IMPROVED SHEA NUT ROASTER
ETHOS 2019

By Brian Gylland, Peter Hamlin, & Paul Means
Agenda

1. Background & Objectives
2. Development Overview
3. Initial Field Testing
4. Baseline Laboratory Testing
5. Development Process
6. Next Steps
Shea is a fruit that grows on trees scattered throughout the shea belt. There is no organized farming of shea trees, and the process is quite extensive with many energy, health, and ergonomic issues. Women are the primary processors.
Project Objectives

- Acceptability
- Economics
- Ergonomics
- Productivity
- Health
- Durability
- Performance
- Quality
## Development Overview - Schedule

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<th>2018</th>
<th>2019</th>
<th>2020</th>
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Initial Field Testing
Initial Field Testing – continued

- **Objective:**
  - Gather baseline measurements on fuel consumption, emissions, and productivity for the 2 primary methods for roasting shea kernels
  - 13 different sites
    - 10 in Tamale, 3 in Wa
    - 6 co-ops, 7 individual processors
  - 15 tests
    - 10 drum roasters
    - 5 pot and paddle
Initial Field Testing – continued

- Variability due to difficulty weighing fuel (wood and shea nut residue) and shea kernels.
- Measuring fuel moisture (hand held conductivity meter)
- Measuring residual char

All Tests Results

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<th>Mass of Kernels Roasted (kg)</th>
<th>Total Fuel Consumed (kg)</th>
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<td>120.00</td>
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R² = 0.6076
Initial Field Testing – continued

- What did we learn?
  - The Drum has a significantly higher capacity than the Pot roaster.
  - The Specific fuel consumption is nearly identical for both roasters.
  - The average final nut temperature (independent or roaster type) was 136°C.
  - No kernels were ever discarded due to burning or over roasting.
  - No consistent method for determining when roasting is completed.
  - Roasting efficiency is very low (<10%).
Baseline Laboratory Testing

- Simulation Simplifications
  - Scaled to 50% by volume (79% by length)
  - Heat water vs. Shea Kernels
  - Fixed drum vs. rotating drum
  - Uniform wood fuel

- Issues with simulating in the lab
  - Roaster is too large to fit in testing hood.
  - No shea kernels available to roast
  - Fuel is very irregular
Baseline Laboratory Testing - continued
## Baseline Laboratory Test Results

<table>
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<tr>
<th>Test #</th>
<th>High Power Efficiency, %</th>
<th>Time to Boil, min</th>
<th>Dry Fuel Consumed, g</th>
<th>HP Output, kW</th>
<th>HP CO, g/MJd</th>
<th>Char after Cold Start, g</th>
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<td>1</td>
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<td>27</td>
<td>1223</td>
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<td>6</td>
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<td>1232</td>
<td>13.0</td>
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## Preliminary Design Process

**Design Concept Matrix Evaluation Tool**

- **Brainstorming and Evaluating Concepts**
- **Designing and Testing Prototypes**
- **Exploring Solidworks Flow Simulation**
- **Agile Project Management**
# Preliminary Design Process

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<th>Name</th>
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<th>Ergono</th>
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<th>Fuel Fie</th>
<th>Mainten</th>
<th>Durabilit</th>
<th>Versabi</th>
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- **Sorts Scores Matrix**
- **Burn Design Lab**
Prototypes

Round 1

Round 2
Testing Results

High Power Efficiency

Dry Fuel Consumed

- SR Baseline:
- SR Front Feed CC2 Small:
- SR Insulated End Feed CC 1:
- SR Insulated Front Feed CC small 3.1:

Graph showing percentage efficiency and dry fuel consumed for different feed configurations.
Testing Results

![Testing Results Chart]

- **SR Baseline:** 10.7
- **SR Front Feed CC2 Small:** 3.7
- **SR Insulated End Feed CC 1:** 1.7
- **SR Insulated Front Feed CC small 3.1:** 2.2
Development Process - Flow Simulation

- Research Phase
- Assist in rapid iteration for heat distribution
Development Process - Flow Simulation

- Research Phase
- Assist in rapid iteration for heat distribution
Development Process – Heat Distribution

DAQ – 6 channel

5 New High-Temp TC (fixed to drum bottom)

Same Roaster Setup
Development Process – Heat Distribution
Development Process – Heat Distribution

24 cm deflector
Development Process – Heat Distribution

2 x 12 cm Deflector with 3 cm gap at center
Development Process – Heat Distribution

Deflector 3 – same open area as Deflector 1 constrained by end points of hour glass shape
Analyzing Temp Data

Average Temp Across Drum

- FF3.1 No Deflector
- FF3.1 Deflector 1
Analyzing Temp Data

Average Temp Across Drum

- Temp (deg C)
- Location (cm)

FF3.1 No Deflector
FF3.1 Deflector 1
FF3.1 Deflector 2
Analyzing Temp Data

Average Temp Across Drum

- Temp (deg C)
- Location (cm)

- FF3.1 No Deflector
- FF3.1 Deflector 1
- FF3.1 Deflector 2
- FF3.1 Deflector 2x2
Analyzing Temp Data

Average Temp Across Drum

- FF3.1 No Deflector
- FF3.1 Deflector 1
- FF3.1 Deflector 2
- FF3.1 Deflector 2x2
- FF3.1 Deflector 3
Analyzing Temp Data

Center of Heat – Front Feed CC Small 3.1 Deflector
Analyzing Temp Data

Average Center of Heat

-4.74  -0.62  -0.33  -1.06  -0.63

-FF3.1 No Deflector
-FF3.1 Deflector 1
-FF3.1 Deflector 2
-FF3.1 Deflector 2x2
-FF3.1 Deflector 3
Analyzing Temp Data

Average Coefficient of Variation

- **FF3.1 No Deflector**: 0.27
- **FF3.1 Deflector 1**: 0.26
- **FF3.1 Deflector 2**: 0.24
- **FF3.1 Deflector 2x2**: 0.25
- **FF3.1 Deflector 3**: 0.08
Next Steps

- Scaling up of Prototypes and sending to Ghana for user feedback and verification of performance.
  - Structural design
  - Material selection for performance/cost/durability
  - Implementation strategy and logistics
Thank You!