Activated Charcoal

Livestock

Executive Summary

Activated carbon was petitioned for veterinary use, principally to remove toxins. It is considered to be the universal poison antidote. Carbon is obtained from a wide variety of sources and is activated by a number of different processes. The reviewers all considered activated carbon in general to be synthetic. All recommended that it be allowed for use in organic production with restrictions. These restrictions would limit it to therapeutic use and prohibit routine feeding in the absence of poisoning.

Summary of TAP Reviewer's Analyses[1]

Synthetic/ Nonsynthetic	*Allow without restrictions?*	*Allow only with restrictions?*	*Prohibit for all uses*	*Prohibit with Limited Uses*
Synthetic (2) Non-synthetic (1)	Yes (0) No (3)	Yes (2) No (1)	Yes (0) No (3)	Yes (1) No (2)

Identification

Chemical Names:
Carbon, Activated

Other Name:
Activated charcoal; Active carbon; Active charcoal; Amorphous carbon; Bone black; Bone coal; Channel black; Charcoal; Decolorizing carbon; Lamp black

Trade Names:
Calgon, MedChar, Superchar Vet, Toxiban,

CAS Numbers:
7440-44-0; 64365-11-3

Other Codes:
EINECS No.: 231-153-3
ECL Serial No.: KE-04671

Characterization

Composition:
Carbon arranged in a quasi-graphitic form in a small particle size.

Properties:
A solid, porous, black carbonaceous material. Tasteless (Budavari, 1996). Activated carbon is distinguished from elemental carbon by the removal of all non-carbon impurities and the oxidation of the carbon surface (Mattson and Mark, 1971).

How Made:
Activated carbon can be prepared from a large number of sources by a wide variety of methods. The Merck Index divides these into four basic forms: *Animal charcoal* is obtained by charring bones, meat, blood, etc.; *Gas black, furnace black, or channel black* is obtained by the incomplete combustion of natural gas; *Lamp black* is obtained by the burning various fats, oils, resins, etc., and *Activated charcoal* is prepared from wood and vegetables (Budavari, 1996).

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[1] *This Technical Advisory Panel (TAP) review is based on the information available as of the date of this review. This review addresses the requirements of the Organic Foods Production Act to the best of the investigator's ability, and has been reviewed by experts on the TAP. The substance is evaluated against the criteria found in section 2119(m) of the OFPA [7 USC 6517(m)]. The information and advice presented to the NOSB is based on the technical evaluation against that criteria, and does not incorporate commercial availability, socio-economic impact, or other factors that the NOSB and the USDA may want to consider in making decisions.*

Activated carbon can be produced from a number of agricultural commodities. Among these are hardwoods, grain hulls, corncobs, and nutshells (Young, 1996). Steam activation can also be used with food-grade carbonaceous material (Burdock, 1997). Acid treatment is also common. For example, pecan shells can be activated by treatment with hydrochloric acid, then heated in an electric furnace for four hours at 800-1,000°C. in an atmosphere of carbon dioxide (Young, 1996).

There is some disagreement among various sources as to whether bone char or bone black should be considered an 'active carbon.' Mantell (1968) devotes an entire chapter to bone char, noting that it contains between 9-10% adsorbent carbon when prepared. Smíšek, and Cerný (1970) dismiss bone char as a form of active carbon because it is predominately composed of calcium phosphate, and notes that many of its properties—particularly its capacity to decolorize sugar and other sweeteners—is related to this heterogenous chemical composition. It is included in this review because of its historical and commercial importance. Bone char is prepared by the removal of all flesh, fat, and oil. After their adsorptive capacity is spent, bone char can be mechanically and physically regenerated through drying and pricking with hot rods (Elmenhorst, 1880).

Among the other raw materials used as precursors to make activated carbon are sawdust, peat, lignite, coal, cellulose residues (Lambiotte, 1942), and petroleum coke, spent ion exchange resins such as styrene-divinyl benzene polymers (von Blucher and De Ruiter, 1999), phenol-formaldehyde resins (Teng and Wang, 2000), and old automobile tires (Whitaker and Grindstaff, 1974; Sang, 1975; Teng, et al., 1999), and sewage sludge (Kermmer, Robertson, and Mattix, 1972; Nickerson and Messman, 1975; Sutherland, 1976). Various binding agents may be added to improve the structure (Baker et al., 1992). Commercial sources appear to be made from a variety of precursors, activating agents, and binders (Tolles, et al, 1993; Ashford, 1994; Ivey and Hoffman, 1998)

Any given carbon sources may be prepared, treated, or manufactured by a wide variety of methods. These may or many not involve synthetic acids, bases, and other substances in a stream of activating gases such as steam (H_2O), nitrogen (N_2) or carbon dioxide (CO_2). Yields and quality can be improved by the removal of moisture (UN FAO, 1985). Lignite and peat are made into activated charcoal by low-temperature charring, followed by treatment with either superheated steam or potassium hydroxide. Cation-exchange resins can be made by sulfonation, or by nitration and reduction. Treatment of low-rank coal with ethylene dichloride and ammonia gives an anion exchange resin (Vorres, 1996). Some processes treat carbonaceous matter with phosphoric acid and / or zinc chloride (Krczil, 1937), with the resulting mixture carbonized at an elevated temperature, followed by the removal of the chemical activating agent by water washing (Food Chemicals Codex, 1996).

Activated carbon can be recycled, reactivated, or regenerated from spent activated carbon. Activated carbon used to treat hazardous waste or that becomes concentrated with adsorbed hazardous chemicals can be considered hazardous waste itself.

Specific Uses:

The petitioned and principal veterinary use is as an antidote to toxic substances—and analogous medical applications include use as a detoxifier. It is regarded as the poison antidote of choice (Aiello, 1996) and the universal antidote to toxic substances (Kanzler, 1995). There is no reported overdosage or acute toxicity (Plumb, 1999). Activated charcoal is highly effective against both natural and synthetic toxins (Aiello, 1996). Studies show activated carbon to be effective in removing various mycotoxins, such as aflatoxin, fumonisins, ochratoxin A, trichothenes, and zearalenone (Dalvi and Ademoyero, 1983; Rotter et al., 1989; Kubena, et al., 1990; Edrington, et al., 1997; Huwig, et al., 2001). Natural toxins from plants are also removed or attenuated by activated charcoal treatment or supplementation (Pass and Stewart, 1984; McLennan and Amos, 1989; Poage et al., 2000; Banner, et al., 2000; Bisson, et al., 2001). Activated carbon can also be used to remove synthetic pesticides from animals that might contaminate milk or meat (Cook and Wilson, 1971; Morgan et al., 1977; Aiello, 1998). Treatment with activated carbon when using certain parasiticides can help reduce the residual levels in flesh and fatty tissue (Crookshank, et al., 1972). Finally, activated charcoal is used to treat animals for drug overdoses (Haddad and Winchester, 1983), with efficacy established on pigs (Lipscomb and Widdop, 1975), dogs (Widdop et al., 1975), and rabbits (Galloway and Liu, 1981).

Pharmaceutical production accounts for about 6% of liquid phase activated carbon consumption (Baker, et al., 1992). Most of this is used for the purification of various fermentation broths that have been solvent extracted. Use as a food and beverage production is covered in a separate TAP review. Activated charcoal is used in agriculture as a soil amendment (e.g. alkali-treated humates and humic acid derivatives), and as a component of nursery or transplant media (Wellen, et al., 1999), as well as to remove pesticide residues (McCarty, 2002). Among the literally hundreds of other uses are agents in gas masks; pollution control devices such as car catalytic converters and flue gas desulfurization (Ashford, 1994).

Action:

Activated carbon has an extraordinarily large surface area and pore volume that gives it a unique adsorption capacity (Baker, et al., 1992). Commercial food grade products range between 300 and 2,000 m^2/g (Burdock, 1997). Some have surface areas as high as 5,000 m^2/g. The specific mode of action is extremely complex, and has been the subject of much study and debate. Activated carbon has both chemical and physical effects on substances where it is used as a treatment agent. Activity can be separated into (1) adsorption; (2) mechanical filtration; (3) ion exchange; and (4) surface oxidation.

Adsorption is the most studied of these properties in activated carbon. Most applications of activated carbon can be characterized by the adsorption that occurs when components of a liquid (the poison) attaches to a solid (activated carbon). This can be either physical or chemical in nature, and frequently involves both. Physical adsorption involves the attraction by electrical charge differences between the adsorbent and the adsorbate. Chemical adsorption is the product of a reaction between the adsorbent and the adsorbate.

Adsorption capacity depends on

a) physical and chemical characteristics of the adsorbent (carbon);
b) physical and chemical characteristics of the adsorbate (the food or beverage);
c) concentration of the adsorbate in liquid solution;
d) characteristics of the liquid phase (e.g. pH, temperature)
e) amount of time the adsorbate is in contact with the adsorbent (residence time).

(Cheremisinoff and Morresi, 1978).

Mechanical filtration involves the physical separation of suspended solids from a liquid passing through carbon arrayed as a porous media in a column or bed. Any finely divided solid—such as sand or cellulose—can accomplish this. While this accounts for some of the clarification properties of carbon, it is seldom the sole reason for the selection of carbon as a clarification medium. The effectiveness of filtration depends on particle size, bulk density, and hardness (Ahmedna et al., 2000). While a smaller particle size results in a clearer liquid, it also slows the speed of processing. Bulk density determines how much carbon can be contained in a given container. Hardness matters because the particles need to have sufficient strength to block the particulate matter being filtered.

Ion exchange is defined as a 'reversible chemical reaction between a solid and an aqueous solution that allows the interchange of ions . . .' (Ockerman, 1991). Coal is a natural ion exchanger (Helfferich, 1962). Ion exchange can be enhanced by chemical activation. Carbon surfaces have both negative (anionic) or positive (cationic) charges to attract free ions in solution or suspension, depending on how they are treated. Treatment of carbon with a base increases the capacity of carbon to exchange anions; acidulation of the surface makes carbon a powerful cation exchanger (Jankowska, et al. 1991).

Surface oxidation involves the chemisorption (=chemical adsorption) of atmospheric oxygen to the carbon and the further reaction of the surface oxides that chemically react with other substances that are oxidized. The surface of activated carbon has an electrical double layer (Mattson and Marks, 1971).

Activated carbon removes the poison from the skin or alimentary tract by all of these methods, and is then shed or excreted (Radostits, et al., 2000).

Combinations:
Activated charcoal for veterinary purposes is generally pharmaceutical (USP) grade. It is complexed with kaolin clay (bolus alba), propylene glycol, and various unspecified wetting and dispersing agents (Kanzler, 1995). Among the wetting agents and dispersants used are naphthalene sulfonates, alkyl aryl polymers, and triethanolamine (Rockwell, 1939). Alternative formulations may use other clays and mined minerals such as bentonite and gypsum; synthetically treated minerals such as dicalcium phosphate and silica gels; vegetable gums; synthetic vegetable derivatives such as sodium carboxymethylcellulose; solvents such as isopropanol; and synthetic suspension polymers such as povidone (Kollidon) (Adler, 1926; Manes, 1975; Vet-a-mix 1995; Bühler, 1998). Injectable carbon may employ a saline solution, sugars such as dextrose and glucose, and vegetable gums (Rockwell, 1939).

Status

Historic Use:
Charcoal dates back to the prehistoric discovery of fire. The Egyptians used charcoal as a topical antidote to poisoning (Yehaskel, 1978). Ancient Hindus filtered their water with charcoal (Cheremisinoff and Ellerbusch, 1978). Scheele discovered the fact that certain types of charcoal had adsorptive capacity—were chemically 'active'—in 1773. Charcoal was found to decolor tartaric acid in 1785. In 1794, charcoal was first applied to the refinement of sugar (Jankowska, et al., 1991).

By 1901, scientists had developed ways to synthesize activated carbon from coal carbon that had equivalent or superior adsorptive and decolorizing capacity to bone black (Smíšek, 1970). These methods were soon introduced to the US (Richter 1911). Use for removal of taste and odor from municipal water supplies in the US began about 1929 (Burdock, 1997).

While the detoxifying effects of activated charcoal have long been documented, optimization of dosage and delivery did not begin in earnest until the 20th century. Excipient packages became refined in the 1920s (Adler,1926). Injectable solutions were made practical in the 1930s (Rockwell, 1939). More recent developments have focused on palatability (Manes, 1975).

OFPA, USDA Final Rule:
Activated carbon does not appear anywhere in the OFPA or NOP Final Rule. However, humic acid derivatives (7 CFR 205.601(j)(3) are usually composed of alkali treated lignite coal, and can thus be considered a form of activated carbon (Vorres, 1996).

Regulatory: EPA/NIEHS/Other Sources
USEPA:
Activated carbon does not itself appear on any of the lists of hazardous substances (US EPA, 1998). However, given that it is used to remove toxic substances from potable water, wastewater treatment, and hazardous waste effluent, spent activated carbon contaminated with toxic substances removed from these production streams can be considered hazardous waste and fall under the EPA's authority under the Resource Conservation and Recovery Act's jurisdiction (40 CFR 264(x); Shapiro, 1996). For the most part, the regulations applied to food processors involve activated carbon as an effluent treatment system for wastewater (US EPA, 1998a).

Carbon is registered as an active pesticide ingredient (54 *Fed. Reg.* 7440; 54 *Fed. Reg.*22706; *54 Fed. Reg. 30848*; 54 *Fed Reg.* 4388; 55 *Fed. Reg.* 31164) and is used as an inert ingredient in pesticides and appears on EPA Inerts List 4B (US EPA, 1995).

NIEHS: Does not appear in the National Toxicology Program database (NTP, 2002).

FDA:
Approved as a drug for over-the-counter (OTC) use in humans (21 CFR 310.545(a)(8)).

The only listing found in EAFUS for activated carbon (accessed July 12, 2002) is at 21 CFR 177.1210. This addresses substances for use as basic components of single and repeated use food contact surfaces. Specifically, activated carbon is permitted to form up to 1% of a closure with sealing gaskets for food containers. Activated carbon is also mentioned in the ion exchange section (21 CFR 173.25).

OSHA:
The Occupational Safety and Health Administration's OSHA Permissable Exposure Levels (PELs) for synthetic graphite (activated carbon) are:
(Total dust): 15 mg/m3
(Respirable fraction): 5 mg/m3
Source: 29 CFR 1910.1000.

DOT:
Activated carbon appears on the US Department of Transportation's Hazardous Materials Table because it is spontaneously combustible
Source: 59 *Fed. Reg.* 67395.

AAFCO:
The official feed term includes both plant and animal derived sources (AAFCO, 2002).

Status Among U.S. Certifiers
Not listed in any published standards.

California Certified Organic Farmers (CCOF) – CCOF Manual Two: USDA Requirements For Organic Producers (Dec. 2001) not listed.

Oregon Tilth Certified Organic (OTCO) – Oregon Tilth Certified Organic Standards, Oct. 8, 2001. Not listed in Section 8, National List that accompanies the standards.

Organic Crop Improvement Association International (OCIA) OCIA Standards Manual NOP Standards plus OCIA International Requirements 2002: not listed

Quality Assurance International (QAI) – No reference.

Texas Department of Agriculture (TDA) Organic Certification Program – TDA Organic Certification Program Materials List (February 2000) not listed

Washington State Department of Agriculture (WSDA) Organic Food Program – Chapter 16-158-060 WAC (rev. January 18, 2001), not listed.

International

22. CODEX – Part B, Section 22 states that the "use of veterinary medicinal products in organic farming shall comply with the following principles:
    a) "where specific disease or health problems occur, or may occur, and no alternative permitted treatment or management practice exists, or, in cases required by law, vaccination of livestock, the use of parasiticides, or therapeutic use of veterinary drugs are permitted;
    b) "phytotherapeutic (excluding antibiotics), homeopathic or ayurvedic products and trace elements shall be used in preference to chemical allopathic veterinary drugs or antibiotics, provided that their therapeutic effect is effective for the species of animal and the condition for which the treatment is intended;
    c) "if the use of the above products is unlikely to be effective in combating illness or injury, chemical allopathic veterinary drugs or antibiotics may be used under the responsibility of a veterinarian; withholding periods should be the double of that required by legislation with, in any case, a minimum of 48 hours;
    d) "the use of chemical allopathic veterinary drugs or antibiotics for preventative treatments is prohibited.

EU 2092/91 – Annex I, Part B, Section 5 states that the "use of veterinary medicinal products in organic farming shall comply with the following principles:

(a) "Phytotherapeutic (e.g. plant extracts (excluding antibiotics), essences, etc.), homeopathic products (e.g. plant, animal or mineral substances) and trace elements and products listed in Part C, section 3 of Annex II, shall be used in preference to chemically-synthesised allopathic veterinary medicinal products or antibiotics, provided that their therapeutic effect is effective for the species of animal, and the condition for which the treatment is intended;

(b) "If the use of the above products should not prove, or is unlikely to be, effective in combating illness or injury, and treatment is essential to avoid suffering or distress to the animal, chemically-synthesised allopathic veterinary medicinal products or antibiotics may be used under the responsibility of a veterinarian;

(c) "The use of chemically synthesised allopathic veterinary medicinal products or antibiotics for preventive treatments is prohibited."

Activated charcoal does not appear on the list of feed materials allowed in Annex II, Part C.

IFOAM – The use of conventional medicines is allowed when no other justifiable alternative is available.

Canada – Not listed in Appendix B—Permitted Substances List for Livestock Production

Section 2119 OFPA U.S.C. 6518(m)(1-7) Criteria

1. *The potential of the substance for detrimental chemical interactions with other materials used in organic farming systems.*
   For the most part, activated carbon will interact to adsorb and neutralize other materials used in organic farming systems. Any detrimental interaction would result from the concentration of these substances. Generally, concentration would be in the feces of the treated animals. Proper manure management and composting should be able to mitigate or eliminate the deterimental chemical interactions resulting from treatment.

2. *The toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.*
   Activated charcoal itself is regarded as an effective treatment for poisoning. Carbon is elemental in form. However, many applications will concentrate the toxic substances that it removes and captures, thus becoming toxic itself.

3. *The probability of environmental contamination during manufacture, use, misuse, or disposal of the substance.*
   Environmental contamination depends on the source. Most—but not all—sources indicate that they are vegetable derived. Medicinal charcoals have long had product specifications that require only the highest purity vegetable source. In some cases the species of plant is named, with corresponding analytical methods developed for quality assurance purposes (Paulssen, 1964; Mantell, 1968). However, it is possible for any source to be used provided it

meets USP grade. That would include coal, petroleum, and polymer derived sources. A review of the environmental impacts of the manufacturing from these sources is beyond the scope of the review, but is deemed by the reviewers to pose a significant probability of environmental contamination. At least one older reference indicates that bone may be a source of pharmaceutical activated charcoal (Haddad and Winchester, 1983).

In general, the charcoal is passed through the animal and excreted in manure. While the toxins are concentrated in the manure, properly handled manure should not constitute any greater contamination risk than manure from conventional farm sources.

4. *The effects of the substance on human health.*
   Can cause respiratory problems to those who handle it, especially as particle size decreases. Inhalation causes cough, dyspnea, black sputum, and fibrosis (Patnaik, 1992). There is also a potential for it to spontaneously combust and incomplete combustion produces carbon monoxide (Cheremisinoff, 1999).

5. *The effects of the substance on biological and chemical interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including the salt index and solubility of the soil), crops and livestock.*
   A number of studies indicate that activated charcoal can be used as a feed supplement to stimulate feeding on unpalatable or poisonous plants (Banner, et al., 2000; Poage, et al., 2000; Bisson, et al., 2001).

   Carbon is necessary for soil organisms. Application to soil has been shown to bind and reduce the availability of a number of antimicrobials in the soil (Tolls, 2001).

   The effects of the substance on livestock are largely beneficial. Activated charcoal reduces suffering and saves many lives of animals (Buck and Bratich, 1986). There are few contraindications or situations where treatment would be life threatening. Treatment may result in dehydration (Kanzler, 1995).

6. *The alternatives to using the substance in terms of practices or other available materials.*
   Most organic farmers would avoid the chemical and allopathic poisons that are the primary reasons for using activated charcoal because these substances are prohibited. In cases of accidental or incidental contamination, there are a number of poison antidotes that are used as alternatives: water, milk, saline (sodium chloride) solution, but activated charcoal is preferred in most situations (Aiello, 1998). One current veterinary reference declares activated charcoal to be the only effective adsorbent (Radostits, et al., 2000). For use to prevent or avoid mycotoxins in feed, various minerals, such as aluminosilicates and bentonite appear to be effective (Kubena, et al., 1990; Huwig, et al., 2001).

   To avoid mycotoxins, better timing of harvest, improved handling, and better quality control can reduce *Aspergillus flavus* and other pathogens. Toxic plants can be avoided through range or pasture management methods that enhance non-toxic species, rotation, or decreased densities.

7. *Its compatibility with a system of sustainable agriculture.*
   Therapeutic use for diagnosed poisons is compatible with the NOSB Principles of Organic Production and Handling (NOSB 2001), which state that organic production promotes animal health and welfare while minimizing stress. NOSB also states that organic producers should avoid the routine use of chemical allopathic veterinary drugs, including antibiotics. Non-routine use with alternative anthelmintics may be controversial. Use as a feed additive to increase the grazing of otherwise toxic crops could improve rangeland by the removal of these plants, but could also lead to overgrazing and depletion of range resources.

TAP Reviewer Discussion

Reviewer 1 *[Veterinarian in the mid-south specializing in ovine and caprine animals]*

"Use as a feed additive to increase the grazing of otherwise toxic crops could improve rangeland by the removal of these plants, but could also lead to overgrazing and depletion of range resources." None of the references included made a strong case for the use of activated charcoal as a feed additive. Use as a feed additive also indicates routine use. Therefore, any reference in the TAP document for the use of activated charcoal as an additive for grazing of otherwise toxic crops should be omitted.

Conclusion

Activated charcoal should be a restricted non-synthetic prohibited because of its very important use in adsorption of toxic substances. By categorizing it as a non-synthetic, this limits the processing to heating and combustion of naturally occurring substances only. This would comply with NOSB's interpretation.

While the use of activated charcoal can create a potential environmental problem when bound with toxic substances, using it in specific cases of ingestion of toxic substances would keep the toxic endproducts to a minimum. Use as a detoxifier would have no toxic waste associated.

Organic livestock producers should have their management of the farm set up so that poisoning of livestock is a rare occurrence. However, those producers should also have available to them a product that is natural, that is more effective in some medical instances than alternatives, and which causes no harm to the environment when used for a very specific instance. Listing it as a prohibited non-synthetic eliminates its use as a feed additive that would be routine and would force livestock to graze plants that could be harmful and which they would not otherwise eat. This would not be compatible with a sustainable system that should strive to manage noxious and poisonous plants by means harmless to livestock and people.

a. The substance is Not Synthetic

b. For Crops and Livestock, the substance should be Added to the National List only with an annotation that restricts use. (List as Prohibited non-synthetic, restricted)

(Note: Synthetic materials are added to the National List of Allowed Synthetics. Non-synthetic materials are added to the National List of Prohibited Non-synthetics. Non-synthetics may be added to the Prohibited list with a restriction that permits some uses.)

Reviewer 2 *[Research chemist on the East Coast who serves on a certification committee]*

Material and manufacturing

Activated carbon or activated charcoal are terms used for a porous carbon manufactured by a two step method (carbonization followed by oxidation). The structure consists of a distorted three-dimensional array of aromatic sheets and strips of primary hexagonal graphic crystallites (Stoeckli, 1990). This structure creates angular pores between the sheets of molecular dimensions that give rise to many of the useful absorption properties of activated carbon (Stoeckli, 1990, Innes et. al., 1989). Pore size ranges from 1 nm to 1000 nm), and the extensive porosity is responsible for the high surface area of the material (usually 500 - 1500 m^2/gm.) (Vohler et. al., 1986, Cooney, 1980).

Carbon black or lamp black is another carbon product with high surface area. Lamp black consists of soot from burning a carbon source (wood, tar, coal, oil, etc.) in a limited oxygen environment (Davidson et al., 1968). The high surface area and surface properties of lamp black are derived from the fine particle size of the material, not from high porosity like activated carbon. The lack of extensive porosity distinguishes activated carbon from other carbon products like lamp black or charcoal. We will consider only true activated carbon in this review and its recommendations. Charcoal and lamp black are distinct materials and should not be considered in an activated carbon TAP.

Charcoal was first used medicinally in 1550 B.C Egypt. and bone char has been in use since 1811 to decolorize sugar (Cooney, 1980). True activated charcoal was not invented until the beginning of the last century and activated carbon derived from coconuts was used in gas mask filters in the 1'st World War (Cooney, 1980).

Most any carbon material can be used to make activated carbon and the academic literature contains many references to activated carbon derived from many agricultural and industrial high-carbon waste products. Commercial activated carbon, however, is manufactured from only a few carbon sources; wood and sawdust, peat, coal, oil products, and nut shells and pits (Vohler et. al., 1986, Davidson et al., 1968). Wood products and low-grade coal have some original porosity and are easier to activate than dense materials such as anthracite (Vohler et. al., 1986; Sun et. al., 1997). However, any high carbon material can be activated, and it is generally not possible to discern the original starting material of an activated carbon product.

Activated carbon manufacturing consists of a charring or carbonization step in which most of the non-carbon material (and much of the carbon) is volatilized by pyrolysis (usually between 500 and 750° C.). The weight loss is usually 60 to 70 % and much CO2 is volatilized (Sun et. al., 1997, Diaz-Teran, 2001). Coal is usually first pre-oxidized at 150° to 250° C. to prevent the coal from becoming thermoplastic during charring and collapsing the pore structure (Sun et. al., 1997).

The fine pore structure is formed in an activation process. In gas activation, an oxidizing gas such as CO2 is used at high temperature to erode pores into the char. In chemical activation, the char is impregnated with a chemical and then fired to high temperatures (usually 800 to 1000° C). The activating chemical corrodes the carbon to form the pore structure. Chemical activation also alters the carbon surface. Activation chemicals are usually strong acids, bases or corrosives (phosphoric acid, sulfuric acid, KOH, zinc chloride, potassium sulfide, or potassium thiocyanate) (Mozammel et. al. 2002). After activation, the chemicals are washed out for reuse. The final pore structure depends on the nature of the starting material and the activation process (Diaz-Teran, 2001). Materials with an original pore structure like wood take less processing than more dense and isotropic material like coal or tar. Impurity amounts are usually higher in the less carbon dense materials, however.

The surface chemistry of the activated carbon is strongly influences by the activation process and subsequent chemical treatment (Pradhan and Sandle, 1999). The surface contains abundant oxygen and hydrogen groups which can decompose to CO_2 and water (Puri, 1966). Other surface oxide complexes that have been found include phenols, carbonyl, lactone, carboxylic acid, and quinones (McCreey, 1991, Pradhan and Sandle, 1999). The abundance of surface complexes causes activated carbon to be a good absorber of many gases and aqueous chemicals. The non-selective absorption of many chemicals makes activated carbon an excellent absorber in poisoning or environmental contamination (Cooney, 1980).

Charcoal is generally considered to be a natural agricultural product. Both charcoal and carbon black form naturally (forest fires), and have been used by man for thousands of years. Activated carbon does not occur naturally. A highly controlled two- or three-stage process is needed to form the high porosity of activated carbon. The activation step also requires either the addition of a synthetic chemical or direct injection of CO_2 or O_2 during the activation firing. Highly porous activated carbon should considered synthetic. Bone char results from the destructive distillation of animal bones (Mantell, 1968; Davidson et al., 1968). Bone char production does not include an activation step. It is more analogous to the left over material in the destructive distillation of coal to make coal tar

Interactions with Other Materials

Any charcoal directly applied to a field would behave as any other organic source of carbon. Problems could arise from the chemicals sequestered by the activated carbon when used on ill livestock, however. The purpose of activated carbon is to absorb toxins accidentally ingested by livestock, allowing these toxins to safely pass through the GI track of the animal without being absorbed by the body. These toxins would be then be deposited in the animal's manure. Animal manure cannot contaminate crops, soil or water with pathogenic organisms, heavy metals or residues of prohibited substances (7 CFR 205.203(c). If the toxins can be broken down by composting without harming the composting organisms, the contaminated manure can be composted (and documented in the organic management plan). If the toxins are heavy metals, the manure must be disposed of without contaminating organic crop lands or water.

Toxicity

Activated carbon is generally considered non-toxic. Large doses are routinely given in human poisoning cases. The human dose for poisoning is 1 gm activated charcoal per kg. body weight (Scharman et. al., 2001, Minocha et. al., 1985). Carthatics such as sorbitol or Magnesium citrate are added to the activated carbon used for Poison cases. Magnesium citrate has caused some fatalities and is rarely used (Benjamin, 1995). Human and animal studies report a small risk of aspiration pneumonia when administering activated charcoal to intubated patients (~ 4%), (Moll et. al., 1999).

Activated charcoal has been shown to inherence in vitro growth of bile-tolerant *Helicobacter* bacteria (an emerging pathogen of humans and animals) (Taneear, 2002). The mechanism appears to be the absorption of chemicals toxic to the bacteria. Activated carbon has been reported to promote the growth of certain pathogenic bacteria (*Listeria monocytogenes,* and *Legionella pneumophilia*) (Erolaeva, 1999, Hoffman et. al., 1983). Potential mechanisms are absorption of toxins or reduction of peroxide free radicals.

Manufacture, Use, Misuse, and Disposal

Activated carbon poses little risk of environmental contamination. The risk of manure of animals treated for poisoning is discussed above. Many of the activation chemicals used to form the pore structure of activated carbon are toxic. Exposure to Zinc Chloride fumes or solutions can cause ulceration and fatal burns Hamilton & Hardy, 1974). These chemicals are reused and should be disposed of safely in large plants.

The carbonization step removes as much as 70 wt. % of the original carbon material as volatiles. 700,000 tons/yr of activated carbon were manufactured in the late nineties (Mozammel et. al., 2002). This would release almost 500,000 tons of volatiles (mostly Carbon Dioxide) to the atmosphere per year. The charring and activation processes also consume large amounts of energy (Sun et. al., 1997).

Pharmaceutical grade activated carbon requires a low amount of non carbon components (Cooney, 1980). Carbon sources like wood, peat or fruit shells generally have higher ash content than high-grade coal. USP grade activated carbon must have < 15 wt % drying loss and < 3.5 % acid soluble residue (Cooney, 1980). Materials with a higher initial ash content would need to be acid leached more than once with low initial ash content.

Almost any carbon source can be made into activated carbon (Vohler et. al., 1986). Without a detailed calculation, it is not obvious which sources of carbon have a lower environmental footprint. Given this lack of knowledge of the environmental costs of the different carbon sources, it would seem prudent to either allow or prohibit activated carbon from any source in Organic management systems.

Human Health

As stated above, there is little danger from ingested activated carbon. Dust at manufacturing sites needs to be managed. There is no unique hazard associated with activated carbon dust that is not encountered with other small particle sized materials (activated charcoal is still used in respirator cartridges).

Interactions with the Agroecosystem

. . .*[M]*icrobiologists *[use activated carbon]* to help culture hard to grow pathogens *in vitro*. The effect of activated carbon on rumen or gut bacteria flora is unknown. Occasional use of activated carbon in accidental poisonings appears to be a trivial risk. Continuous use with tainted feed or poor pasture, however, presents an unknown risk, which may need to be studied. The effect on the ecology of soil micro-organisms is also unknown, but the amount used to treat medical emergencies in individual animals is too small to be of consequence.

Alternatives

Activated carbon absorbs and removes from the body a large range of toxic compounds (Cooney, 1980). It can be administered at home or in the barn and is very effective when given within 30 min to 1 hour after poisoning (Grierson et. al., 2001). Rival treatments include gastric lavage or emesis by mouth of syrup of ipecac or parenterally administered apomorphine. Both can cause problems when used with certain poisons (including digitalis) (Cooney, 1980). Activated carbon has also been shown to be as effective in poison cases as activated carbon + gastric lavage (Christophersen et. al., 2002);

Many substances besides activated carbon are used to remove compounds in chemical and food processing (Adachi et. al., 2000, Grohmann et. al., 1999). Zeolites, clays, and spent yeast cells have also been shown to absorb certain mycotoxins from animal feed as well or better than activated carbon (Huwig et. al., 2001). The efficiency of these alternative absorbers depends on the chemical structure of the toxin (Huwig et. al., 2001). These absorbers do not appear to be used in emergency medicine (Cooney, 1980, Benjamin, 1995). Activated carbon—with its wide range of pore sizes and surface complexes—is the universal antidote of choice.

Compatibility with Sustainable Agriculture

Organic livestock farmers must avoid many of the chemicals that could poison livestock. Accidental poisoning can occur, however, when livestock ingests poisonous plants or mycotoxins on forage or haylage. Use of activated carbon to bind these poisons is an expedient and safe emergency treatment. The main threat to the Organic system would come from the poison present in the animal's manure, which can be easily managed in small quantities. Use of activated carbon in emergency situations is compatible with organic production which promotes animal health and welfare.

Prophylactic use of activated carbon on a large group of animals to allow them to consume grain contaminated with toxins or forage on pastures known to contain poisonous plants does not promote animal health and welfare. Activated carbon absorbs much but not all of a toxin. Some of the toxins will not be removed from the body (Cooney, 1980). Animals should be fed a nutritious ration, not a tainted ration with a poison remover added. Manure management becomes a larger problem with prophylactic feeding of activated carbon mixed with toxic feed. Large amounts of toxin carrying manure need to be composed or disposed of without contaminating the soil or water.

Conclusion

Activated Carbon with high porosity and surface area is a synthetic material. It is manufactured by a multistep process and has no natural analog. Activated carbon also appears to be the most useful and safest antidote for accidental poisoning. *[A farmer can]* quickly *[administer it]* after an animal is poisoned without a vet present. USP pharmaceutical grade has low amounts of contaminants and is suitable for Organic operations.

Activated carbon from any raw carbon source is synthetic and should be added to the National List of Synthetic Livestock Ingredients with the following annotations.

1. The activated carbon is USP pharmaceutical grade.

2. Activated carbon can only be used as livestock medication to treat accidental poisoning.
Prophylactic addition of activated carbon to feed contaminated with prohibited substances or natural toxins is prohibited.
Prophylactic treatment of livestock with activated carbon before turning out to forage in fields with toxic plants or known toxins is also prohibited.

Reviewer #3 *[Analytical chemist and equestrian, West Coast].*

The literature available seems to be based on two subjects: therapeutic adsorption of ingested toxins and use of charcoal to give animals a higher tolerance to plant toxins in their diet. I was unable to find any references to any other uses in livestock management.

Manufacture, Use, Misuse and Disposal

Although the environmental impact of manufacturing charcoal from fossil-fuel derivatives is beyond the scope of this report, the general rule is that fossil fuel based sources are undesirable within the realm of organic production. Unless there is some specific reason to do otherwise (as in the use of summer oils, or plastic packaging in direct contact with foods, for instance), it would be best to continue on with that precedent.

Alternatives

In terms of adsorbants for toxins, most other substances are either less effective, or have difficult side effects to deal with (clays, for instance). And AC is often administered along with the other substances.

In terms of feeding AC to increase the intake of toxic or unpalatable plant materials, there **is** an alternative; the alternative is to manage feeding in such a manner as to avoid the undesirable plants in the first place. I don't think there should be a place in organic management for that practice.

Large applications of carbon to soil could unbalance the C:N ratio, however since carbon administration to animals should be therapeutic, rather than routine, there should be little problem in managing the application.

It is also unlikely that concentrations of toxin in manure from AC treated animals would be high enough to cause environmental problems, unlike AC used in waste and water treatment. When spent, it could, under some conditions have adsorbed enough toxic material to pose disposal problems.

Conclusion

a. the substance is ***synthetic***; vegetable-based AC treated only with steam, CO_2, or N_2 could be considered non-synthetic under current rule. However it is not clear that this class of AC can be adequately separated from all AC classes effectively enough to require its exclusive use.

b. for crops and livestock, the substance should be added to the national list as:

synthetic, restricted

It should not be allowed for all uses noted in the literature provided. The practice of feeding AC routinely to animals to allow them to consume higher quantities of toxic or unpalatable plant material should be prohibited.

Therapeutic use to adsorb accidentally ingested toxins, including microbial toxin, mycotoxins, pesticides, and other toxins should be allowed.

The TAP Reviewers were also asked the following questions:

General

I.. Sources and Manufacturing Processes

Activated charcoal can be made from almost any carbonaceous material.
Are any sources non-synthetic or are they all synthetic?

Reviewer 1

Based on NOSB's clarification, sources of activated charcoal which are generated through a thermal activation process should be classified as non-synthetic. Chemical activation should create a synthetic form of activated charcoal.

Reviewer 2 covered this in the reviewer's comments.

Reviewer 3
I think possibly that there could be sources of non-synthetic AC. However, as the market currently stands, I don't believe that there is any way to differentiate between synthetic and non-synthetic.

2. If some are non-synthetic, please indicate or specify criteria to determine what methods and processes make a 'natural' activated charcoal. Note: while the NOP definition of synthetic includes anything chemically changed from a naturally occurring source, NOSB has historically clarified this and followed the policy that heating and combustion of plants, animals and microorganism is not synthetic, while combustion of minerals is synthetic. (1995- Definition and Interpretations).
Reviewer 1
The synthetic form is impregnated with a chemical agent, whereas the non-synthetic form uses heating and combustion only.

3. Do you think charcoal could be considered an agricultural product?
a. If so, do you agree that it is feasible to produce activated charcoal that meets National Organic Program standards for being an organic agricultural product?
b. Under what circumstances should non-organic activated charcoal be allowed?
c. *If not, do you consider all sources non-agricultural?*

Reviewer 1
I consider all sources of activated charcoal at this time to be non-agricultural. However, if an agricultural product is raised as certified organic, and the processing method is an approved form of processing, then the charcoal could be considered an agricultural product.

I agree that it could be feasible to produce activated charcoal that meets National Organic Program standards. But it would require some company or producer to take the risk of producing such a product.

Therefore, I think that non-organic activated charcoal should be allowed when there is a specific medical reason for using it. I would recommend that the charcoal only be allowed from agricultural products, such as lumber, grain hulls, corn cobs. The use of bones would fall under the voluntary ban on feeding of animal by-products.

Reviewer 2 did not provide a separate answer.

Reviewer 3
No. Some AC is made from wood; forestry is not considered an agricultural practice. The majority of AC is made from agricultural and industrial byproducts, so there is no crop grown specifically for charcoal production.

4. Is it correct to state that the FDA allows activated carbon from any source, provided that it meets food grade (FCC) specifications (as a processing aid) or pharmaceutical (USP) specifications as an animal drug?

Reviewer 1
It is correct to so state this.

Reviewer 3
Yes.

II. Action
5. Is surface oxidation a redox reaction? Can you briefly explain the mechanism and give an example of how that might work with the removal of a non-polar substance from solution?

Reviewer 1 declined to answer.

Reviewer 2
AC absorbs by a variety of mechanisms. Surface complexes (see text) absorb by redox, steric, and ionic reactions (see Puri 1966; Pradhan, 1999; and Cooney, 1980). The micropososity also physically trap neutral molecules of specific sizes like zeolites. *[Multiple]* mechanisms give AC such a wide range of absorbants. They also make it less effective for any specific compound. Ion exchange resins are better for ionic species and certain clays handle certain large organic molecules better. The only specific structure AC seems to be the best on *is* phenolics.

Reviewer 3 declined to answer

For Livestock

6. What are the specifications for USP grade?

Reviewer 1

One gram of activated charcoal must adsorb 100 mg of strychnine sulfate in 50 ml of water.

Reviewer 2

USP activated charcoal should be fine, black, odorless, and tasteless powder which are free from gritty matter and which possess the following additional characteristics: less than 15% weight loss on drying, < 4% residue after ignition, < 3.5% acid-soluble sbstances, <0.2% alcohol-soluble substances, < 0.15% sulfate, < 0.02% chloride, and <0.005 % heavy metal content.

Reviewer 3

loss on drying: <15%, Residue on ashing <4%, Acidity/alkalinity: aqueous filtrate is neutral to litmus paper, Sulfate: aqueous filtrate = <1cc 0.02N H_2SO_4,chloride: <0.2%, acid-soluble substances: < 35mg in 1 g, heavy metals: <50ppm total; adsorptive power: 1 g of AC will adsorb at least 100 mg strychnine

7. Should vegetable-derived sources be allowed from non-organic sources, or should organic sources be required?

Reviewer 1

Vegetable-derived sources should be allowed, if there are no organic sources available.

Reviewer 2 did not provide a separate answer. See commentary.

Reviewer 3

Vegetable-derived sources from non-organic sources should be allowed. The activation process removes almost all impurities, except for some ash. Strictly organic source material would currently be impossible to fine. Also, current manufacturers do not provide such a product.

8. Should animal-derived sources be allowed or should the ban on animal by-products be applied?

Reviewer 1

I answered this above, but they should be banned.

Reviewer 2 did not provide a separate answer.

Reviewer 3

No. Any specific mention that I could find of medicinal uses of activated charcoal did specify "vegetable charcoal" . USP, however, does not specify source material ("…residue of the destructive distillation of various organic materials, treated to increase its adsorptive power…").

9. Should fossilized and mineral sources such as coal, petroleum, and other fossil-fuel derivatives (e.g. polymeric resins and waste tires) also be allowed?

Reviewer 1

I do not think that these sources should be allowed.

Reviewer 2 did not provide a separate answer.

Reviewer 3

Manufacture of AC from fossil-fuel derivatives poses significantly more environmental problems than that of agriculture-based AC. In general, fossil-fuel derivatives are prohibited, except under very specific circumstances. I see little reason to stretch that stricture to include these products.

10. Would use to facilitate grazing of toxic plants be considered a feed supplement or health care?

Reviewer 1

It should be considered a feed supplement.

Reviewer 2

[Purposefully] feeding animals AC before turning out to toxic pasture is . . . added as an annotation.

Reviewer 3

I would consider it a feed supplement.

11. What are the environmental consequences of using activated carbon to facilitate grazing toxic plants?

Reviewer 1

In my opinion, the main issue here is not environmental consequences, but the ethical and animal welfare questions of attempting to change the toxicity of plants in a way that will make them safe(r) for livestock. There are natural methods of introducing certain plants for certain species and classes of livestock. But avoidance is one of the instinctive ways livestock protect themselves from harmful substances. Altering this natural behaviour with a feed supplement does not conform to the principles behind organic agriculture.

Reviewer 2 did not provide a separate answer.

Reviewer 3

One could argue that this produces nothing but good; an easy way to remove undesirable plants from overgrazed and mishandled land, and a good way to get cheap feed into livestock.

However, this practice flies in the face of all good organic practice. It allows the deliberate and systematic feeding of poor-quality forage, which certainly does not support the philosophy of caring for animals in the best possible way.

Environmentally, it allows for continued exploitative pasture management practices, and removes one strong motivation for proper pasture management. Ground should be managed in such a way that toxic and undesirable vegetation is discouraged.

The feeding of AC should be therapeutic; not preventative. To allow animals to graze on pasture so poor that they must eat toxic plants should be discouraged on all levels. AC should be used to remedy the accidental ingestion of mycotoxins, pesticides, etc., not to cover for poor management practices.

I don't think feed-through would pose a major problem; toxic levels of these chemicals are relatively low, in most cases. The chemical would bind tightly to the charcoal, and when excreted would gradually break down and be deposited in the soil. I am finding it difficult to picture a situation where animals with a large enough drug or toxin load would be in a situation to produce enough loaded excrement to engender an environmental threat. Unlike waste and water treatment, it is not likely that there would be large amounts of spent AC to deal with.

12. Should the use of activated carbon to conceal the use of substances prohibited in organic farming—such such as synthetic pesticides and drugs—be a concern of the NOSB?

Reviewer 1

They should not be a concern for several reasons. Certifiers are going to the people responsible for seeing that producers comply with standards. Since pesticides and drugs go through a metabolism process within an animal, treating with charcoal to conceal their use would be unlikely to be of benefit. Finally, if people are going to go to such extreme measures to hide use of prohibited substances, they are going to succeed, no matter what measures are put in place.

Reviewer 3

Yes, this could certainly be a possibility, although I don't have any specific knowledge of such a situation.

Conclusion:

Activated charcoal is essential to save the lives of animals that are accidentally poisoned. The reviewers all advised that the substance should be permitted for use in organic production, provided it was limited to therapeutic use only. Given the nature of the veterinary emergencies likely to be encountered, restrictions on source do not appear to be appropriate. Most pharmaceutical grade activated charcoal is derived from vegetable—as opposed to animal or fossil—sources. Overall restrictions on its prophylactic use as a feed supplement and to conceal the administration of substances prohibited in organic production would protect against possible abuse.

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