Peroxylactic acid

Handling/Processing

Identification of Petitioned Substance

Chemical Names:
(2*S*)-2-hydroxypropaneperoxoic acid;
2-hydroxy-propaneperoxoic acid;
propaneperoxoic acid, 2-hydroxy-;
lactic acid hydroperoxide

Other Name:
perlactic acid

Trade Names:
Neotox™

CAS Numbers:
75033-25-9

Other Codes:
UN Number 3109 (organic peroxide type F, liquid)

Summary of Petitioned Use

Peroxylactic acid has been petitioned for addition to 7 CFR 205.605(b) of the National List as an antimicrobial processing aid (Zee Company, Inc., 2021). It is added to process water, ice or brine which are then used during the processing of organic meat, poultry carcasses, parts, trims and organs (Zee Company, Inc., 2021).

The authors of this report found information on peroxylactic acid to be scarce in scientific literature. While there are numerous patents covering peroxylactic acid, many were issued less than a year prior to the writing of this report, or are only a few years older. Patents are not typically primary sources for the results of scientific studies, as opposed to peer-reviewed journal articles. The information in this report therefore reflects the data available at the time of writing. Peroxylactic acid will be referred to throughout this report by the initialism POLA to distinguish it from the more common substance, polylactic acid (PLA).

Characterization of Petitioned Substance

<u>Composition of the Substance:</u>
Peroxylactic acid (POLA) is a peroxycarboxylic acid[1] (Li, Prideaux, et al., 2021). *Carboxylic* acids (R-COOH) have an OH group (alcohol) bonded directly to a carbon atom. However, in peroxycarboxylic acids, there is an extra oxygen between the carbon and the alcohol group (Ganguly-Mink et al., 2020), as highlighted in Figure 1. These acids have the general formula R-$(COOOH)_n$, where R is a functional group; and "n" represents the number 1, 2, or 3 (Li et al., 2019; Moore, 2019). Peracetic acid (PAA) is a well-known peroxycarboxylic acid (Li et al., 2019; Ogata & Sawaki, 1965). Others include peroxyoctanoic acid and peroxypropionic acid (Li et al., 2019).

Pure POLA has the chemical formula $C_3H_6O_4$ (PubChem, 2021). There are at least two configurations (isomers) of POLA (Baggioli et al., 2012; Christo, 2015). It is formed by reacting lactic acid with hydrogen peroxide (Baggioli et al., 2012; Christo, 2015), and both isomers of POLA exist in equilibrium with unreacted lactic acid and hydrogen peroxide (Baggioli et al., 2012; Christo, 2015).

[1] Peroxycarboxylic acids, also known as peroxy acids or peracids, are a group of substances characterized by a –O–OH group that has replaced the –OH group in the corresponding carboxylic acid (Britannica, 2021).

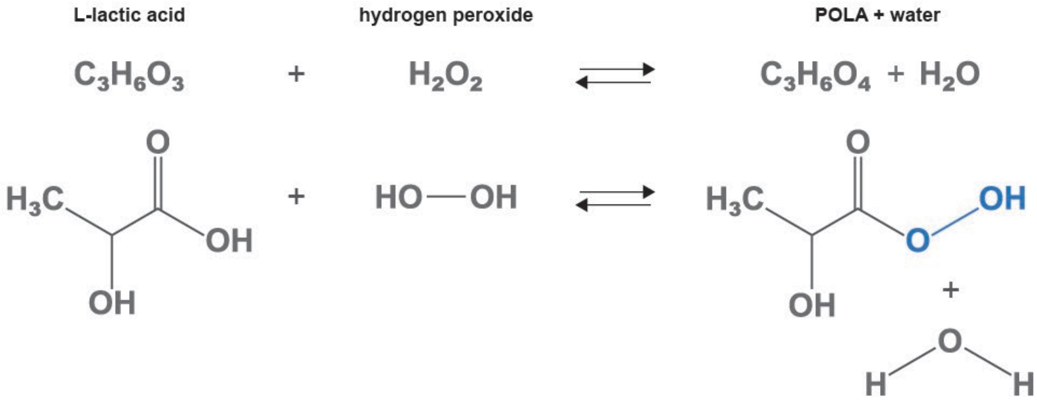

Figure 1: The equilibrium reaction of lactic acid and hydrogen peroxide to create peroxylactic acid, highlighting the characteristic O-OH bond of peroxycarboxylic acids. Adapted from Bullard et al., 2021.

<u>Source or Origin of the Substance:</u>

The petitioned substance is formed through an equilibrium reaction between L-lactic acid (CAS No. 50-21-5) and hydrogen peroxide (CAS No. 7722-84-1). As with other peroxycarboxylic acids, the formation of POLA from lactic acid and hydrogen peroxide can be catalyzed by a strong mineral acid, such as sulfuric acid (Bullard et al., 2021; Ogata & Sawaki, 1965). Ogata and Sawaski (1965) reported that the formation of peroxycarboxylic acids increased with the use of increasingly concentrated sulfuric acid. The rate of formation without an added mineral acid was reported as being negligible (Ogata & Sawaki, 1965). Once formed, peroxycarboxylic acids can be self-reactive and susceptible to exothermic degradation, releasing energy as heat as they spontaneously break down (Li, McSherry, et al., 2021; Nagel & Li, 2021).

Other methods for the chemical synthesis of POLA as described in various patents are discussed in *Evaluation Question 1*.

<u>Properties of the Substance:</u>

POLA is a colorless liquid solution that has been reported to have either no odor (Li, Prideaux, et al., 2021) or low odor (Ganguly-Mink et al., 2020), similar to lactic acid (Zee Company, Inc., 2021). It has a lower odor profile than peracetic acid (PAA) (Ganguly-Mink et al., 2020; Li, Prideaux, et al., 2021; Zee Company, Inc., 2021), which has a strong, punget acrid odor (NOP, 2016a). See other properties of POLA in Table 1.

Concentrated POLA as described in the petition has a pH less than 2 (Zee Company, Inc., 2021). It is fully miscible in water but does not dissolve in food products (Zee Company, Inc., 2021). Some peroxycarboxylic acids are more stable than others, due to the arrangement of functional groups within the molecule (Ganguly-Mink et al., 2020). POLA has been reported to be relatively unstable (Ganguly-Mink et al., 2020; Li, Prideaux, et al., 2021). However, Bullard et al. (2021) found in trials, and reported in their patent, that POLA degraded more slowly initially than PAA.

Table 1: Chemical and Physical Properties of Peroxylactic acid

Property	Value
Color	Colorless
Odor	Odorless – low odor
Average Mass	106.077 g/mol
Density at 20 ºC	1.140 g/cm
Vapor pressure at 20ºC	Not determined
Flash point	>55 ºC (>131 ºF)
pH	<2

Source: Ganguly-Mink et al., 2020; Li et al., 2017; Li, Prideaux, et al., 2021; Zee Company, Inc., 2021

Specific Uses of the Substance:

POLA is a disinfectant with a broad range of antimicrobial activities (Vodolazhenko et al., 2020). It has potential applications in food processing and medical settings, though historically its cost and unstable nature have precluded its widespread use (Vodolazhenko et al., 2020).

POLA is petitioned for use as an antimicrobial agent in process water, ice, and brine used in contact with raw meat and poultry products (Zee Company, Inc., 2021). It may be used in soaking, dipping, chilling, spraying, quenching, rinsing and/or washing food products.

The petitioner claims that it is particularly efficacious in controlling the pathogen *Campylobacter jejuni*, as well as *Salmonella spp.* (Zee Company, Inc., 2021). *Campylobacter* causes campylobacteriosis, one of the most common bacterial infections worldwide (Soro et al., 2020). Contaminated poultry products have been identified as the primary source of these infections (Umaraw et al., 2017). Efficacy trials in the patent claim that POLA is effective as an antimicrobial against *E. coli* O157:H7 on meat products (Bullard et al., 2021). One graduate research study applied POLA to feed water (125 ppm) for broiler chickens during pre-harvest feed withdrawal[2] (Herron, 2000). The purpose was to lower the internal pathogen load and thereby reduce pathogen contamination of the carcass during processing. The POLA treatment was found to significantly reduce *Salmonella* in the upper gastrointestinal tract of broiler hens (Herron, 2000).

POLA is also used as an oxidant (Larson & Tichy, 2010), such as a bleaching agent for pulp, paper, and textiles, as well as in the chemical synthesis of epoxy compounds (Vodolazhenko et al., 2020). It has also been used as a scale inhibiting water treatment (Balasubramanian et al., 2016).

Approved Legal Uses of the Substance:

EPA

Antimicrobial substances added to water that comes into contact with food are excluded from the definition of "pesticide chemical" under 201(q)(1)(B)(i) of the Federal Food Drug and Cosmetic Act (FFDCA), as amended by the Antimicrobial Regulation Technical Corrections Act of 1998 (ARTCA). Thus, antimicrobial substances are not under EPA's jurisdiction, but are instead regulated by the FDA as food additives under §409 of FFDCA.

FDA

POLA is the subject of three different FDA Food Contact Notifications (FCNs; see Table 2). FCNs are approvals issued by the FDA for food contact substances (FCSs) that have been demonstrated to be safe for their intended use (U.S. FDA, 2021a). FCNs are effective only for the manufacturer listed in the FCN and its customers, and only for the intended use(s) stated (U.S. FDA, 2021a).

The first FCN addressing the use of POLA is No. 1558, issued in 2015 to Mantrose-Haeuser Co., for an aqueous mixture of hydrogen peroxide, percitric acid, POLA, citric acid, and lactic acid for use as an antimicrobial in wash water used in the processing and or preparation of whole and cut raw fruits and vegetables. Limitations on this formulation are that the components of the FCS mixture will not exceed 61 ppm peroxyacids or 430 ppm hydrogen peroxide in process water for washing fruits and vegetables in food processing facilities (Mantrose-Haeuser Co., Inc, 2015).

Valley Chemical Solutions is the manufacturer listed in the other two FCNs for POLA formulations, FCN 1496 and FCN 1995. The petition references one of these, FCN No. 1946, issued May 2019. This FCN is for an aqueous mixture of peroxylactic acid, hydrogen peroxide, lactic acid, water, optionally 1-hydroxy-ethylidine-1,1-diphosphonic acid (HEDP), optionally sulfuric acid, and optionally phosphoric acid. It is for use as an antimicrobial agent in process water, ice, or brine used in the production, processing, and

[2] Before birds are harvested, feed and water are withheld so that the animals evacuate their intestines prior to slaughter. Producers use this practice to reduce fecal contamination of carcasses (Northcutt & Buhr, 2010).

preparation of meat and poultry products. The limitations are 1,000 ppm POLA, 2,384 ppm hydrogen peroxide, and 5.5 ppm HEDP in process water or ice that contacts meat or poultry carcasses, parts, trim, and organs. For process water, ice, or brine that contacts processed and pre-formed meat and poultry, the limitations are 495 ppm POLA, 1,180 ppm hydrogen peroxide, and 2.7 ppm HEDP (Valley Chemical Solutions, 2019a).

FCN No. 1995 is for an aqueous mixture of peroxylactic acid (the acronym given in the FCN is PAA, but the CAS No. given, 75033-25-9, is that of peroxylactic acid), hydrogen peroxide, lactic acid, optionally HEDP, optionally sulfuric acid, optionally dipicolinic acid (DPA), and optionally phosphoric acid. Its use is listed as an antimicrobial agent in process water, brine, or ice in the processing of meat and poultry. The FCN limits the components of the FCS mixture to no more than 1,000 ppm PAA (presumably referring to POLA), 2,480 ppm hydrogen peroxide, 5.7 ppm HEDP, and 1.64 ppm DPA in process water or ice that contacts meat or poultry carcasses, parts, trim, and organs. For process water, ice, or brine that contacts processed and pre-formed meat and poultry, the limits are 268 ppm PAA (presumably POLA), 665 ppm hydrogen peroxide, 1.53 ppm HEDP, and 0.44 ppm DPA (Valley Chemical Solutions, 2019b).

USDA-FSIS

The formulation described by FCN No. 1946 is also covered under the Food Safety and Inspection Service (FSIS) Directive 7120.1, "Safe and Suitable Ingredients Used in the Production of Meat, Poultry and Egg Products" (FSIS, 2021c). The petition also refers to USDA "No Objection Letter," Log No. 2019-75-ING for FCN no. 1946. This letter is not publicly available.

<u>Action of the Substance:</u>

POLA's antimicrobial action is thought to be similar to that of other peroxycarboxylic acids (Zee Company, Inc., 2021), where the O—OH bond, or peroxy moiety, (see Figure 1) is highly reactive in the release of oxygen that oxidizes, or reacts with, other compounds (Jean, 2016; Kitis, 2004; Wessels & Ingmer, 2013). In the case of pathogenic microorganisms, oxygen from the peroxycarboxylic acid oxidizes critical bonds[3] in proteins (on cell surfaces and inter-cellular), enzymes, and other metabolites (Kitis, 2004). These reactions cause proteins to denature, or lose their structure and function (Zee Company, Inc., 2021). The peroxy moiety can also cause the dihydroxylation, or breaking, of C-C double bonds in microbial cells. Additionally, peroxycarboxylic acids react with lipids of the phospholipid membrane, thereby disrupting transport into and out of cells (Christo, 2015; Kitis, 2004). Thus, it is by various mechanisms that peroxycarboxylic acids such as POLA are likely to exert antimicrobial effects (Wessels & Ingmer, 2013).

<u>Combinations of the Substance:</u>

The petitioner's product is formulated with hydroxyethylidine-1,1-diphosphonic acid (HEDP) as a stabilizer at a rate of 5.5 ppm per 1,000 ppm POLA (Zee Company, Inc., 2021). Sulfuric acid (13 ppm per 1,000 ppm POLA) may also be optionally included in the formulation as a catalyst to drive the equilibrium towards POLA formation (Zee Company, Inc., 2021).

The list of potential combinations of other substances with POLA is extensive in the patent literature. However, only a subset of these optional additives are approved in Food Contact Notifications. These are described above, under *Approved Legal Uses of the Substance*.

Stabilizers are essential to the stability of POLA and other peroxycarboxylic acid sanitizers, as they maintain the antimicrobial activity of such solutions for a long enough shelf-life to enable effective end use (Li, McSherry, et al., 2021). POLA formulations are susceptible to metal ion impurities such as iron, copper, manganese, and chromium ions (Goor et al., 2012; Nagel & Li, 2021). These impurities catalyze the decomposition of components of the POLA formulation, notably hydrogen peroxide (Nagel & Li, 2021).

[3] These include disulfide bonds, also described as sulfhydryl and sulfur bonds (Kitis, 2004), which are involved in the three-dimensional folding of proteins, essential for proper function (Ustunol, 2015), and present in the active sites of bacterial enzymes such as dehydrogenase (Skowron et al., 2019).

POLA is therefore difficult to stabilize (Christo, 2015; Nagel & Li, 2021). In order to do so, sequestering agents are added to the formulation to chelate metal impurities and bind other reactive chemicals that form over time (Bullard et al., 2021; Nagel & Li, 2021). Li, McSherry et al. (2021) noted the importance of stabilizers in peroxycarboxylic acid compositions for non-refrigerated transport and storage, as they raise the solutions' self-accelerated decomposition temperature. Stabilizers are also often needed in hydrogen peroxide solutions due to the presence of impurities that catalyze hydrogen peroxide decomposition (Goor et al., 2012). The FDA limits the amount of stabilizers that can be used in commercial formulations intended for human consumption, as described in Food Contact Notifications (U.S. FDA, 2021a).

Stabilizers are additionally needed for safe transport and handling of POLA and other peroxycarboxylic acids (Uhl et al., 2000). Due to their reactivity, organic peroxides such as POLA and PAA are strictly regulated by the U.S. Department of Transportation (Li, McSherry, et al., 2021). Reactions involving organic peroxides are exothermic, producing heat faster than they can typically cool (Li, McSherry, et al., 2021). These can result in "runaway reactions," creating large volumes of gas that can lead to explosions (Li, McSherry, et al., 2021). To ensure it can be moved safely, stabilizers are required for POLA solutions that will be transported.

According to Nagel and Li (2021), identifying suitable stabilizing agents can be challenging because few materials have been found to be compatible with strong acids and strong oxidizers, which also have an acceptable toxicity profile for the intended use. However, the patent literature references a wide array of possible stabilizers and other additives. The most common stabilizer in peroxycarboxylic acid compositions is HEDP. Others include salts of HEDP, pyrophosphoric acid and its salts, and phosphonate-based stabilizers, such as phosphoric acid and its salts (Nagel & Li, 2021). Although it is one of the most common stabilizers, HEDP can degrade completely within months, at which time the metal ions it chelated return to solution and again become active catalysts (Nagel & Li, 2021). Stabilizers commonly added to hydrogen peroxide include sodium pyrophosphate and sodium stannate, as well as phosphonic or aminophosphonic acids (Goor et al., 2012).

Several patents suggest the combined use of different types of stabilizers to more effectively deactivate metal impurities (Li et al., 2019; Nagel & Li, 2021). Picolinic acids such as dipicolinic acid (DPA, or 2,6-pyridinedicarboxylic acid), can be used as a synergistic stabilizer with HEDP (Li, McSherry, et al., 2021) (Nagel & Li, 2021). DPA functions as a scavenger of radicals that occur despite the use of another stabilizer such as HEDP. By scavenging radicals, DPA helps protect molecules like HEDP, while HEDP helps reduce the formation of radicals in the first place (Nagel & Li, 2021). One disadvantage to the use of DPA is its cost (Nagel & Li, 2021).

The petition references a patent for POLA generation that includes other alternative substances that may be used as catalysts or sequestering agents (Bullard et al., 2021).

Alternative catalysts are noted as:

- phosphoric acid
- sulfamic acid
- hydrochloric acid
- nitric acid
- boric acid
- or mixtures thereof

Alternative sequestering agents are noted as:

- aminotris (methylenephosphonic acid) (ATMPT)
- ethylenediaminetetra (methylenephosphonic acid) (EDTMP)
- tetramethylenediaminetetra (methylenephosphonic acid) (TDTMP)
- hexamethylenediaminetetra (methylenephosphonic acid) (HDTMP)
- diethylenetriaminepenta methylenephosphonic acid (DTPMP)
- 2 - phosphonobutane 1,2,4 - tricarboxylic acid
- nitrilotrimethylenetris (phosphonic acid)

- DPA
- or mixtures thereof

The petition also notes the possible addition of a buffering agent to the aqueous equilibrium solution to adjust the final pH, such as sodium or potassium hydroxide, the sodium or potassium salt of carbonic acid, phosphoric acid, silicic acid, or mixtures thereof depending on the desired pH (Bullard et al., 2021).

An international patent outlines the use of stabilizers, surfactants, defoamers and a pH adjuster in addition to lactic acid and hydrogen peroxide used to generate POLA *in situ*.

The stabilizers are diphosphonic acids and their derivatives such as:

- diphosphonic (1-hydroxyethylene) disodium acid
- EDTA (ethylenediaminetetraacetic acid)
- phenacetin (N-4 (ethoxyphenyl) ethanamide)
- Nipagin® (methyl paraben)
- phosphate salts
- HEDP

The defoamers are silicone derivatives, such as aqueous emulsions of dimethylpolysiloxane.

The surfactants are generically reported as "ethoxylates, sulphates, phosphates, amphoteres, cationics, anions and mixtures thereof." Cationic quaternary ammonium surfactants such as dialkyl dimethyl benzyl ammonium chloride and or didecyldimethyl ammonium chloride may be added and are noted as having a synergistic antimicrobial effect. Finally, the solution may be pH adjusted with phosphoric acid (Christo, 2015).

Another patent presents the use of urea or a urea/chelator blend as an alternative stabilizer to DPA, and to help reduce or eliminate the need for HEDP as a stabilizer (Nagel & Li, 2021).

A patent by Li et al. (2019) claims that excess hydrogen peroxide may diminish the efficacy of peroxycarboxylic acid antimicrobial products. The patent describes a process to increase the proportion of peroxycarboxylic acid relative to hydrogen peroxide, using DPA and the additives sodium xylene sulfonate or sodium cumene sulfonates. These additives improve DPA's solubility, and therefore its capacity to stabilize. Anionic surfactants and ionic surfactants are also used (Li et al., 2019).

Two patents describe the generation of POLA *in situ*, which can reduce or eliminate the need for stabilizers and/or solvents (Li et al., 2017; Li, Prideaux, et al., 2021). However, these formulations may contain other additives such as acidulants, hydrotropes[4], dispersants, antimicrobial agents, solidification agents, colorants, odorants, and numerous other constituents that can be added to the composition (Li et al., 2017).

Status

<u>Historic Use:</u>

POLA has a short history in food sanitizing applications. Mantrose-Haeuser Co. was granted an FCN approval from the FDA in 2015 for a fruit wash containing percitric acid (the peroxycarboxylic acid formed from citric acid and hydrogen peroxide) and POLA. A patent from 2015 describes POLA as unstable, and therefore necessary to be produced in-situ (Christo, 2015). A patent from 2020 claimed that the instability of POLA prevented its use in practice (Ganguly-Mink et al., 2020). Two patents for POLA formulations that include stabilizers were issued within the last year (Bullard et al., 2021; Li, Prideaux, et al., 2021).

[4] Hydrotropes are substances that "increase the solubility of sparingly soluble organic substances in water" (Kunz et al., 2016).

Organic Foods Production Act, USDA Final Rule:

Peroxylactic acid does not appear anywhere in the Organic Foods Production Act of 1990 (OFPA) or the USDA organic regulations at 7 CFR 205. The related substance, peracetic acid, does appear in several sections of the USDA organic regulations:

- 7 CFR 205.601(a)(6) as an algicide, disinfectant and sanitizer for use in disinfecting equipment, seed, and asexually propagated planting material. Also permitted in hydrogen peroxide formulations as allowed in § 205.601(a) at concentration of no more than 6% as indicated on the pesticide product label;
- 7 CFR 205.601(i)(8) as plant disease control for use to control fire blight bacteria. Also permitted in hydrogen peroxide formulations as allowed in § 205.601(i) at concentration of no more than 6% as indicated on the pesticide product label;
- 7 CFR 205.603(a)(24) Peroxyacetic/peracetic acid (CAS #-79-21-0) as a disinfectant and sanitizer for sanitizing facility and processing equipment;
- 7 CFR 205.605(b) as a synthetic nonagricultural substance allowed as ingredients in or on processed products labeled as "organic" or "made with organic" (specified ingredients or food group(s))," Peracetic acid/Peroxyacetic acid (CAS # 79-21-0) for use in wash and/or rinse water according to FDA limitations. For use as a sanitizer on food contact surfaces.

International

Canada, Canadian General Standards Board—CAN/CGSB-32.311-2015, Organic Production Systems Permitted Substances List

Peroxylactic acid does not appear on the Permitted Substances List (PSL), CAN/CGSB-32.311. A new (but different) peroxycarboxylic acid sanitizing substance, peroxyoctanoic acid, was added to Table 7.4 of the PSL in 2020, permitted on organic product contact surfaces with a mandatory removal event. PAA also appears on the PSL, in Table 7.3 as a food-grade cleaner, disinfectant and sanitizer permitted without a mandatory removal event, for use on food and plants in wash or rinse water, and on food contact surfaces.

When sanitizing substances listed on the PSL are ineffective, producers are allowed to use other sanitizers on organic product contact surfaces as long as a removal event occurs prior to organic production (CAN/CGSB-32.310-2020 subclause 8.2.3). There is no provision for direct-food contact of non-PSL sanitizers with organic products. Thus, while POLA could be approved under 8.2.3 for sanitizing a food contact surface, it could not be approved as labeled for food-contact use.

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

The CODEX Guidelines do not allow for the use of POLA at Annex 2 (Permitted Substances for the Production of Organic Foods). The Guidelines do not cover sanitation in food handling and processing, except to prohibit the use of ionizing radiation for such a purpose. Lactic acid as a food additive is permitted for fermented vegetable products (Annex 2, Table 3), as a coagulation agent and pH adjuster for milk products (Annex 2, Table 4), and in sausage casings (Annex 2, Table 3). Hydrogen peroxide is not included in Annex 2.

European Economic Community (EEC) Council Regulation—EC No. 834/2007, 889/2008, and 2018/848

The European Union (EU) is in the process of implementing new organic regulations, (EU) 2018/848, and associated Commission Implementing Regulation (EU) 2021/1165 (The European Commission, 2021). However, the new regulation's lists of products for cleaning and disinfection will not be established before January 1, 2024. Therefore, those listed in (EC) No 889/2008 are permitted until December 31, 2023. POLA is not an approved material under (EU) 889/2008 Organic Standards; it does not appear in any of the Annexes. Thus, POLA is not currently allowed under organic regulations of the EU.

Japan Agricultural Standard (JAS) for Organic Production

The Japanese Agricultural Standard for Organic Processed Foods (Notification No. 1606 of the Ministry of Agriculture, Forestry and Fisheries of October 27, 2005) does not include any reference to POLA. Sanitizing agents such as sodium hypochlorite, hypochlorous acid water, fumaric acid, and monosodium fumarate are listed for certain disinfection purposes in Table 1: Additives. No peroxycarboxylic acids are included.

IFOAM – Organics International

POLA is not included in the IFOAM NORMS for organic production and processing. Appendix 4, Table 2 lists substances that may be used as equipment cleaners and disinfectants, and that may come into direct contact with the organic product. Lactic acid and hydrogen peroxide, the materials used to form POLA, appear in Appendix 4, Table 2, as does PAA, a more common peroxycarboxylic acid. However, POLA itself is not included and is therefore not permitted under this standard.

Evaluation Questions for Substances to be used in Organic Handling

<u>Evaluation Question #1:</u> Describe the most prevalent processes used to manufacture or formulate the petitioned substance. Further, describe any chemical change that may occur during manufacture or formulation of the petitioned substance when this substance is extracted from naturally occurring plant, animal, or mineral sources (7 U.S.C. § 6502 (21)).

The most prevalent processes to manufacture POLA are identified by patent holder.

Bullard et al. method

The petition for POLA references a patented manufacturing process (Bullard et al., 2021) in which:

1. A solution of lactic acid is mixed with deionized water and agitated.
2. The manufacturer optionally adds acid sequestrants[5] and catalysts. These materials, along with hydrogen peroxide, are added sequentially to the lactic acid solution.
3. The manufacturer mixes and agitates the solution in a vessel for up to six hours. They maintain the product between 20 ^{o}C and 100 ^{o}C for at least 24 hours, for up to seven days, allowing the reaction to reach equilibrium. The molar ratio of the reagents is reported to be approximately 3:1 to 6:1 hydrogen peroxide to lactic acid.
4. After equilibrium is reached, the solution is stored at a temperature between 15 ^{o}C and 25 ^{o}C to help maintain the product's equilibrium and stability (Bullard et al., 2021).

Christo method

A similar process is described in another patent for a peroxylactic acid sanitizing product (Christo, 2015):

1. Lactic acid is diluted to a concentration of 1-6 percent with deionized water, but still maintaining a pH of less than 2.44.
2. Concentrated hydrogen peroxide is added and mixed until the concentration reaches 1-6 percent.
3. Stabilizers are added and mixing continues for two hours.
4. Surfactant(s) and defoamer(s) are added and stirred for approximately two hours or until the hydrogen peroxide concentration reaches at least 1 percent concentration by weight.
5. The pH may then be adjusted with an organic acid to a pH of 2.5 – 3.0 (Christo, 2015).

Li in situ method

POLA and other peroxycarboxylic acids can also be produced *in situ*. The formulation presented by Li et al. (2021) consists of lactide,[6] an alkaline substance, and hydrogen peroxide (or a substance that generates hydrogen peroxide when in contact with a liquid) (see Figure 3). The manufacturer combines these ingredients into a premix that is kept separate from the liquid reagents (such as water). The user then combines the liquid and dry fractions to generate peroxylactic acid on site. This produces a solution with a

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[5] Sequestrants are typically salts that chelate metals or stabilize substances for the purposes of preservation (Msagati, 2013).

[6] Lactide is a powdered crystalline di-lactone formed from two molecules of lactic acid. Lactides may also form from other acids besides lactic acid. A lactone is a carbon-based molecular ring, also containing an oxygen atom within the backbone of the ring; also known as a cyclic ester (Bruice, 2001).

pH less than 7, within five minutes. The final product contains approximately 1 ppm peroxycarboxylic acid (peroxylactic acid in this case) at the point of contact (Li, Prideaux, et al., 2021).

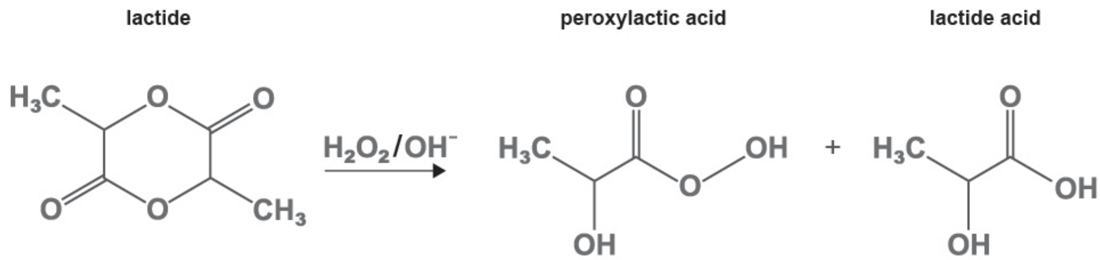

Figure 3. Alternative pathway for chemical synthesis of POLA *in-situ* (Li, Prideaux, et al., 2021).

The benefits of this method include the short time period needed to produce the sanitizing solution, and diminished concerns with instability since the solution is used immediately (Li, Prideaux, et al., 2021).

Other methods:

- A patented process uses a selected catalase or peroxidase enzyme to minimize the concentration of hydrogen peroxide in post-reaction POLA formulations (Li et al., 2019). This claims to diminish the negative effect of hydrogen peroxide on the efficacy of POLA toward some microorganisms (Li et al., 2019).
- Another patent describes a process where a cationic exchange resin (Amberlite IR-120) is used to stabilize POLA produced by mixing a solution of lactic acid and hydrogen peroxide. In this process, the ion exchange resin is placed and remains in the solution (Larson & Tichy, 2010).
- A published study reports a process of electrochemical synthesis of POLA using a pure polished platinum anode to oxidize a concentrated solution of lactic acid and sulfuric acid (Vodolazhenko et al., 2020). In this process, the anode oxidizes the carboxyl group of lactic acid and generates POLA as well as hydrogen peroxide, and releases some oxygen (Vodolazhenko et al., 2020).

<u>Evaluation Question #2:</u> Discuss whether the petitioned substance is formulated or manufactured by a chemical process or created by naturally occurring biological processes (7 U.S.C. § 6502 (21)). Discuss whether the petitioned substance is derived from an agricultural source.

POLA is manufactured by a chemical process, namely, the equilibrium reaction between lactic acid and hydrogen peroxide. Other chemical methods of production have also been explored. The first question in Guidance NOP 5033-1 *Decision Tree for Classification of Materials as Synthetic or Nonsynthetic* asks: "is the substance manufactured, produced, or extracted from a natural source"(NOP, 2016b). While lactic acid can be produced from a natural source (OMRI, 2021), commercial sources of hydrogen peroxide are produced through complex synthetic reactions (Goor, 2012). As a result, POLAis classified as synthetic. While not required, subsequent answers to questions in the decision tree also result in a synthetic classification.

According to NOP 5033-2, POLA is not derived from an agricultural source. It is not a mineral or bacterial culture (Question 1); it is not a microorganism (Question 2); and it is not derived from a crop or livestock product (Question 3) (NOP, 2016b).

<u>Evaluation Question #3:</u> If the substance is a synthetic substance, provide a list of nonsynthetic or natural source(s) of the petitioned substance (7 CFR 205.600(b)(1)).

Scientific literature was not found to indicate that nonsynthetic or natural sources for POLA exist.

<u>Evaluation Question #4:</u> Specify whether the petitioned substance is categorized as generally recognized as safe (GRAS) when used according to FDA's good manufacturing practices (7 CFR 205.600(b)(5)). If not categorized as GRAS, describe the regulatory status.

POLA is not designated as GRAS. As a food contact substance (FCS)(U.S. FDA, 2021a), its legal approval is governed through the issuance of Food Contact Notifications, as described above under *Approved Legal Uses of the Substance*.

<u>Evaluation Question #5:</u> Describe whether the primary technical function or purpose of the petitioned substance is a preservative. If so, provide a detailed description of its mechanism as a preservative (7 CFR 205.600(b)(4)).

POLA is a preservative. The primary function of POLA, as petitioned, is as an antimicrobial agent (Zee Company, Inc., 2021). Antimicrobial agents are defined by FDA at 21 CFR §170(3)(o)(2) as, "Substances used to preserve food by preventing growth of microorganisms and subsequent spoilage, including fungistats, mold and rope inhibitors, and the effects listed by the National Academy of Sciences/National Research Council under 'preservatives'." The National Academy of Sciences/National Research Council has described preservatives as substances added to foods to prevent or inhibit microbial growth (National Academy of Sciences, 1961).

POLA is an effective oxidizer, disrupting the outer cell membrane of pathogenic microorganisms (Christo, 2015). For more information on its mode of action, please reference the above section, *Action of the Substance*.

<u>Evaluation Question #6:</u> Describe whether the petitioned substance will be used primarily to recreate or improve flavors, colors, textures, or nutritive values lost in processing (except when required by law) and how the substance recreates or improves any of these food/feed characteristics (7 CFR 205.600(b)(4)).

As an antimicrobial agent, POLA is not intended to improve the flavor, colors, textures or nutritive values of food that may be lost in processing. The petitioner notes that it meets the FDA definition of a "processing aid" at 21 CFR §101.100(a)(3)(ii)(c), as it does not have a technical effect in finished products (Zee Company, Inc., 2021).

<u>Evaluation Question #7</u>*:* Describe any effect or potential effect on the nutritional quality of the food or feed when the petitioned substance is used (7 CFR 205.600(b)(3)).

The petitioner states that POLA will not remain on organically processed food (Zee Company, Inc., 2021). The mode of action of POLA is as an oxidizer (Christo, 2015). The European Food Safety Authority (EFSA) evaluated similar materials such as peroxyacetic acid and peroxyoctanoic acid and reported no detectable effects on the oxidation status of fatty acids in poultry carcasses following treatment (EFSA, 2006). As a peroxyacid, it is reasonable to expect similar results for POLA. However, no specific data was found in the scientific literature to address whether the application of POLA to food as an antimicrobial agent may alter that food's nutritional quality.

<u>Evaluation Question #8:</u> List any reported residues of heavy metals or other contaminants in excess of FDA tolerances that are present or have been reported in the petitioned substance (7 CFR 205.600(b)(5)).

POLA formulations may contain impurities from hydrogen peroxide in the form of residual transition metal ions that accelerate decomposition, necessitating in many cases the addition of stabilizers (Nagel & Li, 2021). These metals include iron, copper, and manganese (Galbács & Csányi, 1983). Scientific literature was not found that indicated POLA contains contaminants in excess of FDA tolerances, however.

The GRAS listing for hydrogen peroxide indicates that it must meet specifications of the Food Chemicals Codex, 3rd ed. (1981). The limits for toxic heavy metals in hydrogen peroxide are defined in the Food Chemicals Codex as 4 ppm lead (National Academy of Sciences Food and Nutrition Board, 1996). Limits in concentrated sulfuric acid solutions are 3 ppm arsenic and 5 ppm lead (NOP, 2016a).

<u>Evaluation Question #9:</u> Discuss and summarize findings on whether the manufacture and use of the petitioned substance may be harmful to the environment or biodiversity (7 U.S.C. § 6517 (c) (1) (A) (i) and 7 U.S.C. § 6517 (c) (2) (A) (i)).

The patent referenced in the petition claims that POLA can pose a danger to drinking water even if small quantities leak into the ground (Bullard et al., 2021). According to the safety data sheet (SDS) for Neotox™, the product that is the subject of the petition, POLA disposal in water can be hazardous (Zee Company, Inc., 2021). The SDS instructs users to not allow POLA to reach ground water, watercourse or sewage systems, bodies of water, or drainage ditches if undiluted and not neutralized. It also cautions that rinsing large amounts of POLA into drains or the aquatic environment may lead to acidification and harm aquatic organisms. However, dilution of POLA or oxidation resulting from the sanitizing action of peroxylactic acid raises the solution's pH such that it becomes a low danger for water (Zee Company, Inc., 2021).

The patent literature claims that peroxycarboxylic acids are environmentally benign sanitizers because they easily break down into naturally occurring elements and compounds (Li et al., 2019). This is consistent with the characterization of other peroxycarboxylic acids such as PAA, which are hazardous in direct application, but whose environmental impacts are negligible due to their breakdown during use. Bagglioli et al. (2012) studied the molecular geometry of POLA as it decomposes, and reported that the degradation process occurs by the release of CO_2 (Baggioli et al., 2012). The petition notes that POLA breaks down rapidly into lactic acid and, ultimately, CO_2 and water (Zee Company, Inc., 2021).

The patent referenced in the petition describes the results of trials where POLA was applied to the surface of beef and poultry parts at a rate of 2000 ppm (Bullard et al., 2021). The results claimed that POLA completely decomposed into water and lactic acid within about one hour of contact, resulting in no detectable limit of available POLA or hydrogen peroxide. The patent additionally claimed that oxygen was also one of the degradation products of POLA (Bullard et al., 2021). Hydrogen peroxide decomposes into oxygen and water (Li et al., 2019).

While POLA is itself a discrete substance, it exists as an equilibrium mixture of water, hydrogen peroxide, and lactic acid (Baggioli et al., 2012; Christo, 2015). This equilibrium is easily disturbed by various conditions such as dilution or being subjected to temperatures above 56 °C. Other factors that can destabilize this equilibrium include the presence of catalysts, changes in pressure, changes in the concentration of components, photo degradation of hydrogen peroxide, and metal ion contaminants (Christo, 2015).

The breakdown products of POLA, lactic acid and CO_2, are relatively non-corrosive to metallic surfaces as compared to PAA, innocuous for incidental contact, and generally considered environmentally friendly (Li et al., 2019).

No other information on POLA's impact to the environment or biodiversity was found in the scientific literature. However, as it is a peroxyacid similar to peracetic acid, the technical report on *Peracetic Acid* (NOP, 2016a) may be informative to the question.

One way in which the use of POLA may be favorable to the environment and biodiversity is through sanitation of re-used water, to address water shortages including those related to drought (Pereira et al., 2009). POLA is petitioned for use in poultry process water. Poultry processing uses approximately 21 to 30 L of potable water per bird (Micciche et al., 2019). Water use in the food industry increased 40 percent over ten years from 1998 to 2008, and operators have sought to lower the water demand of poultry processing through water re-use. However, food safety concerns require contaminant-free water, necessitating the use of sanitizers (Micciche et al., 2019), such as POLA.

<u>Evaluation Question #10:</u> Describe and summarize any reported effects upon human health from use of 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(m)(4)).

The effects of POLA use on human health are not reported in the literature. However, in 2006, the European Food Safety Authority (EFSA) evaluated peroxycarboxylic acids used as food contact sanitizers, and noted that no data was available that suggested a safety concern (EFSA, 2006). The report noted that because poultry carcasses are processed (washed, cooked) prior to consumption, peroxycarboxylic acid solutions do not present a safety concern when used as a direct application antimicrobial agent (EFSA, 2006).

The SDS for Neotox™ includes lethal dose (LD_{50})[7] toxicity levels for lactic acid, but not the other ingredients or the final formulation (Zee Company, Inc., 2021). The SDS shows that lactic acid has an oral LD_{50} of 3,310 mg/kg in rats, and a dermal LD_{50} of 1,060 mg/kg in rabbits. The SDS also lists hazards information for POLA: "May intensify fire; oxidizer. Causes severe skin burns and eye damage. Causes serious eye damage. Harmful if swallowed. Harmful in contact with skin. Harmful if inhaled" (Zee Company, Inc., 2021). Processors that use POLA in their operation must follow safety procedures regarding the use of personal protective equipment and proper handling and use.

The label submitted with the petition for the brand name product, Neotox™, indicates a GHS (Global Harmonized System) classification of H272. The GHS classification system is an internationally recognized standard for the labeling of chemicals. H272 means that the label must include hazard statements that the substance may intensify fire and is an oxidizer, and prescribes precautionary statements, storage, and disposal measures (Vereinte Nationen, 2019).

Evaluation Question #11: Describe any alternative practices that would make the use of the petitioned substance unnecessary (7 U.S.C. § 6518(m)(6)).

POLA is used as a food-contact sanitizer. Under the Food Safety Modernization Act (FSMA), food facilities must have a plan for risk-based preventive controls to minimize or prevent hazards such as the spread of food borne illness (U.S. FDA, 2020). According to FSIS, the contamination of poultry parts and carcasses with fecal material and enteric pathogens is a hazard reasonably likely to occur in slaughter facilities (FSIS, 2021a). FSIS therefore requires operations to maintain Hazard Analysis and Critical Control Points (HACCP) plans and standard operating procedures for sanitization (FSIS, 2021a). Sanitation controls, including antimicrobial substances used to mitigate pathogens in or on edible food (FSIS, 2021a), are part of required hazard prevention. Other practices are also recommended, such as the use of good manufacturing processes, and cleaning and sanitation of equipment and materials throughout production and processing, as well as proper maintenance of equipment.

There are several points where meat and poultry processors can take steps to prevent contamination of the product with foodborne pathogens. These processing steps include scalding, defeathering, evisceration, final washing, chilling, and storage for further processing. Critical control points in further processing can include receiving, weighing, cooking, chilling, emulsifying, and packaging in the case of ready-to-eat poultry production (Rothrock et al., 2019).

For example, during scalding, the direction of water flow should be against incoming carcasses so that carcasses are cleaned by increasingly cleaner water (dirty to clean gradient) as they move through the process (Umaraw et al., 2017). Multiple stage tanks, high flow rates, and adequate agitation also help dilute the bacterial load in the tanks (FSIS, 2021a). Scalding temperatures above 116.6°F (47°C) can control *Campylobacter* growth and initiate inactivation, however, scalding at 132 °F (56 °C) is more effective at reducing counts (FSIS, 2021a). FSIS also recommends monitoring the pH of the scald water.

Following scalding, poultry carcasses are defeathered, after which producers should use a sanitizer rinse (FSIS, 2021a). Producers can reuse process water for the same purpose, but must follow regulations for decontamination prior to reuse. The Animal and Plant Health Inspection Service (APHIS) requires "that measures be taken to reduce physical, chemical, and microbiological contamination of reused water so as to prevent contamination or adulteration of product" (U.S. FDA, 2021b). Air chilling following evisceration has been found to decrease levels of *Campylobacter* on carcasses (Umaraw et al., 2017).

[7] LD_{50} (lethal dose) describes the quantity of a substance given orally or applied to skin that kills 50% of test animals in a specified period of time (Gowariker, 2009).

Lowering pathogen loads prior to slaughter can reduce risks of contamination. Neal-McKinney et al. (2014) showed that vaccination protected chickens from colonization by *C. jejuni*, mitigating some of the risk for contamination during processing. The vaccine was composed of recombinant proteins from the bacteria's surface (Neal-McKinney et al., 2014).

Sanitizers can also be used for pathogen control preharvest. Herron (2000) found that the addition of POLA (125 ppm) added to poultry drinking water pre-harvest resulted in a 3.21 Log_{10} reduction of *Salmonella* in the crop of harvested birds. POLA was more effective than percitric acid and peracetic acid (Herron, 2000). Umaraw et al. (2017) note that treating poultry with biologics and probiotics on-farm can help prevent *Campylobacter* contamination through competitive exclusion of the pathogen by favorable microorganisms.

High pressure pasteurization is another pathogen control measure that may be employed specifically in the preparation of poultry products that are ground, mechanically separated, or de-boned, and which are further chopped, flaked, minced, or otherwise processed to reduce particle size (FSIS, 2021a).

Soro et al. (2020) highlight a number of novel strategies and technologies for controlling *Campylobacter* in poultry meat. These include cold plasma, ultraviolet light, high-intensity light pulses, pulsed electric fields, new antimicrobials, and modified atmosphere packaging.

The above-mentioned safety control measures are not replacements for the use of antimicrobial treatments during the processing of poultry parts and meat. Rather, a suite of measures should be employed to ensure the safety of food products (Umaraw et al., 2017). Integrated approaches are needed in order to reduce the risk of potential infections in humans (Umaraw et al., 2017). This is due to the ubiquitous nature of pathogens, and their ability to develop resistance to antimicrobial substances (Soro et al., 2020). Additionally, according to Rothrock et al. (2019), the limited number of antimicrobials available to organic processors could become problematic as the organic meat sector grows, with increasing size of operations presenting increased risk of pathogen contamination. Likely, a combination of treatments and strategies is required to ensure food safety through effective control of pathogens (Soro et al., 2020).

<u>Evaluation Question #12:</u> Describe all natural (non-synthetic) substances or products which may be used in place of a petitioned substance (7 U.S.C. § 6517(c)(1)(A)(ii)). Provide a list of allowed substances that may be used in place of the petitioned substance (7 U.S.C. § 6518(m)(6)).

There are numerous sanitizers used in the food industry. These include organic acids, such as acetic, citric, lactic, malic, and propionic acid (Ho et al., 2011). Some of these may be nonsynthetic, such as citric acid and lactic acid (OMRI, 2021). Both citric acid and lactic acid are nonsynthetic substances permitted in or on processed products labeled as organic at §205.605(a).

Other sanitizers used in food processing include chlorine materials, like sodium hypochlorite and chlorine dioxide; peroxides, such as hydrogen peroxide; peroxycarboxylic acids, such as peracetic acid; and others such as ozone. All of the examples listed are synthetic substances permitted in or on processed products labeled as organic at §205.605(b).

The mode of action for pathogen reduction among different sanitizers may be different and can also depend on the pathogen. Ozone, for example, oxidizes bacterial cell membranes' phospholipids and lipoproteins, while in fungi it interrupts viral replication (Skowron et al., 2019). Peracetic acid increases the permeability of bacterial cell membranes (Skowron et al., 2019). FSIS Directive 7120.1 Revision 56 enumerates a list of antimicrobial solutions, including the petitioned POLA formulation covered by FCN 1946, that have been deemed safe and suitable for use in the production of meat, poultry, and egg products (FSIS, 2021b).

Synthetic alternatives

PAA is one of the principle alternatives to POLA that is already permitted on §205.605(b) of the National List. PAA has a high vapor pressure and pungent odor, and is an irritant when inhaled, leading the U.S. Occupational Safety and Health Administration (OSHA) to limit its airborne concentration (Li, Prideaux, et al., 2021). This is an issue in poultry processing plants where PAA may be applied at relatively high concentrations, in large quantities, and in open systems.

A patent for POLA claims that it has higher antimicrobial efficacy in sanitizing applications compared to peroxyoctanoic acid and PAA compositions (Li, McSherry, et al., 2021). The patent also claims that it has a lower odor profile and VOC generation, as well as improved transport and shipping stability (Li, McSherry, et al., 2021). The petitioner's patent for POLA claims increased stability over comparable antimicrobial solutions, enabling the use of less of the antimicrobial solution to achieve the same effect. Similarly, the patent states that less POLA can be used to replenish the antimicrobial solutions as the concentration becomes depleted during food processing, as compared to other antimicrobials (Bullard et al., 2021).

The patent for the petitioned POLA solution reported results of trials that examined POLA's degradation profile as compared to PAA. Poultry proteins were exposed to 2,000 ppm concentration of each antimicrobial solution at 4 ºC, and degradation was measured at dwell times of 0, 15, 30, 45, 60, 90, and 120 minutes. The POLA samples showed higher concentrations than PAA at 15 minutes (545 ppm POLA vs. 122 ppm PAA), at 30 minutes (182 ppm POLA vs. 26 ppm PAA), and at 45 minutes (10 ppm POLA vs. 0 ppm PAA) dwell time. However, POLA (and PAA) showed complete degradation by 60 minutes dwell time. Similar results were found with samples of beef protein immersed in POLA and PAA solutions. The authors state that the results suggested increased stability of POLA compared to PAA, as it degraded more slowly on meat surfaces (Bullard et al., 2021). Scientific literature was not found to corroborate the claims made within the patent.

Chlorine sanitizers are permitted under certain conditions for food contact in the processing of organic poultry and meat, and have long been the sanitizers of choice in the U.S. poultry industry (Micciche et al., 2019). However, drawbacks to the use of chlorine compounds in such application include food bleaching effects, specifically in poultry carcasses, causing the food to be unpalatable to the consumer (Howarth, 2010).

Chlorine solutions have strong odors that are hazardous to workers (Micciche et al., 2019). In addition, poultry wash water contains high levels of nitrogen originating from the fecal matter exposed during evisceration. Chlorine compounds can react with this nitrogen to create chloramines, which are corrosive to surfaces, an eye irritant for plant workers eyes, and diminish the intended biocidal effectiveness of the sanitizing solution (Howarth, 2010).

Sodium lactate and potassium lactate were added to the National List as antimicrobial agents at §205.605(b) in 2019 (NOP, 2018). According to the technical report that supported their review by the NOSB, it is the lactic acid portion of these compounds that has antimicrobial properties, while the sodium and potassium ions can also function as radical scavengers, thereby inhibiting decay (NOP, 2015). POLA is a stronger oxidizing agent than lactic acid, and therefore we expect it to be a stronger antimicrobial agent.

Nonsynthetic alternatives

Nonsynthetic substances that can be used as antimicrobial agents in the processing of poultry parts and meat include bacteriophages, fatty acids, essential oils, and bacteriocins[8] (Rothrock et al., 2019; Umaraw et al., 2017).

Sanitizer combinations

Research investigating the antimicrobial efficacy of different sanitizing regimes is ongoing. The result of one study showed that the sequential use of different oxidizing sanitizers such as ozone and sodium hypochlorite increase antimicrobial efficacy in wash water for fresh-cut produce with high organic loads and low temperatures (Ho et al., 2011). Ho et al. (2011) also noted that adding surfactants like sodium lauryl sulfate increased the antimicrobial efficacy of organic acids.

[8] Bacteriocins are low molecular weight peptides produced in bacterial ribosomes and possess antimicrobial properties (Umaraw et al., 2017).

Skowron et al. (2019) compared the effectiveness of numerous sanitizers in both ozonated and unozonated water against strains of *Listeria monocytogenes* from different sources (i.e., from fish vs. meat). The authors reported a synergistic effect from mixing disinfectants, including POLA, with ozonated water, as these mixes showed increased efficacy over the use of any individual sanitizer or ozone alone. One reason that food processors should use different sanitizers is that microorganisms differ in their tolerances to these substances (Beltrame et al., 2012).

Evaluation Information #13: Provide a list of organic agricultural products that could be alternatives for the petitioned substance (7 CFR 205.600(b)(1)).

Vinegar (containing 5-9 percent acetic acid) is an agricultural product available in organic form. Its use as an alternative sanitizer is discussed in the 2016 technical report on *Peracetic Acid* (NOP, 2016a). The report noted that vinegar would not be a desirable antimicrobial agent for direct food contact, as it is likely to affect the taste and color of the food product, and creates an environmentally problematic waste stream (NOP, 2016a). No other organic agricultural substances are known that could act as a meat and poultry sanitizer.

Report Authorship

The following individuals were involved in research, data collection, writing, editing, and/or final approval of this report:

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References

Baggioli, A., Crescenzi, O., Field, M. J., Castiglione, F., & Raos, G. (2012). Computational 17O-NMR spectroscopy of organic acids and peracids: Comparison of solvation models. *Physical Chemistry Chemical Physics*, *15*(4), 1130–1140. https://doi.org/10.1039/C2CP43021E

Balasubramanian, R., Epps, B., Li, J., Staub, R., & Keasler, V. (2016). *Use of percarboxylic acids for scale prevention in treatment systems* (United States Patent No. US20160176735A1). https://patents.google.com/patent/US20160176735A1/en?oq=+14%2f972%2c727

Beltrame, C. A., Kubiak, G. B., Lerin, L. A., Rottava, I., Mossi, A. J., Oliveira, D. de, Cansian, R. L., Treichel, H., & Toniazzo, G. (2012). Influence of different sanitizers on food contaminant bacteria: Effect of exposure temperature, contact time, and product concentration. *Food Science and Technology*, *32*(2), 228–232. https://doi.org/10.1590/S0101-20612012005000046

Britannica. (2021). *Peroxy acid | chemical compound*. https://www.britannica.com/science/peroxy-acid

Bruice, P. Y. (2001). *Organic Chemistry*. Prentice Hall.

Bullard, R. C., Bullard, J. R., Faller, J. A., & Barnum, A. R. (2021). *Method of Peroxylactic Acid Production and Use for Reduction in Microbial Activity in Food Product Processing* (Patent No. US 10,919,831 B1).

Christo, C. H. (2015). *Stabilised disinfectant composition, method for producing a stabilised disinfectant composition, disinfectant product, use of a composition and use of a product* (World Intellectual Property Organization Patent No. WO2015003233A1). https://patents.google.com/patent/WO2015003233A1/en

EFSA, E. F. S. (2006). Opinion of the Scientific Panel on food additives, flavourings, processing aids and materials in contact with food (AFC) related to Treatment of poultry carcasses with chlorine dioxide, acidified sodium chlorite, trisodium phosphate and peroxyacids. *EFSA Journal*, *4*(1), 297. https://doi.org/10.2903/j.efsa.2006.297

FSIS. (2021a). *FSIS Guideline for Controlling Campylobacter in Raw Poultry*. https://www.fsis.usda.gov/sites/default/files/media_file/2021-07/FSIS-GD-2021-0006.pdf

FSIS. (2021b). *FSIS Directive 7120.1 Revision 56—Safe and Suitable Ingredients Used in the Production of Meat, Poultry, and Egg Products*. 7.

FSIS. (2021c). *Safe and Suitable Ingredients*. https://www.fsis.usda.gov/sites/default/files/media_file/2021-09/7120.1_table_2.pdf

Galbács, Z. M., & Csányi, L. J. (1983). Alkali-induced decomposition of hydrogen peroxide. *Journal of the Chemical Society, Dalton Transactions*, *11*, 2353–2357. https://doi.org/10.1039/DT9830002353

Ganguly-Mink, S., Littel, K. J., & Zhu, S. P. (2020). *Non-alpha substituted peroxy acids and uses thereof* (United States Patent No. US10676430B2). https://patents.google.com/patent/US10676430B2/en?oq=10%2c676%2c430

Goor, G., Glenneberg, J., & Jacobi, S. (2012). Hydrogen Peroxide. In *Ullmann's Encyclopedia of Industrial Chemistry* (Vol. 18).

Gowariker, V., Krishnamurthy, V. N., Gowariker, S., Dhanorkar, M., & Paranjape, K. (2009). *The Fertilizer Encyclopedia*. John Wiley & Sons, Inc.

Gurtler, J. B. (2020). Two Generally Recognized as Safe Surfactants plus Acidulants Inactivate Salmonella, Escherichia coli O157:H7, and Listeria monocytogenes in Suspension or on Dip-Inoculated Grape Tomatoes. *Journal of Food Protection*, *83*(4), 637–643. https://doi.org/10.4315/0362-028X.JFP-19-286

Gurtler, J. B., Bailey, R. B., Jin, T. Z., & Fan, X. (2014). Reduction of an E. coli O157:H7 and Salmonella composite on fresh strawberries by varying antimicrobial washes and vacuum perfusion. *International Journal of Food Microbiology*, *189*, 113–118. https://doi.org/10.1016/j.ijfoodmicro.2014.08.005

Herron, K. L. (2000). *Evaluation of peracids for ante mortem disinfection of the chicken upper gastrointestinal tract to reduce food-borne pathogen transmission* [Thesis, Texas A&M University]. https://oaktrust.library.tamu.edu/handle/1969.1/ETD-TAMU-2000-THESIS-H48

Ho, K.-L. G., Luzuriaga, D. A., Rodde, K. M., Tang, S., & Phan, C. (2011). Efficacy of a Novel Sanitizer Composed of Lactic Acid and Peroxyacetic Acid against Single Strains of Nonpathogenic Escherichia coli K-12, Listeria innocua, and Lactobacillus plantarum in Aqueous Solution and on Surfaces of Romaine Lettuce and Spinach. *Journal of Food Protection*, *74*(9), 1468–1474. https://doi.org/10.4315/0362-028X.JFP-11-110

Howarth, J. N. (2005). *Microbiological control in poultry processing* (United States Patent No. US6908636B2). https://patents.google.com/patent/US6908636B2/en

Howarth, J. N. (2010). *Microbiological Control in Poultry Processing* (United States Patent No. US7767240B2). https://patents.google.com/patent/US7767240B2/en

Jean, J. (2016, May 12). *Shedding some light on inactivation of foodborne viruses*. IAFP's European Symposium on Food Safety.

Kitis, M. (2004). Disinfection of wastewater with peracetic acid: A review. *Environmental International*, *30*, 47–55. https://doi.org/10.1016/S0160-4120(03)00147-8

Larson, B. G., & Tichy, D. J. (2010). *Resin catalyzed and stabilized peracid compositions and associated methods* (United States Patent No. US20100120913A1). https://patents.google.com/patent/US20100120913/en

Lehman, D. S. (1963). Chelates in soils—A symposium; Some principles of chelation chemistry. *Soil Science Society Proceedings*, *27*, 167–170.

Li, J., McSherry, D. D., Brewster, A., Staub, R., DePaula, R., Bolduc, J. W., Ryther, R. J., & Keasler, V. V. (2019). *Stable Percarboxylic Acid Compositions and Uses Thereof* (European Patent Office Patent No. 19160311.7).

Li, J., McSherry, D. D., & Staub, R. (2017). *In situ generation of peroxycarboxylic acids at alkaline pH, and methods of use thereof* (United States Patent No. US9763442B2). https://patents.google.com/patent/US9763442B2/en

Li, J., McSherry, D. D., & Staub, R. (2021). *Efficient stabilizer in controlling self accelerated decomposition temperature of peroxycarboxylic acid compositions with mineral acids* (United States Patent No. US20210259245A1). https://patents.google.com/patent/US20210259245A1/en?oq=20210259245

Li, J., Prideaux, A., & Staub, R. (2021). *Generation of peroxyhydroxycarboxylic acid and the use thereof* (United States Patent No. US20210238135A1). https://patents.google.com/patent/US20210238135A1/en?q=GENERATION+OF+PEROXYHYDROXYCARBOXYLIC+ACID+AND+THE+USE+THEREOF&oq=GENERATION+OF+PEROXYHYDROXYCARBOXYLIC+ACID+AND+THE+USE+THEREOF

Mantrose-Haeuser Co., Inc. (2015, July 10). *FCN No. 1558*. Inventory of Effective Food Contact Substance (FCS) Notifications. https://www.cfsanappsexternal.fda.gov/scripts/fdcc/index.cfm?set=fcn&id=1558

Micciche, A. C., Feye, K. M., Rubinelli, P. M., Lee, J. A., Knueven, C. J., & Ricke, S. C. (2019). Comparison of Acid Sanitizers on Salmonella Typhimurium Inoculated Commercial Poultry Processing Reuse Water. *Frontiers in Sustainable Food Systems*, *2*, 90. https://doi.org/10.3389/fsufs.2018.00090

Moore, R. G. (2019). *Environmentally Preferred Antimicrobial Compositions* (Patent No. US 10,487,297 B2).

Msagati, T. A. M. (2013). Preservatives. In *Chemistry of Food Additives and Preservatives* (First). John Wiley & Sons, Ltd.

Nagel, C., & Li, J. (2021). *Use of urea or a urea/chelator combination to chemically stabilize peroxycarboxylic acid and peroxide formulations* (United States Patent No. US20210246401A1). https://patents.google.com/patent/US20210246401A1/en?oq=20210246401

National Academy of Sciences Food and Nutrition Board. (1996). *Food Chemicals Codex* (4th ed.). National Academy Press.

National Academy of Sciences, N. R. C. (1961). *The Use of Chemicals in Food Production, Processing, Storage, and Distribution*.

Neal-McKinney, J. M., Samuelson, D. R., Eucker, T. P., Nissen, M. S., Crespo, R., & Konkel, M. E. (2014). Reducing Campylobacter jejuni Colonization of Poultry via Vaccination. *PLOS ONE*, *9*(12), e114254. https://doi.org/10.1371/journal.pone.0114254

NOP. (2015). *Lactic Acid and Lactates TR 02-17-15 Final.pdf*. https://www.ams.usda.gov/sites/default/files/media/Lactic%20Acid%20and%20Lactates%20TR%2002-17-15%20Final.pdf

NOP. (2016a). *Peracetic Acid (Handling/Processing) Technical Report*. https://www.ams.usda.gov/sites/default/files/media/Peracetic%20Acid%20TR%203_3_2016%20Handling%20final.pdf

NOP. (2016b, December 2). *NOP-Ag-NonAg-DecisionTree.pdf*. USDA Agricultural Marketing Service National Organic Program. https://www.ams.usda.gov/sites/default/files/media/NOP-Ag-NonAg-DecisionTree.pdf

NOP. (2018, December 27). *National Organic Program; Amendments to the National List of Allowed and Prohibited Substances (Crops, Livestock and Handling)*. Federal Register Number 83 FR 66559. https://www.federalregister.gov/documents/2018/12/27/2018-27792/national-organic-program-amendments-to-the-national-list-of-allowed-and-prohibited-substances-crops

Northcutt, J. K., & Buhr, R. J. (2010). Preslaughter factors affecting poultry meat quality. In *Poultry Meat Processing*. Taylor & Francis Group.

Ogata, Y., & Sawaki, Y. (1965). Kinetics of the acid-catalysed formation of aliphatic peracids from hydrogen peroxide and aliphatic acids in dioxan. *Tetrahedron*, *21*(12), 3381–3386. https://doi.org/10.1016/S0040-4020(01)96959-5

OMRI. (2021). *OMRI Standards Manual, Lactic Acid*. https://www.omri.org/omri-search?page=1&query=lactic%20acid&exactMatch=false

Pereira, L. S., Cordery, I., & Iacovides, I. (2009). *Coping with Water Scarcity: Addressing the Challenges*. Springer Science & Business Media.

PubChem. (2021, September 11). *Peroxylactic acid*. https://pubchem.ncbi.nlm.nih.gov/compound/101668194

Rothrock, M. J. J., Micciche, A. C., Bodie, A. R., & Ricke, S. C. (2019). Listeria Occurrence and Potential Control Strategies in Alternative and Conventional Poultry Processing and Retail. *Frontiers in Sustainable Food Systems*, *0*. https://doi.org/10.3389/fsufs.2019.00033

Schubert, J. (1981). Chelating agents in biological systems. *Environmental Health Perspectives*, *40*, 227–232.

Skowron, K., Wałecka-Zacharska, E., Grudlewska, K., Białucha, A., Wiktorczyk, N., Bartkowska, A., Kowalska, M., Kruszewski, S., & Gospodarek-Komkowska, E. (2019). Biocidal Effectiveness of Selected Disinfectants Solutions Based on Water and Ozonated Water against Listeria monocytogenes Strains. *Microorganisms*, *7*(127). https://doi.org/10.3390/microorganisms7050127

Soro, A. B., Whyte, P., Bolton, D. J., & Tiwari, B. K. (2020). Strategies and novel technologies to control Campylobacter in the poultry chain: A review. *Comprehensive Reviews in Food Science and Food Safety*, *19*(4), 1353–1377. https://doi.org/10.1111/1541-4337.12544

The European Commission. (2021). *COMMISSION IMPLEMENTING REGULATION (EU) 2021/1165 of 15 July 2021 authorising certain products and substances for use in organic production and establishing their lists*. Official Journal of the European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32021R1165

Uhl, A., Bitzer, M., Wolf, H., Hermann, D., Gutewort, S., Volki, M., & Nagi, I. (2000). Peroxy Compounds, Organic. In *Ullmann's Encyclopedia of Industrial Chemistry*. Wiley-VCH GmbH & Co.

Umaraw, P., Prajapati, A., Verma, A., K., Pathak, V., & Singh, V. P. (2017). Control of campylobacter in poultry industry from farm to poultry processing unit: A review. *Critical Reviews in Food Science and Nutrition*, *57*(4), 659–665.

U.S. FDA. (2020). *FSMA Final Rule for Preventive Controls for Human Food*. FDA. https://www.fda.gov/food/food-safety-modernization-act-fsma/fsma-final-rule-preventive-controls-human-food

U.S. FDA. (2021a, July 30). *Inventory of Effective Food Contact Substance (FCS) Notifications*. FDA; FDA. https://www.cfsanappsexternal.fda.gov/scripts/fdcc/?set=FCN

U.S. FDA. (2021b, December 2). *9 CFR Part 416 – Sanitation*. https://www.ecfr.gov/current/title-9/chapter-III/subchapter-E/part-416

Ustunol, Z. (2015). Amino Acids, Peptides, and Proteins. In *Applied Food Protein Chemistry* (First Edition). John Wiley & Sons, Ltd.

Valley Chemical Solutions. (2019a, May 28). *FCN No. 1946*. Inventory of Effective Food Contact Substance (FCS) Notifications. https://www.cfsanappsexternal.fda.gov/scripts/fdcc/index.cfm?set=FCN&id=1946

Valley Chemical Solutions. (2019b, October 30). *FCN No. 1995*. Inventory of Effective Food Contact Substance (FCS) Notifications. https://www.cfsanappsexternal.fda.gov/scripts/fdcc/?set=FCN&id=1995&sort=FCN_No&order=DESC&startrow=1&type=basic&search=75033%2D25%2D9

Vereinte Nationen (Ed.). (2019). *Globally harmonized system of classification and labelling of chemicals (GHS)*. United Nations.

Vodolazhenko, S. A., Deribo, S. G., Chahine, I. H., & Pavlov, B. V. (2020). Influence of Electrolyte Composition on the Electrochemical Synthesis of Peroxylactic Acid. *Promising Materials and Processes in Applied Electrochemistry*, 244–252.

Wessels, S., & Ingmer, H. (2013). Modes of action of three disinfectant active substances: A review. *Regulatory Toxicology and Pharmacology*, *67*(3), 456–467. https://doi.org/10.1016/j.yrtph.2013.09.006

Zee Company, Inc. (2021). *Petition to Add Peroxylactic Acid ("PLA") to Section 205.605 (b) of the National List*. https://www.ams.usda.gov/sites/default/files/media/ZeeCompanyPeroxylacticAcidPetition03012021.pdf