

United States Department of Agriculture
Agricultural Marketing Service | National Organic Program
Document Cover Sheet

<https://www.ams.usda.gov/rules-regulations/organic/national-list/petitioned>

Document Type:

National List Petition or Petition Update

A petition is a request to amend the USDA National Organic Program's National List of Allowed and Prohibited Substances (National List).

Any person may submit a petition to have a substance evaluated by the National Organic Standards Board (7 CFR 205.607(a)).

Guidelines for submitting a petition are available in the NOP Handbook as NOP 3011, National List Petition Guidelines.

Petitions are posted for the public on the NOP website for Petitioned Substances.

Technical Report

A technical report is developed in response to a petition to amend the National List. Reports are also developed to assist in the review of substances that are already on the National List.

Technical reports are completed by third-party contractors and are available to the public on the NOP website for Petitioned Substances.

Contractor names and dates completed are available in the report.

Ammonium Glycinate

Crops

Identification of Petitioned Substance

Chemical Names:	14	Trade Names:
Ammonium Glycinate	15	N/A
Glycine, Ammonium Salt	16	
Glycine, Monoammonium Salt		CAS Numbers:
Ammonium Aminoacetate		29728-27-6
Ammonium Aminoethanoate		
		Other Codes:
Other Name:		EC No. 249-813-4
Azanium 2-aminoacetate		

Summary of Petitioned Use

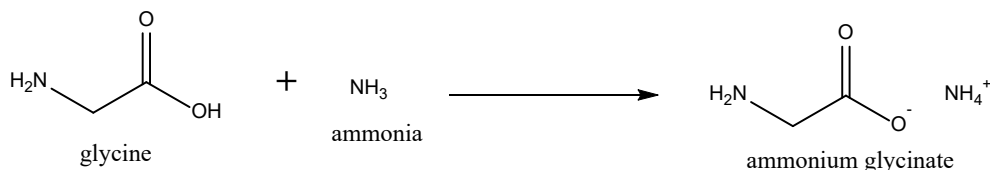
The petitioners are requesting to add ammonium glycinate, the salt resulting from the neutralization of glycine with ammonia, to Title 7 of the Code of Federal Regulations Section 205.601 (7 CFR 205.601) as a chelating agent and "synthetic substance allowed for use in organic crop production."

Ammonium glycinate acts as a chelating agent for inorganic metal micronutrients (Mn^{2+} , Zn^{2+} , $Fe^{2+/3+}$, Cu^{2+}) to increase their bioavailability specifically in alkaline (high pH) soils. The petitioned use of the substance is as a micronutrient chelate rather than as the ammonium glycinate salt. In this instance, the final compound will be a salt composed of a cationic (positively charged) micronutrient and the anionic (negatively charged) glycinate ion. The chelated form of the micronutrient (the micronutrient salt described above) increases the solubility and bioavailability of the nutrients, which are essential for the proper growth and functioning of plant systems.

Characterization of Petitioned Substance

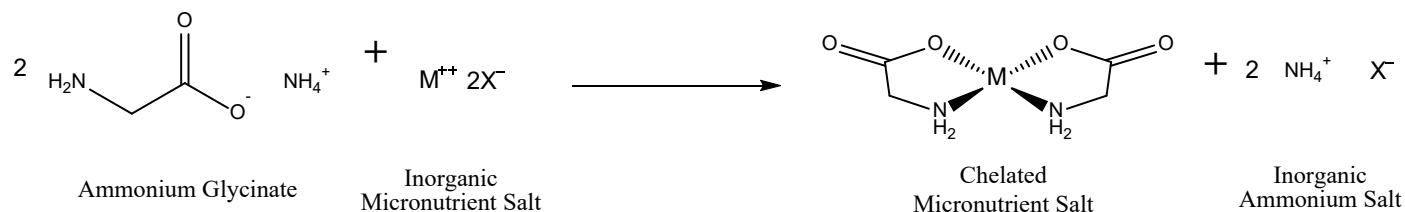
Composition of the Substance:

Ammonium glycinate is a salt produced by neutralizing the naturally occurring amino acid glycine with ammonia. Once neutralized, the amino acid is capable of chelation through the formation of multiple bonds to a central atom. This coordination proceeds through the carboxylate ($-COO^-$) formed in the neutralization process (Equation 1), and from the lone pair of electrons present at the amino group ($-NH_2$). The petitioned substance is commercially available as a powder (BIOSYNTH 2014).



Equation 1

When used as petitioned, the substance will react with an inorganic micronutrient salt (MX_2), as shown in Equation 2. This reaction will result in a chelated form of the micronutrient that has increased water solubility, especially in alkaline (high pH) soils. The identity of the inorganic ammonium salt product shown in Equation 2 is dependent on the inorganic micronutrient salt used.



Equation 2

Source or Origin of the Substance:

Ammonium glycinate is produced by the neutralization of glycine with ammonia (shown above in Equation 1). This is a synthetic process, as ammonium glycinate is not known to occur naturally.

Properties of the Substance:

The properties of ammonium glycinate are summarized in Table 1.

Table 1. Properties of Ammonium Glycinate

CAS No.	29728-27-6
Molecular Formula	C ₂ H ₈ N ₂ O ₂
Molecular Weight	92.1 g/mol
Appearance	Powder

Sources: (PubChem 161644, BIOSYNTH 2014).

Specific Uses of the Substance:

Ammonium glycinate is petitioned to be used as a chelating agent for the delivery of micronutrients (e.g., Mg²⁺, Zn²⁺, Fe^{2+/3+}, Cu²⁺) to crops. Chelating agents, also known as chelators, are defined as having multiple coordination sites to the same metal center. This means that one molecule makes attachments to a central atom (usually a metal center represented in this report by a micronutrient cation (Mn²⁺, Zn²⁺, Fe^{2+/3+}, Cu²⁺)) through two or more single bonds (IUPAC 1997). Once the chelating agent has formed its multiple bond attachment to a central atom, the resulting complex is known as a chelate. If both the central atom and chelating agent are charged (ionic species), the resulting chelate will be a metal salt, as all salts consist of positively charged (cation) and negatively charged (anion) species. Chelates are differentiated from the generic term "salt" since they result in an enveloped central atom, changing its reactivity and chemical properties. Micronutrient chelates take advantage of the change in chemical properties, specifically the increased water solubility (because of ammonium glycinate) to increase the bioavailability and plant uptake of micronutrients.

Chelating agents are also referred to as "sequestration agents" or "sequestrants." However, this nomenclature is only appropriate when the resulting chelation either physically or chemically removes a substance. This sequestration can occur when strong interactions between the central atom and chelating agent result in an unreactive chelate (chemical) or when the chelate produces a change in physical properties of the central atom, reducing its solubility and effectively removing the undesired substance (physical). The use of ammonium glycinate as petitioned is not intended to act as a sequestrant. However, studies have indicated an increased resistance to aluminum toxicity in relation to ammonium glycinate through sequestration, as discussed in more detail in Evaluation Question #8.

Micronutrients are chelated by attachment of a single metal center to a chelating agent (glycinate anion) at multiple coordination sites (IUPAC 1997). The resulting chelate becomes more water soluble, and therefore more bioavailable than the naturally occurring metal salts in most soils (Blancquaert et al. 2017, Datir et al. 2010, Grusak et al. 1999, Janmohammadi et al. 2016). The effect of chelation becomes more dramatic in alkaline and water-deficient settings, where the inorganic micronutrient metal cations tend to form low solubility hydroxide salts (Durrett et al. 2007, Janmohammadi et al. 2016). After chelation occurs, the

88 increased bioavailability of micronutrients provides an efficient system of delivering essential agricultural
89 nutrition, and it is especially powerful for applications in alkaline (high pH) and water-deficient soils.
90

91 Non-synthetic amino acids (including non-synthetic forms of glycine) are allowed as “chelating agents” for
92 organic production (§ 205.105 and NOP 5034-1). However, glycine itself (and all other amino acids) is not a
93 chelating agent. Glycine (reactant in Equation 1) provides the bulk of the structure for the anion that can act
94 as a chelating agent. However, in its natural state (the state approved for use as a chelating agent), glycine
95 is unable to bond to metal centers. This inability is due to the lack of carboxylate groups (-COO⁻), which are
96 required for the coordination of organic acids (glycinate). Upon neutralization with a base (ammonia
97 (NH₃)), glycine becomes the anion glycinate (-COOH converted to -COO⁻, as shown in Equation 1), and the
98 negatively charged species become capable of chelation through the newly formed carboxylate (-COO⁻) and
99 the lone pair of electrons on the amino group (-NH₂).

100
101 Ammonium glycinate has been used as a nutritional additive in animal feeds to increase the bioavailability
102 of trace nutrients in diets. Studies have shown that the addition of glycine and its salts (e.g., ammonium
103 glycinate) increases growth and immune response in shrimp (Lin et al. 2013). Moreover, the introduction of
104 a glycine-micronutrient chelate has shown to increase effectiveness of the micronutrient in shrimp, red sea
105 bream, and rainbow trout (Lin et al. 2013, Sarker et al. 2005, Sarker et al. 2007, Satoh et al. 2001, Watanabe
106 et al. 1980). These growth increases are postulated to result from the increased bioavailability of the
107 micronutrients, causing their increased uptake within the feed animals (Apines et al. 2001, Ashmead 1992,
108 Wang and Lovell 1997).

109
110 The neutral parent compound glycine has been approved by the Food and Drug Administration (FDA) as
111 generally recognized as safe (GRAS) when used in animal feeds with “good manufacturing or feeding
112 practice” at 21 CFR 582.5049.

113 **Approved Legal Uses of the Substance:**

114 Ammonium glycinate has neither been approved nor restricted by the United States government and does
115 not appear in the CFR.
116

117
118 However, glycine, the naturally occurring amino acid and neutral parent compound of ammonium
119 glycinate is approved for a range of uses. The neutral parent compound glycine has been approved by the
120 FDA as GRAS when used in animal feeds with “good manufacturing or feeding practice,” at 21 CFR
121 582.5049. The FDA has also approved glycine for use as a food additive “as a masking agent for the bitter
122 aftertaste of saccharin used in manufactured beverages and beverage bases,” with the limitation of the total
123 amount “not to exceed 0.2 percent in the finished beverage,” at §172.812. Additionally, it may be used “as a
124 stabilizer in mono and diglycerides prepared by the glycerolysis of edible fats or oils,” with a total amount
125 “not to exceed 0.02 percent of the mono and diglycerides,” at §172.812. Glycine has also been approved by
126 the FDA as a “nutrient added to food,” and is allowed in the form of an “individual amino acid in the free,
127 hydrated, or anhydrous form, or as the hydrochloride, sodium, or potassium salt,” at §172.320, with the
128 limitation that the total amount of glycine does not exceed 3.5% of the protein weight. Glycine is approved
129 as a precursor to the food additive guanidinoacetic acid when “manufactured by reacting glycine with
130 cyanamide in an aqueous solution,” at §573.496. Sodium glycinate is allowed as a miscellaneous
131 component of “rubber articles intended for repeated use” in “producing, manufacturing, packing,
132 processing, preparing, treating, packaging, transporting, or holding food,” with a “total not to exceed 5
133 percent by weight of rubber product,” at §177.2600.

134
135 The FDA has also approved glycine as an active ingredient in several medications. Glycine is permitted by
136 the FDA as an active ingredient for “antacid products for over-the-counter (OTC) human use,” at 21 CFR
137 331.11(f), and as an active ingredient for “antidiarrheal drug products,” at §310.545.

138 **Action of the Substance:**

139 Ammonium glycinate acts as a chelating agent that, through multiple bonds to a metallic micronutrient
140 cation (e.g., Mn²⁺, Zn²⁺, Fe^{2+/3+}, Cu²⁺), increases the water solubility of the species. These micronutrients are
141 important for both proper plant function and the subsequent nutritional value of the crop
142

143 (Alvarez-Fernandez et al. 2014, Datir et al. 2017, Durrett et al. 2007, Grusak et al. 1999, Wu et al. 2018).
144 While all the cationic micronutrients previously discussed are important to proper plant function, the
145 iron's importance within the photosynthetic pathway has made it the most widely studied. Moreover, the
146 daily diet iron deficiency affects billions around the globe in what has become known as "hidden hunger"
147 (Blancquaert et al. 2017, Tulchinsky 2010).

148
149 Due to iron's ($\text{Fe}^{2+}/3+$) importance for the proper function of both plants and the human population, as well
150 as the implications for similar divalent cation micronutrients (Mn^{2+} , Zn^{2+} , Cu^{2+}), iron's bioavailability is a
151 relevant concern. While iron is abundant in most types of soils, it is present primarily in the form of iron
152 (III) hydroxides ($\text{Fe}(\text{OH})_3$), which have low water solubility (Durrett et al. 2007). This low water solubility
153 translates to iron's low bioavailability for plant uptake, which becomes a more dramatic problem in the
154 context of soils with high alkalinity or water deficiency (Boiteau et al. 2018, Grusak et al. 1999,
155 Janmohammadi et al. 2016).

156
157 Plants have natural responses to increase the uptake of the essential micronutrients, known commonly as
158 Strategy I and Strategy II, both of which include excreting a chelating agent (Grusak et al. 1999). This
159 chelating agent sequesters the iron present in the soil and increases the water solubility of the
160 micronutrient, which can then be transported to the root and absorbed by the plant. In Strategy I, the efflux
161 of chelating agent occurs with organic acids, decreasing the pH of the soil around the root, and making the
162 iron more soluble (Grusak et al. 1999). While the iron uptake process has been intensely studied, it is also
163 thought to be a general mechanism for other essential micronutrients, such as Cu^{2+} , Mn^{2+} , and Zn^{2+} (Grusak
164 et al. 1999). Among the identified chelating agents excreted by plants with micronutrient deficiencies are
165 amino acids such as mugenic acid (Takemoto et al. 1978). Since this early report in natural micronutrient
166 chelation, many small organic acids and amino acids (e.g., glycinate) have been proposed as possible
167 chelating agents (Adeleke et al. 2017, Altomare et al. 1999).

168
169 Recent studies have shown how important chelating agents are in the translocation of micronutrients upon
170 plant uptake. Amino acids are proposed as chelating agents for micronutrient translocation with the
171 chelated micronutrient having reduced interactions with negatively charged cell walls (Adeleke et al. 2017,
172 Alvarez-Fernandez et al. 2014, Pich and Scholz 1996).

173
174 The action of the petitioned substance is to provide a similar mechanism for increasing micronutrient
175 bioavailability. In these applications, the micronutrient is chelated by ammonium glycinate, increasing its
176 water solubility and enhancing uptake by crops. Chelation enhances the delivery of these species, catering
177 to the micronutrient needs of crops and soil. Moreover, due to the multiple attachment points of the
178 chelating species (glycinate), it is not easily displaced by competing, low-solubility anions, such as OH^- and
179 CO_3^{2-} (Grusak et al. 1999). This strategy has shown promise in several studies where chelated
180 micronutrients significantly increased crop growth, yield, and quality (Datir et al. 2010, Wu et al. 2018).
181 This result is particularly important in areas with limited irrigation, where the chelated micronutrients
182 outperformed conventional fertilization programs (Janmohammadi et al. 2016). Because amino acids are
183 important for micronutrient translocation following plant uptake, the application of glycinate chelated
184 nutrients may result in improved plant function (Alvarez-Fernandez et al. 2014).

185 186 **Combinations of the Substance:**

187 As stated above in the "Composition of the Substance" section, ammonium glycinate is a salt formed by the
188 neutralization of the naturally occurring amino acid glycine with a base (ammonia (NH_3)). Upon
189 neutralization, the glycinate anion is capable of micronutrient chelation through coordination by the
190 carboxylate group ($-\text{COO}^-$) and the amino group ($-\text{NH}_2$).

191
192 However, ammonium glycinate as petitioned is not meant to be applied to crops as a chelating agent alone;
193 rather, it is meant for application in the chelate form (coordinated to a metal cation). In this instance, the
194 coordinated cation would be determined based on the crop of interest and soil conditions. The most likely
195 candidates are Mn^{2+} , Zn^{2+} , $\text{Fe}^{2+}/3+$, and Cu^{2+} , all of which are natural minerals and essential micronutrients.
196 Moreover, salts of these cations have been approved for use by the National Organic Program (NOP) for
197 organic crop production at 7 CFR 205.601.

198
199 **Supplemental Information:**
200 NOP requested technical clarification of the terms “ligand,” “chelating agent,” and “chelate.” It is beneficial
201 to begin with the differences between the related terms “ligand” and “chelating agent.” The petitioner
202 claims that NOP has used “chelating agent” incorrectly (discussed in more detail below) and suggests
203 replacing the term “chelating agent” with “ligand.” Therefore, it seems that, prior to the analysis of NOP’s
204 usage of the term “chelating agent,” a discussion of the two terms may be helpful. A ligand has been
205 defined as an ion or molecule that is covalently bonded to a metal atom that can also have an independent
206 existence (Silberberg 2003, Shriver and Atkins 2008). A chelating agent is a specific type of ligand and is
207 characterized by its ability to form multiple bonds to the metal center from multiple attachment points (i.e.,
208 a polydentate ligand) (Silberberg 2003, Shriver and Atkins 2008). Based on these definitions, it is technically
209 correct to classify all chelating agents as ligands. However, in the United States, it is far more common to
210 refer to these polydentate ligands as “chelating agents,” rather than the more general “ligand.” Moreover,
211 the term chelating agent is typically reserved for ligands that not only have the capacity to form multiple
212 attachment points, but also ligands that tend towards forming these attachment points as a rule – a
213 tendency that results in a specific set of properties and applications. In conclusion, the term ligand is *not*
214 synonymous with chelating agent, with chelating agents comprising a specific mode of coordination while
215 ligand refers to anything molecule or ion that coordinates to a metal atom.

216
217 With the differences between ligands and chelating agents established, the terms “chelating agent” and
218 “chelate” will be discussed. As stated, these terms are related. Chelates are defined as “a complex
219 [molecule consisting of a metal atom(s) that are bonded to a set of ligands] in which a ligand forms a ring
220 that includes the metal atom” (Shriver and Atkins 2008). More simply, a chelate is the result of the
221 chelating agent forming multiple attachment points to a metal atom. This principle is illustrated in
222 Equation 2, in which the ammonium glycinate salt is the chelating agent (left), and the final product
223 consisting of the glycinate ion, having former multiple bonds to the metal center (M) is the chelate (right).
224 Therefore, the difference between a chelating agent and a chelate can be simplified as the chelating agent
225 has the capacity to form multiple bonds to a metal atom, while a chelate no longer has the capacity to form
226 bonds with multiple attachment points. Rather, a chelate includes a metal atom to which bonds from
227 multiple attachment points have been made.

228
229 The petitioner has questioned the use and technical accuracy of the terms “chelate” and “chelating agent,”
230 within NOP documents, including the National List. A review of the National List shows a singular usage
231 of “chelating agent,” which is used to describe the approved usage of lignin sulfonate at 9 CFR 205.601. In
232 this context, the use of the term “chelating agent” is used correctly to describe the ability of the lignin
233 sulfonate to form multiple bonds to a metal atom.

234
235 Further investigation of NOP documents shows the use of the term “chelating agent” in NOP 5034-1,
236 “Guidance Materials for Organic Crop Production.” In this document, a section on chelating agents states:
237 “Natural chelating agents are allowed. Allowed sources of chelating agents include, but are not limited to,
238 non-synthetic amino acids, citric acid (to form citrate in solution), tartaric acid made from grape wine, and
239 gluconic acid. Synthetic chelating agents are only permitted if included on the National List for that
240 purpose” (NOP 5034-1). The technical accuracy of this usage is difficult to gauge given the lack of context
241 in the application and formulation of the chelating agent. However, within this usage, the term is applied
242 in a contradictory manner. This is highlighted with “citric acid (to form citrate in solution),” which uses the
243 term correctly, but implies that in the other natural acids listed, this change would not occur when used as
244 a chelating agent (which is incorrect) (NOP 5034-1). All the listed compounds (citric, tartaric, gluconic, and
245 non-synthetic amino acids) share the same carboxylic acid functional group (shown in the neutralization
246 reaction in Equation 1). Like the formation of citrate from citric acid, all the listed acids would be required
247 to undergo a similar neutralization reaction *before* they could function as chelating agents. Therefore, NOP
248 should alter document 5034-1 in order to reflect the technically correct usage of the term (e.g., “Organic
249 acids such as non-synthetic amino acids and citric acid may be used a precursors to chelating agents, with
250 the chelating agents being the neutralized carboxylate salt of the approved acid.”).

251

252 NOP requested clarification on the ability of neutral acids to act as chelating agents. While the neutral
253 forms of the chelating agents listed in NOP 5034-1 (citric, tartaric, gluconic, and amino acids) technically
254 could form bonds due to the availability of lone pairs of the carboxylic acid groups (-COOH), these neutral
255 forms will include only weak interactions. Therefore, the neutral acids are not considered to be chelating
256 agents until they have undergone neutralization of the carboxylic acid group (-COOH) to yield the
257 carboxylate anion (-COO⁻) (illustrated in Equation 1). This allows for the formation of strong, covalent
258 interactions with the metal atom to form a chelate.

259
260 This leads us to the question posed by NOP as to if citric acid is neutralized to citrate, can it still be
261 considered citric acid? The short answer here is no. Once a neutralization reaction occurs, the citric acid is
262 transformed to a citrate salt, which will have entirely different chemical and physical properties, and is
263 further accentuated by the assignment of a new CAS number (citric acid = 77-92-9, while the citrate CAS
264 number is dependent on its corresponding cation). This same analysis is true of the neutral amino acid
265 glycine and its glycinate salt, which will have differing chemical and physical properties and identification
266 (CAS) numbers.

267
268 There are a wide range of possible cations that will act to counter the negative charge of the carboxylate
269 anion following the dissociation of the carboxylic acid proton (H⁺). These cations include, but are not
270 limited to, lithium (Li⁺), sodium (Na⁺), potassium (K⁺), and ammonium (NH₄⁺). However, due to the
271 characterization of the neutral acids as chelating agents by the NOP, a list of cations found in approved
272 substances does not exist (NOP 5034-1). If the use of ammonium (NH₄⁺) including or producing bases (e.g.,
273 ammonium hydroxide (NaOH), ammonia (NH₃)) are permitted for treatment of approved acids to produce
274 chelating agents, the petitioned substance then appears to fall under this approval.

275
276 The strength of chelation (a chelating agent bonding to a metal atom to form a chelate) is dependent upon
277 many factors. These include the identity of both the chelating agent and metal atom, as well as the
278 environment that the chelate is subjected to (e.g., pH, temperature, etc.). Therefore, it is impossible to
279 predict the widespread utility of any single chelating agent. However, it is also likely that several
280 applications will be better served by a greater diversity of approved chelating agents to choose from,
281 allowing the consumer to choose the chelating agent that is best suited for the application of a specific
282 micronutrient (metal atom) within the given environmental constraints. Chelating agents have been shown
283 to increase the solubility and bioavailability of micronutrients applied as soil amendments. However, the
284 efficacy of the delivery by the chelating agent is dependent on the identity of the chelating agent and
285 micronutrient, as well as the environmental conditions of the agroecosystem. With this in mind, increasing
286 the diversity of approved chelating agents allows for the most effective pairing for a given micronutrient
287 and environmental system. For this reason, the presence of other approved chelating agents on the
288 National List (e.g., humates and lignin sulfonate) does not make the petitioned substance unnecessary.

289

290

Status

291

292 **Historic Use:**

293 There has been no historic use of ammonium glycinate in organic agricultural production. As a
294 non-synthetic substance, the parent compound glycine (an amino acid) is permitted in organic production
295 USDA organic regulations (7 CFR 205.105) when used in a non-synthetic form.

296

297 Glycine and its salts (glycinate) have been used as food additives in beverages and as stabilizers in
298 products made from natural fats and oils, as approved at 21 CFR 172.812. Glycine has been approved as a
299 nutritional food additive at §172.320 and is commonly added to animal feeds both as the free amino acid
300 and as a glycinate-micronutrient chelate (Apines et al. 2001, Ashmead 1992, Lin et al. 2013, Sarker et al.
301 2005, Sarker et al. 2007, Satoh et al. 2001, Wang and Lovell 1997).

302

303 The parent compound glycine has also seen use in agricultural production as a miscellaneous rubber
304 component for repeated use with food as described at 21 CFR 177.2600.

305

306 **Organic Foods Production Act, USDA Final Rule:**

307 Ammonium glycinate is not listed in the Organic Foods Production Act of 1990 (OFPA) or the USDA
308 organic regulations, 7 CFR 205. However, a variety of synthetic micronutrients have been approved for use
309 at 7 CFR 205.601(j), and minerals have also been approved as synthetic substances at §6517.

310

311 International

312

313 **Canadian General Standards Board Permitted Substances List**

314 Ammonium glycinate is not listed in CAN/CGSB-32.311-2015 – Organic production systems – Permitted
315 substances lists.

316

317 **CODEX Alimentarius Commission, Guidelines for the Production, Processing, Labelling and Marketing 318 of Organically Produced Foods (GL 32-1999)**

319 Ammonium glycinate is not listed in the CODEX.

320

321 **European Economic Community (EEC) Council Regulation, EC No. 834/2007 and 889/2008**

322 Ammonium glycinate is not listed in the EEC EC No. 834/2007 or 889/2008.

323

324 **Japan Agricultural Standard (JAS) for Organic Production**

325 Ammonium glycinate is not listed in the JAS.

326

327 **International Federation of Organic Agriculture Movements (IFOAM)**

328 Ammonium glycinate is not listed in IFOAM.

329

330 **Evaluation Questions for Substances to be used in Organic Crop or Livestock Production**

331

332 **Evaluation Question #1: Indicate which category in OFPA that the substance falls under: (A) Does the**
333 **substance contain an active ingredient in any of the following categories: copper and sulfur**
334 **compounds, toxins derived from bacteria; pheromones, soaps, horticultural oils, fish emulsions, treated**
335 **seed, vitamins and minerals; livestock parasiticides and medicines and production aids including**
336 **netting, tree wraps and seals, insect traps, sticky barriers, row covers, and equipment cleansers? (B) Is**
337 **the substance a synthetic inert ingredient that is not classified by the EPA as inerts of toxicological**
338 **concern (i.e., EPA List 4 inerts) (7 U.S.C. § 6517(c)(1)(B)(ii))? Is the synthetic substance an inert**
339 **ingredient which is not on EPA List 4, but is exempt from a requirement of a tolerance, per 40 CFR part**
340 **180?**

341

342 Ammonium glycinate does not contain any of the materials listed in (A). However, as copper is an essential
343 micronutrient for plant development, it may be used in concert with ammonium glycinate in the form of a
344 chelate (Equation 2 where M is Cu^{+2}). In this form, the copper is unlikely to be reactive due to the
345 multiple coordination points of the glycinate, although the water solubility of the copper (if used) is likely
346 to be increased.

347

348 When used as petitioned, ammonium glycinate would serve as an inert ingredient for the delivery of
349 micronutrients. The glycinate chelated micronutrients (product of Equation 2) are inert due to their
350 multiple points of attachment to the micronutrient. The petitioned substance is not listed by the
351 Environmental Protection Agency (EPA) as an inert of toxicological concern and is not listed in 40 CFR 180,
352 per (B).

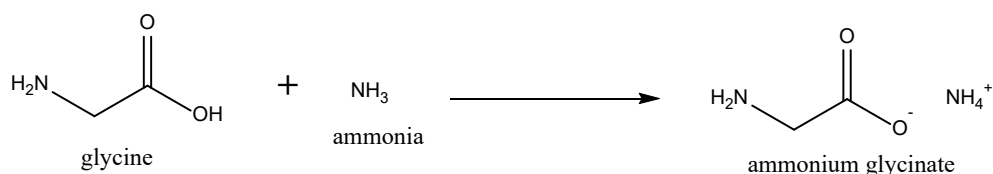
353

354 **Evaluation Question #2: Describe the most prevalent processes used to manufacture or formulate the**
355 **petitioned substance. Further, describe any chemical change that may occur during manufacture or**
356 **formulation of the petitioned substance when this substance is extracted from naturally occurring plant,**
357 **animal, or mineral sources (7 U.S.C. § 6502 (21)).**

358

359 The ammonium glycinate product is synthetic and is not known to exist in nature. As stated above in the
360 “Characterization of Petitioned Substance” section, ammonium glycinate is produced by the neutralization

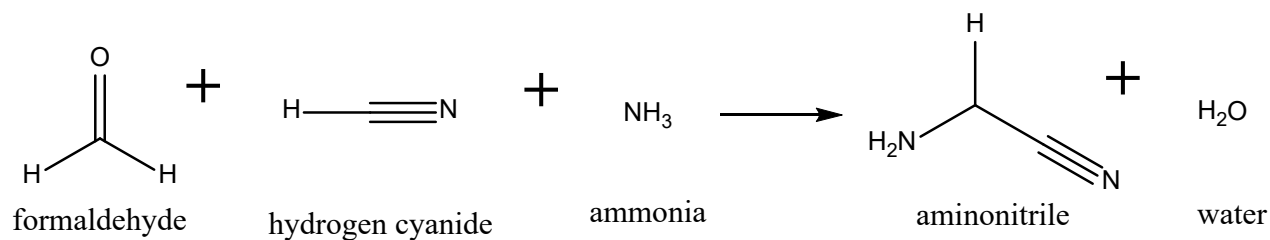
361 (transfer of H⁺ from acid to base) of glycine with the base ammonia (NH₃), resulting in the formation of a
 362 salt between ammonium (NH₄⁺) cations and glycinate anions (Equation 1).
 363



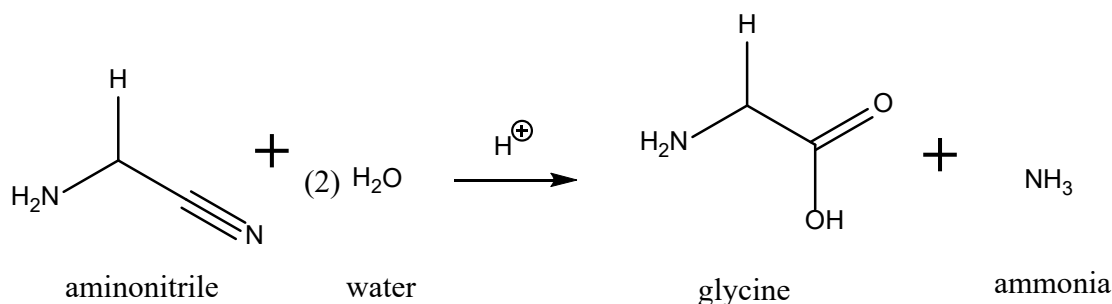
Equation 1

364
 365
 366 Both precursors to ammonium glycinate (glycine and ammonia) are naturally occurring. Glycine is a
 367 naturally occurring amino acid that is produced in animals, plants, and microorganisms; further, the
 368 substance is an inhibitory neurotransmitter in humans (Merck 2001, SCF 1990). Glycine may be isolated
 369 through the hydrolysis of proteins (via acid hydrolysis), although most commercially-available glycine is
 370 produced synthetically through the Strecker process or the amination of chloroacetic acid (Kirk-Othmer
 371 2008). Synthetic forms of glycine are not permitted for crop production under current USDA organic
 372 regulations (7 CFR 205.105). The Strecker process is the most common means of glycine production in the
 373 U.S., as shown in Equation 3 below.
 374

Part 1



Part 2



Equation 3

375
 376
 377 In the first part of the Strecker process formaldehyde (CH₂O), hydrogen cyanide (HCN), and ammonia
 378 (NH₃) react to form an aminonitrile, which then reacts with water and an acid source to produce glycine in
 379 the second part of the process (Kirk-Othmer 2008).
 380

381 Ammonia (NH₃) is an inorganic gas and is produced biologically in the body as a byproduct of several
 382 metabolic reactions (MeSH D000641). Ammonia is an industrially important commodity with a range of
 383 uses from solvents and fuels to agricultural chemicals (PubChem 222). Most ammonia is produced using

384 the Haber-Bosch process, in which atmospheric nitrogen gas (N_2) is reduced with a hydrogen source at
385 high temperatures and pressures in the presence of an iron catalyst (Clayton and Clayton 1994).

386
387 **Evaluation Question #3: Discuss whether the petitioned substance is formulated or manufactured by a**
388 **chemical process or created by naturally occurring biological processes (7 U.S.C. § 6502 (21)).**
389

390 The petitioned substance is manufactured; it is not known to exist in nature. Ammonium glycinate is a salt
391 produced by the neutralization reaction that occurs between glycine and ammonia (Equation 1). Glycine is
392 a naturally occurring amino acid and is prevalent in nature in a variety of organisms, including humans
393 and plants; however, it is typically produced industrially via the Strecker process shown in Equation 2
394 (discussed in more detail in Evaluation Question #2) (EFSA 2005, EFSA 2008c, EFSA 2014, Kirk-Othmer
395 2008, Merck 2001, SCF 1990). Ammonia is made through natural processes and is an industrially important
396 commodity; as such, it is manufactured through the Haber-Bosch process, as described above in Evaluation
397 Question #2 (Clayton and Clayton 1994).

398
399 **Evaluation Question #4: Describe the persistence or concentration of the petitioned substance and/or its**
400 **byproducts in the environment (7 U.S.C. § 6518 (m) (2)).**
401

402 There are no published studies on the environmental persistence of ammonium glycinate. When used as
403 petitioned, ammonium glycinate will not be introduced into the environment. The substance will be
404 reacted with an applicable approved micronutrient (as shown in Equation 2), and a solution of the chelated
405 micronutrient and inorganic ammonium salt will be employed. Due to the use of the petitioned substance
406 as a precursor to the desired chelated micronutrient, ammonium glycinate itself is not anticipated to be
407 used for crop applications, and therefore is not expected to be an environmental concern. Moreover, the
408 need for micronutrients in trace amounts would lead to the introduction of minimal amounts (ppm
409 applications) of ammonium glycinate as a micronutrient chelate when used as petitioned (Boiteau et al.
410 2018, Blancquaert et al. 2017, Janmohammadi et al. 2016).

411
412 Due to the use of the petitioned as a precursor to micronutrient chelates, they will exist in many possible
413 combinations that are dependent on the micronutrient in question, as well as the inorganic salt that is
414 chosen as the micronutrient source. Therefore, an analysis of the individual ions in the environment is
415 important. Both ammonium (NH_4^+) and glycinate ions are naturally occurring in a range of plants, animals,
416 and microorganisms. Due to the persistence of these ions in normal biological environments, and the
417 metabolism of both ammonium and glycinate ions by a variety of organisms (JECFA 1986, EFSA 2008a,
418 EFSA 2008b, EFSA 2008c, EFSA 2014, SCF 1990). Based on the incorporation of these ions into the metabolic
419 pathway of a variety of organisms, they are not expected to be long-lived in the environment; therefore, the
420 petitioned substance does not likely pose a threat to the environment

421
422 **Evaluation Question #5: Describe the toxicity and mode of action of the substance and of its breakdown**
423 **products and any contaminants. Describe the persistence and areas of concentration in the environment**
424 **of the substance and its breakdown products (7 U.S.C. § 6518 (m) (2)).**
425

426 There are no published studies on the environmental impacts of ammonium glycinate. As discussed in
427 Evaluation Question #4, the petitioned substance is a salt comprised of ions that are prevalent in the
428 environment and is reacted with a specific micronutrient to form the chelate that is applied to crops. When
429 used as petitioned, ammonium glycinate is a precursor to chelated micronutrients (product of Equation 2)
430 for agricultural applications; therefore, ammonium glycinate and its breakdown products are not
431 anticipated to be an environmental concern. Furthermore, the requirement of micronutrients in trace
432 amounts would lead to the introduction of minimal amounts (ppm applications) of micronutrient chelates
433 when used as petitioned (Boiteau et al. 2018, Blancquaert et al. 2017, Janmohammadi et al. 2016).

434
435 The chelated micronutrient acts to increase the bioavailability of the metal cation to ensure its uptake by
436 crops. Due to the use of the petitioned as a precursor to micronutrient chelates, they will exist in many
437 possible combinations that are dependent on the micronutrient in question, as well as the inorganic salt
438 that is chosen as the micronutrient source. Therefore, an analysis of the individual ions in the environment

439 is important. Once the water-soluble micronutrient has been absorbed by plant life, the glycinate anion and
440 ammonium salt (product of Equation 2) remain in the soil. However, both ammonium and glycinate ions
441 are prevalent in nature, are readily metabolized by a variety of organisms, and therefore are not anticipated
442 to have any toxicological impact on the environment (JECFA 1986, EFSA 2008a, EFSA 2008b, EFSA 2008c,
443 EFSA 2014, SCF 1990). Furthermore, the need for micronutrients in trace amounts would lead to the
444 introduction of minimal amounts (ppm applications) of ammonium glycinate as a micronutrient chelate
445 when used as petitioned (Boiteau et al. 2018, Blancquaert et al. 2017, Janmohammadi et al. 2016).

446

447 **Evaluation Question #6: Describe any environmental contamination that could result from the**
448 **petitioned substance's manufacture, use, misuse, or disposal (7 U.S.C. § 6518 (m) (3)).**

449

450 As discussed above in Evaluation Questions #4 and #5, there are no published studies of the
451 environmental impact of ammonium glycinate. Furthermore, ammonium glycinate is petitioned for use as
452 a precursor to chelated micronutrients (see Equation 2) and will not be directly applied to crops.
453 Ammonium and glycinate ions are prevalent in nature, are also readily metabolized by a variety of
454 organisms, and given the small quantities (ppm applications) expected when used as petitioned, are not
455 anticipated to have an environmental impact.

456

457 Both precursors to ammonium glycinate (ammonia and glycine) are naturally occurring substances. Both
458 ammonia and glycine are synthetically produced due to high industrial demand and are unlikely sources
459 of environmental contamination (Clayton and Clayton 1994, Kirk-Othmer 2008).

460

461 The production of ammonia (NH₃) and ammonium (NH₄⁺) salts for use in fertilization programs has
462 dramatically increased the agricultural productivity in regions across the world (Ryan et al. 2012, Tilman et
463 al. 2002). However, despite the increased productivity, recent studies have shown a decreased efficiency in
464 uptake of nitrogen nutrients (ammonia and ammonium salts) (Tilman et al. 2002). Much of the "lost"
465 fertilizer occurs through ecosystem transfer and unintentional fertilization, which can result in reduced
466 biodiversity (Erismann et al. 2008).

467

468 Ammonium salts are produced as a byproduct in the synthesis of the chelated micronutrient (Equation 2).
469 The properties and reactivity of the resultant ammonium salts are dependent on their anion (X⁻), which is
470 determined based on the inorganic micronutrient salt employed. When used as petitioned, the potential
471 negative impacts of these ammonium salts (unintentional fertilization, loss of biodiversity as described
472 above) are expected to be minimal due to the small quantities used in the application processes. However,
473 the misuse (overapplication) or improper disposal of the chelated micronutrient and ammonium salt
474 products of Equation 2 may result in negative environmental impacts including unintentional fertilization,
475 loss of biodiversity, and water pollution given the increased water solubility of the chelated micronutrients.

476

477 **Evaluation Question #7: Describe any known chemical interactions between the petitioned substance**
478 **and other substances used in organic crop or livestock production or handling. Describe any**
479 **environmental or human health effects from these chemical interactions (7 U.S.C. § 6518 (m) (1)).**

480

481 When used as petitioned, ammonium glycinate will be introduced as a micronutrient-chelate compound,
482 which is not likely to interact with other substances that have been approved for use in organic crop or
483 livestock production. However, once the chelated micronutrient has been absorbed by plants, the glycinate
484 chelating agent may remain in the soil. Since the remaining glycinate is a chelating agent, there are several
485 cations (Ca²⁺, Cu²⁺, Mg²⁺) that may be impacted in salts allowed for use in organic crop and livestock
486 production in 7 CFR 205.601 and §205.603, respectively. Due to the preference for the multiple coordination
487 sites given from ammonium glycinate with divalent cations, the metal cations may preferentially form
488 chelates and displace the original anion. This interaction may result in the increased water solubility of the
489 cation, which may decrease the effectiveness of the original compound. However, the chelation of cations is
490 not expected to result in negative environmental or human health effects. Moreover, due to the metabolism
491 of glycinate anions by a variety of organisms, coupled with the small quantity of micronutrients applied
492 when the substance is used as petitioned, the anticipated interactions between residual glycinate anions
493 and other substances used in organic agricultural practices are expected to be minimal.

494
495 The potential salts that could be altered by anion exchange (chelation of the cation) via the introduction of
496 glycinate anions are salts containing Ca^{2+} (calcium hypochlorite, lime sulfur, and hydrated lime), Cu^{2+}
497 containing salts (copper sulfate, copper hydroxide, copper oxide, and copper oxychloride), and the Mg^{2+}
498 salts (magnesium hydroxide and magnesium sulfate) listed in 7 CFR 205.603. Additionally, introducing
499 ammonium glycinate would affect other micronutrients that have been added to treat soil deficiency.
500 However, the impact of micronutrients is expected to be negligible since the introduction of the petitioned
501 substance as a micronutrient delivery system is unlikely to be used in concert with other micronutrient
502 programs approved in §205.601 and §205.603.

503
504 **Evaluation Question #8: Describe any effects of the petitioned substance on biological or chemical**
505 **interactions in the agro-ecosystem, including physiological effects on soil organisms (including the salt**
506 **index and solubility of the soil), crops, and livestock (7 U.S.C. § 6518 (m) (5)).**

507
508 When used as petitioned, ammonium glycinate will be introduced into agricultural settings as a chelate
509 with multiple coordination points to a cationic micronutrient. In this capacity, it is unlikely to interact with
510 any other substances or influence any significant change to the biological setting. After delivering the
511 micronutrient, the ammonium glycinate species may coordinate to existing micronutrient sources with
512 limited solubility in their original state in the soil, increasing their water solubility and bioavailability. This
513 movement of existing micronutrients may result in an eventual change to the existing micronutrient
514 concentration until the remaining ammonium glycinate is metabolized. However, when the quantity of
515 micronutrients and the ease of glycinate metabolism are considered, the leaching of existing insoluble
516 mineral and nutrient soil deposits is not anticipated.

517
518 Additionally, the presence of ammonium glycinate may result in increased plant resistance to several
519 toxins, including aluminum (Ma et al. 2001). Like many of the essential micronutrients discussed in this
520 report, aluminum is present ecologically. Typically, the presence of aluminum places little threat to plant
521 function as it is prevalent as unreactive aluminum oxides (Ma et al. 2001). However, in acidic soils, these
522 aluminum oxides are broken down, and aluminum persists as Al^{3+} ions with a strong affinity towards
523 oxygen containing compounds. These interactions with biological oxygen-containing molecules inhibits
524 proper function. Introducing organic acids like glycine (glycinate) has been shown to increase resistance to
525 aluminum toxicity, as chelation of the Al^{3+} ion prevents reactions with other biological compounds (Ma et
526 al. 2001, Wu et al. 2018). It is conceivable that the chelation of other toxic ions (Pb^{2+} , Cd^{2+} , Hg_2^{2+}) may
527 prevent their toxicological impact on the crops and greater ecosystem.

528
529 The application of chelated micronutrients and inorganic ammonium salts from the petitioned use of
530 ammonium glycinate may result in physiological changes to the soil. The application of ammonia and
531 ammonium-based fertilizers has been associated with negative physiological changes to earthworms and
532 native microbial communities (Edwards et al. 1995, Geisseler and Scow 2013, Liu and Greaver 2010, Lu et
533 al. 2011, USDA 2001). In both cases, the negative impacts from nitrogen (ammonia and ammonium)
534 fertilization programs were linked with a reduction of soil pH (acidification) (Geisseler and Scow 2013,
535 Kirchmann et al. 1994, USDA 2001, Yadvinder-Singh and Beauchamp 1988). However, these negative
536 impacts were shown to be most damaging in applications to unmanaged ecosystems, due to more dramatic
537 changes to soil pH (Geisseler and Scow 2013, Treseder 2008). In comparison, studies of nitrogen
538 fertilization programs on managed ecosystems (e.g., commercial organic farms) resulted in increased
539 microbial biomass due to the increased productivity of the crops (Geisseler and Scow 2013, Kallenbach and
540 Grandy 2011). Furthermore, these studies reflect the physiological impacts based on application of nitrogen
541 fertilizers, which are applied in much greater quantity than the ammonium salts from the portioned
542 ammonium glycinate chelated micronutrients. Therefore, the application of chelated micronutrients and
543 corresponding inorganic ammonium salts are not anticipated to have physiological impacts on soil
544 organisms.

545
546 **Evaluation Question #9: Discuss and summarize findings on whether the use of the petitioned**
547 **substance may be harmful to the environment (7 U.S.C. § 6517 (c) (1) (A) (i) and 7 U.S.C. § 6517 (c) (2) (A)**
548 **(i)).**

549
550 As discussed in Evaluation Questions #4 and #5, ammonium glycinate is petitioned for use as a precursor
551 to chelated micronutrients and is not intended to be applied as ammonium glycinate. Ammonium
552 glycinate is a salt whose ions are prevalent in biological systems. Both ions (ammonium and glycinate) are
553 metabolized by a range of organisms, and the addition of ammonium glycinate when used as petitioned is
554 not expected to result in any negative ecological outcomes (EFSA 2005, EFSA 2008a, EFSA 2008b, EFSA
555 2008c, JECFA 1986, SCF 1990). Moreover, the petitioned substance will be added in minimal amounts and
556 is not expected to result in a significant increase in the presence of ammonium or glycinate ions (Boiteau et
557 al. 2018).

558
559 However, as discussed in Evaluation Question #6, ammonia-based fertilization treatments may result in
560 ecosystem transfer and unintentional fertilization, which can result in reduced biodiversity (Erisman et al.
561 2008). The properties of the inorganic ammonium salt produced in Equation 2 is dependent on the anion,
562 which is determined by the inorganic micronutrient source. Since ammonium salts are prevalent in
563 nitrogen fertilizers, some of the salts produced in Equation 2 may be sufficiently volatile and result in
564 unintentional fertilization. However, due to the small quantities of micronutrients required, unintentional
565 fertilization is unlikely to occur in any significant amount when the substance is used as petitioned.

566
567 **Evaluation Question #10: Describe and summarize any reported effects upon human health from use of**
568 **the petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (i), 7 U.S.C. § 6517 (c) (2) (A) (i) and 7 U.S.C. § 6518**
569 **(m) (4)).**
570

571 Ammonium glycinate is a salt that is composed of ions (ammonium and glycinate) that are prevalent in the
572 body, and the metabolites of both ammonium and glycinate ions play a critical role in human metabolism
573 (the citric acid or Krebs cycle). Furthermore, both ions have been designated as safe and are authorized for
574 use in several food additives (SCF 1990, JECFA 1986).

575
576 Within the body ammonium, and its precursor ammonia, are metabolized in the Krebs cycle to urea, which
577 is excreted by the kidneys (EFSA 2008a). Glycinate is a natural component of proteins and is a common
578 food additive that has received an accepted daily intake (ADI) of “not specific” (EFSA 2008c). Glycinate is
579 distributed in cells, where it enters the amino acid pool for use in protein synthesis. Additional glycinate is
580 metabolized to acetyl-coenzyme A, which undergoes subsequent metabolism via the citric acid cycle which
581 is important for human metabolism and the production of energy and coenzymes (EFSA 2008b, JECFA
582 2006).

583
584 As a solid, ammonium glycinate has been documented to cause irritation to the respiratory system
585 (BIOSYNTH 2014). Glycine is also an inhibitory neurotransmitter capable of crossing the blood-brain
586 barrier and impeding normal function of the central nervous system and impacting the retina and spinal
587 cord (Pycocock and Kerwin 1980). Studies have shown that the inhibitory effects of glycine have been linked
588 to temporary blindness in humans and death in mice, when absorbed by the body in high concentrations
589 (Bansal et al. 2002, Hahn 2013, Olsson and Hahn 1999). However, these reports are based on absorption of
590 high concentration glycine solutions taking place in surgical settings with glycine; it is not clear that the
591 ionic glycinate form would be able to effect similar results (Hahn 2013). As stated previously, ammonium
592 glycinate will be applied in minimal quantities where absorption of high concentrations is not possible; and
593 when used as petitioned, it is not anticipated to result in adverse health impacts.

594
595 **Evaluation Question #11: Describe all natural (non-synthetic) substances or products which may be**
596 **used in place of a petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (ii)). Provide a list of allowed**
597 **substances that may be used in place of the petitioned substance (7 U.S.C. § 6518 (m) (6)).**
598

599 There are a range of natural chelating agents that are excreted by plants and microorganisms, or are
600 produced from the decomposition of organic matter, and aid in the delivery of micronutrients in the soil
601 (Adeleke et al. 2017). These compounds are broadly classified as phytosiderophores or phytometallophores
602 (Adeleke et al. 2017, Grusak et al. 1999, Welch 1995). These compounds are wide ranging and include
603 organic (carboxylic) acids and non-synthetic amino acids. However, organic or amino acids must first

604 undergo a neutralization reaction (similar to Equation 1) with bases in the soil before they are able to act
605 as chelating agents. In basic (alkaline) soils, the application of these natural organic and amino acids will
606 result in their neutralization, and the subsequent anions may act as chelating agents for micronutrient
607 sources already existing in the soil. However, applying these acids in sufficient quantity to change the pH
608 of the soil would result in a more dramatic ecological change than application of chelated micronutrients.
609 Moreover, the increased acidity of the soil could result in mineral depletion, and an increase in the toxicity
610 of minerals existing in unreactive states such as aluminum (Ma et al. 2001, Vitousek et al. 1997). A soil
611 acidification program could also result in leaching of natural mineral deposits and water pollution
612 resulting from the mass migration of mineral stores from previously insoluble (hydroxide and carbonate)
613 sources (Treseder 2008). Soil acidification is also associated with the degradation of physiological soil
614 conditions, which has a negative impact on a range of soil organisms (Geisseler and Scow 2013, Kirchmann
615 et al. 1994, USDA 2001, Yadvinder-Singh and Beauchamp 1988). Due to the implications of a strategy to
616 increase micronutrient solubility by soil acidification (loss of mineral content, water pollution,
617 physiological soil degradation, increased mineral toxicity), this approach does not provide a likely
618 alternative to the petitioned substance.

619
620 There are a variety of synthetic substances approved in 7 CFR 205.601 that may be used in place of the
621 petitioned substance as a means of increasing the water solubility of micronutrients. Most of these
622 substances are acids, which would result in a pH change in the soil, converting insoluble hydroxide salts
623 into more soluble micronutrient salts. The approved acids are the following: peracetic acid, boric acid,
624 humic acids, and sulfurous acid. However, like the application of natural organic and amino acids to access
625 natural chelating agents, the application of approved synthetic acids could result in the negative outcomes
626 associated with soil acidification.

627
628 Lignin sulfonate, or lignosulfonate, is a synthetic chelating agent that is approved by the NOP for use in
629 organic agricultural production at 7 CFR 205.601. Like ammonium glycinate, lignosulfonates can form
630 chelates with cationic micronutrients, increasing their water solubility and bioavailability (USDA 2011).
631 Lignosulfonates are derived from the biopolymer lignin via the pulping process (Cieschi et al. 2016, USDA
632 2011). Studies have shown that these chelating agents increase the uptake of both zinc and iron
633 micronutrients in crops (Cieschi et al. 2016). Chelating agents have variable bonding strengths to their
634 central atoms (micronutrients) that are dependent on the media and pH of that media, as well as the
635 identity of the micronutrient itself. Based on these differences, it is likely that ammonium glycinate may be
636 more appropriate as a chelating agent for certain micronutrients and may more efficiently deliver those
637 micronutrients in certain soil conditions when compared to lignin sulfonate.

638
639 **Evaluation Question #12: Describe any alternative practices that would make the use of the petitioned**
640 **substance unnecessary (7 U.S.C. § 6518 (m) (6)).**
641

642 Trace amounts of micronutrients are essential to ensure proper plant function and the nutritional value of
643 the crops harvested. However, these cationic species form insoluble hydroxide salts in alkaline soils,
644 limiting the availability of these nutrients for plant uptake (Grusak et al. 1999, Janmohammadi et al. 2016).
645 This has been shown to be exacerbated when water is also deficient in the soil (Janmohammadi et al. 2016).
646 Ammonium glycinate and other chelating agents overcome this problem by increasing the water solubility
647 of the micronutrients, allowing plants to more efficiently absorb these micronutrients.

648
649 An alternative to the application of micronutrient chelates is the application of organic matter in the form
650 of manure or compost. These sources of organic matter include micronutrients, natural chelates, such as
651 organic and amino acids, and microbes that produce natural chelating agents (Adeleke et al. 2017, Chen et
652 al. 1998, Sorrenti et al. 2012). Sorrenti et al. have reported that compost-based treatments have been shown
653 to enhance yield and quality of pears in calcareous soil, although these results were less successful than the
654 application of iron-chelates (Sorrenti et al. 2012).

655
656 As an alternative to using chelated micronutrients, non-chelated micronutrient are used to remedy
657 deficient soil systems, as approved at 7 CFR 05.601. Non-chelated micronutrients exist as inorganic salts
658 and are both synthetically and minerally derived. They exist in many different combinations of

659 micronutrient cations and inorganic anions. Since natural forms are found in minerals (solids) they have
660 low water solubility, limiting their bioavailability for plant absorption. Furthermore, if the soil is alkaline
661 those micronutrients with water solubility will likely be converted to the insoluble hydroxide salts
662 discussed above. Moreover, this approach remains limited in water deficient soils, which may be unable to
663 sufficiently solubilize the micronutrients for delivery to the root. In comparison, the application of
664 micronutrients as chelates (such as glycinate chelates) prevents the formation of insoluble salts (such as the
665 hydroxides discussed above) since the chelated micronutrient is enveloped by the chelating agent,
666 rendering it unreactive.

667
668 Another alternative to chelated micronutrients is acidifying the soil to prevent micronutrient-hydroxide
669 formation and to liberate the originally insoluble nutrient sources. However, as discussed above in
670 Evaluation Question #11, this approach may result in significant negative ecological changes, including
671 depletion of existing nutrient stores, water pollution, physiological degradation of the soil, and increased
672 mineral toxicity.

Report Authorship

674
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683 All individuals are in compliance with Federal Acquisition Regulations (FAR) Subpart 3.11 – Preventing
684 Personal Conflicts of Interest for Contractor Employees Performing Acquisition Functions.

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