Natural Wood Smoke Technologies

Reciprocation Session
Ron Jenkins – Red Arrow Products
June 22, 2009












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RECIPROCAL MEAT CONFERENCE

RED ARROW
Smoke • Grill • Browning

Why do we Smoke Meats?



- ***Preservation:***
  - **Antioxidant**
  - **Antimicrobial**
  - **Skin formation**
- ***Sensory Properties:***
  - **Flavor**
  - **Color**
  - **Aroma**

Smoked Meat Technologies

An ancient food preservation technique

History

- **Prehistoric:** ***flavor & for drying and warding off flies (fish & game).***
- **Ancient:** ***preservation & flavor.***
  - ***Romans/Etruscans: Parma ham (100 B.C. - Cato's writing), fish, cheese***
  - ***Greeks: fish***
  - ***Gauls: pork***
  - ***Americas: fish, game***
- **Colonial America:** ***preservation & flavor. Examples:***
  - ***Pork: Example - Virginia Country Ham***
  - ***Venison***
  - ***Fish***



Courtesy, The Colonial Willamsburg Foundation

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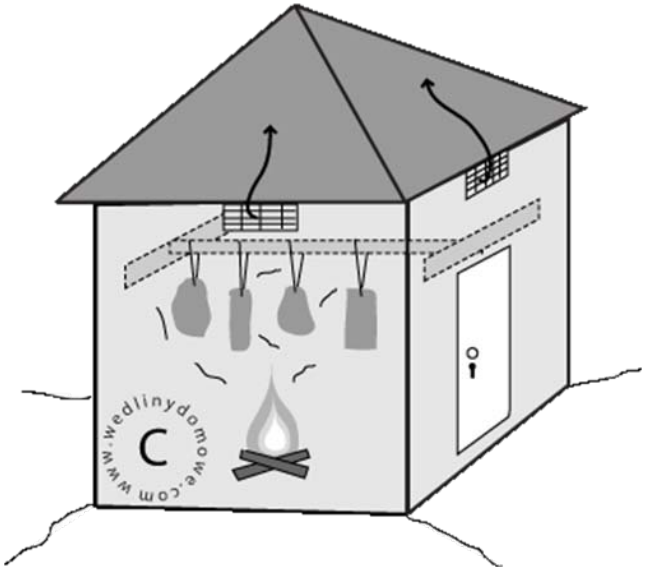
Smoked Meat Technologies

An ancient food preservation technique

Colonial America & 17-18th Century Europe -

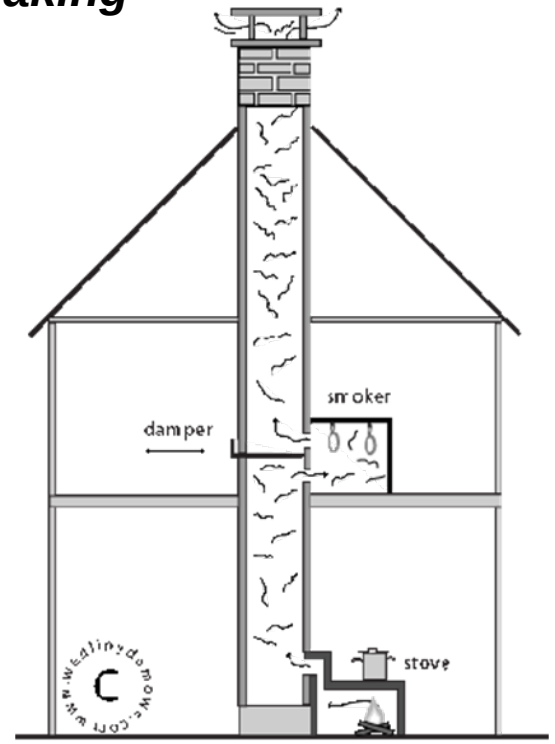
"Smoak-houses", "Meat houses", & In-home "smoaking"



Meats hung for 2+ weeks above the fire. Product was then **moved** to another location **in the smokehouse for up to 2 years.**



Colonial Williamsburg Virginia: **12 original & 50** reconstructed **smoak/meat houses** - wooden & brick construction



"Smoking Closets" in Home Chimney Flues

Sources: Wedlinydomowe.com

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Smoked Meat Technologies

An ancient food preservation technique

Barbequers, Restaurants, & Home Chefs:













Photos Used with Permission by: PolyScience, www.cuisinetechnology.com; ©Weber-Stephen Products Co.; Southern-Pride.com; "Meat Smoking And Smokehouse Design," Publisher: Bookmagic LLC;

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An ancient food preservation technique

Current - commercial:

- **Batch Houses**



Continuous Houses





Certain Batch and Continuous Smokehouses can use traditional and natural smoke condensates.

Courtesy: Alkar.com

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Wood Smoke Composition - Definition

1. ***What is Smoke?*** *a gas or vapor derived from the combustion of wood.*

2. ***Why is it visible?*** *steam and organic compounds condense in the atmosphere*

3. ***Source of Smoke Compounds in Wood:***
   - ***a)*** ***Cellulose*** *(40-45% of wood)****: carbonyls***
   - ***b)*** ***Hemicellulose*** *(20-35% of wood)****: acids, carbonyls***
   - ***c)*** ***Lignin*** *(18-30% of wood)****: phenols***

Wood Smoke Types - Definition

1. **Traditional Wood Smoke** (Naturally smoked) - *smoke generated from the burning of hardwoods, hardwood dust, corn cobs, mesquite, etc. Vaporous and condensed smoke phases are transferred to the smokehouse and meat products.*

2. **Natural Smoke Condensates (NSCs)** - *smoke that has been cooled and condensed to form a liquid – a process identical to that of traditional smoke being applied to a meat product.*

Natural Wood Smoke Components

Traditional Wood Smoke

- **Gaseous Phase**
- **Liquid Phase**
  - **Tars – *largest component***
  - **Acids**
  - **Phenols**
  - **Carbonyls**
- **Solids**

Natural Smoke Condensates

- **Acids**
- **Phenols**
- **Carbonyls**

Smoke Components: Functional Properties

Organic Acids - acetic (primary)

- Skin Formation - coagulation of surface proteins.
- Flavor - tartness
- Antimicrobial – bacteriostatic
- Accelerate Cure Reaction

Smoke Components: Functional Properties

Carbonyls

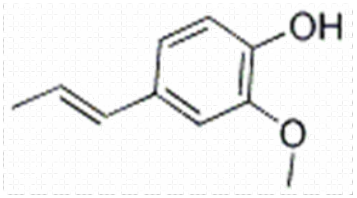
- ***Color*** **-** ***via heat related rxn w/ proteins*** *(carbonyl-amine groups)*
- ***Crosslink proteins -*** *Skin formation & stabilization (amino- & sulfhydryl groups)*
- ***Flavor & Aroma***
- ***Most reactive:*** *glycolic aldehyde & methylglyoxal*

Smoke Components: Functional Properties

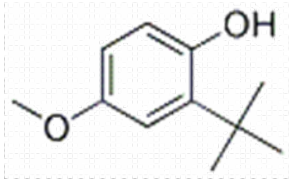
Phenols

- ***Flavor & Aroma -*** ***Primary Flavor Components of Smoke.***
- ***Antioxidant -*** ***Structure similar to BHA & BHT but Natural.***

Ex. Isoeugenol:



BHA:



  - ***Strongest Smoke Antioxidants:*** ***Catechol, Syringol, Eugenol, Isoeugenol, 4-substitued syringols***

- ***Antimicrobial -*** *Isoeugenol, 4-Methylguaiacol, Guaiacol*
  - ***Strongest Impact:***
    - ***Listeria***
    - ***Staphylococci***
    - ***Bacillus***
    - ***Yeasts***
  - ***Weakest Impact:***
    - ***E. coli***
    - ***Lactobacillus***
    - ***Aspergillus***

- ***Color*** *(minor role)*

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Smoke Flavor Profiles

Flavor Compounds

Sensory Profiles of Major Smoke Phenols

	Odor Descriptor	Flavor Descriptor
• Dimethylphenol:	• Phenolic, aromatic Sweet.	• Sweet, phenolic, sharp, charred dry.
• 4-Methylguaiacol:	• Sweet, vanilla-like, fruity, cinnamon-like, smoky, pleasantly sharp, phenol notes.	• Sweet, vanilla, caramel & pleasant smoke notes, burning, aromatic.
• Guaiacol:	• Phenolic, smoky, aromatic, sharp, sweet.	• Phenolic, sharp, spicy, smoked sausage notes, sweet, dry.
• Syringol:	• Smoky, spicy, aromatic, smoked-sausage, sharp, sweet.	• Smoky, freshly charred wood, whiskey notes, dry, sharp.
• *o*-Cresol:	• Phenolic, fruity, sweet, aromatic, caramel and smoked sausage notes.	• Sweet, sharp, unpleasant smoky, burning, phenolic
• Isoeugenol:	• Sweet, fruit, vanilla, & rhubarb notes, phenolic.	• Hydrolyzed Vegetable protein-like flavor, smoked ham notes, hot, sweet.

Source: *Maga, J.A., 1988.* Flavor Chemistry of Wood Smoke. *In, Smoke in Food Processing. CRC Press. Chap 3. pg. 49.*

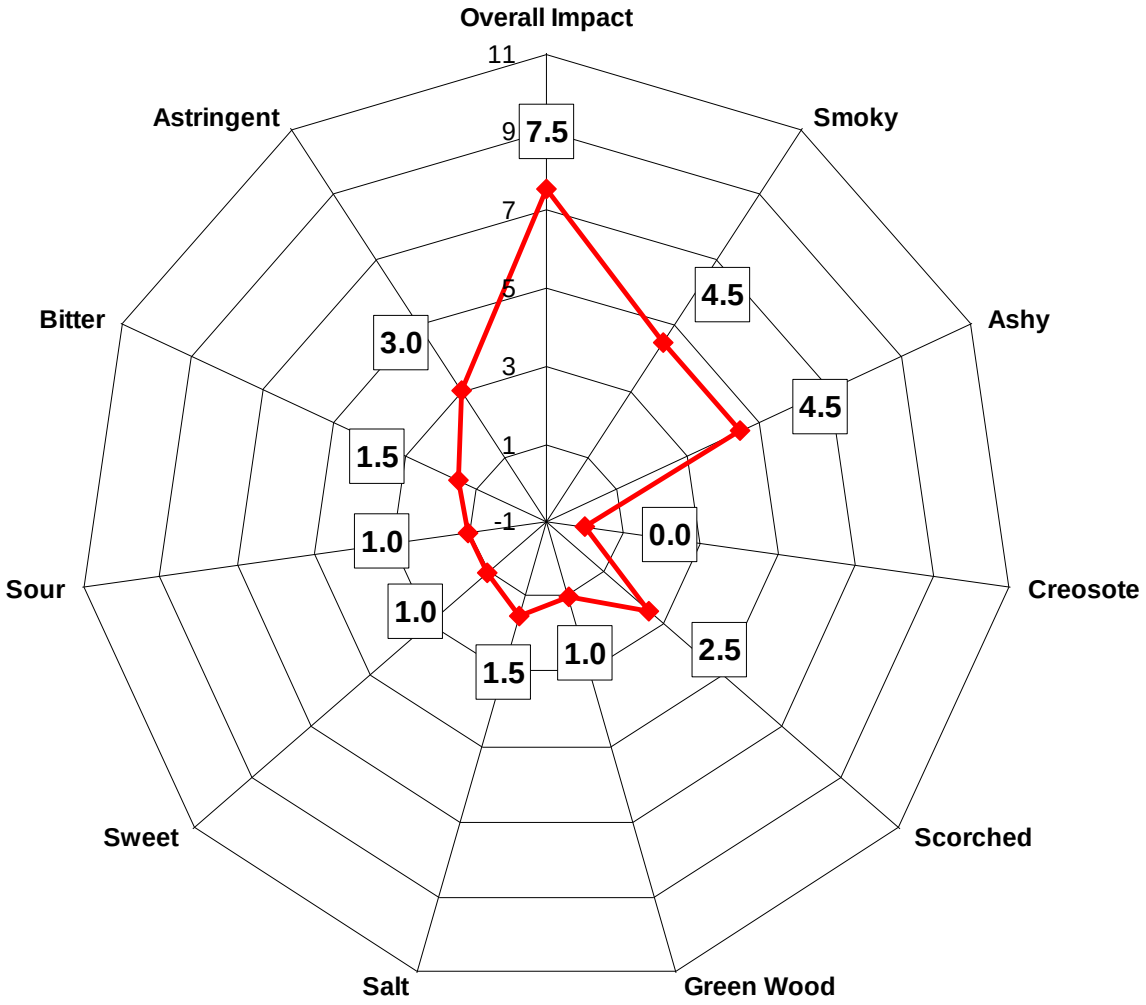
Smoke Flavor Profiles

- ***Primary Smoke Descriptors:***
  - ***Smoky*** - **The penetrating, dark brown, acrid aromatic of charred wood.**
  - ***Ashy*** - **Black, charred aromatic associated with residue of unwashed ashtrays.**
  - ***Scorched*** - **Aromatic associated with charring or burning.**
  - ***Creosote*** - **Tarry, phenolic aroma associated with smoke and solvents.**
  - ***Green Wood*** - **Aromatic associated with green wood/small young branch wood.**

- ***Secondary Smoke Descriptors:***
  - ***Salty***
  - ***Sweet***
  - ***Sour***
  - ***Bitter***
  - ***Astringent***

Smoke Flavor Mapping

Example: Lexicon for a Hickory Smoke Condensate



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Traditional Wood Smoke
Application Technologies

a. Smoke Pit – oldest style

1. Fire pit: logs, sawdust, wood chips.
2. Gas jets – ignition source
3. Ventilator
4. Atmosphere impact
5. Smoke Color and Flavor Quality

b. Smoldering Smoke Generator – most common.

1. Auger drops sawdust upon metal ignition plate.
2. On-demand smoke cloud.
3. Smoke quality controlled by:
    a. Heat plate temperature,
    b. Air supply,
    c. Sawdust moisture content.

Traditional Wood Smoke
Application Technologies

c. Steam-generated Smoke Generator

1. *Wood Chips + Super-heated steam (400° C/750° F)*
2. *No open flame in generator.*
3. *Rapid smoke availability.*
4. *Shorter smoke cycles.*

d. Friction Smoke Generator

1. *Logs – fuel souce*
2. *A flameless process.*
3. *Friction Wheel*
4. *Rapid smoke availability.*
5. *Hermetic smoking process – no exhaust air escapes.*
6. *Limited flavor, Low Tar*

Traditional Wood Smoke
Application Technologies

e. ***Electrostatic Smoke Generator*** ***– a two phase process***

1. *Conventional smoke generator*
2. *Two electric ionizers in Smokehouse*
3. *Electrostatic action.*
4. *Flavor issues – low uptake of phenolics.*
5. *Carbonyl fraction predominates*
6. *Worker safety issues*
7. *PAH levels may be high*

Traditional Wood Smoke –
Fuel Sources & Quality Factors

1. Smoke Fuel Sources:

a. **Hardwoods** - *hickory, mesquite, alder, maple, oak, cherry, poplar, apple, beech, etc.*
b. **Softwoods -** *from conifers. Ex.pine, cedar, spruce, etc.*
c. **Corncobs**



2. Smoke Fuel Forms:

a. **Logs -** *used in Pit-style house or Smoker*
b. **Sawdust & Wood Chips -** *used in generator*

3. Factors affecting Smoke Quality

a. **Wood or Fuel Source**
b. **Generation Temperature** - *Recommended range:* ***600°F - 650°F***
   1. *Acids: 400-500°F*
   2. *Phenols & Carbonyls: 600°F*
   3 *Polycyclic Hydrocarbons: 750°F*
c. **Air flow**
d. **Moisture: ↑Moisture, ↓ Phenols, Acids, & Carbonyls.**



Cabinet Photo Courtesy of: Southern-Pride.com;

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Traditional Wood Smoke:
Advantages

1. **Marketability -** *the allure and nostalgia of natural or traditional wood smoking - extremely marketable. Marketing and sales campaigns can promote the "old-fashioned" or "traditional" values associated with traditional smoking applications.*
2. **Sensory -** *while traditional smoked products can be flavor and color matched by smoke condensates, such alternatives may not carry the cooked **aromas** associated with traditionally smoked meats & poultry.*

Traditional Wood Smoke:
Advantages

3. **Equipment needs -** *alternatives to traditional smoking, i.e., natural smoke condensates (liquid smokes), may require special equipment for applying the smoke flavor - hence an initial cost outlay.*
4. **Natural -** *the traditional smoke process is considered natural as are certain natural smoke condensates.*

Traditional Wood Smoke:
Disadvantages

1. **Lacks Consistency of Color, & Flavor between batches -** *Tar and ash deposits can occur.*
2. **Lengthy Smokehouse Schedules** – *reduced throughput*
3. **VOC, CO, CO_2 & Methane emissions –** *EPA air-inventoried substances - regulated. Future carbon tax liability. Environmental issues.* **NOT a "Green Process."**
4. **Contains *PAH's - Polycyclic Aromatic Hydrocarbons* -** *some of which are carcinogenic.*

Traditional Wood Smoke:
Disadvantages

5. **Major Fire Hazards –** *tars lining the ductwork provide the fuel.*
6. **Creation of Solid & Liquid Waste**
7. **More Costly:**
   a. *Greater energy usage.*
   b. *Complicated handling & cleaning requirements & greater labor usage.*
   c. *Meeting pollution control requirements with permits and costly filtration devices.*
   d. *Decreased smokehouse life.*

Natural Wood Smoke Condensates

- ***Natural Smoke Condensates*** **- *produced through a controlled pyrolysis of hardwood sawdust.***
- ***Vapor phase components*** **– *cooled & captured in water as a condensate.***
- ***Phase separation (purification)*** **- *removes Tars*** *(contain PAH).*
- ***Condensate*** **- *lacks Particulate phase***



Captures the Beneficial Components of Traditional Smoke.

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Natural Smoke Condensates

Smoke Fuel Sources



1. **Natural Smoke Condensate Fuel Sources**
   a. **By Wood Species & may include:**
      1. Hickory, Oak, Maple, Beech
      2. Mesquite
      3. Fruitwoods (Cherry, Apple)
      4. Others
   b. **Other Sources:** Corn Cobs, etc.
2. **Factors affecting Natural Smoke Condensate Qualities**
   a. **Temperature of the Wood Pyrolysis:**
      1) Higher temperatures = higher Carbonyl and traditional Smoke flavor.
      2) Lower temperatures = higher Phenolic and Acid levels.
   b. **Natural Condensate Production**
      1. Separation of tar phase from water phase – sedimentation
      2. Filtration & Concentration
      3. Blending

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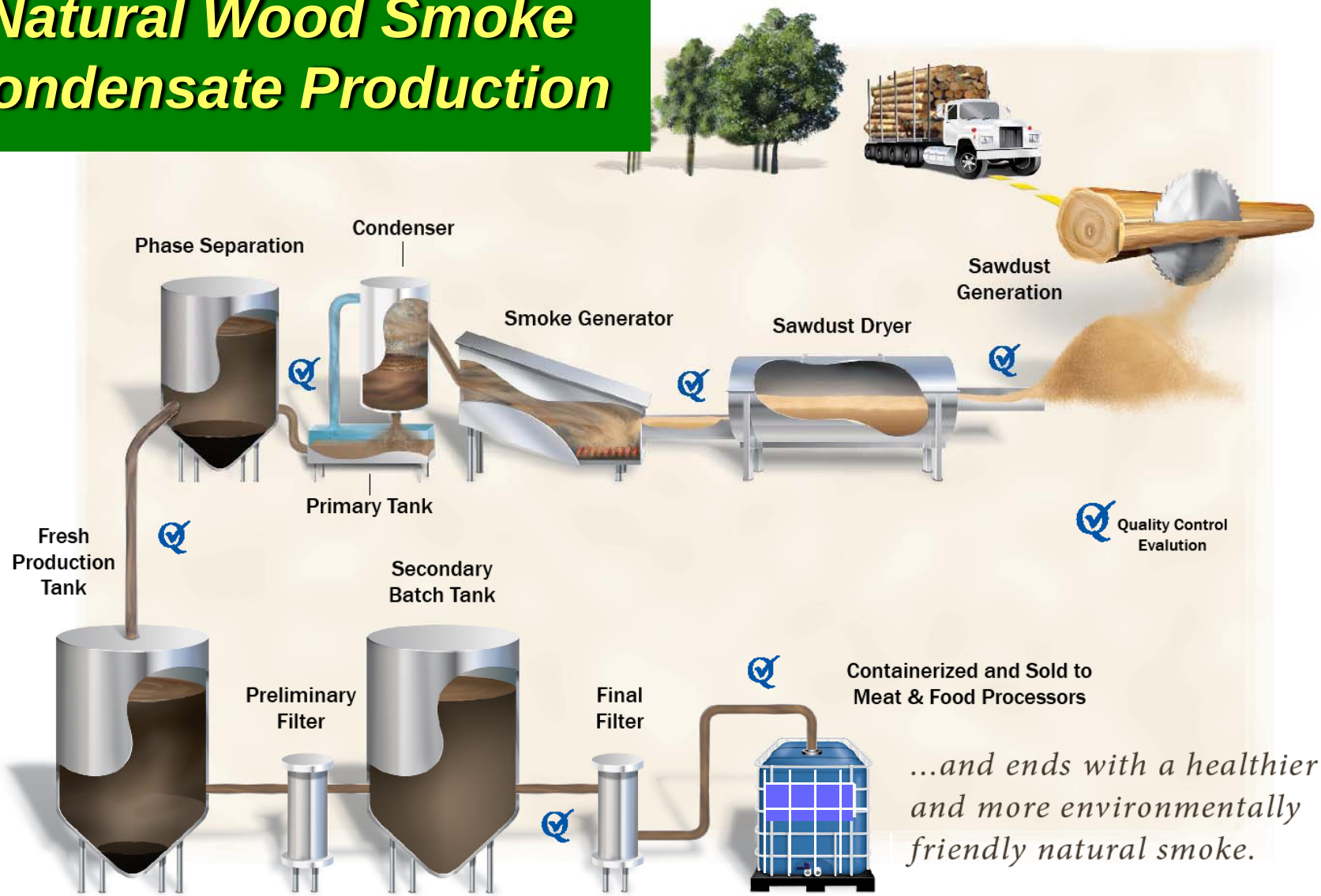
Natural Wood Smoke Condensate Production



NATURAL SMOKE CONDENSATE PROCESS

Natural Wood Smoke Condensate Production









Natural Wood Smoke Condensate Production

Sawdust is Dried



Natural Wood Smoke Condensate Process Technologies:
Calciner & RTP





Calciner Reactor

Original technology

1. Lower Carbonyls
2. Higher Phenol Content
3. Higher Acid Levels

Rapid Thermal Processing (RTP)

A New High Temperature Process

1. Higher Carbonyls
2. More Traditional Natural Smoke Flavor
3. Lower Acid Levels

Smoke Condensate Production





Primary Storage Tank

- Newly formed Smoke Condensate is collected here.
- Particulate Matter settles out at this stage.
- Key to a Clean Product.

Secondary Storage Tank

- Smoke Condensate is transferred here from the Primary Tank.
- The Smoke Condensate is adjusted to meet the customer's needs.

Smoke Condensate Production





Bulk and Barrel Filling of Natural Smoke Condensate

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Natural Smoke Condensates: Delivery Forms

1. *Concentrated liquid*
2. *Water soluble liquid*
3. *Oil-soluble liquid*
4. *Neutralized*
5. *Dry*
6. *With All Browning and No Flavor*
7. *With All Flavor and No Browning*



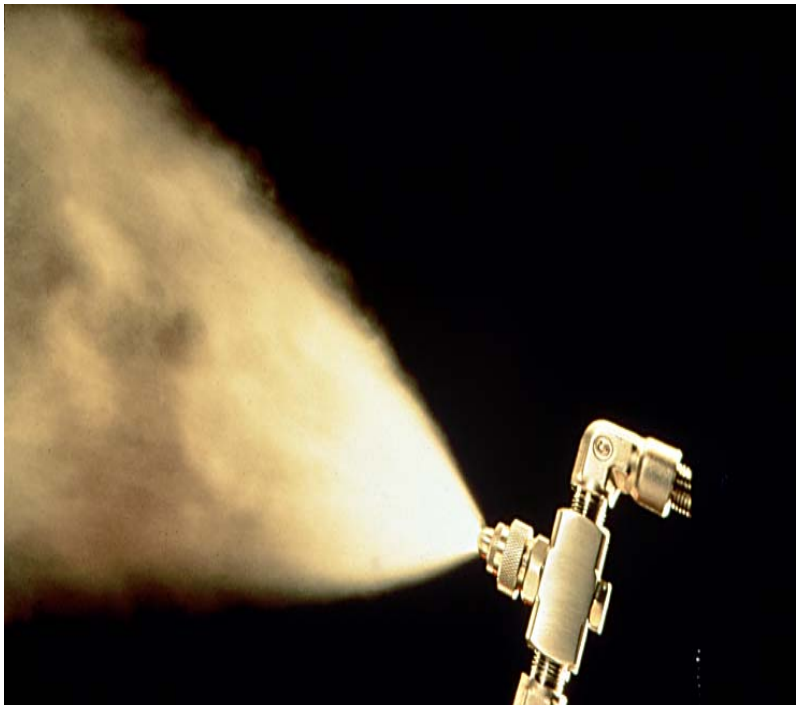
Application Techniques:
Natural Smoke Condensates

- Atomization
- Drenching
- Direct Injection (Brine)
- Vacuum Marinating
- Smoked Nets
- Coated Casings
- Spraying Systems
- Dry Topical Coatings

Smoke Condensate Application Techniques: ATOMIZATION

Pressurized Air to Vaporize Smoke Condensates

- *Easily adaptable for Installation*
- *Dry surface prior to atomization*
- *Permits Customization*
- *Improved Product Uniformity*
- *Cost Savings:*
  - *Increased Throughput*
  - *Improved Sensory Uniformity*
  - *Eliminate Smoke Emissions*
  - *Reduced Solid Waste Disposal*
  - *Reduced Downgraded Product due to Tar spots.*
  - *Cleaner Operation*



Smoke Condensate Application Techniques: DRENCHING

Drenching/Showering: ***floods external surface with water-soluble smoke condensates***



Environmentally Sound -
reduced air emissions,
cleaner operating environment,
less landfill waste,
less energy use,
less water and cleaning chemical needs

- **Most Efficient Topical Smoke Application**
- **More Product Uniformity -** *No tar/ash*
- **Reduced Processing Costs**
- **Increased Cook Yields** *due to higher humidity earlier in the cook schedule (skin set during drench).*
- **Increase Throughput -** *shortened cook schedules (30-40%).*
- **Excellent for Continuous Smokehouses**
- **Smoke Reuse.**
- **Smoke step - outside of house.**
- **Labeling - no labeling requirements.**
- **Customization.**

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Smoke Condensate Application Techniques - DRENCHING



Drench System Types

- Continuous
- Flow-through Drench
- Trolley / Tree Drench Cabinet
- Belt Drench (Linear Processing)

A Customization Capability

Smoke Condensate Application Techniques - DRENCHING



Smoke Condensate Application Techniques: Smoked Nets and Casings

- *Most efficient & consistent method of producing surface Color*
- Smoke applied using “impregnated” casings or nets
- *Smoke is absorbed during cooking process.*
- Considered a “natural” method of smoke application by the USDA
- *Smoke Application Step is eliminated – it occurs during the stuffing process*
- No Tar or Ash residue on products.
- *Allows for customization of flavor & color qualities.*
- *Smoke-coated plastic casings minimize risk of post-process contamination.*







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Smoke Condensate Application Techniques:

Direct Addition with Neutralized Smoke Condensates - INJECTION

***Natural Smoke Condensates** must be partially Neutralized or manufactured to a low acid level for use in Curing (nitrite-containing) brines*

BENEFITS:

- **Most efficient method to add natural smoke flavoring**
- **Brings uniform smoke flavor throughout the product interior**
- **Can achieve high flavor profile throughout product**
- **Can be used in Cook-In Bags**
- **Provides antioxidant function throughout product - longer flavor shelf life**
- **No disposal of used smoke is required**
- **No additional application equipment is needed**

Smoke Condensate Application Techniques: Spraying Systems - Microwaved Bacon

Spraying of Smoke Condensates directly onto bacon slices - either immediately before or after it is pre-fried

BENEFITS:

- **Smoke flavor can be tightly controlled and easily adjusted.**
- **No premature release of nitrite as nitrite reaction is complete at time of spray application.**
- **No need for a neutralized smoke.**
- **Labeling:**
  - **Pre-fried Application:** No labeling requirements**.**
  - **Post-fried Application:** Must be labeled as “Smoke Flavoring Added” ***USDA Policy Memo # 058A***



Smoke Condensate Application Techniques:
Vacuum Marination/Tumbling & Topical Applications

FEATURES:

- **Topical applicatons are typically applied via:**
  - **Seasoning Blends**
  - **External Glazes**
  - **Passive Marinade Provides uniform internal and external flavor and browning.**
- **Water or oil-soluble smokes condensates & dry smoke products - added to marinade, then vacuum tumbled.**
- **Requires special labeling (ex. “Smoke Flavoring Added”).**



COMBINATION PROCESS:

Traditional Smoke + Natural Smoke Condensate Application

NATURAL WOOD SMOKE CONDENSATES + TRADITIONAL SMOKE =

THE BEST OF BOTH WORLDS

BENEFITS:

1. **"Traditional" or "Naturally smoked" labeling and marketing.**
2. **Enhances flavor consistency.**
3. **Decreases inconsistencies in smoke color.**
4. **Increased aroma.**
5. **Smoked Color - more quickly achieved = decreased smoking time (50 to 70%) = thus, more throughput and cost savings.**
6. **Reduced emissions *(PAH and particulates)* and solid waste - reduces cleaning time/expense and water usage = cost savings.**
7. **Cleaner operating environment.**
8. **Reduced thermal energy expenditures (20%) - cost savings**

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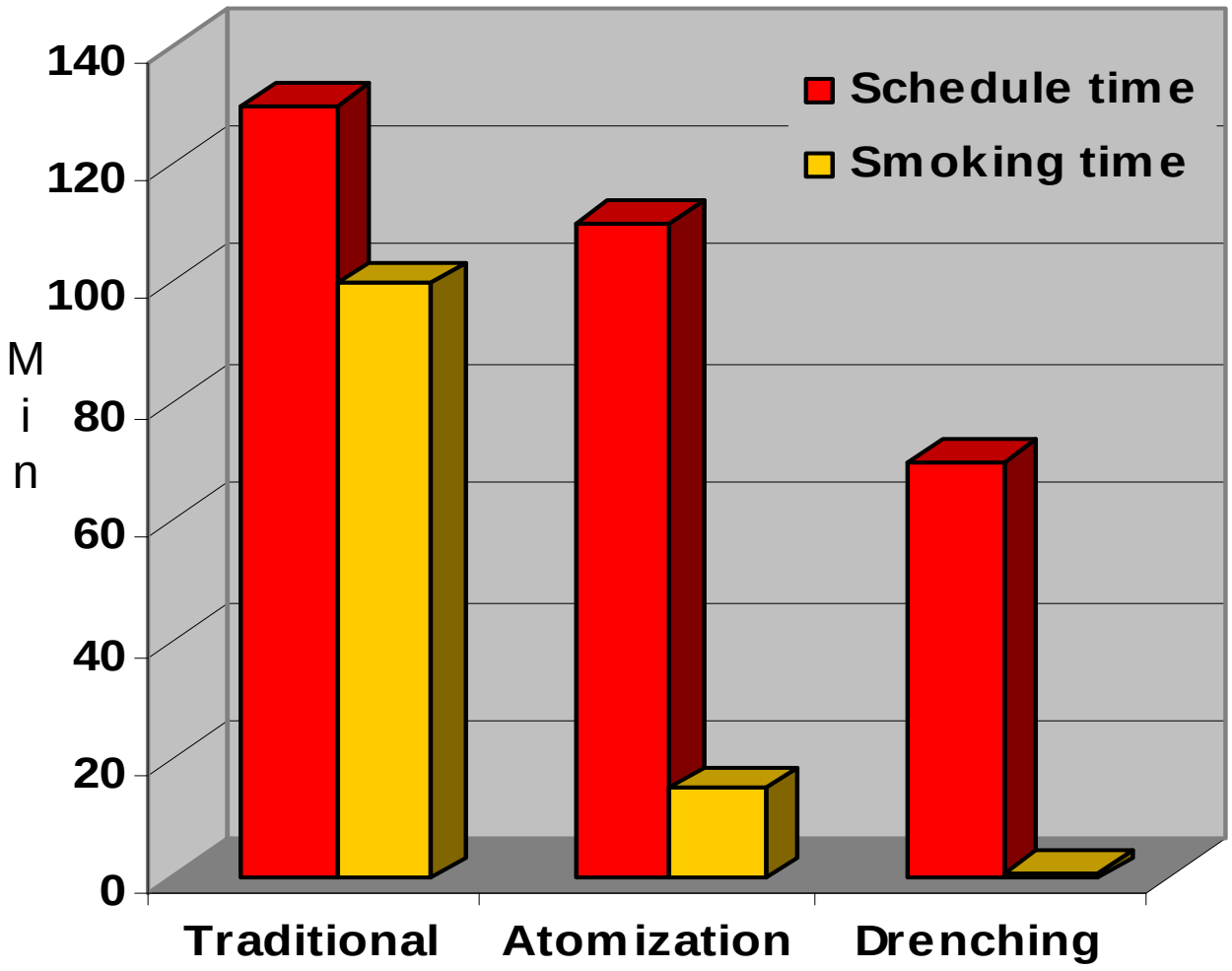
Comparison of Smoke Application Cook Cycles

Total Schedule and Smoke Time: Natural Casing Sausage



Reduction of Schedule Time

- Atomizing saved 25 minutes. (19%)
- Drenching saved 60 minutes. (46%)

Reduction of Smoking Time

- Atomizing saved 75 minutes.
- Drenching saved 88 minutes.

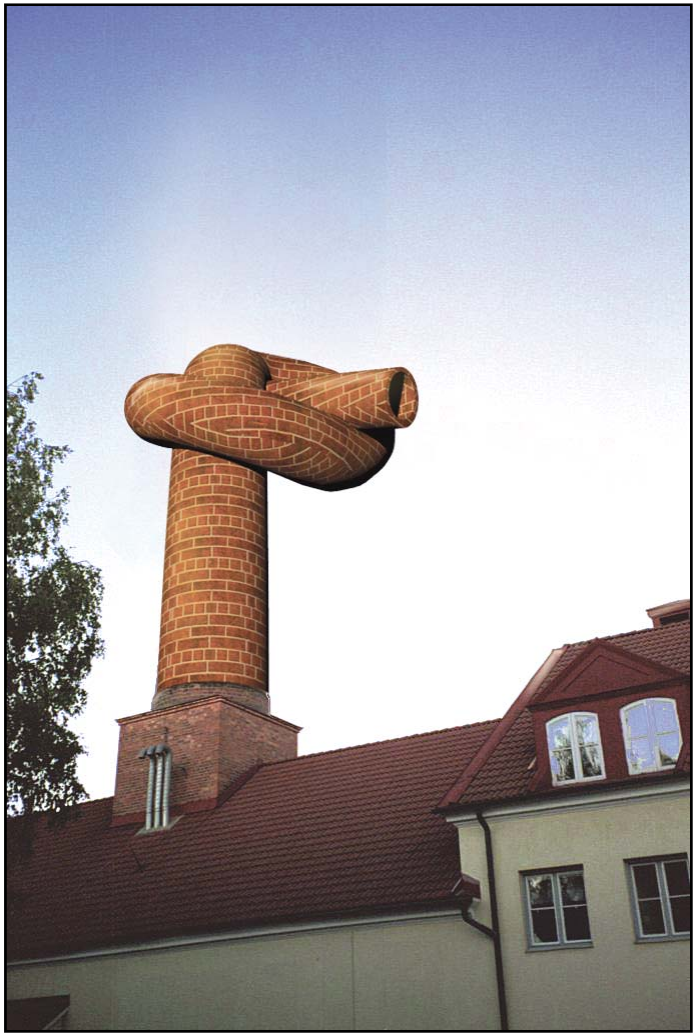
Environmental Impact: *Smoke Condensate Applications*: A Green Process

NATURAL SMOKE CONDENSATES

Either separately, or in conjunction with Traditional Smoking……

Can Reduce the Negative Impact that Traditional Smoke has on the Environment.

Provides an opportunity to Improve the Processor's Sustainability Program



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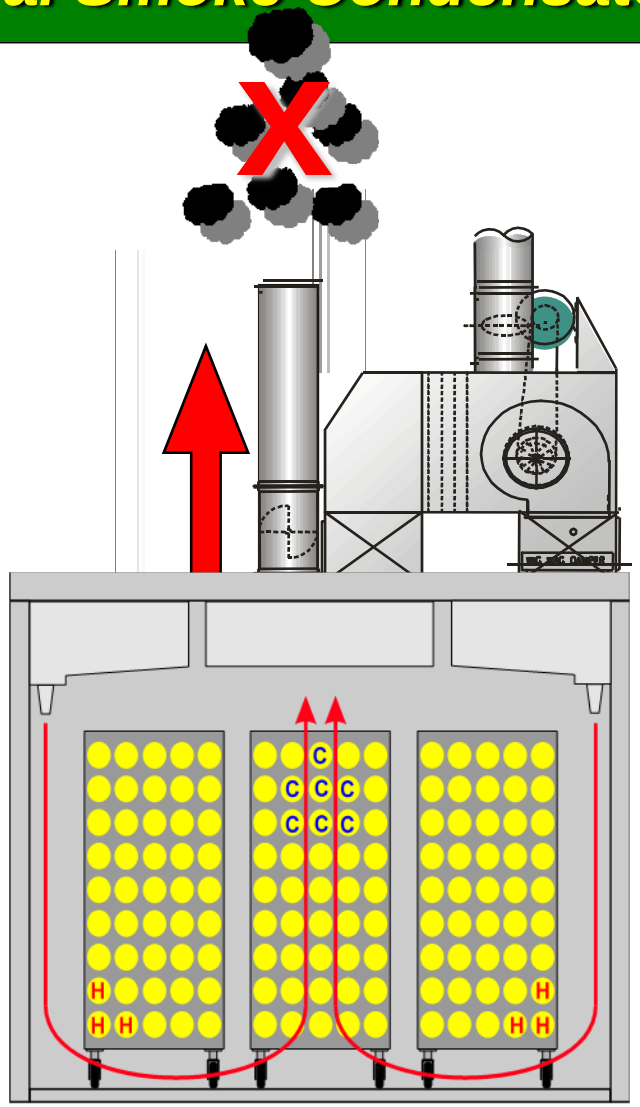
Green Process:

Reduced Air Emissions with Natural Smoke Condensates

- **Reduced Air Emissions:** ***a Comparison to Traditional Smoking*** ***(In a lbs./hour basis)***
  - ***Atomize:***
    - ***64% less Volatile Organic Compounds (VOC's)***
    - ***87% less Particulate Matter (PM)***
  - ***Drench:***
    - ***81% less VOC's***
    - ***85% less PM***
- **Cleaner Operating Environment:**
  - ***Eliminates smoke clouds in the plant.***
  - ***Minimizes splash or irritating gases from caustic cleaners used in cleaning smoke tar buildup.***



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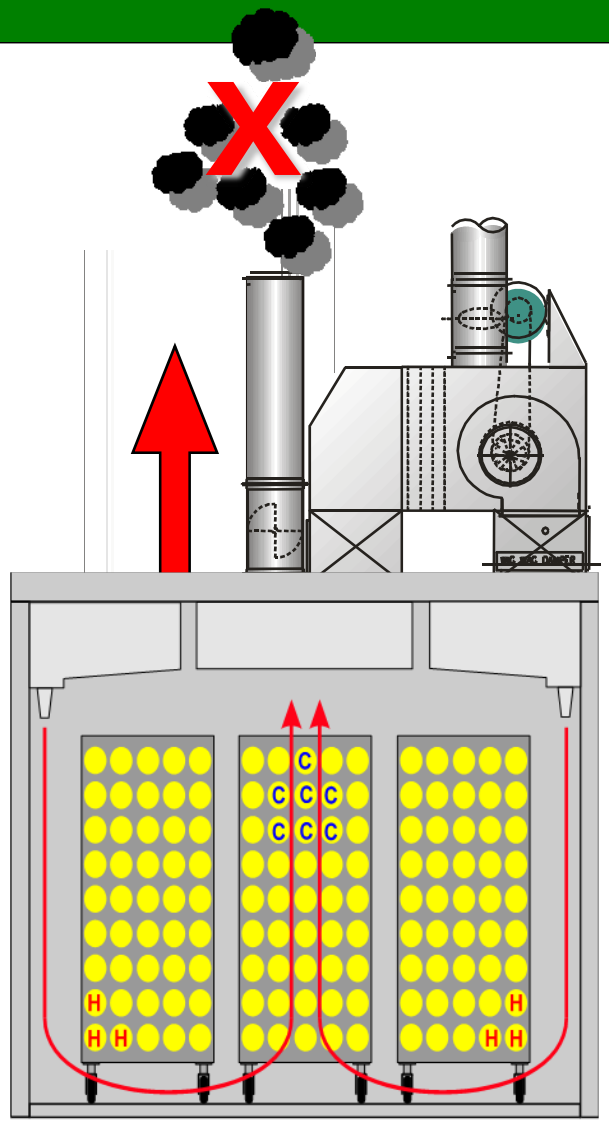
Green Process:

Reduced Water Pollution & Landfill Waste with Natural Smoke Condensates

- **Environmental Impact:**
  - ***99.5% less Landfill waste***
    - *Eliminate paper sawdust containers*
    - *Eliminates Ash from Smoke generators*
    - *Natural Smoke Condensates (NSCs) packaged in recyclable containers.*
    - *NSCs produced with minimal energy expenditure and landfill use.*
  - ***80% less chemical detergents***
    - *Eliminates tar, creosote, and particulate matter buildup in ducting and house surfaces - hence lowers the need for chemical detergents / caustics.*
  - ***Less Water Treatment Needs*** *- due to lower volume of water needed for cleaning .*



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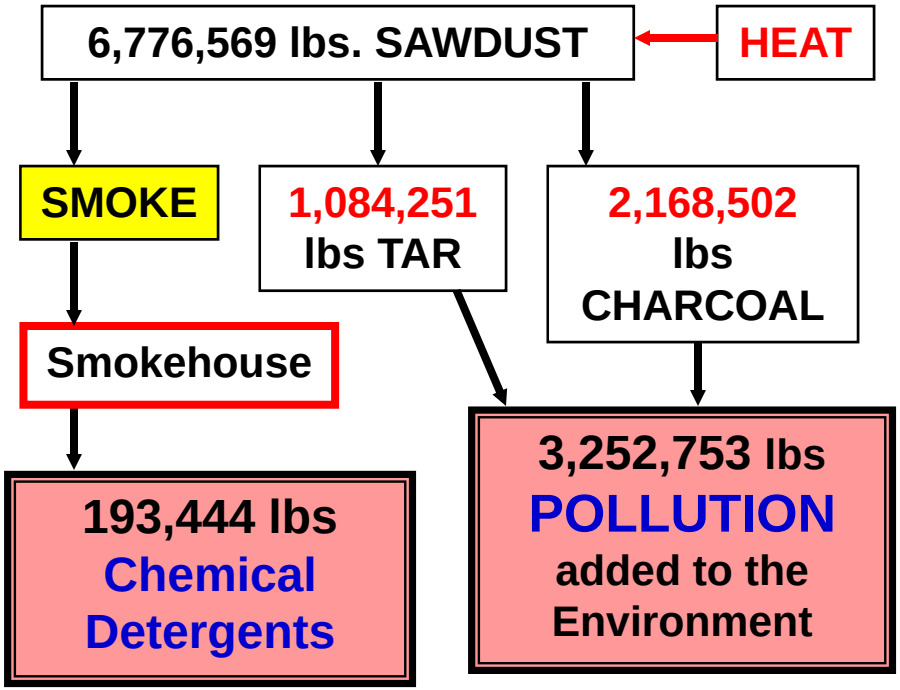
Green Process:

Traditional Smoke vrs Natural Smoke Condensates

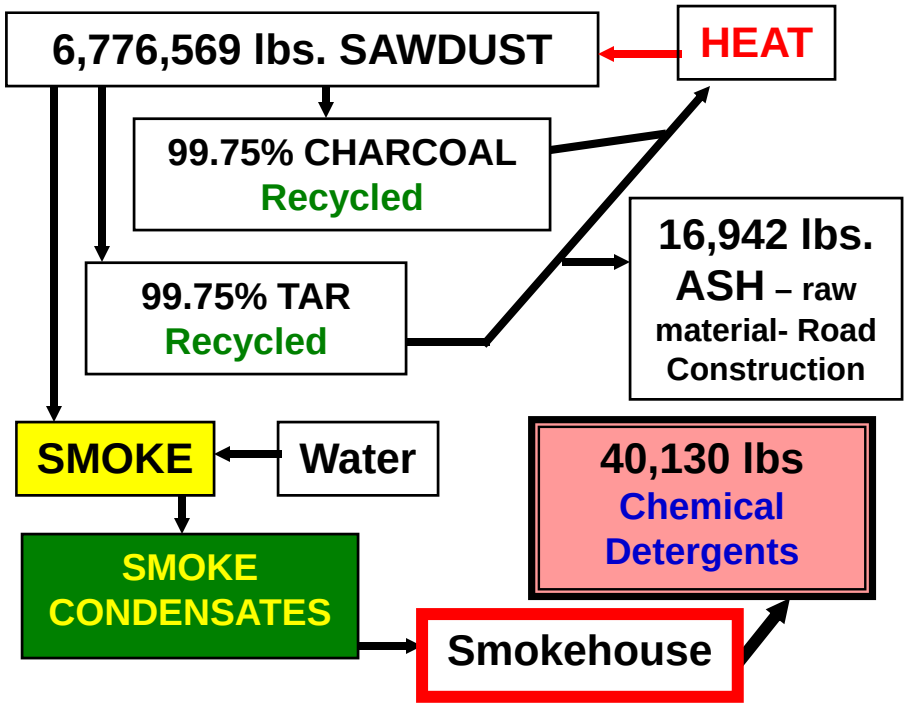
Wood Smoke Generator



Waste Summary: TRADITIONAL SMOKE:

1. Tar: 1,084,251 lbs.
2. Charcoal: 2,168,502 lbs.
3. Chemical Detergents: 193,444 lbs.

Natural Smoke Condensates



Waste Summary - NSCs:

1. Tar & Charcoal: Recycled.
2. Ash: *for Road Construction*: 16,942 lbs.
3. Chemical Detergents: 40,130 lbs.

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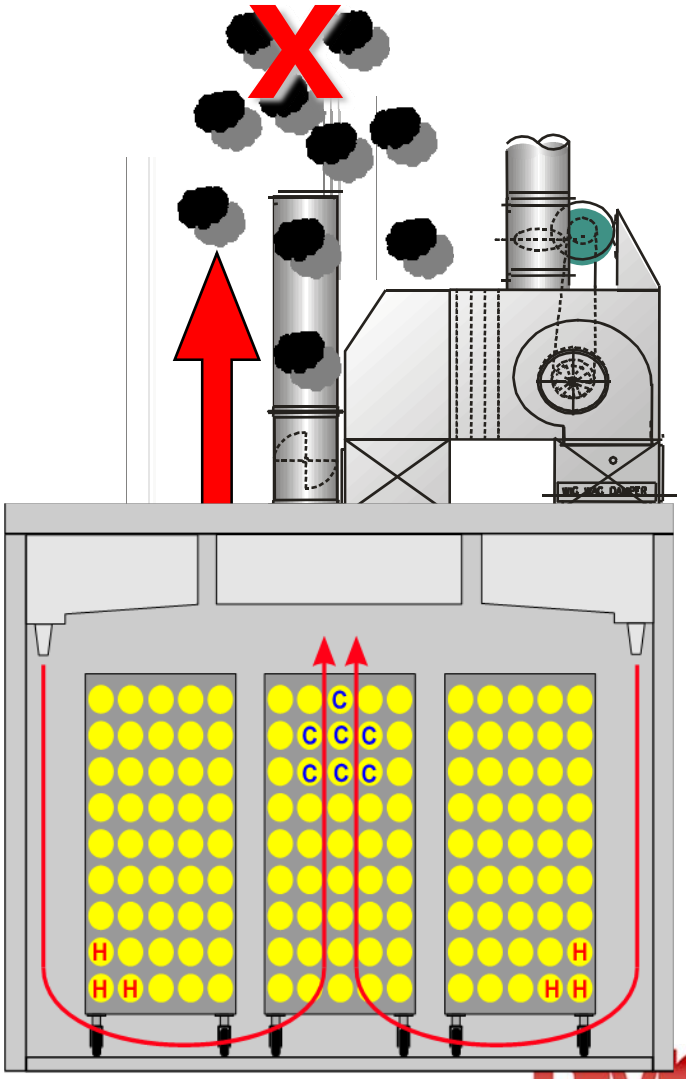
Green Process:

Reduced Energy Requirements with Smoke Condensates

Reduced Energy Requirements:

- ***Eliminates need for Smoke Generators***
- ***Shortens Smokehouse Process Cycles***
- ***Costly Emission Scrubbers not needed***
- ***Lowers Hot Water needed for Cleanup***
- ***Eliminates need for Afterburners to remove PM, VOC's, and Carbon Monoxide from Traditional Smoke Exhaust.***

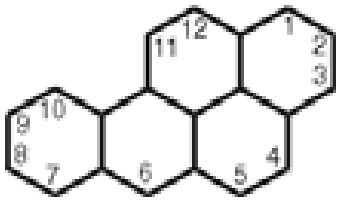


HEALTH IMPACT

Health Concerns are Associated with Traditionally Smoked Food Products!

- **Why?** - *presence of Polycyclic Aromatic Hydrocarbons (PAHs) in the Traditional Smoke.*
  - *PAHs - a diverse class of organic compounds, formed and released during various combustion and pyrolysis processes. Each PAH contains two or more aromatic rings.*

EXAMPLE:



Benzo(a)pyrene (BaP)

  - *Certain PAH's are carcinogenic.*
  - *Benzo(a)pyrene is used as a marker or indicator of carcinogenic PAHs in food.*
  - *The European Food Safety Authority has identified 15 PAHs that provide evidence of mutagenicity and genotoxicity. 14 of these have shown carcinogenic effects in various bioassays.*

Source: EFSA / DATEX / 002 (rev 1), July 2008

European Food Safety Authority (EFSA) Report:

PAH's in Food (July 2008; EFSA/DATEX/002 – rev 1))

Table 20: The influence of smoke generation method on BaP concentrations (µg/kg)					
Smoke Generation	N	Median	Mean	Maximum
Burning of sawdust	411	0.05	0.20	3.50
Burning of wood chips	55	0.10	0.47	5.90
Friction of wood	13	0.08	0.16	0.40
Overheated steam	6	---	2.61	14.10
Smoke Condensate	9	0.03	0.06	0.30

EU Maximum Levels of Benzo(a)pyrene:

Smoked Meats & Smoked Meat Products: 5.0 µg/kg
Smoke Condensates: 10 µg/kg

European Community (EC) Regulation # 1881/2006; Council Directive 88/388/EEC(1); Reports of the Scientific Committee for Food, 34th Series – EU 1995.

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HEALTH IMPACT

- The **FDA** and the **EFSA** have agreed that ***the elimination of the tarry fraction that contains unhealthy products of combustion is a preferred way to impart smoked flavor to foods***.

- **Smoked foods** prepared with **natural smoke condensates** are a ***healthier alternative to exposing food products to all of the smoke constituents found in direct combustion smoke.***

Safety & Health Advantages:

Smoke Condensates vs. Traditional Wood Smoke

At the production level:

- **Reduced levels of harmful components – *Polycyclic Aromatic Hydrocarbons* (PAH's)**
- **Reduced levels of air emissions.**
- **A healthier working environment.**
- **Elimination of fire hazard.**
- **Elimination of scrubbers and afterburners and energy from fossil fuels required to operate this equipment.**
- **Reduction of chemical cleaners required to clean tar from the smokehouse.**

At consumer level:

- **Reduced levels of harmful components in finished food products**
- **Improved shelf life of products**

Regulations - Labeling

- **Traditionally Smoked meat/poultry products can be labeled as "Smoked" or "Naturally Smoked."**
- **Products to which natural smoke condensates have been applied topically and transformed to a gaseous state by the application of direct heat are considered "Smoked."**
- **Internal addition of liquid smoke flavors requires the addition of the phrase "Natural Smoke Flavoring Added" on the principal display panel.**



Ref: USDA Policy Memo #058-A

Wood Smoke Technologies: *Questions?*



Photos Courtesy of: The Colonial Williamsburg Foundation; "Meat Smoking and Smokehouse Design," Publ.: Bookmagic LLC; http://www.flickr.com/photos/tiarescott/33596303/;

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