Modified Atmosphere Bulk Packaging: Principles and Practice of Biochar Storage and Transport

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Why Package Biochar?

- **Safety**– to reduce fire risk by preventing possible ignition
- **Logistics**- to make the biochar easier to handle and less expensive to transport and store
- **Moisture Content-** to keep moisture level stable for applications which require a certain moisture threshold
- **Branding-** to establish a uniquely identifiable biochar brand to increase sales- good looking packaging sells more product

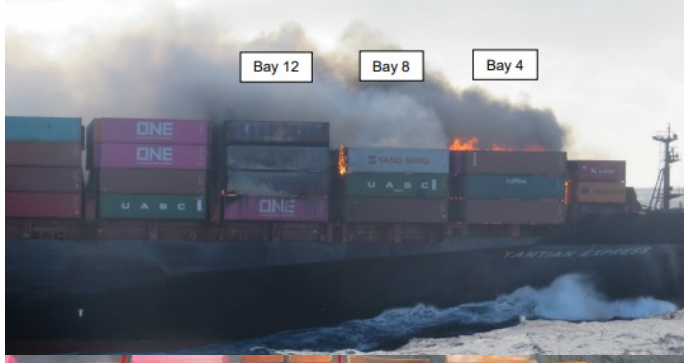
- **MSC Katrina**. File Photo: Gerd Frick / MarineTraffic.com

Porous Carbon Materials Can Self Heat and Ignite

- Investigators in Germany are calling on the International Maritime Organization to update regulations related to the carriage of charcoal cargoes in containers after separate fires on board two containerships.

- **In both cases, the self-ignition of charcoal cargoes was found to be the source of the fires.**

- The fires broke out on board the Panamanian-flagged MSC Katrina on November 2015 and on board the German-flagged Ludwigshafen Express on February 2016.



The Yantian Express

- The Federal Bureau of Maritime Casualty Investigation (BSU) published an investigation report concerning the fire in the area of the deck cargo on board the container ship YANTIAN EXPRESS on the Atlantic Ocean, identifying Coconut Biochar as the likely cause of the fire.

- Authorities believe the fire was caused by self heating and ignition of coconut biochar briquettes that were loaded into the container in woven polypropylene bags, because of the length of time between the start of transport (Dec. 13, 2019 and the outbreak of fire on Jan. 4, 2019.

Self-Heating of Biochar during Postproduction Storage by O_2 Chemisorption at Low Temperatures

https://www.mdpi.com/1996-1073/15/1/380/htm

EXCERPTS:

- **Biochar is prone to self-heating and often leads to spontaneous ignition and thermal runaway during storage, resulting in production loss and health risks. It was observed that char temperature slowly increased from the initial temperature due to heat released during O_2 adsorption.**
- **However, if O_2 is not permeable through the container materials, the temperature starts decreasing after the consumption of O_2 in the container.**
- **The results suggested that self-heating can be somewhat mitigated by decreasing the void fraction, reducing storage volume, and lowering the initial char temperature.**

Quantifying self-heating ignition of biochar as a function of feedstock and the pyrolysis reactor temperature

https://www.sciencedirect.com/science/article/pii/S0016236118315138

SIGNIFICANT EXCERPTS:

- Because biomass, biochar and torrefied biomass are reactive porous media and can undergo self-heating, there is a fire hazard associated to their production, transport, and storage. This hazard needs to be tackled.
- biochar is most prone to self-heating when produced at 450 °C. Reactivity decreases at higher reactor temperatures, and at 600 °C the biochar is less reactive than the original feedstock.
- there are voids in the biochar structure formed as pores (macro, meso and micropores)… making biochar a reactive porous structure. **This porous structure makes biochar prone to self-heating ignition.**
- the effect of moisture content (MC) on self-heating ignition of reactive porous media has been shown to be complex. **At low MC an increase in moisture content increases the reactivity of the material, and also the tendency for it to self-heat.** At higher MC values the reactivity of the material decreases dramatically with moisture content.
- **At low MC, up to approximately 50% MC, the presence of moisture increases the self-heating process.** At higher MC (over 50%)… excess moisture takes up extra heat and slows down the release of heat from oxidation.

International Bulk Maritime Cargoes Code for Biochar

- **No bulk shipment of biochar- must be bagged**
- **The CINS guidelines and IMDG codes believe that charcoal with a moisture content of over 10% represents an increased self-heating risk, and therefore do not allow it.**
- **Shipping container must be fully packed to limit headspace void**
- **Must have passed the test as not self-heating within 6 months of shipping date**
- **Can be packaged in super sacks or 50kg or smaller bags**
- **Without the self-heating test certification the char has to be packed into smaller bags (max. 50kg) and declared as dangerous goods**
- **must have been cooled for two weeks prior to packaging**
- **must be specifically declared to the shipper**
- **must come with corresponding paperwork documenting all of the above**

Biochar Risk Factors

- Biochar self heating is likely caused by spontaneous exothermic oxidative reactions. Ratio between Oxygen and biochar is a determining factor. **Less O2 means less oxidation and less self heating.**
- Reducing voids (airspace) inside containers of biochar is beneficial. **Lower O2 volume means less O2 entering the biochar pores.**
- The effect of moisture content (MC) on self heating is complex. **Below 50% moisture content can increase exothermic reactivity.** Above 50% MC biochar reactivity decreases dramatically.
- Movement of the biochar particles caused by absorption and desorption of moisture creates **friction heat and can be a source of ignition** (shaking during transport can also create friction).

Packagin g Biochar

Design Objectives:

- Reduce O2 content inside the bag to prevent oxidation
- Reduce voids and headspace inside the bag to further limit oxidation
- Prevent transfer of gas and moisture in and out of the bag
- Keep moisture level at 10% or below
- Prevent moisture loss from evaporation or leakage through woven materials
- Prevent friction from biochar particle movement
- Reduce open headspace inside shipping containers during transport

Design Solutions:

- Reduce O2 content inside the bag through Modified Atmosphere Packaging- Nitrogen gas purge
- Reduce voids inside the bag through vibratory compaction
- Eliminate headspace void inside the bag by vacuum sealing
- Immobilize biochar particles by vacuum sealing
- Prevent transfer of O2, N2 and moisture through the bag by using a high barrier property, hermetic film liner
- Size the bag to stack to within 6” of a container ceiling to reduce headspace during transport

Definition of MAP

- Modified Atmosphere Packaging is a method of preserving food and other reactive or perishable products. MAP typically involves a hermetic (watertight, airtight) bag that is filled with an inert gas that displaces oxygen inside the bag. The goal of MAP is to create a “microclimate” inside the bag that preserves and protects the contents against spoilage factors.

Example of a MAP Bag: Lay's Potato Chips

PROBLEM: Dry, crisp chips absorb moisture from ambient air and become soggy. Oxidation and light causes oils to go rancid and ruins flavor. Microbial decomposition begins.

MAP SOLUTION: Hermetic film bag prevents transfer of moisture and oxygen. Nitrogen gas flush displaces oxygen inside the bag. Oxidation is prevented, moisture can't transfer in, and shelf life is extended.

What is the main spoilage factor for biochar?

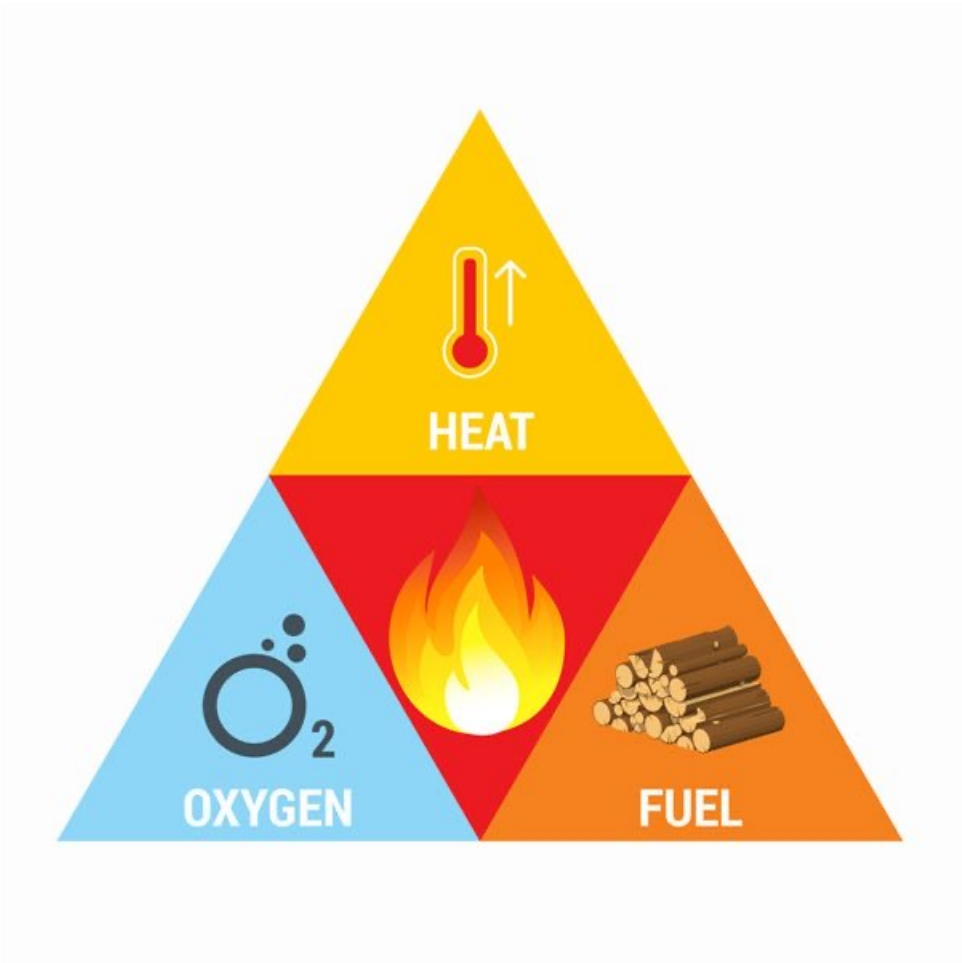
ANSWER:

Self heating and ignition

How can MAP help prevent biochar fires?

The Fire Triangle

- Fire needs 3 elements to occur: Fuel, oxygen and a source of ignition (heat). If any of these elements is missing, fire cannot occur.
- MAP removes the Oxygen leg of the fire triangle
- Fire risk is reduced
- Reactive biochars can be kept stable during storage and transport



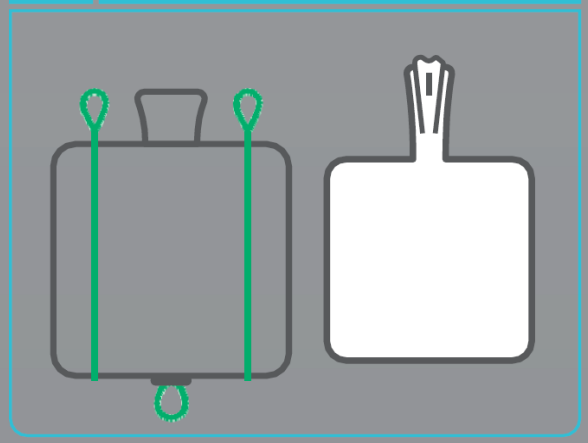
Vibratory Compaction and Vacuum Sealing Combined with MAP

- **Vibratory compaction removes O2 and permits 20% more material to fit in a container by settling out the air voids between biochar chips**
- **Headspace air void is eliminated by air evacuation**
- **N2 Purge and vacuum sealing assures the only residual gas in the bag is N^2**
- **Efficient cubic shape produced by vacuum sealing stacks to within 6” of a shipping container ceiling**

Patented Bulk Scale Modified Atmosphere Packaging: TORRESAK®

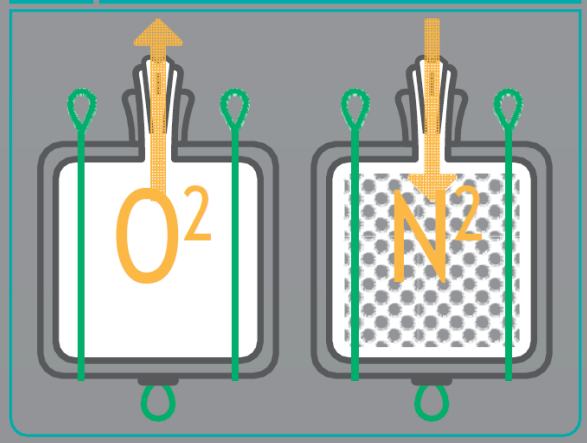
- 42x42x44 (1.7 Cubic Yard Capacity)
- Cubic Vibratory Compaction Table
- Anti static, food grade materials prevents sparking
- Designed to stack in a shipping container to the ceiling
- Patented MAP technology helps to prevent biochar fires
- N2 purge and vacuum seal removes O2 Inside the bag
- Hermetic waterproof and airtight liner
- Reusable

1 PROVIDES MODIFIED ATMOSPHERE PACKAGING (MAP)



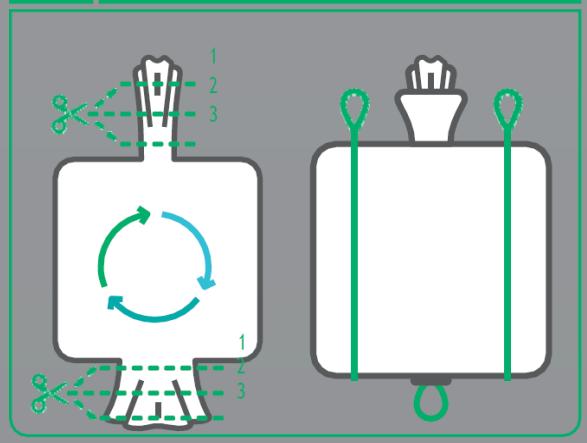
- Cubic shape optimizes space
- Retains cube shape for easy stacking
- Reduced risk of punctures and snags
- Very strong – constructed with 5x safety factor

2 REPLACE O^2 WITH N^2 AND SEAL THE BAG



- Package specifically designed for biochar
- Trilaminate hermetic liner-Nitrogen flush
- The vacuum sealing process immobilizes biochar particles to minimize friction and hot spots
- Made from static dissipative materials to minimize sparking
- Oxygen content reduced to just 1%

3 EMPTY, CUT AND REUSE THE BAG



- Cut the seal off the top and bottom spouts to reuse
- Up to 3 uses per bag

CHOOSE SAFETY, CHOOSE TORRESAK!

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Summary of Biochar Packaging Principles

- **MAP Packaging with N2 Purge reduces O2 content around the biochar, reducing oxidation to minimum level**
- **Vibratory compaction removes airspace between particles, further reducing oxidative reactions**
- **Vacuum sealing after N2 purge eliminates headspace at the top of the bag, further reducing oxidation**
- **Very low biochar to air ratio (1%) inside the bag prevents self heating**
- **Hermetic liner prevents transfer of O2, N2 and H2O through the film barrier**
- **Vacuum sealing immobilizes the particles, preventing friction and hotspots**
- **Anti-static film additive prevents ignition from static sparking**
- **42”x42”x 44” bags are stackable 2 high on a pallet to within 6” of a high cube shipping container**
- **Shipping container headspace is minimized to 6”, increasing both safety and freight efficiencies**
- **Bags can be moved by corner lift loops for stacking with a forklift**

Final Lesson:

A pile of biochar out in the open air– why is this a bad idea?

- Ratio of air to biochar is infinite, leading to maximum oxidation of biochar and self heating risk
- Exposure to moisture can lead to uneven distribution of moisture content and particle movement
- Movement caused by desorption and absorption of moisture by biochar particles can create friction
- **This is exactly what not to do!**

Brand Your Biochar with TORRESAK®

Print 2 bag side panels 2 ink colors with your Brand!

Let your bag graphics help sell your biochar!


THANKS
FOR LISTENING.
SMOKEY