Soil Wealth
NURTURING CROPS

Integrated Crop Protection
PROTECTING CROPS

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BIOCHAR - WHAT IS ITS POTENTIAL FOR VEGETABLE PRODUCTION

KEY MESSAGES

- ✔ **Biochar can be used to build soil organic carbon, improve nutrient and water retention, and improve soil structure**
- ✔ **Biochar quality, and thus its effectiveness, may vary with feedstocks used**
- ✔ **Biochar should be used in conjunction with other soil amendments like compost to maximise soil health benefits**
- ✔ **It's important to start small – test out how biochar performs on a small scale before rolling out widespread application across the whole block or multiple farms**
- ✔ **Existing research has produced variable results and quality assurance standards are limited**
- ✔ **Biochar can be made on-farm or purchased commercially.**

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Interest is growing around biochar as both **a soil amendment and to increase carbon sequestration to soil**. This fact sheet explores what biochar is, how it can be used in vegetable production, what to consider if using biochar, and where you can get it.

WHAT IS BIOCHAR?

Biochar is **a solid charcoal-like material** that can be mixed with soils, amongst other uses, including biofuel or hydrogen production. It is an option for improved recycling of organic materials that are often considered to be waste.

Biochar is made by heating organic materials (biomass) in a low oxygen environment, through a process called pyrolysis (Figure 1).

The '**feedstock**' organic materials used to make biochar can include:

- Agricultural wastes – crop residues, manures and food waste
- Woody wastes – hard or soft wood
- Biosolids and organic industrial wastes.

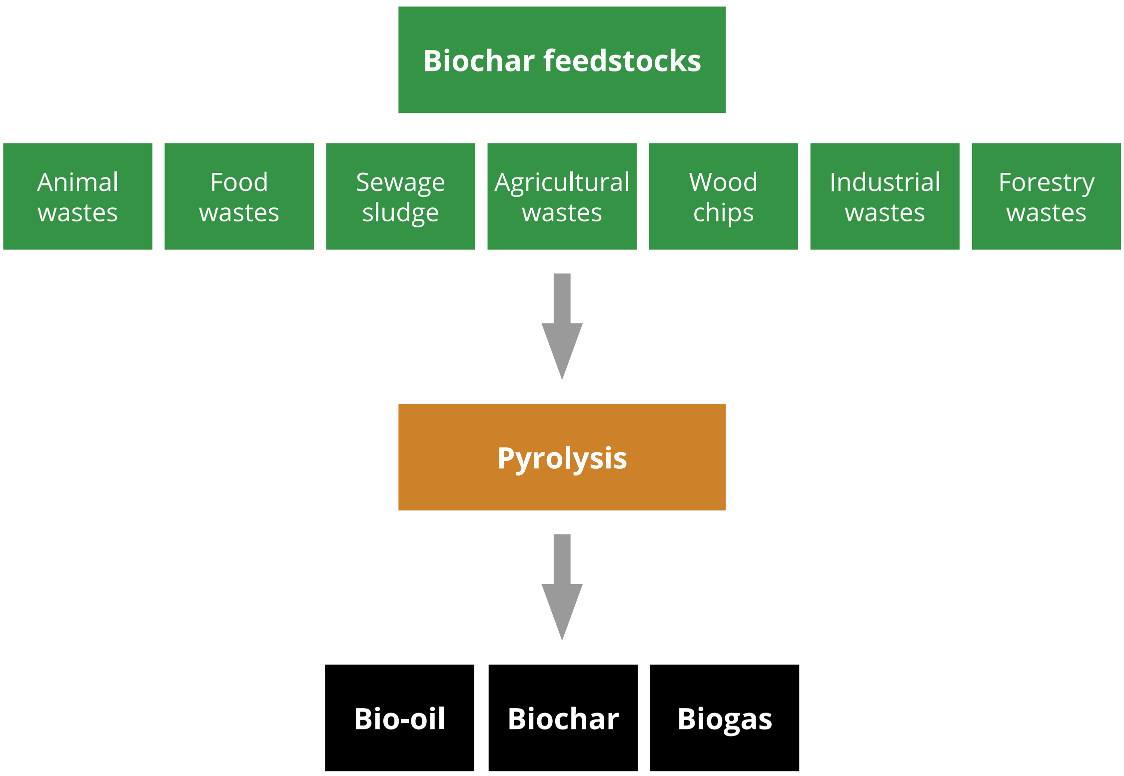

Figure 1. Diagram of the biochar production process

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FEEDSTOCK VARIABILITY

Due to the diversity and variability of feedstock material sources and production processes (including temperature, time and feedstock preparation), there is significant variability in the chemical and physical properties of biochar (see Table 1). As a result, the effect of biochar on soil health is dependent on the feedstock and production process of the biochar itself. Differences in vegetable production systems – including soil type, crop and rotations with other crops or cover crops – will also have impacts.

An example of the impact of the variability of feedstock on biochar quality and its influence on soil and plant health is shape and size of the resulting product.

Table 1. Characteristics of 14 different biochars^ (from Chan and Xu 2009)

Characteristic	Lower Value	Upper Value	Mean	Median	n
pH	6.25	9.66	8.1	7.93	6
C (g/kg)	172	905	543	540	14
N (g/kg)	1.7	78.2	22.3	11.4	14
N (NO_3^- + NH_4^+) (mg/kg)	<2	2			2
C:N	7	400	67	35.5	14
P (g/kg)	0.2	73	23.9	7.93	9
K (g/kg)	0.9	58	24.3	22.1	7
P plant* (g/kg)	0.015	11.6	0.42	0.04	4

^ biochars from a variety of feedstocks (wood, green wastes, crop residues, sewage sludge, litter, nut shells) and pyrolysis conditions (350°C-500°C) used in various studies

* plant available P

Figure 2 illustrates how biochar made from hardwood has relatively larger chunks, making it more suitable for improving drainage compared to the other biochars. Alternatively, the example made from bagasse would be more useful in reducing nutrient leaching due to the higher surface area.

In addition to shape and size, the chemical composition of biochars can vary greatly. The range of some key fertility indicators in biochar is shown in Table 1. Due to product variability, it is recommended to test the chemical composition of the biochar before purchase and prior to using it for soil application.

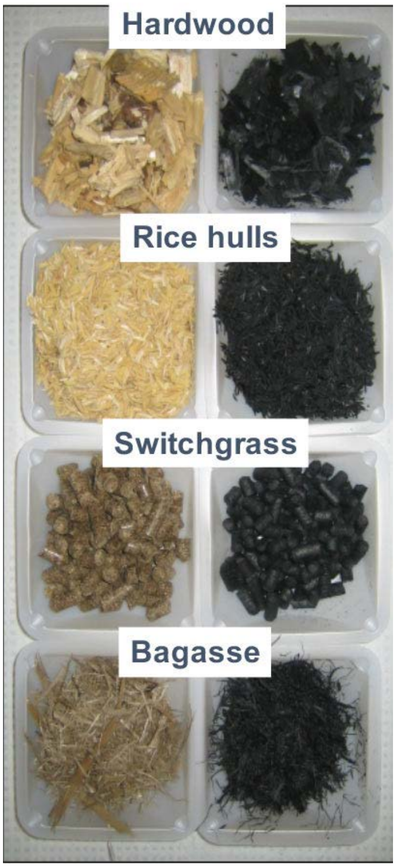

Figure 2. Different biochars and their feedstocks (from IBI website)

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WHY USE BIOCHAR IN VEGETABLE PRODUCTION?

Biochar has a wide diversity of potential uses in vegetable production, from improving soil structure to building stable organic carbon levels.

The potential benefits associated with various intended uses of biochar are described in Table 2. **Biochar can be used with other soil amendments** (e.g. compost) to realise cumulative benefits for soil health.

Generally, biochar benefits seem to be greatest on light, sandy soils with low organic matter content than in heavier soils and soils with a satisfactory (or good) organic matter content.

Depending on the intended use and the demonstrable effects of incorporating biochar into your soils, **the use of biochar can be accounted for in the vegetable industry's environmental best management practice program,** EnviroVeg.

HOW CAN YOU USE BIOCHAR?

Key considerations

Key considerations and questions to ask before using biochar in a vegetable production system include:

- **Intention** – What problem am I trying to solve? Is biochar the most appropriate solution?
- **Properties** – What are the characteristics I need in a biochar that will help me to achieve my goal?
- **Sourcing logistics** – How will I acquire the biochar that has the properties I need? How much will it cost? Can I make it myself? Can the supplier guarantee the quality? Will the supplier provide an analysis of the batch I am buying?
- **Trialling** – How will the biochar interact with my soils and crops? Have I tested the effects on a small segment of my farm and compared it to 'management as usual'? What are the experiences of other growers or agronomists with a comparable biochar?

When trialling soil amendments, positive effects may not be observed in year one. Sometimes several applications over a longer timeframe may be required.

Biochar has the potential to improve soil health, however it is not a silver bullet, and **it should be considered as one of the tools available in the soil improvement toolbox**. Table 4 (page 8) illustrates a useful decision tree for mitigating a variety of problematic soil conditions, noting that the addition of soil amendments such as biochar is only one of the many mitigations that could be implemented among a suite of options (e.g. growing cover crops, reducing tillage, fine-tuning timing, sources, amounts and placement of nutrients).

As always, an important principle is to not make too many changes to the same crop at any one time and remember the "monitor to manage" imperative.

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Table 2. Potential benefits of biochar use

Purpose	Reported potential benefit
Carbon sequestration	Biochar is made from plant biomass residues. **Plants are a carbon sink** as they remove CO_2 from the atmosphere. Biochar is stable, biologically unavailable carbon. The carbon contained in the biomass previously fixed by plants and used to make the biochar will be sequestered in the soil for a very long time.
Build 'stable' organic carbon	**Improved habitat for soil macro- and microbiota** **Increased slow or passive carbon storage** that lasts in soils much longer than carbon from compost or other soil amendments which are more labile and food for soil life, especially microorganisms
Improve soil structure	**Reduced compaction** (low bulk density of biochars) **Improved soil permeability** to water
Enhance nutrient and water retention (through sorptive properties)	Improved ability to hold on to introduced macronutrients and trace elements (e.g. via added fertilisers) **Reduced nutrient leaching**, i.e. may reduce amount of fertiliser required **Improved water holding capacity of soils**
Improve nutrient bioavailability (high cation exchange capacity – CEC)	**Improved bioavailability of nutrients to plant roots**
Improve root system function	**Enhanced root biomass and thus nutrient uptake efficiency**
Soil conditioner	Generally, biochar is alkaline and can be used to **raise soil pH** (see Table 1)
Improve soil biology	**Increased soil surface area** (due to the porosity of biochar) and therefore increased 'living area' for microbiota **Increased microbial activity and mycorrhizal fungal colonisation** **Decreased disease severity** due to improved biology

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Quality Assurance of biochar products

Currently there are no Quality Assurance standards for biochar within Australia. A Draft Standard has been prepared by a taskforce of the Australian and New Zealand Biochar Initiative.

The Standardized Product Definition and Product Testing Guidelines for biochar that is used in soil (the International Biochar Initiative (IBI) Biochar Standards) provide common reporting requirements for biochar and form the foundation of the IBI Biochar Certification Program.

Food safety considerations

Pyrolysis by its very nature can transform the chemistry of some of its constituent parts of the feedstock. It can potentially both reduce and produce potentially hazardous materials. **There may be reduced hazards from biological lifeforms including pathogens**, and some carbon-based chemicals. **There may also be toxic compounds produced.** One category that is not altered in the pyrolytic process is the amount of heavy metals from the feed source. For vegetable producers, it is highly recommended that you research the biochar you are thinking of using to **ensure none of the feedstocks are derived from biosolids or other sources high in heavy metals**.

At the time of publication, there is no specific reference to biochar within existing food safety guidelines.

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WHERE CAN I GET IT?

Biochar can be purchased from a supplier or produced on farm through pyrolysing biomass.

Purchasing Biochar

Table 3 lists some key questions to ask suppliers.

Table 3. Key questions to ask suppliers about biochar

Question	Why?
What is the average chemical composition of the biochar?	This will assess the quantities of nutrients and other chemicals you may be adding to your soils. **It provides important information to complement your nutrition program** and use of other complementary soil amendments.
What is the feedstock and process used to make the biochar?	This will assess characteristics that may not be included in a test of chemical composition, such as macroscopic and microscopic structure or the presence of pesticide residuals or other contaminants.
What is the recommended application rate?	This will vary between biochars as well as the problem you're trying to solve with biochar.

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Making Biochar

Making biochar is a simple and straightforward process that involves:

1. Acquiring biomass
2. Heating biomass (primarily through combustion/ burning) in a low oxygen environment.

There are several different methods you can use to create biochar from biomass. Figure 3 describes four common methods producers use to create biochar, with a kiln, an earth pit, a retort or pre-existing charcoal. The ideal method to use is different for every producer, dependent on:

- Volume and timeframes of desired production
- Available resources (e.g. equipment, space and human resources)
- Experience
- Type of biochar used as feedstock.

There are by-products from biochar production including biogas (a mix of methane, carbon monoxide, carbon dioxide and hydrogen) and bio-oil.

Figure 3. Four simple methods of biochar production (from Olivia Thierley 2020)

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Table 4. Options for mitigating a variety of problematic soil conditions (adapted from Paustian et al. 2016)

Issue	Mitigation practices	SWICP reference fact sheets
Degraded or marginal land for vegetable production	Rest or convert to perennial crop e.g. long term cover crops, pasture	Basics of cover cropping 9 min podcast
Fertility issues, nutrient imbalances	Identify liming factor(s), add nutrients as required, use nutrient budgeting based on removal rates, review timing, amounts, placement and type of fertilisers used	Developing a fertiliser program – webinar
Excess nutrient levels in the soil	Reduce inputs of identified excess nutrients, use nutrient budgeting based on removal rates, review timing, amounts, placement and type of fertilisers used	Guide to Soil Wealth nutrition resources
pH too low	Add lime or dolomite depending on soil calcium and magnesium levels, avoid acidifying fertilisers (e.g. sulphate of ammonia, urea)	Getting soil pH right – Lime quality and application rates
pH too high	Use acidifying fertilisers but NOT if the soil is high in sodium and/or magnesium Use soil amendments that are low in pH	
Salinity or sodicty	Use best management practices, avoid Muriate of Potash, use soil amendments to add carbon	Managing sodicity in vegetable crops
Bare fallow, erosion	Grow suitable cover crops, consider contour drains on slopes	
Intensive tillage, compaction, poor root growth	Reduce tillage, i.e. via strip tillage, use cover crops to improve soil structure and retain residues as much as possible	Grower Ed Fagan discusses cover cropping/ strip till
Low residue crops e.g. baby leaf crops	Introduce cover crops	East Gippsland cover crop trial discussion
Soil-borne diseases	Improve soil structure and drainage, rotate crop types if possible, use biofumigation crops	Biofumigant cover crops – webinar
Low organic carbon/ organic matter	Add amendments such as quality compost to improve labile carbon levels, add biochar to increase stable carbon Use cover crops and reduce tillage	Soil amendments global scan
Uneven crop performance within a paddock	Use precision agriculture tools to identify issues and solutions	Using drones for insights – webinar
Water logging: water draining slowly or pooling after rain and or soil surface sealing	Check for high sodium and/or magnesium levels and, if found use practices to mitigate sodicty Reduce tillage, use cover crops to improve soil structure and retain residues as much as possible, add amendments such as quality compost Use precision agriculture tools to identify issues and potential drainage solutions	Summary of resources: Phase 2 SWICP – 14 pages of resources by topic

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FURTHER READING

If you're looking for more information on biochar the below resources are useful.

CSIRO (2014). Opportunities and constraints for biochar technology in Australian agriculture: looking beyond carbon sequestration – https://www.publish.csiro.au/sr/fulltext/sr14112

GRDC (2013). Biochar fact sheet – https://grdc.com.au/__data/assets/pdf_file/0026/83915/biochar-fact-sheet.pdf.pdf

NSW DPI (2012). Biochar in horticulture: Prospects for the use of biochar in Australian horticulture – https://archive.dpi.nsw.gov.au/content/land-and-natural-resources/soil-management/biochar-in-horticulture

Western Australia Department of Agriculture (2021). Carbon farming: applying biochar to increase soil carbon – https://www.agric.wa.gov.au/soil-carbon/carbon-farming-applying-biochar-increase-soil-carbon

Major, J. (2010). Guidelines on Practical Aspects of Biochar Application to Field Soil in Various Soil Management Systems. International Biochar Initiative. https://biogrow.co.za/wp-content/uploads/2017/11/Biochar-Info-BI1.pdf – aimed mainly at those in developing countries but still has useful information.

References

Paustian, K, Lehmann, J, Ogle, S & Reay, D (2016). 'Climate-smart soils', Nature, vol. 532, no. 7957, pp.49-57. DOI: 10.1038/nature17174. Available here: https://www.researchgate.net/publication/300372553_Climate-smart_soils

Chan and Xu (2009). Biochar: Nutrient Properties and Their Enhancement. In: Lehmann, J. and Joseph, S., Eds., Biochar for Environmental Management: Science and Technology, Earthscan, London, UK, 67-84. Available here: http://www.css.cornell.edu/faculty/lehmann/publ/First%20proof%2013-01-09.pdf

Resources

Draft Australian Standard – https://anzbig.org/wp-content/uploads/2020/07/AANZBI-Proposed-Australian-Standard-for-Biochar-in-Soils_Draft-For-Comment_RevC_18-09-2019.pdf

International Biochar Initiative Standards – https://biochar-international.org/ibi-biochar-standards/

Australian New Zealand Biochar Initiative (ANZBI) – https://anzbig.org/resources/:

- **Biochars directory includes biochar suppliers** – click link to 'Trade Directory'
- **Draft Code of Practice** for the Sustainable Production and Use of Biochar in Australia and New Zealand (June 2020) – click link to 'Code of Practice'
- A Report on the Value of Biochar and Wood Vinegar: **Practical Experience of Users in Australia and New Zealand** (Robb and Joseph 2020) – click link to 'Users Report'

Olivia Thierley (2020). Biochar a Practical Guide – https://bottom-up-biochar.com/biochar-practical-guide/

AUSVEG/EnviroVeg – https://ausveg.com.au/enviroveg/, https://enviroveg.com.au

Making biochar

Nebraska Fire Service – https://nfs.unl.edu/publications/small-scale-biochar

University of Arizona – https://extension.arizona.edu/sites/extension.arizona.edu/files/pubs/az1752-2017.pdf

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