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.

Paper Pots and Containers

Crops

Identification of Petitioned Substance

Chemical Names:
Cellulose (the primary constituent)

Other Names:
Paper, hemp paper, cannabis paper, kraft paper, paper chain pots, chainpots, paper containers, bond, paperboard, cardboard, non-recycled paper, virgin paper

Trade Names: Nitten paper pot transplanting system; Ecopots; Ellepots; Paperpots; Western Pulp Fiber Pot

CAS Numbers:
9004-34-6 (Cellulose, the primary constituent)

Other Codes:
ChEMBL2109009
EC 232-674-9
INS 460
PubChem CID 14055602

Summary of Petitioned Use

The petition is to add hemp paper or other paper, without glossy or colored inks, to the National List at 205.601(o) for use as a plant pot or growing container (Hendrickson 2018a).

Characterization of Petitioned Substance

Composition of the Substance:
Paper pots are composed primarily of cellulose made from non-recycled fibers derived from plants. Other constituents of paper are hemicellulose, lignins, and starch (Hubbe 2005). Cellulose and starch comprise about 95% of paper by weight (Hagiopol and Johnston 2012). Figure 1 represents a cellulose molecule as a network of a carbohydrate molecule, $(C_6H_{10}O_5)n$, held together by glucose, a simple sugar (Merck 2015). Cellulose monomer fibers are bound together by starch to form longer polymer chains. Hemicellulose and lignin are more complex structures than the cellulose monomers or the amorphous carbohydrates in starch.

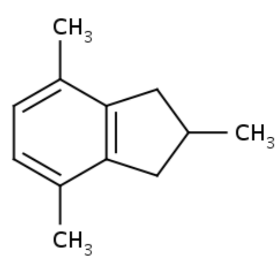

Figure 1: Cellulose Monomer (US EPA 2015)

In addition to cellulose, paper used for transplanting contains additives that function as strengtheners, adhesives, and fibers for reinforcement. Specifically, polyvinyl alcohol (PVA) and polylactic acid (PLA) have been confirmed as synthetic fibers used in the production of some of the commercial paper pot products currently used. Other synthetic fibers may be used in addition to PVA and PLA, which are further discussed in the *Combinations of Substance*. A growing number of lignocellulose composites made with both natural and synthetic fibers have been introduced to the market and are in development stages for various applications to replace synthetic polymers. Even when natural fibers are used, many of these will use various synthetic additives as binders, linking agents, stabilizers, strengtheners, and other agents (Thakur 2014).

The petition also mentions the following additives used to manufacture paper chain pots: magnesium chloride, dimethylol dihydroxy ethylene urea (DMEU), polyvinyl acetate (PVAc), ethylene vinyl acetate (EVA) resin, and acrylic acid ester copolymers (Hendrickson 2018b). Other additives may also be used. The functionality of these and selected other additives used to make paper pots is discussed further in *Combinations of the Substance*. An exhaustive list and evaluation of all possible components of paper pots and containers is beyond the scope of this Technical Review.

Source or Origin of the Substance:

Paper is made from a variety of plant sources and can be sourced from recycled paper. Recycled content has steadily increased over the past twenty years, with recovered sources of cellulose surpassing virgin paper by some measures. Newspaper recycling rates surpassed 70 percent in 2010 (US EPA 2011). According to the United Nations Food and Agriculture Organization (FAO), more than 401 million metric tons (MMT) of paper and paperboard were produced globally in 2015, and 226 MMT were recovered, for a recycling rate of 55 percent (FAO 2018). The same report shows that about 42 percent of all paper is made from virgin sources, with the remaining 58 percent coming from other recovered sources of fiber. However, these crude figures do not reflect the wide variation both geographically and by product type (Martin and Haggith 2018). Most virgin paper continues to be produced from wood fiber (Hubbe 2005), but a growing percentage of paper is produced from agricultural byproducts or co-products. Agricultural sources of cellulose pulp include grain straw, hemp, bamboo, sugarcane bagasse, kenaf, sisal, jute, and sunflower stalks (Hunsigi 1989; Smole et al. 2013; Martin and Haggith 2018).

The 2017 Technical Review for newspaper and other recycled paper noted that genetically modified trees are being developed for pulp and paper production, but commercialization has been slow (USDA 2017). Since then, one commercial scale project to make paper from genetically modified eucalyptus trees in Brazil was cancelled (Ledford 2019). Trees developed by biotechnology face numerous technical, economic, social and ethical challenges before they can be commercially released, according to a recent report by the National Academy of Sciences (2019).

Properties of the Substance:

The physical and chemical properties of paper vary widely, as demonstrated in Table 1 below. Paper chain pots are generally made from unbleached kraft pulp paper, which is one of the heavier, thicker and more durable grades of paper. Bursting strength is relevant to protect the seedlings from broken pots. This type of paper typically has higher lignin and hemicellulose content than other newsprint or white paper.

Table 1: Chemical and Physical Properties of Paper

Property	Value	Source
Grammage (Basis Weight)	Kraft linerboard: 127 - 439 g/m^2	(Hubbe 2005)
Color	Brown (Unbleached)	(Hubbe 2005)
Thickness	Linerboard: 230 – 640 µm	(Hubbe 2005)
Cellulose content	Sack kraft: 85%	(Sundqvist 1999)
Lignin content	Sack kraft: 14%	(Sundqvist 1999)
Cadmium (Cd)	Other paper: 0.90 ppm	(Tucker et al. 2000)
Chromium (Cr)	Other paper: 18.60 ppm	(Tucker et al. 2000)
Lead (Pb)	Other paper: 30.20 ppm	(Tucker et al. 2000)
Mercury (Hg)	Other paper: 0.16 ppm	(Tucker et al. 2000)
Bursting strength	Bleached kraft (60 g / m^2): 210-260 KPa	(PaperOnWeb 2019)
Alum	Sack kraft: 0.4%	(Sundqvist 1999)
Resin glue	Sack kraft: 0.2%	(Sundqvist 1999)
Phenol-formaldehyde resin	Sack kraft: 1.0%	(Sundqvist 1999)

Specific Uses of the Substance:

The specific petitioned use is for paper to serve as a container for media used to grow transplants of various crops (Hendrickson 2018a). Reinforced paper is formed into structures that can be filled with growth media and seeded. As the water-soluble adhesives are degraded by watering, individual cells or "pots" separate to form a chain, with pots connected by perforated paper. These structures are called "chainpots." The pots are then mechanically pulled by a transplanter that separates each pot at the perforation. Paper pots are used primarily for closely spaced vegetables and other crops, including sugar beets, onions, leeks, salad greens, cut flowers, and tobacco (Masuda and Kagawa 1963; Suggs et al. 1987; Robb et al. 1994; Hendrickson 2018a). The system is also used for transplanting tree seedlings (Tervo 1999).

Approved Legal Uses of the Substance:

Paper pots used for transplants are not regulated by EPA, USDA, or FDA. The FDA does regulate paper and paperboard as an indirect food additive [21 CFR Part 176]. Various additives used as components of paper and paperboard are also approved as indirect food additives, including adhesives and coatings [21 CFR Part 175], and other substances used in the manufacturing process that are present in the paper [21 CFR Part 181]. As such, these substances may already come into incidental contact with organic food via packaging. Table 2 contains the components identified in paper pots and their FDA-approved uses. Note that the regulations often specify what can be considered food grade and limit the uses to specific types of food or applications. These are described in greater detail in the cited reference.

Table 2: FDA Status of Selected Paper Additives

Additive	CAS #	FDA Approved Uses	Reference
Acrylic acid polymer	58152-79-7	Flocculant for sugar clarification Adhesive in packaging Components of paper and paperboard Resinous and polymeric coatings for polyolefin films	21 CFR 173.5 21 CFR 175.105 21 CFR 175.320 21 CFR 176.110 21 CFR 176.180
Ethylene vinyl acetate (EVA)	24937-78-8	Basic components of single and repeated use food contact surfaces (copolymer with vinyl alcohol) Finding of No Significant Impact on the environment.	21 CFR 175.320 21 CFR 177.1350 FCN 1198
Magnesium chloride	7786-30-3	Modified Hop Extract Generally Recognized As Safe	21 CFR 172.560 21 CFR 184.1426
Polylactic acid (PLA)	26100-51-6	Finding of No Significant Impact	FCN 178
Polyvinyl acetate (PVAc)	9003-20-7	Diluent in color additive mixtures Chewing gum base Adhesive in packaging Resinous and polymeric coatings Components of paper and paperboard Basic components of single and repeated use food contact surfaces Textiles and textile fibers for repeated use Surface lubricants Substances used in the manufacture of paper and paperboard products used in food packaging	21 CFR 73.1 21 CFR 172.615 21 CFR 175.105 21 CFR 175.300 21 CFR 175.320 21 CFR 176.170 21 CFR 176.180 21 CFR 177.1200 21 CFR 177.2260 21 CFR 177.2800 21 CFR 181.30
Polyvinyl alcohol (PVA)	9002-89-5	Diluent in color additive mixtures Adhesive in packaging Resinous and polymeric coatings Components of paper and paperboard Substances for use as basic components of single and repeated use food contact surfaces	21 CFR 73.1 21 CFR 175.105 21 CFR 175.300 21 CFR 175.320 21 CFR 176.170 21 CFR 176.180

Additive	CAS #	FDA Approved Uses	Reference
		Textiles and textile fibers for repeated use Surface lubricants Finding of No Significant Impact	21 CFR 177.1200 21 CFR 177.1670 21 CFR 177.2260 21 CFR 177.2800 21 CFR 178.3910 FCN 100
Urea-formaldehyde resin	9011-05-6	Substances used in the manufacture of paper and paperboard products used in food packaging	21 CFR 181.30

PVA is permitted in food packaging adhesives [21 CFR 175.105]. PVA of certain specifications of viscosity and alcoholysis may be used as a dispersing agent at levels not to exceed 6 percent of the total coating weight in film used in food containers [21 CFR 175.320]. EVA copolymer is allowed as a basic component of both single- and repeated-use food contact surfaces [21 CFR 177.1350]. Various acrylic acid copolymers are also permitted. PVAc, urea-formaldehyde polymer, and various other chemical additives are also permitted for use as paper and paperboard additives used to make food packaging by prior sanction [21 CFR 181.30]. The FDA has issued a Finding of No Significant Impact (FONSI) for food contact use of polylactic acid (FDA 2004).

PVA, PVAc, EVA and magnesium chloride are all on EPA List 4B, Minimum Risk Inert Ingredients (US EPA 2004). The other ingredients were not found, and therefore considered unclassified or List 3. This may reflect that they have no history of use as inert ingredients in pesticide formulations.

Action of the Substance:

Paper pots form individual cells to hold growth media used for starting transplants. Seedlings are grown to the stage where they are viable outside. The paper pots including the medium and seedlings are transplanted as a unit into soil. The paper cells then decompose, which allows the roots to penetrate the soil. Ideally, the paper pots fully decompose by the end of the growing season. The mode of action is as a physical production aid. Paper cells hold the transplant media in place and form a separable root ball for transfer into the soil.

Combinations of the Substance:

Paper pots contain various additives that help the pots hold the soil media, last through multiple watering periods for the seedlings, hold the sides of the containers together, inhibit microbial decomposition prior to placement in the soil, and contain root growth prior to transplanting. These can be categorized as (1) strengtheners, (2) reinforcement fibers, (3) adhesives and binders, and (4) antimicrobials. It was not possible to compile an exhaustive list of all possible additives used to make paper pots because of the proprietary nature of some commercial products.

Strengtheners

Paper pots require additives to increase wet strength so that they will not break during watering and transplanting. Fibers are used to maintain the structure of the paper pots and reinforce wet strength. Though kraft paper is a more durable type of paper, unrefined kraft paper has relatively low wet strength. Kraft paper used in applications that involve repeated wetting, such as paper pots for transplants, is usually treated with various wet strengthening additives. Plastic resins, for instance, are added to kraft paper to decrease water absorption and increase wet strength (Bralla 2006). Polyamidoamine-epichlorohydrin resins compromise the most widely used class of wet strength additives (Hubbe 2005). The petition specifically names magnesium chloride and urea resin for one brand of product; magnesium chloride and DMEU (CAS 136-84-5) may be added to strengthen the paper walls (Hendrickson 2018a). Other wet strengthening additives include various resins, urea-formaldehyde resins, melamine-formaldehyde resins, epoxidized polyamide resins, glyoxylated polyacrylamide resins, polycarboxylic acids, polyethylenimine, and polyvinylamines (Auhorn 2012; Hagiopol and Johnston 2012). These may be applied to the paper before it is manufactured into pots. Aluminum sulfate and rosin from tall oil are also commonly used in the pulping process (Hubbe 2005).

Adhesives

Paper pots are often held together by adhesives. The structures use both water-soluble and water-insoluble adhesives. The water-soluble adhesives gradually dissolve as the seedlings are watered, which causes the cells to separate from each other. The water-insoluble adhesives maintain the structure of the individual cells holding the seedlings after transplanting into soil. The petition specifically identifies PVA, PVAc, EVA resin, and acrylic acid ester copolymers (Hendrickson 2018b).

Water insoluble adhesives are generally applied by a hot melt process, where the adhesive is liquified before being applied to the paper surface. EVA is historically the main hot melt adhesive used with paper products (Midwest Research Institute and Franklin Associates 1975). EVA is being replaced by polyolefin and polyamide based adhesives in many hot melt applications (Onusseit et al. 2012). PVAc is a water-insoluble aliphatic rubbery polyvinyl ester. It is the primary ingredient in the commercial product Elmer's Glue-All (CROW 2019).

The oldest adhesives were glues derived from animals in the form of glutin (Bogue 1922), and gum arabic was the first plant-based water-soluble adhesive used in paper chain pots (Masuda 1965). Most modern glues and adhesives used in paper are synthesized from polyvinyl, ethylene, or polyurethane (Onusseit et al. 2012).

Reinforcement fibers

Paper pots may be reinforced with synthetic or natural fibers. Some commercial products currently on the market use polyvinyl alcohol fibers in the form of vinylon (Hendrickson 2019). PLA may also be used in some cases (Ellegaard and Kulmbach 2016). Other products may also contain various compounds to strengthen the paper to withstand the transplanting equipment. These include polymer coatings and fibers such as polyethylene, polypropene, polyester, or polyacrylonitrate to maintain product strength and to delay decomposition (Ruuska 1980). Natural fibers are potential substitutes for synthetics, but none appear to be used in commercial products currently on the market. The petition proposes hemp fiber as a non-synthetic alternative (Hendrickson 2018b). However, such paper pots are currently in the experimental phase (Hendrickson 2019).

Antimicrobials

Antimicrobials, such as copper 8-hydroxyquinolinolate, may also be used to prevent the growth of fungi and bacteria that may accelerate decay or be pathogenic to the seedlings (Tsuru et al. 1991). Copper pentachlorophenate (Crandall 1956) and copper naphthenate (Cotton 1958) may also be impregnated in papers that are exposed to repeated wetting. The molded paper pots may also be treated with various synthetic fungicides to inhibit degradation. Among the fungicides that may be used are various thiocyanates, including 2-(thiocyanomethylthio) benzothiazole (TCMTB) (Dall 1994). Such treatments are used to inhibit biodegradation in cases of soil burial or under greenhouse conditions.

Out-of-scope additives

Molded paper products are made with proprietary additives (Lee 2019). These additives are outside the scope of this Technical Review. It is public information that some molded paper pots contain paraffin wax (Western Pulp Products 2019; Lee 2019). These pots are not intended for transplanting into soil; the manufacturer recommends removal of the transplant before planting (Lee 2019).

Status

Historic Use:

Market gardeners were making and using folded and pasted paper pots to grow seedlings for transplants by the late 19th century (Harris 1922). Mass-produced paper pots made with manila were commercially available to market gardeners in the early 1900s (Massey 1908). These had some advantages over direct seeding and clay pots for transplants but also had their drawbacks—the paper pots would buckle at the bottom, collapse, tear, or the paste would wash out, all resulting in plant losses (Massey 1908; Harris 1922).

A system of cutting and locking bands of boxes by tabs and slots was invented in the early 20th century (Harris 1920). The locked paper plant bands did not require paste, and no additives are mentioned in the patent. The bands saved labor and space and were more economical to ship than transplants in clay pots, before plastic pots were invented. These were made of card stock rather than kraft paper, making them sturdier but also taking longer to break down. However, the plant bands had problems with drainage, root development, stunting, and susceptibility to root-borne diseases. Paper plant bands were later treated with copper fungicide to control the root-borne diseases (Harris 1922).

By the early 1960s, organic farmers began preferring to use peat pots. Paper collars were used around peat pot transplants to prevent specific pests, such as cutworms (Rodale 1961). Transplantable paper chain pots were invented in Japan during this time (Masuda 1965) and were first used by the Japanese sugar beet industry (Masuda and Kagawa 1963; Wilson et al. 1987; Robb et al. 1994). The technique was adopted in Finland by the late 1960s (Tervo 1999). Biodegradable composite paper-polymer chain pots reinforced with synthetic fibers were developed in Finland in the 1970s (Ruuska 1980). Nippon Beet Sugar Manufacturing Co., assignee of the original patent, licensed the Finnish sugar company Lännen Tehtaat Oy to distribute paper pots in Europe and North America. The paper chain pots were part of a system to mechanize and automate the transplanting process.

Plant containers made from molded paper pulp were invented in the mid-1950s (Emery 1957). These were mainly used for nursery and patio planters and were designed for above-ground use (French 1967). However, they were subsequently used as biodegradable soil planters (Kuehny, Taylor, and Evans 2011; Sun et al. 2015; Nambuthiri et al. 2015). While molded products do use the adhesives or strengtheners used to make paper chain pots, Western Pulp Products— the patent holder and main US manufacturer—does not claim that they are allowed to be planted in soil on certified organic farms (Lee 2019; Western Pulp Products 2019). Another system patented in the 1960s involved mixing paper pulp and bark with a non-ionic surfactant and urea-formaldehyde resin to make molded transplantable pots (Mccollough and Ferguson 1965). There is no evidence that the invention was ever commercialized or used in organic production. A pending patent claims that the paper chain pot system can be adapted for use in hydroponic troughs (Storey et al. 2018).

Paper pots with various transplanters were used on an experimental basis for onion, sugar beet and tobacco transplanting in the mid-1980s in the United States (Suggs et al. 1987; Wilson et al. 1987; Robb et al. 1994). One article found that the transplanting of paper pots with three different transplanting tools was not cost competitive with hand transplanting, in part because of a high rate of damage to the chain pots (Robb et al. 1994). Transplanters for chain pots in the 1980s and 1990s were relatively expensive, inefficient and unreliable compared with models that are available at the time of this report. Researchers noted that if certain production issues were addressed, the technique had the potential to reduce both labor costs and chemical applications (Robb et al. 1994).

Nippon Sugar Beet Manufacturing developed sturdier paper pots that resisted decomposition prior to transplanting by mixing PVA in the pulp (Oki and Ota 1970). The invention was coupled with the development of specific equipment used to transplant paper chain pots. These transplanters have evolved over time to accommodate various scales of production, cropping systems, and field conditions. Paper pot transplanters can now be mounted to walk-behind hand tractors (Kumar and Raheman 2011) and can be fitted with an automatic feeding mechanism (Kumar and Raheman 2012). Many of the innovations in the reinforcement of the planting cells and the mechanization of transplanting were pioneered in the automated transplanting of tree seedlings (Tervo 1999). Automation and improved reliability of the transplanters resulted in the unit costs coming down as the practice has become more widely adopted.

Organic Foods Production Act, USDA Final Rule:

Newspapers or other recycled paper are listed in the NOP regulations at §205.601(b)(2)(i) under "mulches" with the annotation "without glossy or colored inks," and at §205.601(c) under "compost feedstocks" with the annotation "without glossy or colored inks." Both listings were included in the Final Rule creating the NOP regulations on December 21, 2000 [(Federal Register 2000)]. Paper was the subject of an original technical report in 1995 (USDA/AMS/NOP 1995), with sunset Technical Reviews conducted in 2006 (USDA 2006) and 2017 (USDA 2017). The earlier petition and reviews were for the use of newspaper and other recycled paper as a mulch or compost feedstock.

Some USDA-accredited certifying agents (ACAs) permit paper chain pots to be used on certified operations but others do not. In 2018, the USDA National Organic Program (NOP) issued a letter notifying ACAs that "paper chain transplanting pots do not comply with the requirements at section 205.601 of the National List" (USDA/AMS/NOP 2018a). The notification required previously permitted uses to end after the 2018 growing season. A petition was submitted to the NOP to add plantable containers made from non-recycled paper to the National List (Hendrickson 2018a). The NOSB recommended that the use of paper pots continue while the review and potential rulemaking process proceeded (NOSB 2018b). The NOP notified ACAs that they accepted the NOSB's resolution to continue the allowance of paper chain pots until further notice (USDA/AMS/NOP 2018b).

In terms of specific products, Ellepots Membrane are Washington State Department of Agriculture (WSDA)-registered as organic inputs with the annotation, "Must be removed prior to planting into soil." Membrane Bio is registered with WSDA with the annotation "Must be removed prior to planting into soil. Must not be used as a feedstock in compost for organic production" (WSDA 2019). Similarly, the manufacturer of the molded pulp products states that their containers may be used to start organic transplants provided that the plant is removed from the container prior to being planted in the soil (Western Pulp Products 2019).

International

Canadian General Standards Board Permitted Substances List (Amended March 2018)
The Canadian Organic Regime permits "biodegradable plant containers," which include pots or cell packs on Table 4.3 of the Permitted Substances List. Biodegradable containers may be left in the field to decompose if all ingredients are listed in Table 4.2 of the Permitted Substances List (CAN/CGSB 2018). Biodegradable plant containers that have waxes, glues, and other substances not on Table 4.2 must be removed before the transplant is set in the soil (Canadian Organic Growers 2018). EcoCert, a USDA-accredited certifying agent that certifies organic farms and evaluates inputs under the Canadian Organic Regime (COR), permits Ellepots to be transplanted in the soil without restriction under the COR (EcoCert 2019).

CODEX Alimentarius Commission, Guidelines for the Production, Processing, Labelling and Marketing of Organically Produced Foods (GL 32-1999)
The Codex Guidelines do not mention paper chain pots (FAO/WHO Joint Standards Programme 2007).

European Economic Community (EEC) Council Regulation, EC No. 834/2007 and 889/2008
Paper chain pots are not mentioned in the current European regulation governing organic food (EU Commission 2007, 2008). Soil Association UK issued a certificate of registration to Ellepots for non-organic raw materials used in organic farming certified to the Soil Association standard (Soil Association UK 2019).

Japan Agricultural Standard (JAS) for Organic Production
The general management provisions of the JAS prohibit substances that are not on the tables of allowed ingredients for the specified purposes. Paper chain pots do not appear in the tables (Japan MAFF 2017). The status of paper chain pots was the subject of a specific policy directive that did not permit paper pots with chemical treatments and adhesives to be used in the field unless the seedlings were removed before transplanting (Japan MAFF 2016).

IFOAM-Organics International
The current IFOAM Standard does not mention paper chain pots (IFOAM 2014). The IFOAM Standards Committee did not identify any cases where the matter arose for accreditation of a Certification Body accredited under the IFOAM Standards. No use is known to be certified organic under the current IFOAM Standards.

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

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

Paper pots are a production aid that are not formulated with active ingredients identified in OFPA. Unlike other containers that are used for starting transplants, they are incorporated in the soil rather than separated from the root and transplant media prior to planting. As petitioned, the substance is not a synthetic inert ingredient and its compliance is not limited to EPA assignment as a substance of toxicological concern.

<u>Evaluation Question #2:</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)).

Most paper pots are made by the kraft process, which is also the prevalent technology for pulping (Hubbe 2005). Kraft pulping accounts for more than 80 percent of total U.S. virgin pulp production (US EPA 2010). Most kraft paper is derived from wood from timber that has been debarked and mechanically chipped. These wood chips are cooked in an alkaline solution, usually involving sodium hydroxide and sodium sulfide or polysulfide (Hagiopol and Johnston 2012). The lignin then undergoes a series of reactions that break it down into dissolved carbohydrates. The pulp and spent cooking liquor or "black liquor" are then separated by a series of brown stock washers (US EPA 2010). The pulping, defibration, and refining of the coarse pulps are wet processes.

The separated pulp is then dewatered and fed into a set of machines that dry and press it into sheets or other desired forms (Holik et al. 2000). During the process, wet strengthening agents and reinforcing fibers may be introduced. Two wet strengthening agents mentioned in the petition are magnesium chloride and urea resin. A number of different urea-based additives may be used in papermaking, with urea-formaldehyde resin being the one commonly added to sack paper (Auhorn 2012; Jang and Li 2015). DMEU is made from the condensation of urea-formaldehyde (Wayland 1958), while magnesium chloride may be extracted from seawater or salt brine (Butts 2003).

Artificial or natural fibers can be used to reinforce paper. Fibers also add bulk, improve structure, and increase porosity. Hydrophilic fibers also increase absorbency. Plantable paper pots without additional artificial or natural fibers in addition to cellulose are more likely to tear and damage the seedlings. Most if not all paper pots that are now commercially available use artificial fibers; two specific ones mentioned in the petition are PVA and PLA. Both polymers have been considered by the NOSB in previous petitions. PVA was included in the 2017 Technical Review on newspaper and other recycled paper (USDA 2017). PLA was evaluated as part of the biodegradable plastic mulch petition (Mojo 2012). Lactic acid is produced by the fermentation of starches by various *Lactobacillus* species. The lactic acid monomers are then polymerized by a chemical process (USDA 2012). The NOSB determined the films used to make biodegradable plastic mulch to be synthetic (NOSB 2012).

The petitioner proposed hemp as a non-synthetic fiber to substitute for the synthetic polymers that are currently used in paper pots, as well as a source of cellulose to make virgin paper without the harvesting of trees (Hendrickson 2018a, 2018b). Prior to the invention of synthetic fibers, hemp fiber was used to strengthen paper, as was sisal and manila (abacá) (Holik et al. 2000). Paper may also be made from hemp (Dewey and Merrill 1916; Bowyer 2001; Johnson 2018).

Hemp production in the United States peaked in the mid-1940s and fell rapidly following World War II (Ash 1948). By the late 1950s, there was no recorded hemp production in the U.S., largely because of its association with marijuana production and marijuana's status as a narcotic under the Controlled Substances Act [21 U.S.C. 802(16)]. Because the cultivation of *Cannabis sativa* has been illegal in the U.S. under most circumstances, and because of the higher production costs, hemp paper has been relatively expensive and limited in supply (Bowyer 2001; Johnson 2018). Similarly, there was an extensive supply chain infrastructure for handling hemp fiber prior to the 1950s that no longer exists (Ash 1948; Johnson 2018).

Except possibly for gum arabic, all adhesives considered for this Technical Review are the result of a chemical process (Onusseit et al. 2012). Glue from animals generally goes through a chemical transformation, starting with the cooking of glutin (i.e., collagen)-containing organs in calcium hydroxide (Dawidowsky 1905).

Evaluation Question #3: 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)).

Paper is manufactured by a chemical process. Most paper pots are made from the kraft process described above in *Evaluation Question #2*. The pulping process involves a series of acid-base reactions over a broad pH range. Various other cellulose and hemi-cellulose sources used to make paper are also made by chemical processes or by naturally occurring biological processes.

As was noted in the 2017 Technical Review, it is possible to produce cellulose by microbial fermentation (USDA 2017). Bacterial cellulose was first produced under laboratory conditions in 1886 (Brown 1886). Because of its high cost relative to chemical processing, commercial applications remain limited (Campano et al. 2016). Research continues to evaluate various microorganisms and enzymes used to replace chemical processes. While most has focused on wood decay processes, recent research has looked at the use of food processing waste as a possible source of fiber for pulping. One study explored using the fungi *Aspergillus oryzae* and *A. awamori,* and the bacterial strain *Komagataeibacter sucrofermentans*, to produce cellulose from oilseed wastes that are the by-product of biodiesel and confectionary manufacturing (Tsouko et al. 2015). The genetic engineering of cellulose-producing microorganisms is ongoing to increase yield, reduced production time, and improve fiber quality (Campano et al. 2016).

A comprehensive review of the manufacturing processes of all possible additives, adhesives and reinforcement fibers is beyond the scope of this review. All the additives mentioned in the petition are manufactured by chemical processes, even for those that are biologically based. One exception is magnesium chloride. The NOSB reviewed magnesium chloride derived from seawater in 1995 and classified it as synthetic (NOSB 1995). A Technical Review was prepared to re-evaluate the status of magnesium chloride (USDA 2016a). The NOSB voted to reclassify magnesium chloride obtained from seawater as non-synthetic (NOSB 2018a).

Because the petitioned substance is for a specific use or application as a production aid, additional ingredients besides the main ingredient of cellulose need to be considered. It is not within the scope of the review to evaluate all possible alternatives or to limit the evaluation to the specific product described in the petition. Most—but not all—of the additives used to make paper pots are formulated or manufactured by a chemical process and are not created by a naturally occurring biological process. One adhesive that might be considered non-synthetic is gum arabic, which is derived from the acacia tree and is considered an agricultural product on the National List [7 CFR 205.606]. Starches derived from plants can also be used as water-soluble adhesives, such as paste made from wheat flour. However, most modern adhesives are petroleum derivatives and are derived from various chemical processes. Of the adhesives mentioned in the petition, PVA is most commonly manufactured from polyvinyl acetate by a base-catalyzed transesterification process (Hallensleben, Fuss, and Mummy 2015).

<u>Evaluation Question #4:</u> Describe the persistence or concentration of the petitioned substance and/or its by-products in the environment (7 U.S.C. § 6518 (m) (2)).

The USDA organic regulation defines "biodegradable" as "[s]ubject to biological decomposition into simpler biochemical and chemical components" (7 CFR 205.2). Cellulose is readily and intrinsically biodegradable (Béguin and Aubert 1994; Sivan 2011). Hemicellulose and lignin are also biodegradable but are more resistant to hydrolysis and take longer to decompose in the environment (Richard 1996).

PLA and other biodegradable plastic mulches were the subject of a previous petition and technical review (USDA 2012). The USDA organic regulation [7 CFR 205.2] refers to "[b]iodegradable biobased mulch film" and defines it as follows (testing methods for biodegradability are incorporated by reference in 7 CFR 205.3):

> "[a] synthetic mulch film that meets the following criteria:
>
> (1) Meets the compostability specifications of one of the following standards: ASTM D6400, ASTM D6868, EN 13432, EN 14995, or ISO 17088 (all incorporated by reference; see §205.3);
>
> (2) Demonstrates at least 90% biodegradation absolute or relative to microcrystalline cellulose in less than two years, in soil, according to one of the following test methods: ISO 17556 or ASTM D5988 (both incorporated by reference; see §205.3); and
>
> (3) Must be biobased with content determined using ASTM D6866 (incorporated by reference; see §205.3).

Various fibers woven into paper pots to increase wet strength and provide more structural rigidity for the pots may not be biodegradable. Those that are biodegradable may vary widely in both the degree and rate of biodegradation. Many factors influence polymer degradation, and it can be difficult to predict how much a given polymer will degrade under highly variable natural conditions (Garlotta 2001; Lucas et al. 2008; Kawai and Hu 2009; Leja and Lewandowicz 2010; Nambuthiri et al. 2015; Laycock et al. 2017). The degree (percentage) and timeframe for degradation of the synthetic fiber depends on (1) the specific polymer, (2) environmental conditions, and (3) the presence or absence of specific organisms known to biodegrade the polymers. Container biodegradation in the soil depends on many factors as well. Moisture, temperature, pH, available nitrogen, soil biological activity, soil type, and climate all interact to determine the amount of degradation that will occur (Nambuthiri et al. 2015).

Degradation of synthetic polymers is a complex process that involves the interaction of both abiotic and biological factors and mechanisms (Lucas et al. 2008). Biodegradation alone is seldom enough to decompose synthetic polymers (Lucas et al. 2008; Laycock et al. 2017). Specific polymers can be made in a ways that make them more or less prone to biodegradation (Laycock et al. 2017). Biodeterioration, biofragmentation, and assimilation are all subject to abiotic factors, such as mechanical, thermal, and chemical factors, as well as to photodegradation (Lucas et al. 2008).

PVA and PLA are both considered to be biodegradable (Kawai and Hu 2009; Leja and Lewandowicz 2010). However, both can be recalcitrant, and a certain percentage can be expected to be undegraded under unfavorable conditions. PLA has a degradation time of between six months and two years (Garlotta 2001; HSDB 2015).

The PVA monomer is biodegradable and some polymeric fibers made from PVA are also biodegradable. The percentage and rate of PVA polymer biodegradation depends in part on polymer chain length, density, water solubility, and molecular weights. The Zahn-Wellens test showed that PVA at a concentration of 500 mg/L in activated sludge inoculated with suitably acclimated microorganisms was able to achieve 20 percent, 50 percent, and 90 percent biodegradation after 17, 24, and 28 days, respectively. Natural degradation of PVA can be readily 100 percent biodegradable in 30 days under ideal conditions (HSDB 2015). Two kinds of water-soluble Vinylon were compared to aniline, which was used as a reference standard. Aniline was almost 100 percent biodegraded after 35 days. One kind of water-soluble PVA fiber was 80 percent biodegraded and another was more than 60 percent biodegraded over the same time period under the Japanese Industrial Standard (JIS K6590) protocol (Lewin 2006). In some cases, soil degradation took more than 120 days with some field conditions showing little degradation after two years of being buried in soil (Chiellini et al. 2003). The authors attributed this in part to the relative scarcity and poor distribution of PVA degrading microorganisms.

The metabolic degradation of PVA is a two-step process (Kawai and Hu 2009). First, the hydroxyl groups are oxidized to form diketone or monoketone structures. This requires the presence of microorganisms that are capable of oxidizing PVA, which means that they produce an oxidase enzyme specific to PVA. Certain *Pseudomonas* strains were discovered to produce the enzyme (Suzuki 1976; Watanabe et al. 1976). The second stage is the hydrolysis of the carbonyl structures, which could be either enzymatic in the presence of the enzyme hydrolase, or non-enzymatic in either acid or alkali conditions (Sakai, Hamada, and Watanabe 1984). Non-enzymatic degradation is temperature dependent, with the reaction rate being nearly zero at temperatures below 122°F (50°C). Under soil conditions, that means that the ß-diketone hydrolase enzyme must also be present for continued PVA biodegradation to occur. This metabolic pathway is less well understood (Kawai and Hu 2009). The *Pseudomonas* species that biodegrade PVA also produce enzymes that biodegrade polyacrylamide and polyacrylic acid (Shimao 2001).

In field conditions, PVA-based films biodegraded between 8–9% over 74 days in a solid culture (Chiellini, Corti, and Solaro 1999). Water-insoluble PVA polymers are not expected to be as readily biodegradable by microorganisms and may require chemical treatment before the fibers can be hydrolyzed and biodegrade (Chiellini et al. 2003). Biodegradation of PVA-based polymers can also vary widely according to soil physical and biological properties, as well as climate. However, none of the studies reviewed found PVA to be 100 percent biodegradable. One reason that PVA remains in the soil is that it will readily adsorb to clay particles and organic matter (Chiellini et al. 2003). PVA will decompose more rapidly in composting or aqueous conditions than buried in soil (Chiellini et al. 2003). Controlled experiments evaluating actual biodegradation of pots reinforced with PVA under field conditions were not found in the scientific literature. The FDA issued a FONSI on the environment for the use of PVA as a packaging material because it is non-toxic and biodegradable (Cox 2000).

Polylactic acid is also considered biodegradable (Tokiwa and Calabia 2006; Tokiwa et al. 2009; Leja and Lewandowicz 2010; Karamanlioglu, Preziosi, and Robson 2017). The lactic acid monomer is considered readily biodegradable (US National Library of Medicine 2019). The biodegradability of polylactic acid—like other polymers made from biodegradable monomers—depends on several abiotic and biotic factors. Most of the research on biodegradation of PLA has been either with compostable plastics or biodegradable plastic mulch and takes place under thermophilic composting conditions. The biodegradation—and conditions limiting the biodegradation—of PLA in thermophilic aerobic compost is relatively well documented (Iovino et al. 2008; Shah et al. 2008; Sedničková et al. 2018).

Despite numerous studies in various soil conditions, the degradation mechanisms and soil biological conditions needed for degradation in mesophilic ambient soils remain poorly understood (Tokiwa and Calabia 2006; Karamanlioglu, Preziosi, and Robson 2017). The results for field trials for degradation of biodegradable plastic mulches was summarized in the Technical Review for that petition (USDA 2012; USDA 2016b). No comparable third-party studies were found in the published literature for PLA used as a fiber in transplanted paper pots in soil. Alkali conditions enhance PLA degradation under certain conditions (Cam, Hyon, and Ikada 1995). Photodegradation through exposure to ultraviolet light can also increase the rate and the degree of PLA decomposition (Tsuji, Echizen, and Nishimura 2006).

Various additives can increase PLA degradation in soil. Starch and wood flour significantly increased the rate of degradation of PLA (Lv et al. 2017). The hydrophilic starch helps with the dispersion of water in the

PLA. For example, a combination of PLA with paddy straw powder as a source of lignocellulose was found to increase PLA biodegradation nearly ten-fold. PLA alone was about 2 percent biodegraded in soil after six months, while PLA with paddy straw powder was nearly 50 percent biodegraded, with greater colonization by microorganisms, lower tensile strength, and greater elasticity (Yaacob, Ismail, and Ting 2016). PLA-degrading microorganisms are necessary for the biodegradation process to be effective, and they are not naturally widespread in the environment (Shimao 2001). The FDA issued a FONSI on the quality of the environment for the use of PLA in manufacturing food contact items (Chappell 2001).

Natural fibers such as flax, cotton, hemp, kenaf, sisal, kapok, and jute are readily biodegradable and non-toxic (Smole et al. 2013). Like paper, they are composed mainly of cellulose and decompose in soil as carbohydrates that feed microorganisms.

Ellepot claims that their paper pots are 100 percent biodegradable; however, supporting documentation and the amount of time needed for complete degradation was not provided by the manufacturer. The Nitten paper chain pots do not make a claim of percentage biodegradability. Neither provided an estimate of the timeframe for biodegradation. No data to support biodegradability of the pots in soil using the testing methods contained in ISO 17556 or ASTM D5988 was found. Original research replicating use in multiple sites under various conditions would be needed to determine the percentage and timeframe of degradation requested in Supplemental Questions 2 and 3. Such experiments are beyond the scope of this Technical Review.

<u>Evaluation Question #5:</u> Describe the toxicity and mode of action of the substance and of its breakdown products and any contaminants. Describe the persistence and areas of concentration in the environment of the substance and its breakdown products (7 U.S.C. § 6518 (m) (2)).

Toxicity and Mode of Action

Paper is considered non-toxic. Cellulose decomposes into carbohydrates and water. Previous Technical Reviews evaluated the toxicity of various components of recycled paper, with an emphasis on the heavy metals found in inks and dyes (USDA 2006; USDA 2017). With the growing complexity of paper and the replacement of heavy metals, other chemical contaminants pose possible risks. These include bisphenol A (BPA) and various phthalates that are considered endocrine disruptors (Pivnenko, Eriksson, and Astrup 2015; Pivnenko, Laner, and Astrup 2016; Rosenmai et al. 2017).

The only additives commonly found in virgin kraft paper that is likely to pose any toxicological health risks are formaldehyde resins. Urea-, phenol-, and melamine-formaldehyde all readily degrade into urea and formaldehyde (Lithner and Larsson 2011). Formaldehyde is considered a Group 1 carcinogen by the International Agency for Research on Cancer (IARC 2018) and as a gas is on the California Proposition 65 list of known carcinogens (Cal-EPA 2019). Specifically, formaldehyde exposure is linked to leukemia, cancer of the nasopharynx and nasal sinuses (IARC 2012). Much of the epidemiological evidence of cancer resulting from occupational exposure is of workers in paper factories (NLM 2016). Formaldehyde used to make paper may also be a mutagen—papermakers heavily exposed to formaldehyde were significantly more likely to have chromosome damage than workers who were less exposed (Bauchinger and Schmid 1985).

PVA was non-toxic when administered orally to rats, mice, and dogs at the highest reference doses, making it virtually non-toxic (HSDB 2015). In a terrestrial plant study, *Brassica rapa* (Wisconsin Fast Plant) and *Lepidium sativum* (garden cress) were used as models. PVA inhibited the growth of garden cress (Arfsten et al. 2004). The mode of action was not understood by the authors and no effect on *B. rapa* was reported. No other studies found PVA to be phytotoxic to other plants.

PLA was also found to be non-toxic when administered orally to mice (HSDB 2015). Onions (*Allium cepa*) were used as a test organism for phytoxicity. The study concluded that PLA was not phytotoxic, cytotoxic, genotoxic, or mutagenic to onions. PVA and PLA are not considered carcinogens (IARC 2018).

Persistence and Areas of Concentration
Cellulose is readily biodegradable into water and carbohydrates by a diverse array of cellulolytic microorganisms that produce a battery of enzymes (Béguin and Aubert 1994). Water soluble adhesives are washed out in aqueous solution before the paper pots are transplanted. Water insoluble adhesives are biodegradable. Most synthetic polymers used in fibers are wholly resistant to biodegradation (Alexander 1999). PVA and PLA are somewhat biodegradable, but empirical research shows that ideal conditions required for 100 percent biodegradability are unlikely. Natural fibers are more likely to be 100 percent biodegradable into water, starch, and carbon dioxide and to not produce any toxic decomposition products.

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

The environmental contamination of paper's manufacture, use, misuse, and disposal was covered in the 2017 Technical Review (USDA 2017). That review focused on newspaper and other recycled paper products. The petitioner requested consideration of non-recycled or virgin paper. The environmental impacts of manufacturing virgin paper are considered to be significantly greater than recycling paper (Roberts 2007; Martin and Haggith 2018). Harvesting trees to make virgin pulp and paper predictably results in soil erosion and water sedimentation through road-building activity, exposure of bare soil, and accelerated water runoff (Corbett, Lynch, and Sopper 1978; Croke and Hairsine 2011; Anderson and Lockaby 2011). While forestry best management practices (BMPs) may mitigate these effects, BMPs are not always implemented and there are still environmental quality concerns that have not been addressed by BMPs (Anderson and Lockaby 2011). Reduction of forest disturbance by recycling is seen as an environmental benefit (Villanueva and Wenzel 2007). One ton of virgin kraft paper requires 4.4 tons of trees to produce; the same amount of recycled kraft paper requires 1.4 tons of recovered paper to produce (Roberts 2007).

The ability of the forest to sequester carbon is curtailed by harvest (Martin and Haggith 2018). Additionally, recycling waste paper consistently uses less energy and results in fewer greenhouse gas emissions compared with landfilling or incinerating it (Björklund and Finnveden 2005; Villanueva and Wenzel 2007; US EPA 2011; Ghinea et al. 2014). Agricultural by-product sources of pulp fiber can mitigate the adverse impacts of the reliance on wood from forests (USDA 2017; Martin and Haggith 2018). However, the workers who are making the paper pots are more likely to be exposed to chemicals that have adverse health effects than the farmers and farmworkers using the paper pots or those who eat the food grown from the transplants.

Recycled paper products generally have greater contaminant content than virgin paper (Biedermann and Grob 2010; Blechschmidt et al. 2012; Rosenmai et al. 2017). Inks, dyes, and other chemicals not applied to virgin paper will still be present in recycled paper, with only the highest grades of recycled papers being free of impurities and contaminants (Blechschmidt et al. 2012). Recycled paper can include a wide variety of chemical contaminants that are either not present or found at much lower levels in virgin paper. These include heavy metals that may be used in inks and dyes; synthetic polymers used in gloss and as reinforcement; and various adhesives, including the ones being considered in this Technical Review (Borchardt 2006).

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

A literature search found no evidence to support that paper pots or the additives used to make them interact with other substances used in organic crop or livestock production or handling. Contaminants found in recycled papers were summarized in Evaluation Questions #9 and #10 of the most recent Technical Review on newspaper used as a mulch or compost feedstock (USDA 2017). The chemicals used to make the paper chain pots are commonly found in other sources of paper. A search of the scientific literature did not find any evidence of harmful effects on the environment or human health from the planting of paper chain pots.

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

As the major carbohydrate found in plants, cellulose represents an important part of the carbon cycle in the biosphere (Béguin and Aubert 1994). The effects of paper as mulch and as a compost feedstock additive on the agro-ecosystem and soil organisms were the subject of previous reviews (USDA 2006; USDA 2017). The 2017 Technical Review included consideration of various additives to paper, including those used in making paper pots (USDA 2017).

While there is no salt index published for paper, cellulose is insoluble and non-ionic and can thus be assumed to have a salt index of zero. Alternatively, some additives may increase soil salinization, as noted in the 2017 Technical Review. This is likely to be the case for magnesium chloride. However, no published empirical research was found to evaluate how much of the chloride is leached from the paper prior to transplanting and how much would be left to decompose in the soil along with the cellulose and other fibers.

In considering PVA's use as a coating on the inedible peels of fruits and vegetables, the FDA issued a FONSI, citing that it had a low toxicity and was biodegradable (Cox 2000).

The various additives, contaminants, and impurities found in paper products were also covered briefly in the 2017 Technical Review (USDA 2017). Polylactic acid was also evaluated in the biodegradable plastic mulch Technical Review (USDA 2012; USDA 2016b).

<u>Evaluation Question #9:</u> Discuss and summarize findings on whether the use of the petitioned 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) (i)).

Paper, by itself, is not harmful to the environment and cellulose comprises a large amount of the natural biomass found in the environment. However, the manufacture of virgin paper is harmful to the environment (Roberts 2007; Martin and Haggith 2018). The harvest of trees results in the loss of soil and water-holding capacity in forests and reduces atmospheric carbon sequestration. Biomass cultivation can result in potential loss of biodiversity, soil carbon depletion, increased soil erosion, deforestation, and increased greenhouse gas emissions (Weiss et al. 2012). Various additives used to manufacture paper pots and containers may be harmful to the environment. Only a few possible additives are mentioned, and no studies have been conducted on their environmental impact when buried in the soil as part of the paper pots or containers.

A comprehensive life-cycle analysis (LCA) comparing the different environmental impacts of all the possible additives, adhesives, and polymers is beyond the scope of this Technical Review. The LCA comparison of a single synthetic polymer with a bio-based substitute requires a considerable amount of data (La Rosa et al. 2014).

<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)).

No studies showing adverse health effects were found in a search of the medical or epidemiological literature for paper pots used for transplanting. Most of the secondary effects of paper were related to exposure to heavy metals found in inks and colored paper. These were evaluated in the previous Technical Review on newspapers and other recycled paper (USDA 2006; USDA 2017).

<u>Evaluation Question #11:</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)).

Two alternative non-synthetic products are commercially available and are used on organic farms. One is Fertilpot (Fertil USA 2019) made from pressed wood fiber. The other is Jiffy Pot (Jiffy Group 2019), made from coconut coir. Both are OMRI Listed (OMRI 2019). A review article of various alternatives compared the sustainability of various biodegradable planting containers, including molded paper (Nambuthiri et al. 2015). Jiffy Pot also has products made from pressed peat moss and polylactic acid (Speedypot) (Nambuthiri et al. 2015). Another coir pot manufacturer is ITML of Middlefield, OH. The article also notes straw (StrawPot, Baiting Hollow, NY), cow manure (CowPot, East Canaan, CT), rice hulls (NetPot, Akron, OH), and bamboo (Biopot, Nanjing, China) used as biodegradable pots of biological origin (Nambuthiri et al. 2015). However, it is unclear whether these products contain any synthetic additives as binders, for reinforcement, or other functions. It also was not clear from the article whether the cow manure pots would be subject to the 7 CFR 205.203(c) requirements for uncomposted manure applied on organic farms.

A study compared the performance of Jiffy Pots and Fertilpots with various other biocontainers made from coir, peat, cow manure, or rice hulls (Sun et al. 2015). The model plants were *Impatiens x hybrida, Lantana camara,* and *Cleome x hybrida* in experimental sites in Illinois, Kentucky, Mississippi, Texas, and West Virginia (Sun et al. 2015). Seedlings in the plantable containers performed similarly to those in plastic pots in all cases. The experiments did not include paper chain pots or any other paper pots used for transplanting. The manure pots had the highest rate of decomposition, and were on average 88 percent decomposed at the end of the growing season (Sun et al. 2015). Coir and rice hulls decomposed the least.

One study compared the growth of geraniums (*Pelargonium x hortorum*), vinca (*Catharanthus roseus*), and impatiens (*Impatiens wallerana*) grown in paper, coconut fiber, peat, and Fertilpots, soil wrapped in a bioplastic sleeve, straw pots, wood fiber, and pots made of injection molded plastic with other biodegradable and plastic components (Kuehny, Taylor, and Evans 2011). Paper pots had the highest shoot growth for geraniums; coconut fiber and peat had the lowest. However, peat containers had the highest root growth for impatiens. Otherwise, the different pots were similar in performance (Kuehny, Taylor, and Evans 2011).

Jiffy Pots, like paper chain pots, are used to grow forest seedlings. Improvements have been made for mechanized planting of Jiffy Pots large seedlings to reduce labor and increase transplanting speeds (Landis 2007). Mechanical peat pot transplanters are commercially available from the Mechanical Transplanter Co. of Holland, MI (Mechanical Transplanter Co. 2019). The manufacturer claims a transplanting rate of up to 60 plants per minute.

Various plant-derived fibers may be potential non-synthetic alternatives to PVA or PLA for paper reinforcement in biodegradable plant pots. Hemp (*Cannabis sativa)* was one alternative proposed in the petition (Hendrickson 2018a). At least one source of transplantable pots made entirely from hemp is commercially available from iEarth of Humboldt County, CA (iEarth LLC 2019). Other natural fiber alternatives include cotton (*Gossypium hirsutum*), flax or linen (*Linum usitatissiumum*), jute (*Corchorus capsularis*), sisal (*Agave fourcroydes*), manila or abacá (*Musa textilis*), bamboo (*Bambusa* spp.) and coir from coconuts (*Cocos nucifera*) (Dewey and Merrill 1916; Ash 1948; Faruk et al. 2012). While these fibers do not appear to be currently used to make commercially available paper pots, most have historically been used in papermaking (Hubbe 2005). Research and development of other biocomposite applications of plant fibers is on-going, so they may be technically feasible (Faruk et al. 2012). Experimental pots made from a combination of hemp fiber and canning tomato wastes linked by sodium alginate, polyglycerol, and calcium chloride were found to reduce planting shock and improve establishment of transplants compared with seedlings started and removed from polystyrene pots. The pots were completely biodegraded within two weeks (Schettini et al. 2013). It is not clear whether these products are commercially available.

Unspecified "pastes" were also used to make transplantable paper containers prior to the 1920s (Harris 1922). While the specific source and manufacturing process were not disclosed, those pastes may have been non-synthetic. Paper pastes can be made from various starches derived from grains and potatoes, among other sources of starch that would bind to cellulose. The patent filed for Japanese paper chain pots referred to gum arabic as a non-synthetic water-soluble adhesive (Masuda 1965).

Water-insoluble adhesives may pose a greater formulation challenge. Defatted soy flour and magnesium oxide have been proposed as an "all-natural" alternative adhesive with low water solubility for wood (Jang and Li 2015). Even though the adhesive is prepared from natural sources, the substance may be considered synthetic under the definition at 7 CFR 205.2.

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

Direct seeding as an alternative to transplanting is an option for most crops, and may be preferable for many crops given their marketing windows (Maynard and Hochmuth 1997). Transplanting of crops, including with paper chain pots, is generally more expensive than sowing (Heege and Billot 1999). Starting plants indoors is advantageous when the growing season is short. Transplants can also have other advantages that outweigh the additional expense for supplies, facilities, and labor as compared to direct seeding. While direct-seeding is faster and is lower cost than transplanting, stand establishment is less uniform, seed-borne diseases are a greater risk, and thinning and weeding can lead to higher labor costs over the entire season (Macias-Leon and Leskovar 2019).

The extensive literature that documents which crops, locations, climate types, varieties, cropping systems, soil types, planting dates, irrigation systems, weed management techniques, and other factors that make direct sown seeds preferable to transplanted seedlings is beyond the scope of this review. Many of the studies that compared transplanted seedlings with direct seeding either did not use biodegradable transplant containers in their experimental designs, removed the plugs from the trays, or did not specify what polymers were in the containers. Several studies that transplanted the containers used biodegradable material other than paper, such as peat blocks or coir.

The traditional alternative practice to planting paper pots with the seedlings in the soil is to remove the seedlings from the pots when they are transplanted. Non-renewable, petrochemical based transplant containers made from polymers with limited recycling options are currently used in organic production. These containers are commonly made from polystyrene, high-density polyethylene, and polypropylene, none of which are biodegradable. The removal of seedlings from pots when they are transplanted is currently being implemented on organic farms for biodegradable pots as well, including the Ellepots (WSDA 2019) and the molded pulp fiber pots (Western Pulp Products 2019), as well as for non-biodegradable and non-recyclable plastic pots which are also allowed for use in organic production. Removal of the seedlings from the planting cells is more labor intensive and increases the risk of root damage and other transplant injuries (Thompson 1939; Splittstoesser 1979; Maynard and Hochmuth 1997; Schrader 2000).

Transplant media, such as peat moss, can be molded into soil blocks without containers (Quillen and Billerbeck 1934; Splittstoesser 1979; Maynard and Hochmuth 1997; Coleman 2018). Small-scale operations can make soil blocks with relatively inexpensive hand-held equipment (Johnny's Selected Seeds 2016). The process can also be mechanized, but the equipment is specialized and relatively expensive (Maynard and Hochmuth 1997).

Few studies comparing direct seeding with paper pot transplants or transplants in other or unspecified biodegradable containers are published in peer-reviewed journals (Theurer and Doney 1980; Suggs et al. 1987; Wilson et al. 1987; Leskovar et al. 2004). None of the comparison studies were identified as being conducted in organic farming systems. In several cases, the methods described involved the application of inputs that are prohibited by the USDA organic regulations.

Several of the studies comparing paper chain pots with other techniques were conducted before the current equipment used for transplanting was invented or commercially available. These studies noted ways that the designs could be improved. The early prototypes were more unwieldy and expensive than what is on the market today.

One study conducted in Logan, Utah compared direct-seeded sugar beets with sugar beets transplanted using Japanese paper pots over three seasons. The transplanted seedlings grew more rapidly and had larger canopies for the first two months. The transplanted beets tended to have stubbier branched roots that broke during harvest, but still had higher overall yields than the direct-seeded sugar beets (Theurer and Doney 1980). Another study found that sugar beets in paper pots transplanted into fields treated with pre-plant herbicides were not subject to injury and had a growth advantage over direct-sown beets, which reduced weed pressure (Wilson et al. 1987). Tobacco and sweet corn grown in Japanese paper pots were transplanted by machine at a rate of about 100 plants per minute when mounted to a two-wheel walk behind tractor (Suggs et al. 1987). Higher speeds had higher incidents of double, skipped, and misaligned plants. One of the transplanters was relatively large, unwieldy, and expensive. Containerized transplanted onions had comparable yields to bare-root transplants, but bulb sizes were significantly smaller (Leskovar et al. 2004).

A comparison of hot pepper (*Capsicum* spp.) plants transplanted bare-root and in paper pots in Java, Indonesia and Klang, Malaysia showed that the transplants grown in paper pots performed about the same as those transplanted bare-root, with paper pots doing better in some trials and worse in others. The use of screen covers to exclude virus-vector insects was a more reliable predictor of transplant viability and productivity than how the seedlings were produced and transferred (Vos and Nurtika 1995).

Supplemental Questions Cross-Referenced and Summarized

<u>Supplemental Question #1:</u> What types of synthetic fibers are used in paper-based crop production aids?

See the *Characterization of the Petitioned Substance* and *Combinations of the Substance* sections above for more information on the types of synthetic fibers used in paper-based production aids. It was not possible to compile an exhaustive list of synthetic fibers used in making paper-based crop production aids because of confidentiality. The main synthetic fiber documented in the petition to be used in current commercially available transplantable paper pots are PVA (Hendrickson 2019). PLA fibers may also be used in another paper-based crop production aid (Ellegaard and Kulmbach 2016; Pedersen 2017). Other possible synthetic fibers mentioned in the scientific and patent literature for reinforcing paper are polyester, acrylic, polypropylene, and polyacrylonitrile (Ruuska 1980; Hubbe 2005). Other commercially available paper pots may use undisclosed proprietary fibers.

<u>Supplemental Question #2: What percentage of the synthetic fiber biodegrades, if at all?</u>

See *Evaluation Question #4*. A search of the literature and requests to the petitioner—the North American representative of Nippon Sugar Beet Manufacturing Company (Nitten)—and two other manufacturers of commercial transplantable paper pots (Ellepot A/S and Western Pulp Products) yielded no peer-reviewed or third-party independent data to support the manufacturers' claims about the actual biodegradation of synthetic fiber in paper pots using either ISO 17556, ASTM D5988 or equivalent methods. The petition did not provide data or references to biodegradation percentages. The percentage is expected to vary between 0–100% depending on a complex combination of conditions.

<u>Supplemental Question #3: In what timeframe does the synthetic fiber degrade?</u>

See *Evaluation Question #4*. Most synthetic fibers do not degrade. The timeframe for the few that are degradable depends on a complex set of abiotic and biotic conditions explained in greater detail in *Evaluation Question #4*. The fibers may take months or years and under some conditions may not degrade at all. No independent or third-party studies using either ISO 17556 or ASTM D5988 or equivalent methods were provided by the petitioner or found in the literature that documented the timeframe for paper pots to degrade.

Supplemental Question #4: Are there any soil health or environmental effects caused by the degradation of these synthetic fibers?

See *Evaluation Questions #9* and *#10* for more information. No peer-reviewed or independent third-party studies documenting the effects of paper pots on soil health or environmental effects were found in a review of the scientific literature.

Supplemental Question #5: How do these production aids differ in synthetic fiber content from newspaper, cardboard and other recycled papers already permitted on the national list?

See the *Characterization of the Petitioned Substance* and *Combinations of the Substance* sections above for more information on the synthetic fiber content of different types of paper. All the synthetic fibers confirmed to be components of the production aids evaluated in this Technical Review have been evaluated in previous Technical Reviews for newspaper, cardboard and other recycled papers permitted on the National List (USDA 2006; USDA 2017). One possible exception was PLA, which was included in the Technical Review of biodegradable plastic mulch (USDA 2012; USDA 2016b). The content of the recycled waste paper stream is highly variable based on methods of source separation, regional content, collection method, and other factors. Original research is needed to evaluate the synthetic fiber content of recycled paper in order to compare it to that of paper pots, which is beyond the scope of this Technical Review.

Report Authorship

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

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