Biochar in Poultry Farming

unexpected uses for biocarbon

***David Yarrow*, January 2015**

With origins in South America's legendary Amazon *Terra Preta* soils, biochar is seen as a soil amendment. Attention has focused on using biochar to boost soil fertility, expand soil microbiology, upgrade soil structure, and accelerate plant growth.

But a rising tide of research shines new light into this ancient substance. Once mostly fuel or filter media, char has suddenly sprouted dozens of new uses. Significant to **Carbon-Smart Farming** is reduce greenhouse gas levels, and convert infertile, inert dirt into fertile, living soil to grow food and feed. Science confirms biochar sequesters carbon for centuries to mitigate climate change, and creates arable land from unproductive soils.

However, remarkable new uses have been discovered:

- Stormwater management & treatment
- Phosphorus traps to reduce water pollution
- Nitrogen traps to reduce ammonia & nitrate pollution
- Reclamation of mine tailings
- Building material blended with cement, mortar, plaster, etc.
- Electronic microwave shielding
- Electron storage & release as a "super-capacitor"
- Carbon fiber textiles for odor-absorbent clothing
- Carbon nano-fibers to replace plastic & metal

A new area of unexpected uses is livestock farming. Animals from earthworms to chickens, cattle, even monkeys, show shrewd interest to add biochar to their food. Farmers and scientists in Japan, Korea, China, Australia, Britain, Germany, Switzerland, India, and elsewhere have investigated these methods for over a decade. In European Union regulations, biochar is carefully defined and approved for use in agriculture, but currently, wisely, most is fed to livestock, then spread on land with manure.

My comments mostly address poultry production, but similar issues and opportunities face other livestock producers. As example, research data from several countries show that adding 1 to 3% biochar to cattle feed can improve feed efficiency 22%, reduce methane 28% and increase daily weight gain 20%. Biochar feeding has other documented benefits to improve digestive efficiency, animal health and farm profits.

Biochar in Litter

An immediate, obvious use is to reduce—even eliminate—gases and odors from manure and urine, especially ammonia. Biochar has a strong appetite to adsorp gases, liquids and ions, and ammonia ($NH4+$) is all three. Activated carbon's effectiveness for odor control is well-known, and preferred in air purifiers. So, a farmer's first small step is to blend 5 to 20% biochar with conventional litter to spread on a barn or coop floor.

Figure 2: High population density in a poultry barn

Ammonia's strong positive electric charge makes it corrosive, toxic to breathe, electron thief, thus a serious health stress. This gagging gas emitted by bird droppings, animal poop and pee, makes air unhealthy, toxic to birds and humans. Ammonia irritates skin on contact, and degrades even hard tissue, such as hooves. It also attracts insects, such as flies. Even a modest farmyard coop is afflicted by irritation, dust, disease encouraged by toxic bedding and air.

Poultry crowded in coops, barns and cages means constant contact with excrement. Nutrient-rich, moist, porous conditions are ideal to multiply pathogenic microbes. Microbial decay emits significant ammonia–a pungent gas, harmful to animals, irritates mucous membranes, attacks lungs, weakens immunity, accumulates in blood, ties up trace elements, depletes liver detox enzymes. Animal health degrades, productivity also declines.

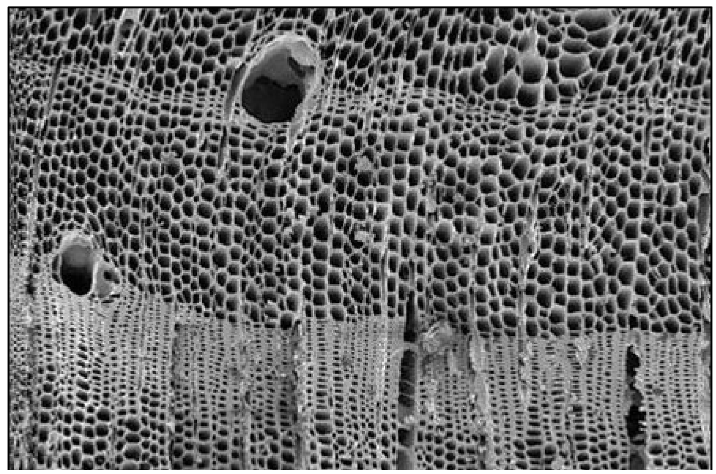

Figure 1: Biochar is lightweight due to extensive micropores

Ammonia also does environmental harm, deposited as nitrogen in rain. Ammonia and nitrous oxides are highly climate-disturbing, increase soil acidification and water body eutrophy.

Ammonia isn't a USEPA Top Six air pollutant, but is significant in livestock production. Lower ammonia improves air quality and livestock health. In 2009, USEPA gave farm operations exemption for ammonia emission. This protected the industry to address and curb their emissions. But now, large poultry operators face regulation or litigation to reduce emissions. In one situation, Oklahoma is suing Arkansas poultry farms for pollution upstream on the Illinois River.

Farmers use sawdust, shavings, straw, or other biomass to absorb these odors, reduce toxic troubles, and routinely remove bedding and manure to avoid toxic accumulation. Large confined animal feed operations (CAFO) with thousands of birds closely crowded in pens and cages are a concentrated emission source.

Adsorption with Biocarbon

Biochar is extremely porous, making it an excellent natural filter, with a huge internal capacity for water and ions. Thus, biochar has a larger, more robust appetite for ammonia, ions, other irritants, and nutrients than any other organic material.

Biomass burned or baked with little or no oxygen is “reduced” to a very black, very inert, very dry, very porous substance. In this very contracted, scorched state, char will vigorously attract and absorb minerals, molecules, ions, electrons, even photons. Char captures and separates them from soil solution, confines them in its vast micropore interiors.

Research at several universities shows activated carbon captures up to 63% of ammonia emitted from poultry poop. Char also curbs methane, nitrous oxide, hydrogen sulfide, urea, organic acids, ketones, volatile vapors, and noxious liquids.

Reduced ammonia is a major health improvement for environment, birds and farmworkers. Lower moisture content and ammonia levels curtail risk of footpad diseases, skin lesions and respiratory afflictions. Infections heal as animals’ resistance improves, to benefit vitality, egg production and final weight.

Because biochar also absorbs liquids, it changes the physical quality of poultry poop. Floor droppings are far less sticky, almost dry, lighter in weight, easier to handle. Litter and bedding can be handled with greater safety and sanitation.

Instead, biochar keeps these toxic chemicals and valuable nutrients safely in litter, renders them non-toxic and immobile, converts them to precious plant food. Biochar doesn’t do all this on its own, but supports the minerals and microbes needed to digest, breakdown and convert wastes.

Careful attention to biomass source, temperature and time can produce a grade of biochar optimized for this barnyard adsorption service. Depending on type of litter, biochar can be mixed 5-10 % by volume with litter. Effects are strong at 5% biochar and reach saturation beyond 15%. For best effect, biochar should be screened to uniform particle size (1/4 to 1/16 inch), cleaned of dust, dusted with calcium, trace elements, clay, and rockflours, lightly moistened, inoculated with digestive bacteria and fungi. With straw pellets as litter, char is best added at pelleting stage.

Commonly, lime and other cations are added to litter to help reduce odors and raise pH. Biochar’s high adsorption capacity means less lime is needed, since calcium and other cations are adsorped into char micropores and delivered with greater efficiency. Char captures and conserves calcium and other cations, holds them where microbes and roots can get them. This further reduces any ammonia emissions, and improves litter’s value as soil amendment.

Figure 4: Effect of Biochar + Compost on Corn Shoots & Roots

Char can also be added when making silage. Char mixed with silage is bound well and doesn’t rub off, and it provides its usual services to conserve moisture, buffer pH, retain cations and anions, provide stable refuges for fermenting microorganisms.

But benefits don’t end there. Biochar keeps on giving gifts.

Biochar in Compost

When litter or bedding are spread on land, significant nutrients normally outgas and leach, and some are lost. Biochar bestows significant extra capacity to adsorp and hold nutrients in compost materials, thus minimize losses and possible pollution. Properly deployed, biochar sharply improves retention of ammonia, phosphorus, potassium, calcium, and other valuable nutrients. Char has a rare ability to adsorp and conserve anions, beginning with nitrates and phosphates.

During composting, biochar continues to absorb liquids, capture gases, adsorp nutrient ions, and keep them in compost. Biochar retains water in its micropores to keep moisture stable in composting biomass. Biochar micropores have a remarkable ability to change the state of water in compost and soil, while sharply increasing soil’s water holding capacity. Water and carbon are ancient and intimate allies in Nature’s recipe to cook up life. They interact to create the fundamental matrix for life to organize and operate.

This begins when biochar micropores absorb water out of the solution, and conserves water to keep the media wet. In contact with biocarbon, water forms thin films and nano-structures, and shifts from freely-moving “blue water to a captive, contained form of “green water” held in a biological context, such as bodies and protoplasm of living cells and organisms. Green water more easily passes through cell membranes to support and participate in the dance of cell biology, including nutrient transport.

Biochar is derived from plant biomass, and creates an environment that benefits cell biology. Providing air, water and nutrients favors healthy, beneficial microbes that improve composting rate and digestive efficiency. Biochar micropores are ideal refuges for bacteria and fungi, so adding this uniquely inert biocarbon stabilizes, strengthens and sustains compost’s teeming populations of digestive organisms.

Activated Carbon vs. Biochar

Activated Carbon (AC) has been around decades, and has an industrial identity and technical pedigree. Biochar, however, is the “new” carbon kid on the farm, and few know about the extra-ordinary uses of this ordinary substance. Thus, AC is widely approved for farm and food operations, but biochar is unknown in most minds, classifications and regulations.

AC can be made from coal as well as organic biomass, but biochar is only made from biological sources, not geological or synthetic substances.

AC is typically produced at high temperature (1000+ degrees C) to completely burn tar and resin out of micropore matrix. Biochar is preferably cooked at low temperature (550-900 degrees C) to leave hydrocarbon residues in char as starter food for bacteria and fungi.

AC is further processed with steam or solvents to flush out residues from char micropores. AC is fractured and split at micro-scale to increase surface area for ion adsorption.

AC is preferably made from high density feedstocks such as peach pits, coconut shells, or hardwood, but soil often benefits from biochar that is softer and lighter, made from less dense biomass like cornstalks or straw.

AC and biochar are very similar chemically, physically, yet different enough in physical properties and mode of action to need extra scrutiny of biochar before standards and regulations can clearly classify and authorize its use. Already, we have learned biochar works best if properly processed and prepared.

Compost resulting from adding 3 to 5% biochar will likely be a higher quality, premium fertilizer, with more nutrients, better physical properties, and more vigorous, healthy microbial communities. Biochar's benefits, especially its enhancement of microbial diversity and activity, can improve the overall efficiency of the composting process.

Biochar as Feed Supplement

Farmers who add biochar to litter soon notice birds will peck bits of char. They deliberately eat char – an intentional behavior, not accidental or casual. Birds seem to know char is a useful substance. So, beyond use in litter, biochar is also being used as a feed supplement.

Substantial data on four continents consistently reveal biochar as feed additive provides direct benefits to livestock. Asia is ahead of America in this practice, too, but this is now getting attention in US and Canada. Farmers and researchers are experimenting with adding biocarbon to animal feeds and report success, and blogging useful observations.

At Univ. of Georgia, Dr. Casey Ritz researched adding char to poultry bedding to control ammonia since 2007. He showed carbon added cuts ammonia outgassing by converting it to stable ammonium. Dr. Ritz wondered if he could do this inside a chicken, rather than after.

"We must stop ammonia before it's made, instead of trying to mitigate it after it's emitted," Casey Ritz said. "Char is a strategy with a good chance of success."

So, Dr. Ritz fed chickens feed with 3 percent activated carbon added, while another group got normal feed with no char. Sure enough, Ritz found significant drops in ammonia in manure from char-fed chickens compared to chickens fed regular feed. Seems within birds, biochar binds ammonia into ammonium before excretion, resulting in little nutrient out-gassing and loss.

One Missouri farmer who feeds his chickens char observed, "When dressing chickens, I examine their gizzard and craw. I see black bits of char used to grind food. In gizzards, they're ground smooth, almost-oval, with round ends, shiny, like river stone. So, biochar is introduced before intestinal digestion–like they chew food with charcoal teeth. Nutrient absorption starts immediately."

He adds, with emphasis, "No ammonia smell—or any other smell, for that matter!!!"

The small, polished black balls form by abrasion with pebbles and food particles in the gizzard. Very fine carbon powder ground off bits of char is a catalyst to improve digestive efficiency. This benefit is both chemical and biological: it increases ion adsorption and transport, while improving microbe function.

So, birds hardly excrete nitrogen as waste ammonia at all. Instead, nitrogen is now more fully metabolized into amino acids, which then can become proteins. Thus, birds exhibit better weight gain and growth.

Chicken feed is usually light brown, but char turns it black. Happily, the color doesn't bother chickens. Char also changes manure color, making it obvious which birds get char in their diet.

Digestive Catalyst

Charred carbon has no nutrient value for animals. Scientists say it is "only a filler" in feed, but that label is misleading, and at the least, understates char's significant roles. As in soil, char provides essential services beyond being a nutrient source

Biochar is a catalyst that brings essential elements, especially charged ions, together to encourage their reaction, but biochar itself remains largely unchanged by these reactions. Biochar provides sheltered spaces and selective surfaces for ions and microbes to assemble and interact. So, while biochar is a classic "inert" ingredient, it creates an environment that enhances chemical processes essential for biology, especially digestion.

Char also changes the properties of poop, making it lighter, drier, easier to handle. This eliminates toxic trouble at its source, to further improve bird health. And since poop already has biochar in it, this improves other properties of the litter.

Biochar is also a catalyst to facilitate populations of microbes. Many bacteria, fungi and other simple life forms prefer biochar as habitat, and take up residence in char micropores. Bacteria play indispensable roles to stabilize digestive tract, intestinal barrier and liver function. Feeding biochar stimulates beneficial bacteria in the GI tract to strengthen digestion and immunity. Biochar can

Figure 5: Fungus-Biochar Symbosis

increase nutrient adsorption, retention and transport to improve the liver-intestine circuit.

Biochar's probiotic benefits improve if char is pre-inoculated with digestive microbes. Thus, a wise way to use char is as a substrate to culture, transport and deploy diverse, complex microbe communities. A fully probiotic approach must adapt to unique conditions and needs. A microbe culture for seed planting is different than for compost tea, or cooking compost, or foliar feeding spray, or planting trees must be modified to meet each specialized environment and purpose.

The immediate case needs a culture of digestive microbes to boost the power of an animal's intestinal tract. Too little is known yet about these complexities to have many off-the-shelf solutions for each animal species. But we now understand digestive tract microbioiogy is also the root of animal immunity and disease resistance. The gut is the first line of defense.

Infectious diseases may be caused by bacteria, but non-infectious diseases are often due to poor feed quality and biocide contaminants, such as herbicides. This creates susceptibility to disease, growth depression, infertility, and digestive disorders.

Biochar promotes digestion, improves feed efficiency, and thus, energy absorbed from feed. Toxins are efficiently bound to biochar, thus mitigating adverse effects on the digestive system and intestinal flora. Health and vitality of animals also improves, as will meat and egg production. With animals' immune systems stabilized, infection risks from pathogens decrease.

Biochar's catalytic effects on chemistry are boosted by microbes, with their greater abilities to cycle nutrients, maintain optimum pH, detox fluids, and convert wastes to metabolites. A few digestive inoculants are commercially available for this, but much more research is needed for complete understanding.

Scientific experiments attempt to determine how much char to add to poultry feed for optimum effects, but most often, char is raw, and is not pre-charged with minerals or pre-inoculated with microbes. Dr. Ritz's best guess, based on experiments to figure a final formulation, is 1 or 2 percent of feed. His results aligns closely with those from Asia, Europe, Australia, and India.

Wider adoption of this old substance for this new use in farming is encumbered by three major obstacles:

1) equipment and businesses are needed to produce and sell biochar affordable for poultry producers as a feed additive;

2) USFDA, USDA, organic certification agents, most states, and regulatory bodies must review and approve char as a feed additive. Activated carbon is already approved for human use.

3) need to develop formulations of biochar with minerals, microbes, metabolites and other nutrients, and protocols for use in varied farm operations and crops.

Convert Litter to Bioenergy

Not just plant biomass can be converted to char. Manures can be dried, then burned or baked into biocarbon. At the least, this sterilizes manure to reduce immediate biohazards and odor to make handling easier and cleaner. Depending on equipment and technology, this can retain most major nutrients and trace elements in the char.

Developing activated carbons and char from broiler litter is very effective to reduce waste volume, and treat waste emissions from production, storage and land application of litter.

Mississippi State researchers compared char made from poultry litter with commercial activated carbon made from coal for air purification. The poultry litter was mostly pine shavings, plus the poop. Lab results suggest char from litter performs as good or slightly better than the commercial product.

This reduces the need to use high-value feedstocks or hard-to-harvest sources to make biochar. Rather, this allows farmers to convert an abundant on-farm resource – manure – into assorted valuable products, starting with bioenergy and biochar for soil.

Figure 6: Josh Frye and his Gasifier

Char from manure also supports minerals and microbes in soil, but has extra properties. USDA researchers recently found that charred poultry manure is extra effective to selectively adsorp heavy metals, such as mercury, lead, cadmium, etc. Scientists now speculate about creating "designer biochars" tailored for specialized uses.

CHPB: Combined Heat, Power & Biochar

Carbonizing manure also yields heat, and can also produce syngas and bio-oil for on-farm power and biofuel. Gasifiers burn biomass to generate heat as well as biochar. But baking biomass by pyrolysis (coking) allows extraction of useful gas and liquid biofuels. These are well-developed technologies, but must be adapted to make low-temperature biochars for soil.

Most poultry barns are heated in winter and early spring, and many farms burn propane to produce that heat. Two problems: burning propane produces excess moisture, and imported fossil fuel costs a pretty penny. A chicken producer typically spends at least $20,000 each winter on propane heat.

An alternate approach is heaters that burn biomass, not fossil fuel, and yield biochar as byproduct instead of oxide ash. Three immediate, abundant, cheap farm feedstocks are cornstalks, manure and sawdust. Controlled combustion technology can capture 20 to 50% of biomass carbon as biochar. By restricting air flow, and controlling time and temperature, farms can cut costs for off-farm fuels and fertilizers, by making on-farm energy, soil amendment, litter additive, feed supplement, and water purifier.

In Wardensville, West Virginia, 3rd generation poultry farmer Josh Frye raises 800,000 chicks a year. To maintain production in winter, he burned propane to heat his barn. A buddy suggested a biomass gasifier could extract energy from poultry manure, and save money by not buying propane. Josh researched this, and learned this also yields biochar, a non-odorous, dry soil conditioner and "fertilizer." Biochar saves more money by reducing fertilizers, and converts manure into an easier-to-market, higher value soil enhancer.

For gasifier technology to meet his needs, Josh selected a fixed-bed gasifier built by Coaltec in Illinois, US sales representative for Westside Energies of Canada. They helped him apply for grants to purchase and install a $1,000,000 unit. A 30-by-50-foot fixed bed gasifier installed in March 2007 burns at lower temperature to produce biochar and heat. Maximum feed rate is 1000 pounds per hour, to yield five million BTU of heat, burning 12 tons of litter a day to produce 3 to 4 tons of char.

Josh's gasifier began operating in 2009, producing high quality biochar and fossil-free heat. He sold his first biochar ton at net price $480 a ton to a New Jersey farmer to test on corn and soybeans. A South Carlina farm is testing Josh's char on pharmaceutical grapes. With IBI leaders Johannes Lehmann and Stephen Joseph, Josh optimized his gasifier to make char rich in phosphorous and potassium. Test burns range from P 1.7 - 3.2 percent, and K at 5.4 - 9.6 percent.

The first year of test burns produced 30 tons of biochar and saved 4000 gallons of propane. Eventually, Josh expects to cut propane consumption over 80 percent. He also wants to use gasifier heat in summer to run a chiller to cool poultry barns.

Frye's annual production of 125 to 600 tons of poultry litter yields 25 to 120 tons of biochar. His gasifier-produced biochar had a 10 to 34% carbon content. Carbon content largely depends on manure moisture content. Lower moisture yields higher carbon biochar.

Biochar can be impressive income, but Josh isn't just about money. He's concerned how waste-to-energy gasification changes the fertilizer value of poop he sells to other farmers. "I feel I'm making a real contribution to the Ag world," Josh said. "Converting a raw waste to stable carbon-rich biochar is great." In 2009, WV Dept. of Environmental Protection awarded Frye the first-ever "Clean Energy Award" for his poultry litter gasification.

In Columbia, Missouri, Phil Blom of TerraChar works with Roger Reed, a combustion engineer, to install furnaces that burn sawdust into biochar to heat a boiler and heat exchanger. Roger adapted his sawdust burner to restrict air supply and make fine-texture biochar instead of ash. Roger's high-efficiency, automated, low maintenance, small-scale gasifier uses air to move sawdust through a combustion zone, and can be adjusted for other feedstocks such as cornstover, shavings or pellets.

These burner-boiler systems are installed in barns to create hot water and deliver radiant heat. This eliminates excess moisture from burning propane. Sawdust biochar is then mixed with litter to mitigate ammonia and other odorous gases, and eventually ends up in soil as nutrient-rich, composted manure.

The current system they are building will produce 2.5 million BTUs of radiant heat per hour to heat two poultry barns. The equipment will consume 300 tons of biochar a year from 1500 tons of sawdust biomass. In addition, the new system will send excess heat from the burner-boiler to a steam-driven 60 kilowatt per hour electric generator. The farmer will save up to $2000 per month in electric power expense in addition to savings from avoided propane expense.

RESOURCES

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