirements by forging during different times of the year. The objectives of the study focused on assessment of performance, carcass characteristics and meat quality of organic broilers fed with and without synthetic methionine. However, all chicks (0-3 weeks) were reared with synthetic methionine and during the study, feeding strategies were used to encourage foraging during the 3-8 week growing phase. They found that allowing the birds to forage decreased marginal methionine deficiencies in broilers and environmental conditions and time of year had an effect of feed intake and carcass quality.

Information from the Organic Seed Producers from the NOP website
This research group attempted to contact those organic seed producers from the website: http://www.ams.usda.gov/NOP/ProdHandlers/FeedProducers.html#AR maintained by the National Organic Program. We attempted to electronically contact each electronic e-mail or website address organic supplier with three questions related to our methionine research (please see sample letter in Appendix under NOP List of organic suppliers):

1) How will your seed company meet the 'no added methionine' guidelines for October 2008?
2) Which high organic sources of methionine will you be adding to the feed to conform to the organic regulations?
3) Has your company heard of any large studies or practices that are using alternative sources of feed high in methionine that will conform to the proposed 100% organic US standards—that is plant-based, no added methionine, and contains non-genetically modified organism (GMO) feed?

We contacted 32 electronically from the NOP site, and 6 were immediately were returned as not having a valid e-mail address. One was stated as forwarded, another had a spam-blocker and 2 attempts were made to contact one supplier, but we were not successful. Recently it was learned that some suppliers did not respond because they were on the Methionine Task Force (Martinelli, personal communication, 2007).

Responses:
SK Foods is not a Feed/grain producer (Personal Communication, SK Foods).

We know of a few small privately run trials that have used natural sources of methionine and lysine (Personal Communication Lakeview Organic Grain). The results are only anecdotal but a few of them seem worth following up.

1) There is a rice hull extract that is very high in methionine (I was told it contains about 4 to 5% methionine). My source said that it worked as well as the synthetic material when used in broiler feed.

2) Pearl millet is much higher in both methionine and lysine than any other grains. Chickens have done very well when it was substituted for part of the corn and small grains in poultry feed. Grain sorghum is higher in methionine and lysine than corn too but not as high as millet.

3) Crab shell meal, lobster shell meal, or other such byproducts can supply part of the methionine needed in poultry feed.

4) Fishmeal has been used with good results too.

5) Fertilizing the soil where grain and soybeans destined for use in poultry feed with extra sulfur may improve methionine and cystine levels too.

I hope that synthetic amino acids will be phased out in stages to allow supplies of alternative sources to be built up. As long as synthetics are allowed and cheap, nobody will go to the expense and trouble of developing adequate supplies of alternatives. I have suggested implementing a maximum rate in a ton of feed of synthetic amino acids that can be reduced in stages as supplies of the alternatives increase. A cold turkey ban is not practical for an industry as large as organic poultry production (Personal Communication Lakeview Organic Grain).

After 8 years, Northernmost Feeds closed in May due to rising corn, fuel prices and the changes in the NOP rule that excluded several key feed ingredients. However, prior to closing they received a grant to research methionine sources. This study is attached to the personal communication. They suggested using de-hulled sunflower seeds, fishmeal and duckweed. The duckweed they tested could not be farmed organically in large quantities and the analyses proved lower methionine than they originally believed, however dehulled sunflower seeds may be an excellent methionine alternative (Personal Communication Northernmost Feeds).

Other communiqués from other organic supplier websites
We use crab meal and fishmeal. For 3 years, they have been supplying organic feed without methionine, with no customer complaints. The birds are within 0.5 pound of conventionally raised birds (Personal communication Fertrell, 2007).

Moritz et al, 2005 fed corn-soybean-based broiler diets containing synthetic methionine and diets without methionine after week 3. From 0-3 weeks synthetic methionine was added to all diets. Results indicate that marginal methionine deficiencies can be largely overcome by foraging, and feed restriction was an effective strategy to increase foraging behaviors and intakes in the non-synthetic methionine broilers.

The USDA / National Organic Program regulations on the allowance for synthetic Methionine in organic chickens and turkeys

Support for the use of methionine—petition to amend National List for use of Methionine. See attached in USDA references under the date of January 07, 2005.

Please also see:
National Organic Standards Board. Formal Recommendation by the National Organic Standards Board (NOSB) to the National Organic Program (NOP).March 18, 2005. Renewal of DL-Methionine on National List until October 1, 2008.

This was published in the Federal Register. Please see:
Federal Register. Friday, July 29, 2005.Proposed rule to amend the USDA National List of Allowed and Prohibited Substances (Livestock). Extension of Methionine in poultry feed until October 21, 2008.

Testimony presented to the National Organic Standards Board (NOSB) supporting the use of Methionine and the discussion of Methionine

Due to the amount of testimony and relevant discussions in the transcribed meetings on the subject of methionine, we have included the following as hardcopies in the binders that accompany this review.

National Organic Standards Board Materials Database.1999.Amino Acids-Methionine. Pages 6-12. TAP review. There were 3 reviewers on this topic-names were not supplied in this document.

National Organic Standards Board Technical Advisory Panel Review for the USDA National Organic Program. May 21, 2001. Methionine Livestock.1-20.

National Organic Standards Board. Public Meeting. June 06, 2001. Transcript. Heritage Reporting Corporation. Pages 8-39, 68, 80, 88-89, 107, 182.

National Organic Standards Board. Public Meeting. June 07, 2001. Transcript. Heritage Reporting Corporation. Please see pages 464, 514-517.

National Organic Standards Board. Meeting. Monday, October 15, 2001. Transcript. Neal R. Gross Court Reporters and Transcribers. Please see pages 66, 77-88, 126, 151-154, 181-183, 315.

National Organic Standards Board. Meeting. Tuesday, October 16, 2001. Transcript. Neal R. Gross Court Reporters and Transcribers. Note that only pertinent pages are included. Pages 406-477.

National Organic Standards Board. Meeting. Wednesday, October 17, 2001. Transcript. Neal R. Gross Court Reporters and Transcribers. Please see pages 66, 77-88, 126, 151-154, 181, 283, 315.

European Union (EU) organic poultry production standards concerning the use of Methionine –Council Regulations (2092/91/EEC)

To skip subsequent documentation and amendments, please go to **Summary**.

The following is the section of the Council Regulation (EEC) no 2092/91 of 24 June, 1991 containing all amendments to the present time regarding additives to feed:

C. FEED MATERIALS

▼M26

1. **Feed materials from plant origin**

1.1. Cereals, grains, their products and by-products. Only the following substances are included in this category:

oats as grains, flakes, middlings, hulls and bran; barley as grains, protein and middlings; rice germ expeller; millet as grains; rye as grains and middlings; sorghum as grains; wheat as grains, middlings, bran, gluten feed, gluten and germ; spelt as grains; triticale as grains; maize as grains, bran, middlings, germ expeller and gluten; malt culms; brewers' grains.

1.2. Oil seeds, oil fruits, their products and by-products. Only the following substances are included in this category:

rape seed, expeller and hulls; soya bean as bean, toasted, expeller and hulls; sunflower seed as seed and expeller; cotton as seed and seed expeller; linseed as seed and expeller; sesame seed as expeller; palm kernels as expeller; pumpkin seed as expeller; olives, olive pulp; vegetable oils (from physical extraction).

1.3. Legume seeds, their product and by-products. Only the following substances are included in this category:

chickpeas as seeds, middlings and bran; ervil as seeds, middlings and bran; chickling vetch as seeds submitted to heat treatment, middlings and bran; peas as seeds, middlings, and bran; broad beans as seeds, middlings and bran; horse beans as seeds middlings and bran, vetches as seeds, middlings and bran and lupin as seeds, middlings and bran.

1.4. Tuber, roots, their products and by-products. Only the following substances are included in this category:

sugar beet pulp, potato, sweet potato as tuber, potato pulp (by-product of the extraction of potato starch), potato starch, potato protein and manioc.

1.5. Other seeds and fruits, their products and by-products. Only the following substances are included in this category:

carob, carob pods and meals thereof, pumpkins, citrus pulp; apples, quinces, pears, peaches, figs, grapes and pulps thereof; chestnuts, walnut expeller, hazelnut expeller; cocoa husks and expeller; acorns.

1.6. Forages and roughages. Only the following substances are included in this category:

▼**M26**

lucerne, lucerne meal, clover, clover meal, grass (obtained from forage plants), grass meal, hay, silage, straw of cereals and root vegetables for foraging.

1.7. Other plants, their products and by-products. Only the following substances are included in this category:

molasses, seaweed meal (obtained by drying and crushing seaweed and washed to reduce iodine content), powders and extracts of plants, plant protein extracts (solely provided to young animals), spices and herbs.

1.8. The following feed materials may be used until 30 June 2004: rice as grain, rice broken, rice bran, rye feed, rye bran, turnip rape seed expeller, turnip rape seed hulls and tapioca.

2. **Feed materials from animal origin**

2.1. Milk and milk products. Only the following substances are included in the category:

raw milk as defined in Article 2 of Directive 92/46/EEC (1), milk powder, skimmed milk, skimmed-milk powder, buttermilk, buttermilk powder, whey, whey powder, whey powder low in sugar, whey protein powder (extracted by physical treatment), casein powder, lactose powder, curd and sour milk.

2.2. Fish, other marine animals, their products and by-products. Only the following substances are included in the category:

fish, fish oil and cod-liver oil not refined; fish molluscan or crustacean autolysates, hydrolysate and proteolysates obtained by an enzyme action, whether or not in soluble form, solely provided to young animals. Fish meal.

2.3. Eggs and egg products for use as poultry feed, preferably from the same holding.

3. **Feed materials from mineral origin**

Only the following substances are included in this category:

Sodium:

unrefined sea salt

coarse rock salt

sodium sulphate

sodium carbonate

sodium bicarbonate

sodium chloride;

Potassium:

potassium chloride;

Calcium:

lithotamnion and maerl

shells of aquatic animals (including cuttlefish bones)

calcium carbonate

calcium lactate

calcium gluconate;

Phosphorus:

defluorinated dicalcium phosphate

defluorinated monocalcium phosphate

monosodium phosphate

calcium-magnesium phosphate

(1) OJ L 268, 14.9.1992, p. 1.

▼M26

calcium-sodium phosphate;

Magnesium:

magnesium oxide (anhydrous magnesia)

magnesium sulphate

magnesium chloride

magnesium carbonate

magnesium phosphate;

Sulphur:

sodium sulphate.

Bone dicalcium phosphate precipitate may be used until 30 June 2004.

▼M15

D. FEED ADDITIVES, CERTAIN SUBSTANCES USED IN ANIMAL NUTRITION (DIRECTIVE 82/471/EEC) AND PROCESSING AIDS USED IN FEEDINGSTUFFS

▼M26

1. **Feed additives**

1.1. Trace elements. Only the following substances are included in this category:

E1 Iron:

ferrous (II) carbonate

ferrous (II) sulphate monohydrate and/or heptahydrate

ferric (III) oxide;

E2 Iodine:

calcium iodate, anhydrous

calcium iodate, hexahydrate

sodium iodide;

E3 Cobalt:

cobaltous (II) sulphate monohydrate and/or heptahydrate

basic cobaltous (II) carbonate, monohydrate;

E4 Copper:

copper (II) oxide

basic copper (II) carbonate, monohydrate

copper (II) sulphate, pentahydrate;

E5 Manganese:

manganous (II) carbonate

manganous oxide and manganic oxide

manganous (II) sulfate, mono- and/or tetrahydrate;

E6 Zinc:

zinc carbonate

zinc oxide

zinc sulphate mono- and/or heptahydrate;

E7 Molybdenum:

ammonium molybdate, sodium molybdate;

E8 Selenium:

sodium selenate

sodium selenite.

▼M36

1.2. Vitamins, provitamins and chemically well-defined substances having a similar effect. Only the following substances are included in this category:

Vitamins authorised under Regulation (EC) No 1831/2003 of the European parliament and of the Council (*):

— vitamins derived from raw materials occurring naturally in feedingstuffs,

— synthetic vitamins identical to natural vitamins for monogastric animals,

— with prior authorisation of the Member State competent authority, synthetic vitamins A, D and E identical to natural vitamins for ruminants.

▼M26

1.3. Enzymes. Only the following substances are included in this category:

Enzymes authorised under Directive 70/524/EEC.

1.4. Microorganisms. Only the following microorganisms are included in this category:

microorganisms authorised under Directive 70/524/EEC.

1.5. Preservatives. Only the following substances are included in this category:

E 200 Sorbic acid

E 236 Formic acid

E 260 Acetic acid

E 270 Lactic acid

E 280 Propionic acid

E 330 Citric acid.

The use of lactic, formic, propionic and acetic acid in the production of silage shall be only permitted when weather conditions do not allow for adequate fermentation.

1.6. Binders, anti-caking agents and coagulants. Only the following substances are included in this category:

E 470 Calcium stearate of natural origin

E 551b Colloidal silica

E 551c Kieselgur

E 558 Bentonite

E 559 Kaolinitic clays

E 560 Natural mixtures of stearites and chlorite

E 561 Vermiculite

E 562 Sepiolite

E 599 Perlite.

1.7. Antioxidant substances. Only the following substances are included in this category:

E 306 Tocopherol-rich extracts of natural origin

1.8. Silage additives. Only the following substances are included in this category:

as from 19 October 2004, enzymes, yeasts and bacteria authorised by Regulation (EC) No 1831/2003 on additives for use in animal nutrition.

2. **Certain products used in animal nutrition**

Only the following products are included in this category:

(*) OJ L 268, 18.10.2003, p. 29.

▼**M26**

brewer's yeasts.

3. **Processing aids used in feedingstuffs**

3.1. Processing aids for silage. Only the following substances are included in this category:

— sea salt, coarse rock salt, whey, sugar, sugar beet pulp, cereal flour and molasses,

— up to 18 October 2004, enzymes, yeasts, and lactic, acetic, formic, and propionic bacteria.

▼**M15**

E. PRODUCTS AUTHORISED FOR CLEANING AND DISINFECTION OF LIVESTOCK BUILDINGS AND INSTALLATIONS (E.G. EQUIPMENT AND UTENSILS)

Potassum and sodium soap

Water and steam

Milk of lime

Lime

Quicklime

Sodium hypochlorite (e.g. as liquid bleach)

Caustic soda

Caustic potash

Hydrogen peroxide

Natural essences of plants

Citric, peracetic acid, formic, lactic, oxalic and acetic acid

Alcohol

Nitric acid (dairy equipment)

Phosporic acid (dairy equipment)

Formaldehyde

Cleaning and disinfection products for teats and milking facilities

Sodium carbonate

F. OTHER PRODUCTS

There are no ‘other products.’ This is the end of pertinent information from that document.

Subsequent changes not added directly to this document are found in 82/471/EEC the Council Directive 82/471/EEC of 30 June 1982 concerning certain products used in animal nutrition. The directives state the following:

> Whereas non-protein nitrogenous compounds, by reason of their indirect provision of protein, must be subject to the provisions of this Directive ; whereas it is consequently desirable to amend with regard to its Annexes Council Directive 70/524/EEC of 23 November 1970 concerning additives in feedingstuffs (4), which temporarily regulates the use of products of this group; (1) OJ No C 197, 18.8.1977, p. 3. (2) OJ No C 63, 13.3.1978, p. 53. (3) OJ No C 84, 8.4.1978, p. 4. (4) OJ No L 270, 14.12.1970, p. 1.
>
> Whereas the nutritional value and safety of the products in question depend to a large extent on their compositional characteristics, conditions of use and processes of manufacture ; whereas it is therefore essential to provide in certain cases for labelling to protect the user against fraud and to facilitate the optimal use of the products available to him;
>
> Whereas it is not appropriate to apply Community provisions to the products concerned, or to feedingstuffs containing these products, intended for export to third countries because in general these countries have their own regulations;
>
> Whereas, in order to ensure that the requirements of this Directive are satisfied when these products, or feedingstuffs containing these products, are placed on the market, Member States must make provision for appropriate control arrangements;
>
> Whereas products, or feedingstuffs containing such products, satisfying these requirements must be subject only to the marketing restrictions provided for in this Directive;
>
> Whereas an appropriate Community procedure is essential to adapt the provisions of the Annex and the guidelines laid down for the submission of dossiers relating to certain products and, where necessary, to fix criteria of composition and purity as well as the physico-chemical and biological properties of these products in the light of the development of scientific and technical knowledge;
>
> Whereas, with a view to providing all necessary guarantees, the Community procedure adopted should make provision in certain cases of amendment of the Annex for the compulsory consultation of the Scientific Committee for Animal Nutrition and the Scientific Committee for Food, set up by the Commission;
>
> Whereas Member States should retain the power, if human or animal health is endangered, temporarily to suspend authorization of the use of a product or to amend any provisions relating thereto;
> Whereas, in order that a Member State should not abuse that power, possible amendments to the Annex based on supporting documents should be decided by emergency Community procedure;

> Whereas, in order to facilitate implementation of this Directive, a procedure should be applied which establishes close cooperation between Member States and the Commission within the Standing Committee for Feedingstuffs set up by Decision 70/372/EEC.
> (82/471/EEC the Council Directive 82/471/EEC of 30 June 1982)

The Commission Regulation (EC) no 599/2003 of 1 April 2003 amending Regulation (EEC) No 2092/91 allowed eggs and egg products to be used as poultry feed, from the same holding and restricted the feed formula in the fattening stage to 65% of a mixture of cereals, protein crops and oilseeds.

The Advisory Committee on Animal Feedingstuffs did not address the requests by the UK, France and Ireland to include certain amino acids in synthetic form to organic poultry diets, due to their laws that constraints the use of fishmeal (The Advisory Committee on Animal Feedingstuffs Seventh Meeting of ACAF on 04 December 2002).

In the Proposal for a Council regulation amending Regulation (EEC) No 2092/91, the reason for this was concluded to be that, “No synthetic amino acid has been authorised so far in ‘organic farming.” The Proposal also stated that, “Essential substances, such as certain amino acids and vitamins for certain species, should be covered by natural inputs (52002PC0561-Proposal for a Council regulation amending Regulation (EEC) No 2092/91).”

The latest communication from the Advisory Committee on Animal Feedingstuffs is as follows:

Feedstuffs for Organic Farming

61. The Committee were kept up to date on discussions within the Standing Committee on Organic Farming about the derogation relating to the use of conventional feedstuffs within organic farming. Whilst Council Regulation (EC) No. 2092/91 required organic feed to be used, paragraph 4.8 of that Regulation allowed certain percentages of non-organic feed to be used for organic livestock for a transitional period. Annex IIC to the Council regulation set out a list of feeds for which a derogation could be permitted.

62. This derogation was due to end on 25 August 2005. However, Member States agreed to amend paragraph 4.8 to provide that from 25 August 2005:

- diets for herbivores may contain 5% conventional feed until 31 December 2007, after which a 100% organic diet must be provided;

- diets for other animals may contain 15% conventional feed from 25 August 2005 to 31 December 2007, 10% from 1 January 2008 to 31 December 2009 and 5% from 1 January 2010 to 31 December 2011, after which a 100% organic diet must be provided.

In the January 2007 Council Regulation (EC No 1804/1999) the reference to 'aminoacids' paragraph states:

▼M12

A.5. Minerals (trace elements included), vitamins, aminoacids and other nitrogen compounds

Minerals (trace elements included), vitamins, aminoacids and other nitrogen compounds, only authorized as far their use is legally required in the foodstuffs in which they are incorporated.

However, it should be noted that this paragraph is absent in the latest version of (EEC) 2092/91-June 2007.

New modifications (January 2007) to the EEC 2092/91 (which are not on the latest published document); outlined industry requirements for organic feedstuffs. This new requirements are as follows:

The changes to Annex IB, 4.8 of the Council Regulation (EEC) No 2092/91, in relation to the percentages of conventional feedstuffs permitted in organic rations, follow the proposed changes that were in the draft regulation circulated prior to the meeting.

For clarification, this means that paragraph 4.8 permits a maximum non-organic feed allowance of:

- 5% until 31 December 2007 for herbivores; and

- 15% from 25th August 2005 to 31 December 2007,
- 10% from 1 January 2008 to 31 December 2009 and
- 5% from 1 January 2010 to 31 December 2011 for other species, primarily pigs and poultry.

These percentages are to be calculated on an annual dry matter basis of ingredients from agricultural origin. The maximum daily non-organic allowance is 25% dry matter.

The list of permitted non-organic ingredients in Annex IIC of Regulation 2092/91 remains unchanged in the short term, although the Commission seem likely to begin reviewing this in the autumn.

How the derogation will be applied

The Regulation specifies that the use of conventional feedstuffs, up to these maximum percentages can be authorised where farmers can show to the satisfaction of the inspection body that they are unable to obtain feed exclusively from organic production.

We have made it clear that we expect certification bodies to ensure that conventional feedstuffs are only used where organic feedstuffs are not available, as far as it is possible.

We are aware that a system whereby individual derogations are issued would be labour intensive for certification bodies and producers and onerous for those feedstuffs that we know are not available organically or that there are insufficient quantities of. We have therefore decided, after consultation with the certification bodies, to operate a list of feedstuffs – primarily protein sources – for which farmers would not need to apply to their certification body to use (the so-called 'green list'). Please see Annex 1 for list.

We do, however, <u>expect the farmer or producer to have written justification as to why a derogation was needed</u> so that the certification body can look at this at the annual inspection.

For feedstuffs not on the 'green list' but contained within Annex IIC, the farmer or producer has to apply to his/her certification body with written justification <u>prior</u> to purchasing the feed for permission to use conventional feedstuffs. We do not expect there to be many requests for these individual derogations because we have been told by the feed sector that feedstuffs other than those on the list are available in sufficient quantities.

Who has to apply for a derogation?

It has been brought to our attention that paragraph 4.8 of Annex I states that the 'farmer' has to demonstrate that they are unable to obtain feed exclusively from organic production. This will be correct in certain circumstances, where the farmer is buying in straights and composing his/her own feed.

However, in relation to those farmers buying in compound feedstuffs this, for the most part, will not be practical and therefore sensible approach is for compound feedstuff manufacturers to be required to request derogations from their certification body, according to the procedures set out above, for the conventional feedstuffs they use in their compound feeds. They can then demonstrate they have this derogation to the farmers they supply, who can in turn use this as their written justification for their records when it comes to their annual inspection. We do not expect farmers buying only compound feedstuffs, with confirmation of a derogation from their supplier, to also apply to their certification body for a derogation.

There will, however, still be the onus on the farmer to ensure that the total diet of the livestock complies with the percentages set out in 4.8 annually and the maximum percentage of 25% of conventional feed in the daily ration.

Organic Farming Branch
Defra
July 2005 (amended January 2007)

2006/1925/EC: Regulation (EC) No 1925/2006 of the European Parliament and of the Council of 20 December 2006 on the addition of vitamins and minerals and of certain other substances to food. Methionine was not included.

2005/580/EC: Commission Decision Regarding Betaine
On January 24, 2003 Finnfeeds Finland Ltd, made a request in reference to Article 7; EC Regulation No 258/97 concerning novel food and food ingredients. Initial assessments (July 03, 2003) made an allowance that Betaine may be placed on the market, however the European Food Safety Authority came to the conclusion that Betaine lacked adequate safety information, so it was banned from the market.

2003/599/EC-Eggs and egg products be used as poultry feed
Commission Regulation (EC) No 599/2003 of April 1, 2003 amending Regulation No 2092/91-on organic production of agriculture products and indications referring thereto on agriculture products and foodstuffs added to Annex II Part C '2.3 Eggs and egg products for use as poultry feed, preferably from the same holding.'

Use or Allowance of Methionine in the EU

Even though there were many suggestions from producers, European country committees, researchers (Sundrum et al., 2005; Lemme, Damme, Petri, 2005), the Ministry of Agriculture, Fisheries and Food- the Final Project Report-Workshop and a desk study to appraise technical difficulties associated with organic pullet rearing (Ministry of Agriculture, Fisheries and Food, 2000), synthetic methionine is presently not permitted in poultry foodstuffs. The absence of amino acids in the latest amended version of (EEC) 2092/91 of 24 June 1991 and the lack of listing on annex II Parts C or D, confirms this. Additional correspondence from the European Commission Directorate-General for Agriculture and Rural Development; Directorate F. Horizontal aspects of rural development, F.S. Organic farming, Jean-Luc DEMARTY confirms our research. DEFRA has suggested that the commission may be considering changes to the list of non-organic permitted ingredients sometime in Fall 2007 according to Annex IIC of the Regulations (EEC) 2092/91; however, no specific changes or proposals were mentioned (DEFRA, 2007).

It is also apparent that many organic farmers and poultry producers are not aware that synthetic methionine is banned in EU organic poultry production. Feed producers and even industry professionals (Watt Poutry.com) still believe that synthetic methionine is allowed to be included in organic feeds.

How producers raise poultry without Methionine

Ireland and France

In 2004, The Partnership Expert Working Group (PEWG), a subgroup of the Organic Poultry Production in Ireland issued a report on the problems and possible solutions in poultry production (O'Connell & Lynch, 2004). At this time, crystallized methionine and cysteine is not permitted in poultry production, however this report recommended: "The prohibition of the use of crystalline amino acid should be considered since there are significant advantages for animal welfare, animal health and environmental impact" (pg. 74). "Even though turkeys require a very high protein diet, these birds are outdoor foragers and are in small groups, and it seems that removal of synthetic AAs from their diets is not a problem" (pg 59). The PEWG also reported that the development of the French organic poultry production has stopped and the number of farm conversions has become very low since the passage of Regulation (EC) No. 1804/1999 supplementing the regulation of Regulation (EEC) No. 2092/91 (pg. 74). Slow-growing chickens are now predominately being used there, and the cost of production is three times that of conventional production. Presently organic poultry production in Ireland uses a high protein content of the diet, which results in high uric acid output, leading to wet litter, more infections and discolored spots on the flesh. Suggestions for using slow-growing and conventional strains are being proposed. Their report indicates that more research is needed as for:

1. Amino acid requirements of meat birds and layers used under organic production systems
2. Effect on the environment of feeding excess protein in the diet
3. Effect on the health and welfare of the birds of feeding excess protein in the diet
4. Effect of nutrient concentration in the diet on the economics of organic production
5. Effect of climate on organic/free range production systems

(pg.75)

The following tables are PEWG's suggestions for adding crude protein to organic poultry diets.

Table 46. Crude protein and principal amino acid content of potential ingredients for organic poultry diets

		As % of CP				
	C. Protein %	Lysine	SAA	Methionine	Threonine	Tryptophan
Wheat	12.96	2.68	3.79	1.54	2.81	1.18
Barley	11.35	3.44	3.83	1.64	3.32	1.23
Oats	10.30	4.01	4.55	1.63	3.36	1.36
Maize	8.16	2.96	4.42	2.17	3.58	0.81
Triticale	11.66	3.28	3.93	1.63	3.06	1.03
Soyabean meal	47.03	6.00	2.87	1.36	3.87	1.33
Roasted soyabean	35.89	6.08	2.95	1.38	3.92	1.33
Rapeseed meal	35.77	5.32	4.41	1.99	4.27	1.32
Maize gluten feed	20.07	2.97	3.81	1.65	3.55	0.62
Maize gluten meal	61.53	1.60	4.14	2.36	3.31	0.53
Wheat feed*	17.5	2.86	4.00	2.29	4.00	1.43
Peas	20.66	7.18	2.43	0.96	3.72	0.92
Beans	25.86	6.24	1.97	0.71	3.46	0.87
Lupine seed	32.36	4.63	2.03	0.62	3.37	0.80
Sunflower meal	34.21	3.39	3.94	2.24	3.62	1.21
Potato Protein	74.45	7.64	3.66	2.20	5.60	1.40
Fishmeal	63.68	7.33	3.63	2.73	4.08	1.06
Linseed	30.58	3.84	3.64	1.84	3.72	1.53

Source: Degussa (2001) * calculated from Ewing 1997

The figures below show the potential feed ingredients (1) ranked by the SAA content of the crude protein, (2) the crude protein content of those ingredients, and (3) the lysine content of feed ingredients as a percentage of crude protein content. O: oats, MA: maize, RSM: rapeseed meal, MGM: maize gluten meal (prairie meal), WF: wheat feed (pollard), SFM: sunflower meal, TR: triticale, B: barley, MGF: maize gluten feed, W: wheat, PP: potato protein, LS: linseed, FM: fishmeal, SFF: roasted soyabean meal (full-fat), SBM: soyabean meal, PE: peas, LU: lupins, BE: beans

Figure 1. Potential ingredients for organic diets ranked by the SAA content of the crude protein

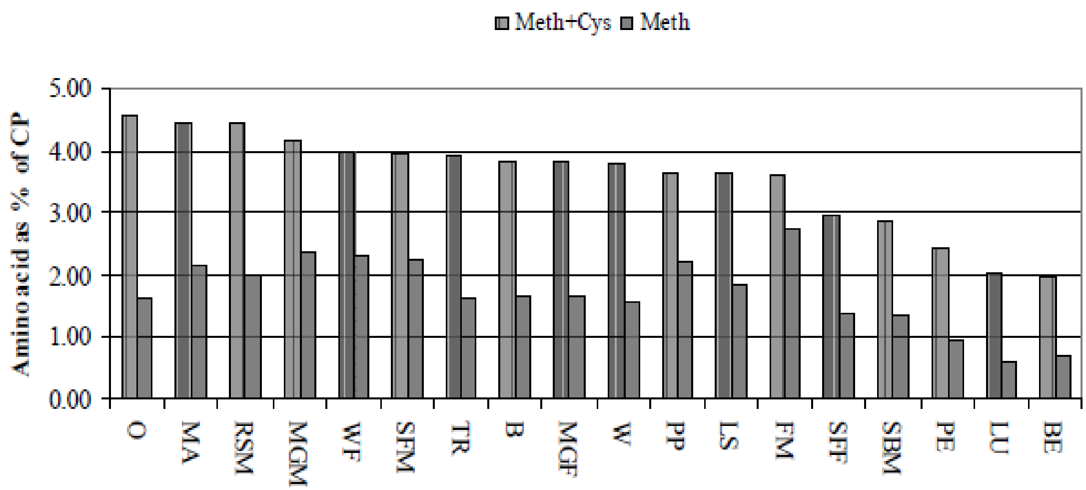


Figure 2. Crude protein content of the potential feed ingredients

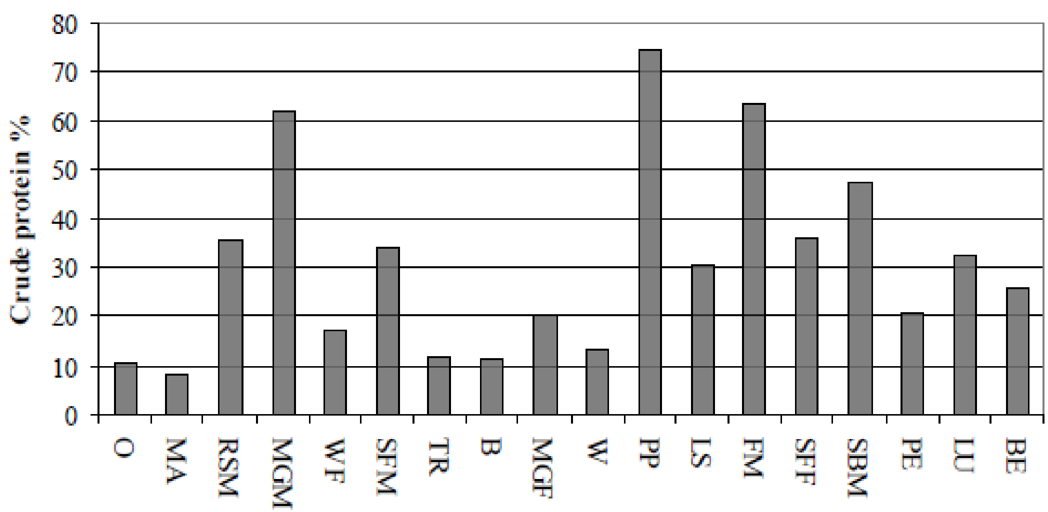
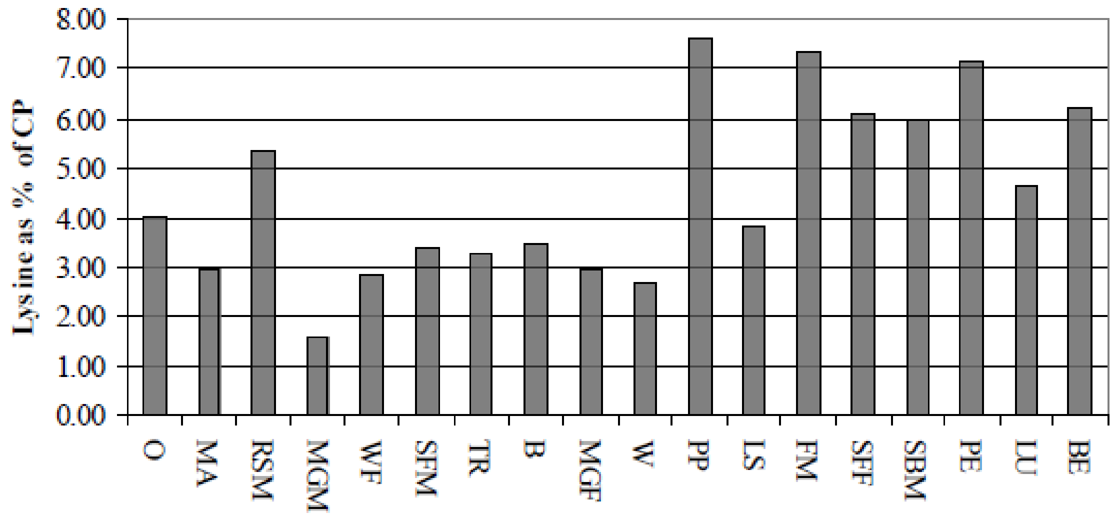


Figure 3. Lysine content of diet ingredients



Conventional maize gluten, potato protein and brewer's grains currently make it possible to meet the protein needs of the animals. But this will become more difficult and expensive after 2005, when conventional raw materials will not be allowed in organic rations.

As of 2002, Label Rouge still used methionine but also uses slow-growing chickens in a 'pasture-based' approach. Feed rations are 75% cereal, non-medicated, starter rations can be 50% with higher soybean content. Rations do not contain animal products, stimulants, additives and fishmeal is not permitted (Fanatico and Born, 2002).

Italy

Catellini et al. (2002) used very slow (Robusta maculate), slow (Kabir) and fast growing (Ross) chickens strains in their study, when they measured growth rat in an organically-reared system as of ECC-1804/1999 standards. At that time, producers were allowed to use up to 80% organic ingredients and still be able to call their product organic. This is no longer the case, however, organic soybean is available in Europe however it must be imported into many areas, which increases production costs. The researchers found that the fast growing chickens did not adapt well to the organic conditions. The Robusta required 120 days to grow, resulting in high production costs, and so the Kabir genotype seemed to show the most suitability to the organic system.

United Kingdom

A recent study, termed the HEN study, researchers attempted to validate the HEN model for layers as well as an assessment of nutritional issues in organic poultry production. They measured feed intake, rate of lay, egg weight, house temperature, and outside temperature in 3 UK commercial flocks of free-range hens in late autumn/winter. They searched the literature on essential amino acid requirements for poultry and interviewed some of the UK's major producers of organic eggs and table chickens. The results of those studies indicated that the hens in the outdoor production systems did not have consistent relationships between feed metabolizable energy intake and temperature, indicating that the HEN model is not applicable to free range productions systems, and therefore not conducive to organic laying hens. Interviews suggest that there continues to be a reliance on permitted non-organic sources of protein for feeding organic poultry and organic laying hens. Their concerns are that methionine deficiencies will increase and nitrogen excretion will cause poultry health problems and nitrogen pollution of the environment. At the time of the study, they investigated 80% organic ingredients and 20% non-organic ingredients. The 20% portion of the feed contained maize gluten feed, which is not organic, and which has limited production in the US. One of the other approaches in the study examined the amino acid content of the feed (lysine, methionine and threonine) of the organic soft wheat, peas, and beans. The organic dry matter soft wheat (Claire) values of lysine were 3.3g/kg, 1.4 g/kg of methionine, and 3.3g/kg of lysine. The dry matter organically grown peas contained 14.0-17.1 g/kg, 1.83-2.42 g/kg and 8.6-9.4g/kg respectively. The dry matter of organic beans was 15.2-19.1g/kg, 1.60-2.4g/kg, and 9.3-9.8g/kg, respectively. The study also estimates the amounts of total feed needed for laying hens, pullet, breeder chickens and table chickens in table 3-6 (Gordon-DEFRA project, 2005).

Austria (Vienna)

The following is a review study done by Zollitsch and Baumung (2004) Their suggestions for layers are:

Rations for laying hens

Component, %	+ conventional components	100 % organic components
Triticale, wheat, maize	48.0	50.0
Peas, faba beans, lupins	25.0	--
Maize gluten (conventional)	10.0	--
Expeller (sunflower, soybean)	--	35.0
Alfalfa meal, dehydrated	5.0	5.0
Fat	2.0	--
Minerals + premix	10.0	10.0
ME, MJ/kg	11.2	10.1
CP, g/kg	187	160
Met, g/kg	3.4	2.8
Lys, g/kg	7.0	6.8

(Zollitsch et al. 2003, Joost Meyer, 2004)

Broiler genotypes in both organic and conventional free-range farming usually requires a diet lower in protein than laying hens. These are the present grower diets for organic broilers:

Grower diets for organic broilers

Table 4 Grower diets for organic broilers, containing different amounts of conventional feedstuffs (Zollitsch *et al.* 2003, Weller 2004)

Component, %	Diet A	Diet B
Wheat, triticale, maize, barley	55.0	49.3
Peas, faba beans, lupins, soybeans	25.6	20.0
Expeller (sunflower, soybeans)	5.0	24.0
Maize gluten (conventional)	--	2.0
Potato protein (conventional)	10.0	--
Fat	1.8	1.0
Minerals + premix	2.6	3.7
ME, MJ/kg	12.3	12.1
CP, %	22.0	19.8
Met, %	0.39	0.39
Lys, %	1.25	1.02

(Zollitsch et al. 2003, Joost Meyer, 2004)

The researchers also discuss the problems associated with raising 100% organic turkeys, because they require high levels of lysine (more so than methionine), and that this may not be attainable using present genotypes and 100% organic diets. The researchers also discuss the limited availability of information on successful organic turkey production. The table below represents requirements of amino acids for turkey during different stages of growth:
Recommendation for turkey strains

Table 5 Recommended dietary nutrient contents for various turkey strains (BUT 2004)

Phase, weeks	ME, MJ/kg	Lys, g/kg	Met, g/kg	Met+Cys, g/kg
0-4	11.8	18.5	6.7	12.0
4-8	12.0	16.1	6.3	11.3
8-12	12.2	13.4	5.7	10.1
12-16	12.2	10.9	4.9	8.7
16-20	12.4	9.3	4.4	7.9
20-24	12.6	8.2	4.0	7.2

(Sundrum et al. 2005)

Wales

In a report prepared for the Organic Centre Wales by the Soil Association Producer Services, and assisted by IGER, the report recommends that Label rouge/traditional free range chickens should have synthetic amino acids in organic diets, and recommend less restrictions on the types of ingredients used to make up organic poultry rations (Hancock, Weller & McCalman, 2003). The report also forecasts that poultry would become small-scale farming and produce for only the local markets, especially because non-organic feed supplies such as fishmeal potato protein and prairie meal will also be required to be removed from feed-thereby decreasing most of the dietary sources of high quality protein, including methionine.

The report suggests and forecasts that present organic farmers may return to conventional farming practices. Representatives of Netherlands and Belgium both ask that the commission support their use of synthetic amino aids for poultry in organic feed. Belgium is worried that this may result in importing feed from third countries because they have no organic alternative for high quality protein (Hancock, Weller & McCalman, 2003).

Additionally, this group recommended that non-allowance of certain proteins such as non-organic linseed expeller & maize meal, and fishmeal (which may never be considered organic-only farmed organic fish are considered organic) would have catastrophic impact on the poultry sector if lost. They believe soy will be the critical ingredient, however with the restrictions of 65% cereals in the diet, the amount of soy needed will not be enough to cover the protein requirement. They also suggest that pulses (beans) be included in the 65% EU cereal ration (Hancock, Weller & McCalman, 2003).

Switzerland

Under European Union and Swiss regulations, organic livestock can be fed a low percentage of non-organic feed. The FiBL research institute uses a balanced poultry ration with no synthetic methionine. A local organic feed mill makes this ration from small grains, sunflower seeds, field peas, alfalfa meal, corn gluten meal, potato starch, yeast extract, vitamins and minerals. Birds are not de-beaked and mortality is less than 2%.The birds get essential amino acids from field peas, alfalfa meal, sunflower seeds, and from grazing and scratching outdoors (Riddle, The New Farm, 2007).

Germany

Lemme, Damme and Petri (2005) investigated the effects of three kinds of diets in Hubbard ISA J 257 broiler chicks on performance, feed and protein conversion and related parameters under organic farming conditions with and without synthetic methionine. Performance of the birds was equal in the first period (1-26 days), but it was apparent that synthetic methionine was needed in the second period (26- 69 days). In the non-methionine group there was significant impairment in nitrogen utilization and the water/feed ration increased (by the high protein load.) The authors suggest that 0.1% synthetic methionine be a legal food component in organic poultry production-due to the animal welfare and environmental pollution that is a result of feeding such high protein diets, and that about 20-24% of the organic protein sources could be spared.

Sundrum et al. 2005, has provided some examples of foodstuffs for broilers and layers in Annex 1 of their paper, shown on the next page:

Suggested vegetable feed sources for organic poultry

A-1: Some published suggested maximum inclusion rates of various vegetable protein sources (g/kg) (GORDON, 1999)

	Broiler feeds	Layers feeds	References
Peas	250-300 Starter 50, finisher 100	150-200, 300 for better egg taste 100 100 300 200	UNIP-ITCF (1995) LEESON & SUMMERS (1997) LARBIER & LECLERCQ (1994) CASTANON & PEREZ-LANZAC (1990) IGBASAN & GUENTER (1997B)
Lupins	50 Starter 80, finisher 100	100 150 200	MCDONALD *et al.*, (1995) LEESON & SUMMERS (1997) CASTANON & PEREZ-LANZAC (1990)
Beans	300	100	LARBIER & LECLERCQ (1992) JANSMAN *et al*, , (1993)
Sunflower	Starter 80, finisher 100	100 150	MCDONALD *et al.*,, (1995) LEESON & SUMMERS (1997)
Rapeseed	50 100 (double 00 varieties) Starter 50, finisher 80	100 (double 00 varieties, white layers only)	MCDONALD *et al.*, (1995) VAN KEMPEN & JANSMAN (1994) LEESON & SUMMERS (1997)

Examples of diets for broiler growing period:

A-2: Examples of 100% organic feed ration for broiler (starter period) (1. - 4. week)

	Ingredients	I [1]	II [1]	III [2]	IV [2]	V [3]	VI [3]	Average
Cereals	Wheat	18	14	40	40.5	13	25	
	Wheat bran						2.5	
	Barley	10	14					
	Oat		7.5					
	Maize	21	18	18	18	15	15	
	Portion in the diet	**49**	**53.5**	**58**	**58.5**	**28**	**42.5**	**48**
Pulses	Faba beans							
	Peas	10	12	8.5	14		12.6	
	Lupini							
	Portion in the diet	**10**	**12**	**8.5**	**14**	**0**	**12.6**	**10**
High protein fees	Soya bean	10				35	35	
	Soya cake	13	15			26.5		
	Maize gluten	2		7				
	Linseed cake	5	7					
	Sunflower cake	6	9	9	11	5	5	
	Fish powder				10			
	Portion in the diet	**36**	**31**	**27**	**21**	**66.5**	**40**	**37**
Addi-tives	Minerals	3.7	3.5	3.5	3.5	3.5	3.9	
	Oil	1		3	3	2	1	
	Portion in the diet	**5**	**3.5**	**6.5**	**6.5**	**5.5**	**4.9**	**5**
Compon-ents	Energy MJME	12	11	12.5	12.5	12.1	12.2	
	Crude protein			21.3	17.5	27.2	21.9	
	Lysin g	10.2	9.4	9.9	9.2	14.3	11.5	
	Methionin g	3.7	3.4	4.4	3.8	4	4.1	

1 BELLOF & SCHMIDT, 2005 2 DAMME, 2001 3 DAMME, 2005

Some diet examples for the fattening period

A-3: Examples of 100% organic feed ration for broiler (fattening period)

	Ingredients	I [1]	II [1]	III [1]	IV [1]	V [2]	VI [2]	VII [3]	VIII [3]	Average
Cereals	**Wheat**	21	23	21	20	20	30	18.5	32.7	
	Wheat bran								3	
	Barley	11.2	15.2	14	20					
	Oat			9.3	10.3					
	Maize	19	21	19	18	33.5	40	10	10	
	Portion in the diet	**51.2**	**59.2**	**63.3**	**68.3**	**53.5**	**70**	**28.5**	**45.7**	**55**
Pulses	**Faba beans**									
	Peas	14	14	12	12	17	10		15	
	Lupini									
	Portion in the diet	**14**	**14**	**12**	**12**	**17**	**10**	**0**	**15**	**12**
High protein feed	**Soya bean**	15	12					35	28.5	
	Soya cake			12	10			25.3		
	Potatoe protein					6	6			
	Maize gluten	2				8				
	Linseed cake	5	4	4	3					
	Sunflower cake	7	5	5	3	10	8.5	5	5	
	Portion in the diet	**29**	**21**	**21**	**16**	**24**	**14.5**	**65.3**	**33.5**	**28**
Addi-tives	**Minerals**	3.8	3.8	3.7	3.7	2.5	2.5	3.5	3.85	
	Oil	2	2			3	3	2.75	2	
	Portion in the diet	**5.8**	**5.8**	**3.7**	**3.7**	**5.5**	**5.5**	**6.3**	**5.85**	**5**
Componet s	**Energy MJME**	12.4	12.4	11.2	11.2	12.8	12.8	12.3	12.3	
	Crude protein					20.5	15.6	27.8	21	
	Lysin	7.2	6.5	7.2	6.5	9.3	7.8	14.5	10.5	
	Methionin	2.7	2.4	2.7	2.4	4.2	4.2	3.9	3.9	

1 Bellof & Schmidt, 2005; 2 Damme, 2001; 3 Damme, 2005

An overall table showing demand in broiler production, at start, fattening period and demand per broiler:

A-12: Demand of nutrient supply in broiler production.
Percentages are taken from tables A-2 and A-3. Data of feed intake (Kamphues et al., 1999).

Broiler	Starting (28 days)		Fattening period (53 days)		Demand per broiler	
	%	kg	%	kg	kg	%
Total	**100**	**1.0**	**100**	**4.8**	**5.8**	**100**
Cereals	48	0.48	55	2.64	**3.1**	**53.8**
Pulses	10	0.10	12	0.58	**0.7**	**11.7**
High protein feed	37	0.37	28	1.34	**1.7**	**29.5**
Additives	5	0.05	5	0.24	**0.3**	**5**

(Sundrum et al. 2005)

Sundrum et al 2005 report provide examples of 100% organic feed ration for laying hens (Sundrum, Schneider, Richter, 2005).

Examples of 100% organic feed rations

A-5: Examples of 100% organic feed ration for laying hens

	Ingredients	I[1]	II[2]	III[2]	IV[3]	V[3]	VI[4]	Average
Cereals	Wheat	35	49	47.7	29.3	28.3	39.4	
	Triticale						16	
	Barley	5			7.5	7.5		
	Oat	10			5	5		
	Portion in the diet	**50**	**49**	**47.7**	**41.8**	**40.8**	**55.4**	**48**
Pulses	Faba beans	6		10				
	Peas	15	23	15	44	43	12.5	
	Lupins							
	Portion in the diet	**21**	**23**	**25**	**44**	**43**	**12.5**	**28**
High protein feed	Potatoe protein						4.5	
	Maize gluten	12	10.6	9.9			9.8	
	Dried grass meal	3	5	5	2	4	5	
	Linseed cake						1	
	Whey powder	2						
	Portion in the diet	**17**	**15.6**	**14.9**	**2**	**4**	**20.3**	**12**
Additives	Minerals	10	10.4	10.4	10.2	10.2	10.2	
	Oil	2	2	2	2	2	1.6	
	Portion in the diet	**12**	**12.4**	**12.4**	**12.2**	**12.2**	**11.8**	**12**
Components	Energy MJME	11	11.3	11.2			11.2	
	Crude protein	18	18.6	18.8	15	15.4	19.6	
	Lysin g	7.5	7	7	8.1	8.1	7.9	
	Methionin g	2.8					3.5	
	Methionin+Cystin g		6.5	6.4	4.2	8.2	6.8	

1 DEERBERG, 2004 2 ZOLLITSCH & BAUMUNG, 2004 3 KJAER&SØRENSEN, 2002 4 STROEBEL et al., 2002

Sundrum et al. believes that due to the requirement for higher methionine in the 22nd through 34th week is critical, and can compensate for this by increasing amount of feed and lowering energy intake (Sundrum et al 2005). Sundrum et al. 2005, utilized the information from table 6 and came up with the overall percentage of nutrients in laying hens:

Nutrient Supply in Laying Hens

A-14: Demand of nutrient supply in laying hens:
Percentages are taken from table A-6. Data of feed intake (Kamphues et al., 1999).

	Laying hens	
	%	**kg**
Total	**100**	**6.4**
Cereals	**48**	**3.0**
Grain legumes	**28**	**1.8**
High protein feed	**12**	**0.8**
Additives	**12**	**0.8**

A diet that is 100% organic is given for turkeys below:

100% Organic feed rations for turkeys

A-4: Examples of 100% organic feed ration for turkey

	Ingredients	I 0-5[1]	II 6-9[1]	III 10-13[1]	IV 14-17[1]	Average
Cereals	Wheat	30	35	46.5	53	
	Tritticale					
	Portion in the diet	**30**	**35**	**46.5**	**53**	**41**
Pulses	Faba beans	10	10	5	5	
	Peas	37.6	32.8	27.8	22.9	
	Lupini					
	Portion in the diet	**47.6**	**42.8**	**32.8**	**27.9**	**38**
High protein feed	Soya bean					
	Soya cake					
	Potato protein	13.5	12.5	11	9	
	Maize gluten	3	3	3	3	
	Brewer's yeast	2	2	2	2	
	Portion in the diet	**18.5**	**17.5**	**16**	**14**	**16**
Additive	Minerals	3.4	3.2	3.2	2.6	
	Oil	0.5	1.5	1.5	2.5	
	Portion in the diet	**3.9**	**4.7**	**4.7**	**5.1**	**5**
Components	Energy MJME	11.8	12.1	12.3	12.6	
	Crude protein	27.4	26.1	24	22	
	Lysin	17.3	16	13.9	12.2	
	Methionin	4.5	4.3	4.1	3.7	
	Methionin + cystin	9	8.7	8.2	7.6	

1 RICHTER, 1996

These components closely match the requirements for amino acids.

A-13: Demand of nutrient supply in turkey production
Percentages are taken from table A-4. Data of feed intake (Kamphues et al., 1999).

	Age in weeks									
	0-5		6-9		10-13		14-17		Total Turkey	
	%	kg	%	kg	%	kg	%	kg	kg	%
Total	**100**	**1**	**100**	**4**	**100**	**18**	**100**	**30**	**55**	**100**
Cereals	30	0.30	35	1.4	46.5	8.4	53	15.9	**27**	**49**
Pulses	47.6	0.48	42.8	1.71	32.8	5.9	27.9	8.37	**17**	**30**
High protein feed	18.5	0.18	17.5	0.7	16	2.88	14	4.2	**8**	**15**
Additives	3.9	0.04	4.7	0.19	4.7	0.9	5.1	1.53	**3**	**6**

Sundrum also determined that Kelly turkeys are more suited for organic growing than Big 6 turkeys, which are 'high performance,' and require additional amino acids. To date, there are few studies comparing the high performance strains and slow growing strains using a 100% organic diet. More research is needed.

Netherlands
A recent study done in the Netherlands by van Harn & van Krimpen (2007) of the Animal Sciences Group in Wagneingen UR (mostly in Dutch), recently released a study using 1680 organic housed broiler. One of their aims was to determine the effect of methionine on performance and slaughter quality. They recommend that methionine concentrations be kept on the current 85% organic diets to maintain performance of those broilers fed a 100% organic diet.

Other Non-EC/EU Organic Requirements

Brazil
Brazil calls their broiler chickens (448 ISA S 757-N or ISA JA label naked neck) that are raised in free-range or semi-extensive systems with access to green pastures, fed diets free from antibiotics, anti-coccidials, growth promoters, chemical therapeutic agents, and free of animal raw materials, "Label chickens" (Saldanha et al. 2006). However, DL-methionine, vitamin and mineral supplements are utilized.

Canada
Under the Organic Production Systems Permitted Substance lists, synthetic methionine would be excluded. However, under the 'soil' 3.2.4 amino acids are permitted if they are non-synthetic. They permit 'amino acids produced by plants, animals and micro-organisms that are not from genetic engineering and that are extracted or isolated by hydrolysis or by physical or non-chemical means are considered non-synthetic. Non-synthetic amino acids may be used as plant growth regulators or chelating agents. In 4.2.6 under 'Protein Feed' in the 4.2 Feed, Feed Additives, and Seed supplements, 'Shall be from organic sources.' This implies that amino acids that are from non-synthetic sources (as given as a definition above) can be used? (Organic Production Systems Permitted Substances Lists; CAN/CGSB-32.311-2006).

Manitoba Agriculture, Food and Rural Initiatives released a comment about the diet published in 1945 "Poultry Rations and Feeding Methods" however some of the diets are inadequate for modern strains of poultry (Manitoba Agriculture, Food and Rural Initiatives, 2006).

Sweden
There are not many studies in Europe after 2005 regarding 100% organic diets in free-range poultry (see *Present Research* section). One pilot study from Sweden showed that successful free-range penned chickens fare well, however these birds were also given synthetic methionine in the feed (Bassler & Ciszuk, 2002).

On-Going/Present Organic Research

DARCOF III: Research in Organic Food and Farming-2006

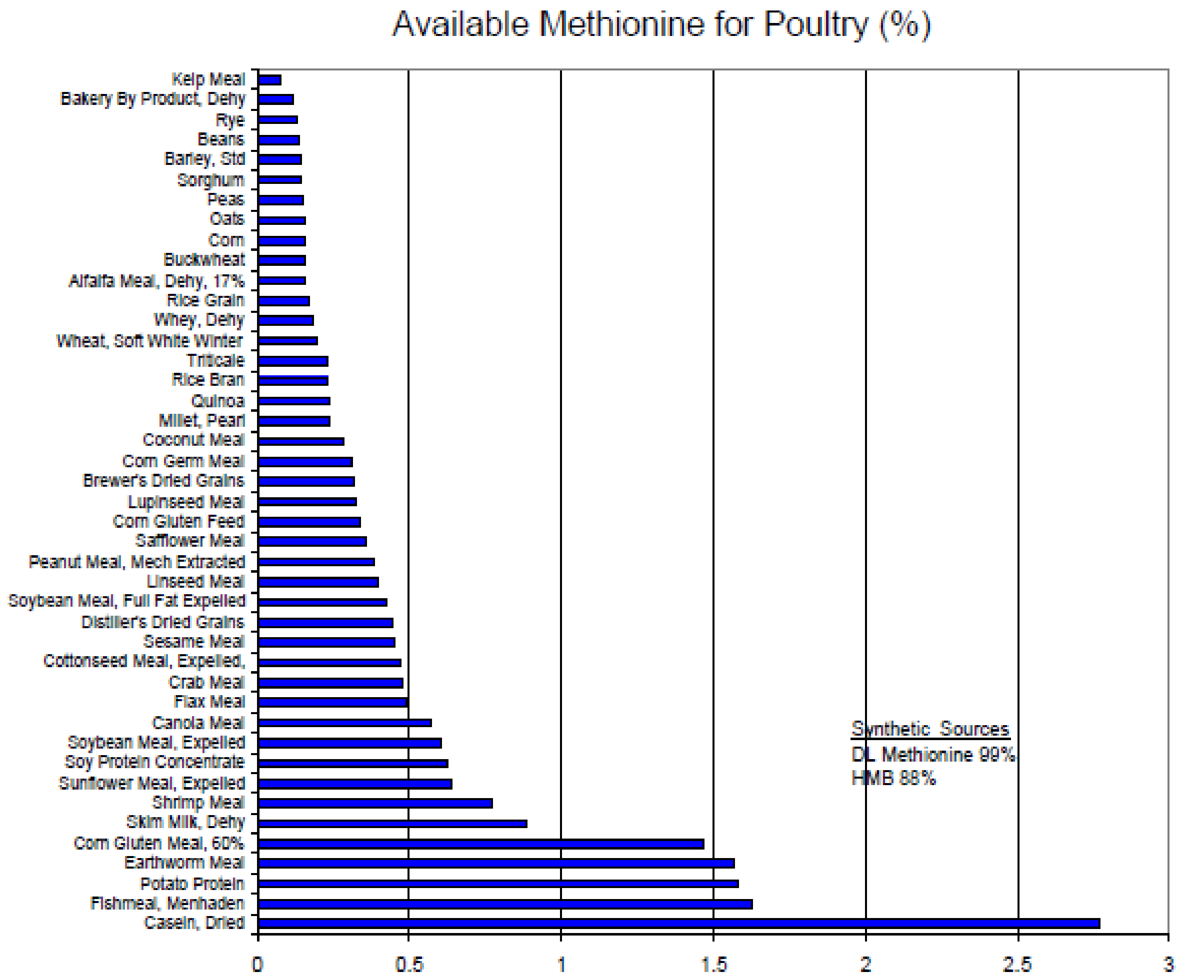
- Danish Institute of Agriculture Organic Farming
- John Hermansen, Head of Research Unit
- Project timeline 3 years
- The poultry portions of the study include:
- WP 2- obtaining high and differentiable organic eggs; and WP3- concerned with broilers and apple production.

WP 2 involves using a more docile hen-the Hellevad hen and the Swedish hen, both of which requires a low protein and SAA diet. The researchers intend on using 2 different genotypes and feeding three diets-the control (presently used), a diet based on organic foodstuffs grown in Denmark, which includes lupine, soya beans, and quinoa in the second diet; and based on the protein composition of diet #2 but lower in protein. Diets will include a forage of maize-sludge and carrot; maize-sludge and chicory roots. Chicory roots contain inulin and oliofructose, which can improve eggshell quality. Chicory will be especially effective for in the Hellevad hen, which has a thinner eggshell than the Swedish hen.

WP 3 uses male chicken raised from WP 2, then putting them in an apple orchard to help control sawfly infestation, and additionally provide nitrogen (through excreta) to orchard trees. There will be some additional sub-experiments involving self-selected diets for hens by giving them access to various troughs with: different cereals (whole seeds), a mixture of protein sources with vitamins and minerals included (milled with course structure), a calcium source and roughage. Two other studies, one using a sensory on egg flavor by feeding the hens basil, chicory and thyme will study the human taste and flavor of the eggs (if any) as compared to grass (DARCOF III, 2007).

Netherlands
The Applied Poultry Research Centre is starting trials using chickens fed a 100% organic diet. The study is funded by the Dutch Ministry of Agriculture and sponsored by Lohmann Tierzucht, Verbeek, Van Beek and ABCTA. It will test (4) layer breeds-Lohmann Tradition, Lohmann LSL, Lohmann Sandy and H & N Silver Nick. The study finished in November 2006, however results have not been published as of the date of this paper (Applied Poultry Research Centre, 2005).

University of Minnesota, Dr. Jacquie Jacob
Dr. Jacquie Jacob has recently compiled a list of available alternative methionine sources for poultry. It will be published soon (Jacob, personal communication, 8-18-2007). Casein is the highest source (from milk products) with high DL-methionine sources including menhaden meal (fish), potato meal, and high gluten corn. Please see next page for graph.



(Dr. Jacquie Jacob, e-mail personal communication)

Suggestions For Further Research

Increasing feed at certain critical times

Sundrum from the University of Kassel suggests that producers use slow-growing strains, optimize the feeding and housing conditions to reduce requirement of limiting amino acids, increase feed intake by reducing energy content of the diet, implement multi-phase feeding and adapt to the requirements of different stages of production, and the purchase of protein sources of rapecake, soybean cake, or organic skim milk powder (Sundrum, Schneider, Richter, 2005).

Sundrum et al. believes that due to the requirement for higher methionine in the 22nd through 34th week is critical for laying hens, and can be compensated by increasing amount of feed and lowering energy intake (Sundrum et al 2005). Further studies are needed to investigate this theory, and determine if it can be applied here in the US.

Research of high-methionine containing feed

Plant-based

Much more research is needed to identify high plant-based sources of methionine in potential feed. Some suggestions by other researchers (Sundrum et al 2005, Rahman and Bohm, 2005) include expeller of oil plants (*Brassica napus, Helianus annuus, Linum usitatissimum, Camelina sativa*), grain and roughage legumes (*Trifolium* spp, *Lupinus* spp-see below, *Vicia sativa*), high protein-high digestible plants (*Vicia faba, Pisum sativum*), microbial produced sources of essential amino acids (*Chlorella vulgaris, Spirulina platensis*), and new processing measures-such as toasting grains, fermentation, germination. These alternative protein sources need to be studied for use in US poultry.

Sesame meal

Screw-pressed sesame meal is higher than solvent-extracted soy in methionine and lower in lysine. However, one study determined that it is not suitable as a sole source of vegetable protein for poultry diets (Mamputu & Butr, 1995).

Sunflower seed meal

Selvaraj and Purushothaman (2004) determined that their hybrid sunflower seed meal had about 0.46 ± 0.01 methionine, and had successful results with Vencobb strain broiler chicks, however their study used additional synthetic methionine in the feed. More studies are needed to determine if sunflower seed could be an adequate protein replacement for methionine. Dehulled sunflower seeds may also be an excellent methionine alternative (FNE05-540).

Lupine

Lupine is a nitrogen-fixing plant, which is a great advantage in organic farming due to the recycling of the nitrogen in the system to the subsequent crop (Doyle et al.,1988). However, lupine may not be the best methionine source for layers. Inclusion of 25% lupine in organic layer diets is only recommended when supplying some other methionine source, as egg production and quality parameters are dramatically impaired/compromised. However, supplement of foraging material significantly improves egg production (Hammershoj, Steenfeldt, 2005), however Vogt et al.,1987 found that lupines added to feed affected egg taste. For laying hens, the use of lupine as a feed component together with foraging material must be without detrimental productivity and egg quality effects. Hammershoj, Steenfeldt, 2005, found that the foraging material gives the eggs a sulfur-like taste. More research is needed to substantiate this.

The content of total SAA is low in lupine (Alloui et al., 1994; Petterson, 2000), which could make it difficult to optimize diets with adequate amounts of the essential amino acids, thereby limiting the inclusion level of lupine in layer diets. The high level of the nonstarch polysaccharides (NSP) in lupine is almost twice as high as in other protein-rich plants and could potentially be another factor restricting its use in layer poultry diets (Daveby and Aman, 1993; Bach-Knudsen, 1997). A study done in Australia with low methionine diets supplemented with *Lupinus augustifolius*, found lupine to be a poor source of methionine and a very low source of lysine. Supplementation with methionine and lysine improved the protein quality (Wiryawan & Dingle, 1995).

Lupines contain low concentrations of alkaloids (Milford and Shield, 1996; Petterson, 2000), has a high protein content, and may be a good alternative or supplemental addition to soybeans, which are presently used as the main protein source in organic poultry feed, and may not be difficult to attain in all geographic areas (Petterson, 2000).

High Gluten Corn Meal
Sundrum et al. (2005) used high gluten corn meal as a high protein feed. Owings et al. 1987 had success using corn gluten feed up to 10% in growing turkey hens, but they used DL-methionine in the experiments. Some researchers and producers are concerned that there are insufficient supplies to meet need. More information is needed whether this can be a viable methionine alternative in turkeys without supplementation.

Other by products of feedstuffs
More research is needed to determine if potato pulp, pumpkin seed and lentils are good sources of methionine (Rahman and Bohm, 2005). Lakeview Organics suggest a rice hull extract that may contain up to 4-5% methionine.

Betaine
Perhaps establish safety of Betaine for use as a food or feed ingredient (2005/580/EC-does not). If betaine was derived from beets without the use of chemicals, it may be permitted. Possibly use of organic dried beet extract as an addition to feed could be researched? Danisco was a major supplier of betaine for turkeys (increased breast-meat yield), (Danisco, 2004), however the EC ruled that betaine was not permitted in organic feed in 2005 (2005/580/EC: Commission Decision Regarding Betaine).

Soy
A recent study showed that soy meal variations occur in amino acid content between samples, especially lysine. Crude protein and fiber concentrations were significantly different (Grieshop et al. 2003). Perhaps those varieties containing higher amounts of lysine and methionine can be identified and utilized. More research is needed.

Whole Wheat
Pilot studies carried out in Sweden determined that whole-wheat feed worked well in organic broiler production, however methionine and lysine supplements were given (Bassler & Ciszuk, 2002). More research needs to be done using a high-gluten type of wheat (red, hard wheat), which is higher in protein than the soft wheat varieties to determine whether it will be a good source of methionine for poultry.

Quinoa
Quinoa is a source of methionine and lysine. It contains 2.2g/16g N as compared to wheat (1.7g/16g N) and soy (1.4 g/16g N) (Quinoa Corporation, 2007). One drawback is that it prefers high altitude areas with warm days and cool nights. It may not produce seed in cooler climates (Prim, 2007).

High protein feeds not suitable as methionine sources
The following were found not to be adequate sources of methionine: peanut meal (Costa et al., 2001), expander cottonseed meal (Gamboa et al., 2001), hull-less barley cultivar (Newman and Newman, 1987), mango seed meal (Odunsi, 2005), and oat flour (Hahn, Chung, Baker, 1990).

Potential off-flavors in eggs
Other potential methionine replacements, rapeseed (Goh et al., 1979; Pearson, Butler & Fenwick, 1980), fish products (Koehler and Bearse, 1975), and grape seeds (Tallarico et al., 2002), were found to produce unwanted and off flavors in hen eggs.

Animal products as feed
Fish or fishmeal
Consider petitioning the use of organically grown (farmed) fish or fishmeal for chicken feed. Presently, some US organic farmers are having good luck using crab and fishmeal as methionine replacements (Fertrell, personal communication 2007).

Amino acid analysis revealed that fishmeal had higher concentrations of lysine, methionine, arginine and tryptophan than squilla (type of crustacean). The gross protein value of squilla was lower than that for fish, and this was consistent with the other measures of protein quality such as the amino acid profile and protein digestibility (Reddy VR, Reddy VR, Qudratullah, 1997). However, more studies are needed to determine levels of fat-soluble pollutants and subsequent entry of these lipid-based pollutants into eggs.

Organically grown chicken eggs and egg products
Organically grown chicken eggs and egg products can be used as feedstuffs in Europe under (EEC) No 2092/91. Consider investigating and testing the use of eggs or egg products for feed (preferably from the same establishment). These products are presently being used in the EU as a high-protein, potential replacement of synthetic methionine. (Commission of the European Communities, 2002)

Organic Dried Milk Powder, Casein, or Milk Solids
Consider petitioning the use of organic milk powder or solids for use in poultry feed (Sundrum et al 2005).

Foraging Birds
In Asian Luong-Phuong chickens, scavenging birds could partially compensate for protein and amino acid deficiency in the basal diet. Mortality was 4.2% for caged birds, whereas it was 0% for the scavenging birds. There was also more breast muscle and less fat in the scavenging birds than the caged birds (Minh & Ogle, 2005). Moritz et al. (2005) found in foraging birds marginal methionine deficiency can be overcome in broilers.

The environmental impact of high protein animal-based or plant-based poultry diets
Studies need to be done to determine the cost/benefit on the environment (mainly high excreta nitrogen levels) of including/not including synthetic methionine in the diets of chickens. Some questions have been raised by a number of researchers that high protein

100% vegetarian diets for chickens may be more detrimental to the environment than the addition of methionine to feedstuffs.

Addition of naturally high food sources of methionine

Brewer's Yeast

Brewers' yeast (*Saccharomyces cerevisiae*) contains the potential for biosynthesis of methionine through inorganic sulfur biosynthesis pathways. *Saccharomyces cerevisiae* (*Sc*) also synthesize homoserine from aspartate. Homoserine can then be esterified to form O-acetyl ester, producing hydrogen sulfide (H_2S), which then reacts with O-acylated homoserine. This results in a replacement of the acetyl group by sulfide to form homocysteine, which is then methylated to methionine via either a cobalamin-dependent or independent enzyme (depending on the growth conditions) (*Saccharomyces* Genome Database 2006).

Preliminary studies using dried distillers' yeast sludge (a solid waste) was found to be safe for growing chicks at up to about 50% level and with economic benefits. This study's distillery yeast sludge (DYS) contained 21% protein 4% methionine, 2.4% tryptophan 10% lysine, as well as 3% calcium, 0.35% iron and 0.23% phosphorus (Rameshwari & Karthikeyan, 2005). This product is considered in the EU as a potential replacement of synthetic amino acids, primarily methionine (Commission of the European Communities, 2002). However, even though the EU suggests that brewers yeast may be a good supplement of methionine, the results of earlier studies with yeast fed to chickens, however, have not been consistent.

It had been reported (Bonomi and Vassia, 1978; Ignacio, 1995; Onifade et al., 1998) that feeding yeast to chicks improves body weight (BW) gain and feed/gain ratio. On the other hand, Madriqal et al. (Abstract1993) failed to observe a positive effect of feeding yeast on BW of broiler chicks. Kanat and Calialar (Abstract 1996) reported that active dry yeast effectively increases BW gains without affecting feed/gain ratio in broiler chicks. However, in contrast, supplementation of yeast to broiler diets improves feed/gain ratio but not growth rates (Valdivie, 1975; Onifade et al., 1999)

Recently, it has been reported that yeast could be an alternative to antibiotic-based drugs in feed in broiler chicks on new litter (Hooge et al., 2003) or on recycled litter (Stanley et al., 2004).

In addition to growth performance, there are trials showing that enrichment of diets with yeast could favorably improve the quality of edible meat from broilers. For example, edible meats from broiler chicks fed a diet containing chromium-enriched SC exhibited increased tenderness (Bonomi et al., 1999) and increased water-holding capacity (Lee et al., 2002).

Another study was conducted to evaluate the effects of whole cell, cell wall, and cell content of *Sc* on growth performance, various meat qualities, and ileal mucosa development of broiler chicks (Zhang et al., 2005). The experiment appeared to provide evidence that feeding of *Sc* cell components to broiler chicks could improve growth performance, meat tenderness, and oxidative stability of meat. The researchers also determined that it is the yeast cell wall, not yeast extract that could improve ileal mucosal development of broiler chicks. Bonomi & Vassia (1978) also did a chemical analyses of Zimoyeast-a combination of *SC* and *Kluyveromyces fragilis (K. fragilis)*. *SC* contained 1.36 methionine, 14.58 lysine, and 1.02 cystine, and *K. fragilis* contained 1.06, 12.03 and 1.12, respectively. An added benefit to using yeasts as a potential methionine source is their antibiotic properties (Bonomi & Vassia, 1978; Onifade et al., 1997)

However, more research is necessary to determine if yeast is a viable alternative to adding methionine in the feed.

Naturally derived methionine from non-GMO organisms

Presently, Canada only excludes synthetic methionine from feedstuffs (Canada Standards). Perhaps the USDA would also allow this if methionine was derived through hydrolysis, microorganism production or liberation (non-GMO), or enzymatic means using non-GMO organisms. A website source states that raw Spirilina may contain up to 907.8/mg/200 calories making it 331/999 highest sources of methionine, while dry Spirilina contains 792.4mg/200 calories--but more studies are needed to confirm this (Nutrition Data Website, 2007).

Ferecto (a blend of fermentation products) may also be re-evaluated (Harms & Miles, 1988). More research is needed to determine if there are other types of non-GMO yeasts, fungi, or bacteria that produce high levels of methionine.

In a review of microbes and production of L-methionine, Gomes and Kumar (2005) discuss different strains of microbes that produce L-methionine. One of the biggest problems with large-scale production of L-methionine in microbes is that L-methionine creates a feedback inhibition. This means that large quantities of L-methionine production stops production of the L-methionine through a feedback loop. One species, *Corynebacterium sp*s might be the most promising of the microbes. The following page contains a list of L-methionine producing microbes.

Table of L-methionine producing microbes

Table 1
A list of microorganisms producing methionine

S. no.	Microorganism	Genetic marker	Methionine yield (mg ml^{-1})	Method of methionine analysis
1.	*Arthrobacter* sp. DSM9771 [58]	–	23.00[a]	HPLC
2.	*Bacillus megaterium* [22,142]			
	B_6US-215	–	4.50	PC
	B71	–	0.072	PC, MB
3.	*Brevibacterium heali* [18,19]			
	BhLT 27	Lys$^-$, Thr$^-$	25.5	–
	BrEthR_2^{50}	Eth^R	13.0	PC, MB
4.	*Candida boidinii* [105]			
	2201	–	6.2 mg g^{-1}	
	E500-78	Eth^R	16.02 mg g^{-1}[b]	MB
	AKU 4618	–	4.54 mg g^{-1}	
	Candida sp. 25 A	–	6.12 mg g^{-1}	
5.	*C. glutamicum* [12]			
	ER 107	Thr$^-$, Eth^R	0.100; 0.200[c]	
	ER 108	Thr$^-$, Eth^R	0.100; 0.150[c]	
	ER 109	Thr$^-$, Eth^R	–; 0.500[c]	
	ESLMR 724	Thr$^-$, Eth^R, SLM^R MetHx^R	2.00	
	ESLR 146	Eth^R, SLM^R	0.550	COL, PC, MB
	ET_z R 754	Thr$^-$, Eth^R, Triazole^R, TFM^R	0.754	
	ET_z R 606	Thr$^-$, Eth^R, Triazole^R,	0.610	
	ET_zFR 619	Thr$^-$, Eth^R Triazole^R, TFM^R	0.950	
	ET_z MR 510	Thr$^-$, Eth^R, MetHx^R, Triazole^R	0.850	
	ESLFR 736	Thr$^-$, Eth^R, SLM^R, TFM^R	0.100	
6.	*C. lilium* M128 [70]	Eth^R, Norleucine^R, MetSo^R	1.98	SP
7.	*E. coli* [68,108,109]			
	K12	5BU^R	1.00	–
	K12	AHV^R, Eth^R, 5BU^R	2.00	PC
	JM109-TNI	Eth^R, Norleucine^R	0.91	AAA, MB
8.	*Hansenula polymorpha* DL1 [105]	–	5.00 mg g^{-1}	MB
9.	*Kluyveromyces lactis* IPU126 [141]	Eth^R	14.20	–
10.	*Methylomonas* sp. [23]PC, MB			
	OM33	Eth^R	0.07	
	OE120	Eth^R	0.42	
11.	*Micrococcus glutamicus* X_1 [16]	Biotin$^-$	2.00	PC
12.	*Pichia pastoris* IFO 0948 [105]	–	5.60 mg g^{-1}	MB
13.	*Pseudomonas* sp. FE-244 [21]	Eth^R	0.80	MB
14.	*Pseudomonas putida* VKPMV-4167 [110]	Eth^R	3.5	–
15.	*Serratia marcescens* var. *kiliensis* [107]	–	0.78[d]	PC
16.	*Torulopsis glabrata* IFO 005 [105]	–	5.04 mg g^{-1}	MB

Abbreviations for methionine analysis method: COL, colorimetry; MB, microbiological assay (all reported assays used *Leuconostoc mesenteroides* ATCC No. 8042); PC, paper chromatography; SP, spectrophotometry; AAA, amino acid analyser. Abbreviations markers: MetHx, methionine hydroxamate; SLM, selenomethionine; MetS, methionine sulphoxide; 5BU, 5-bromouracil; AHV, α-amino-β-valeric acid.

[a] Hydantoin bioconversion.
[b] Productivity in optimized medium.
[c] Productivity when cysteine was added in medium.
[d] *n*-Alkane as substrate.

(Gomes & Kumar, 2005)

Addition of 'helper' vitamins and inorganic sulfur to spare methionine

Research is needed to determine if addition of biotin, choline, folate, Vitamin B12, or betaine added to poultry feed spares methionine.

Genetic Studies

There needs to be more research into feed requirements and genotype of poultry. Average nutrient requirements for poultry, are exactly that -average. This means that there are some poultry even within breeds that require less than or more than the requirement for certain nutrients. It is possible that low-methionine requiring birds can be identified within certain strains and bred, resulting in poultry requiring lower amounts of methionine.

Given the peer-reviewed published requirements, it seems that there is not one diet that works for all breeds of poultry. More research is needed to determine if there are missing enzymes or other genetic factors related to feed requirements.

Maritime Certified Organic Growers recommend Rhode Island Red (70%), Rovan Neara (capable pf reaching commercial production), (Rhode Island Red x Barred Rock female) and Barred Rock (lays 60%) as organic layer breeds (Henry 2002). Cyber-Help for Organic Farmers (UK) suggest using Redbro, MasterGris, JA 57, Colopak, Co'Nu abd Gris Barre for broiler breeds (Cyber-Help for Organic Farmers). They are not able to ship birds to Canadian markets. Sustainable Poultry recommends Cornish Cross, SASSO Label Rouge, Hubbard ISA females like JA 57, ISA P6 N, Shaver Redbro, Isacolor, and Hubbard ISA males-naked neck (fast), Redbro, MasterGris, Silver Cross, Barred Silvers, Cebe Red, Cebe Black (medium growers). They also suggest the following turkey breeds: Bourbon Red, Narrangansett, White Holland, Black Spanish, Royal Palm, Eastern Wild, Broad-breasted, Blue State (Sustainable Poultry). The Sustainable Agriculture Network recommends raising turkeys on pasture using Bourbon Red, Spanish Black, the Bronze and the Royal Palm (Sustainable Agriculture Network, Livestock Alternatives- Profitable Poultry: raising birds on pasture, 2006). Alberta Agriculture and Rural Development recommends some possible breeds: Hubbard, Cornish Cross, Arbor Acre, Arbor acre x Peterson, La Belle Rouge (Sharpe, 2000).

The Hellevad and/or the Swedish Hens for Egg and Broiler Production are said to be less aggressive (less chance of fighting, feather eating, etc…) and require a lower protein and SAA diet than conventional chickens (DARCOF III; Sorensen, 2001). The Silver Cross is a medium growing chicken, but there is little information is available regarding temperament.

A recent comparison of turkey diets from 1966 (pre-methionine) and 2003 showed that 2003 turkeys are twice as heavy as the 1966 turkeys (Havenstein et al., 2007). The researchers compared the relative performance of the RBC2 (from Ohio State University) vs. composite pens of 3 modern turkey breeds (Nicolas, British United Turkeys of America, and hybrid turkeys), and the relative contribution to genetics and nutritional management. They found that the strains and gender reacted very differently to the two diets over the study period. The source of the variation in the strain x gender x diet was significant after the 112th day and continued until the 196th day for body weight. Strain x gender was significant from day 56 onward to day 196, and gender was consistently significantly different from hatching to day 196. Diet and gender was significant towards the ending period. This indicates that there is some genetic and gender variation in the turkeys in their dietary requirements.

Foraging

Some researchers have suggested that foraging or pasturing poultry may be an alternative to methionine supplementation (Fanatico, personal communication; Moritz et al., 2005). Moritz et al., 2005 suggests that marginal methionine deficiency can be overcome in broilers by foraging (Moritz et al., 2005).

Foraging material

In organic egg production, the free-range keeping of hens can, in some flocks, present problems with higher incidences of feather pecking that in severe cases may lead to cannibalism. One way to minimize feather pecking and cannibalism in free-range laying hen flocks could be supplementation of foraging material (Wechsler and Huber-Eicher, 1998). One of the most important quality parameters for the consumer buying retail eggs is yolk color**.** Hence, with the requirement of 100% organic feed components in organic production, it is crucial to have feed components with sufficient natural content of xanthophylls to ensure the preferred level of yolk color**.** Corn silage was found to have positive effect on yolk color when include in diets for laying hens (Jeroch, 1986).

Turkeys and lysine/methionine

There is very little research as to exploring alternative feedstuffs for present turkey genotypes. Much more research is needed as to the possibility of producing slow-growing turkeys that require lower levels of lysine (protein).

Searches for ‘turkey organic’ in PubMed and other search engines (Google Scholar) returned no results. More research and publishing of studies regarding organic turkey farming is needed.

Darkling Beetle Larva (Mealworms)

Experiments were conducted to determine the effects of feeding larvae of the darkling beetle (mealworms) to turkey poults on poultry growth and a beak trimming on poultry feeding on the larvae (Despins & Axtell, 1994). Those birds that did not have beaks trimmed ate more larvae than those that had trimmed beaks. Young turkeys fed only the larvae exhibited reduced growth in the absence of other feed, however those eating both the larvae and the starter feed showed no deficiencies in amino acids. The starter diet contained 0.67 % DM methionine, while the starter feed and darkling beetle larva contained 1.87% DM of methionine.

Problems with Animal Protein-Heat and oxidation

Methionine and cystine are exceedingly sensitive to heat and oxidation and can disintegrate. Methionine was lowered by 60% in oxidized anchovy meal and 16% in herring meal Protein rich foodstuffs do, however, differ in their susceptibility to heat. For instance the digestibility of blood meal is low and this is attributed to its particularly high sensitivity to heat, yet hydrolyzed feathers and hair, both of which have been subjected to serve treatment, appear to be highly digestible by the chick (McNas, 1975).

Petition NOP/NOSB alternatives
The Methionine Research Team also suggests that some compromises may be reached between all parties, and has provided some suggestions for compromises and alternatives. We have provided the vision and mission statements for both the NOSB and the USDA. The Vision and Mission statements for the NOSB are (http://www.ams.usda.gov/nosb/BoardPolicyManual/BoardPolicyManual8-23-05.pdf):

NOSB VISION STATEMENT

The NOSB's vision is an agricultural community rooted in organic principles and values that instills trust among consumers, producers, processors, retailers and other stakeholders. Consistent and sustainable organic standards guard and advance the integrity of organic products and practices.

NOSB MISSION STATEMENT

To achieve its vision, the NOSB provides effective and constructive advice, clarification and guidance concerning the National Organic Program (NOP) to the Secretary of Agriculture, seeking to represent a consensus of the organic community. In carrying out the mission, key activities of the Board are:

- Assist in the development and maintenance of organic standards and regulations;
- Review petitioned materials for inclusion on the National List of Approved and Prohibited Substances (National List);
- Recommend changes to the National List;
- Communicate with the organic community, including conducting public meetings, soliciting and taking public comments;
- Communicate, support and coordinate with the NOP staff;
- Provide information and education on the NOP.

Petition/review for an extension of the October 28, 2008 deadline
Because there is not enough published data on conversion feed (feed that has levels high in naturally occurring-non GMO sources of methionine), studies done on this feed for US organic poultry production, and not enough information as to the biological reasons for increased need of methionine in commercial poultry, more studies need to be done by qualified scientists at research universities/facilities. The USDA Mission and Vision statements are given below from the website at:
http://www.usda.gov/wps/portal/!ut/p/_s.7_0_A/7_0_1OB?parentnav=ABOUT_USDA&navi

Mission Statement

Mission Statement

We provide leadership on food, agriculture, natural resources, and related issues based on sound public policy, the best available science, and efficient management.

Vision

We want to be recognized as a dynamic organization that is able to efficiently provide the integrated program delivery needed to lead a rapidly evolving food and agriculture system.

Perhaps a tiered approach to discontinuing methionine replacement could be implemented over time
Stockpiles of organically grown potential methionine-replacing feed are needed are not available (Personal communication-Klaus Marten, Lakeview Farms, 2007). Perhaps an extension could be requested to allow time to increase stores of organic feed, and to provide an investigation of how long it should take to increase stores to meet the organic poultry feed demand.

Petition for an allowance of use of locally produced organic feedstuffs
Petition for an allowance of use of organic feedstuffs made in state or within a feasible geographic area that would be cost-effective for both the producer and the feedstuff supplier.

Petition for use of a disclaimer on the packaging (FDA), which is still labeled as organic
An example of what the package could state: This product has conformed to the requirements set by the USDA as an Organic product, except that synthetic amino acids are added to the feed as a way of preventing poultry deficiency (resulting in poultry suffering) and excess nitrogen pollution (from excreta), and promotes good organic farming practices.

Petition for a different definition similar to 'Organic' but that uses methionine in the feed
A system in France, called 'Label Rouge' still uses methionine, but markets poultry as a 'pasture-based' approach. Feed rations are 75% cereal, non-medicated, starter rations can be 50% with a higher soybean content. Rations do not contain animal products, stimulants, additives and fishmeal is not permitted (Fanatico and Born, 2002). Another option would be similar to the Brazil system of 'Label Chicken,' that uses synthetic methionine in the feed.

Another option would be something similar to the 'Certificate of Conformity' in France, which utilizes medium growing genetic strains, with growth in about 56 days as compared to the Label Rouge's 99-day growth period. Natural feeding is required, but access to outdoors is not required.

-END-

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