SUSTAINABLE IMPROVEMENT FOR GUATEMALAN CARDAMOM SPICE DRYERS

The Choice Between Environmental and Economic Devastation

Guatemala is the world's largest producer and exporter of cardamom, accounting for 80% of the global cardamom trade, producing approximately 30,000 metric tons of cardamom each year valued at an impressive $580M. 300,000 indigenous farmers produce almost 70% of Guatemala's cardamom exports on small plots of 10 acres or less. Approximately 720,000 m^3 of firewood and 27 million liters of diesel are consumed to dry cardamom in inefficient spice dryers, representing an increasing threat to cardamom farmers as wood prices continue to climb.

The cardamom farmers and dryer operators, with the support of a Guatemalan agricultural NGO, set out to improve the efficiency of cardamom spice dryers in order to protect the welfare of those involved in the cardamom trade and preserve the integrity of the local environment.

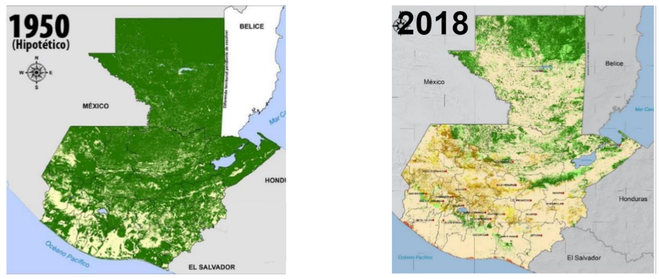
A team of mechanical engineering students, faculty, professional engineers (P.E.s), and other professionals from Guatemala and the U.S. collaborated to help the cardamom community solve this problem.

Processed cardamom pods

Deforestation in Guatemala

Cardamom spice dryer

Protecting Land and Livelihood



Maps illustrating the extent of Guatemalan deforestation, 1950 - 2018

87% of Guatemalan households rely on firewood as a fuel source

Land – The Challenge

- Half of Guatemala's forests have been destroyed since 1950
- Unsustainable agricultural practices have resulted in rapid depletion of the country's resources
- Some regions lack any local sources of firewood
- The annual processing of cardamom requires 720,000 m^3 of firewood equivalent to 7,500 ha of forests

Livelihood – The Challenge

- 87% of households rely on firewood as fuel for cooking and heat
- 57% of Guatemala's total energy consumption comes from firewood
- Scarcity in firewood has led to an exponential rise in wood prices
- The increase in firewood prices reduces the profit to cardamom farmers

The Engineering Design Process

Idea: Bagasse Fuel (sugar cane chaff). Using a different fuel source.

Why Not? Begasse is already used for drying in the Guatemalan sugar cane industry and difficult to obtain.

Idea: Swirler. Increasing mixing in heat exchanger tubes to improve heat transfer.

Why? Inexpensive. Easy to fabricate with locally available materials. Proven effectiveness in industry.

Idea: Sun drying.

Why Not? UV rays damage the green color of the cardamom pods, thereby decreasing the spice quality and sales price.

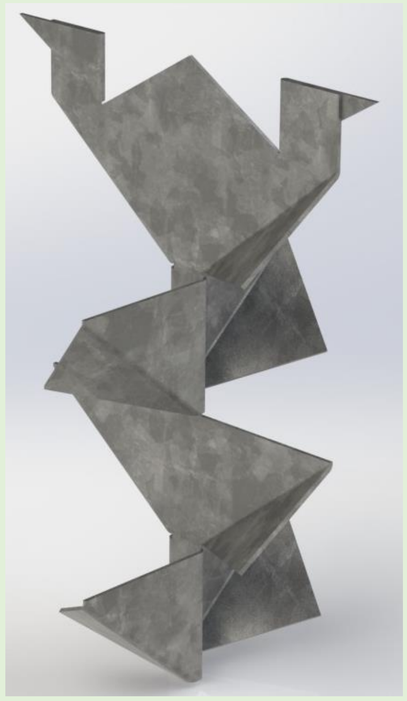
Idea: Desiccants. Drying the incoming air to allow greater moisture absorption.

Why Not? Expensive specialized material, toxic to environment, and complicated disposal process.

Idea: Water-Air Heat Exchanger. Using a new exchanger design to improve heat transfer.

Why Not? High cost, requires expensive stainless steel and more complicated maintenance.

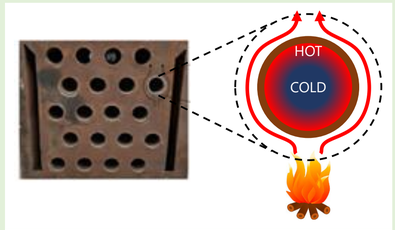
The Swirler



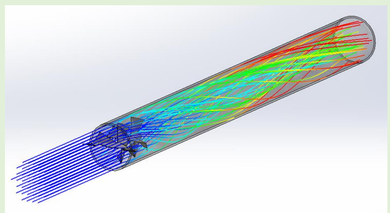
Cut and bent sheet metal inserted into heat exchanger tubes to improve heat transfer

The Theory

As the firebox heats the heat exchanger, the air inside the tubes also heats up. Without swirlers, the air flow is laminar and air around the perimeter is heated while air in the center stays cold. This non-uniform heating is inefficient.



When the swirler is placed in the tube, the air flowing through the tube becomes turbulent and the heating is more uniform, resulting in warmer air reaching the moist cardamom pods.



The Team

The students were supported by an international multidisciplinary support team of P.E.s, faculty, and other professionals to serve the end users

End Users
Guatemalan farmers, dryer operators, cardamom cooperatives

Students
mechanical engineering, industrial engineering, agricultural engineering

P.E.s
U.S. & Guatemalan mechanical engineers, civil engineers agricultural engineers

Faculty
mechanical engineering, civil engineering

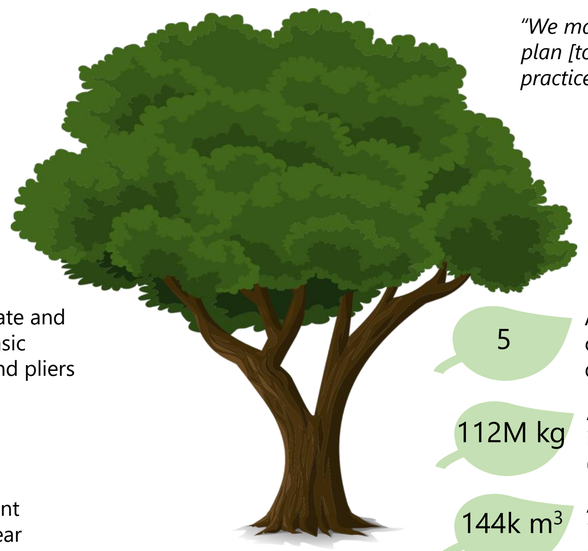
Professionals
U.S. & Guatemalan agro-foresters, agronomists, executives of international NGOs, technicians, fabricators, marketing professionals

ME student showing dryer operators how to make a swirler

Students, faculty, P.E.s, and Guatemalan fabricators discuss heat exchangers

Measurable Impact of Swirler Implementation

20%	Reduction in wood consumption
14%	Reduction in drying cycle time
15%	Reduction in total processing costs (wood, diesel, & labor)
5 min.	Time needed to fabricate and install a swirler with basic hand tools: tin snips and pliers
$2	Material cost per dryer with locally available materials
$1100	Return on $2 investment per dryer in the first year of swirler implementation
$0	External financial investment required to implement this appropriate technology throughout Guatemala
6	Guatemalan professionals trained to disseminate swirler technology via multilingual videos and instructional materials produced by the team



"We may need to rethink our 10-year plan [to improve the agricultural best practices in Guatemala] based on the work of these students."

Guatemalan Agricultural NGO Executive

5	Additional projects to improve cardamom dryer subsystems due to this project's success
112M kg	Annual CO_2e reduction if implemented to the estimated 6,000 dryers in the country
144k m^3	Annual wood savings if implemented to the estimated 6,000 dryers in the country
1500 ha	Annual forests savings if implemented to the estimated 6,000 dryers in the country
3.8M L	Annual diesel savings if implemented to the estimated 6,000 dryers in the country

Knowledge and Skills Gained

Design Process

- Design to empower, not impress
- Incorporate appropriate technology
- Design for simplicity and scalability
- Brainstorming and problem solving
- Iterative engineering design process
- Economic sustainability and return on investment

Testing

- Prototyping
- Experiment design
- Taguchi method for experiment optimization
- Data collection and analyzation
- Design optimization

Technical Topics

- SolidWorks
- Computational Fluid Dynamics (CFD)
- Fluid dynamics
- Heat transfer
- MATLAB programming
- Manufacturing and material science
- Multilingual technical writing

Project Management

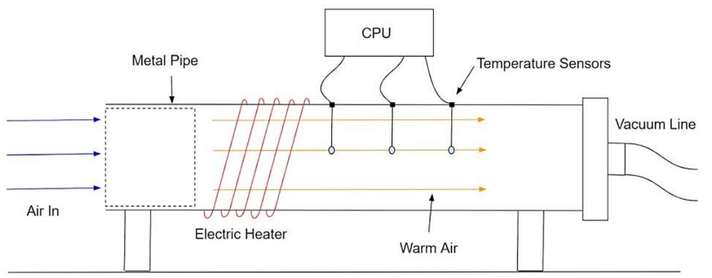
- Stakeholder involvement
- Cross-cultural communication
- Time management and Gantt charts
- Conflict resolution

"The diverse and complex network of stakeholders in this project allowed me to collaborate and grow as an engineer in ways sitting in a classroom could never teach. I had to fill many different roles, constantly moving from the 10,000-foot view of project management to the 1-inch view of detailed engineering analysis."

ME Student

Students testing swirlers in lab

Students field testing swirlers



Swirler testing apparatus