EcoPot: A More Efficient Pot for Wood Fires

1[st] Robert L. Read *Public Invention*
Austin, TX, USA
ORCID: 0000-0003-4749-7045
email: read.robert@gmail.com

2[nd]Cledden Obeng-Poku Kwanin 3[nd]Ivan Urdiales

4[th]Aditya Choksi

May 23, 2025

Abstract

One billion people cook daily on open fires with hand-gathered firewood. A more efficient cooking pot would save firewood, saving them time. Using the OpenFOAM computational fluid dynamics system, we have evaluated different pot designs seeking a more efficient pot. We expect gathered-wood fires to be cooler and more turbulent than gas fires, and to transfer heat more through conduction than smoldering coal fires. We hypothesize that a pot which encourages smooth, fast flow of the hot "flue" gases around the pot will maximize heat transfer on gathered-wood fires. In particular, we have compared a rounded-bottom pot with heat conduction fins to a simple cylindrical pot.

1 Introduction

In 2025, about one billion people cook on wood gathered from the ground or cut by hand. Often this wood is not seasoned (dried), causing the fire to inefficiently waste heat vaporizing the moisture content.

Cooking varies widely based on available ingredients, technology, and custom. One of the main ways of cooking is to cooking something relatively moist in pot. This is generally a grain-based porridge (rice, maise, barley, quinoa, millet, wheat, oats) or some kind or a "stew" of starchy vegetables such as potatoes or cassava. Sometimes legumes (beans and peas) are cooked, and sometimes fruit or meat products or eggs are also added. Of course, sometimes food is baked (bread), or grilled or roasted. However, it seems that world-wide a majority of calories consumed by people are in the form of starches cooked in moist conditions. Increasing the efficiency of this kind of cooking therefore is mostly likely to benefit the most people by saving them the labor and cost of gathering fuel.

Often this cooking is done on a ”three stone fire” with a pot propped on stones above the fire. Sometimes a metal grill or grate is available, but sometimes not.

1.1 Motivation

1.2 Cultural Considerations

Some cultures may have traditional pots, which are essential to some traditional, culturally significant dishes. However, our approach is to make as utilitarian a pot as possible for making the most common fare, rather than foods cooked for feasts and special occasions.

However, cleanability and handles remain an important consideration.

2 Related Research

3 Some Hypotheses

This research is designed to test several hypotheses:

1. Pot design can greatly effect the fuel usage of a pot.
2. A pot design which makes the flue gases move quickly against the pot in a smooth flow is more efficient than a pot that does not support a smooth, fast flow.
3. Rounded (hemispherical) pots will be more efficient for cooking than cylindrical pots.
4. The efficiency of a pot will be enhanced with heat transfer fins.

We emphasize that these are untested hypotheses which may be false. However, they are supported by they following reasoning:

1. Ancient people seem to have preferred round-bottomed pots for cooking, and flat-bottomed pots of food storage. This is particular evident in the Museum of Athens, which displays a wide variety of bronze cooking and storage vessels, consistently labeling the round-bottomed ones as cooking pots and the flat-bottomed ones as storage pots.
2. If the flow around a pot is fast, the flue gases will be entrained against the pot by the Bernoulli/Coanda effect. Because the flow total, this may cause the flames of a yellow-flamed gathered-wood fire to be ”held” against the pot, which will increase both conductive and radiative heat transfer. A stagnant flow would be expect to ”insulate” the pot. Heat transfer is always a function of time, so it may be that fast-flowing gases will leave the vicinity of the pot too quicly, still hot and before they have transferred all of their heat. Nonetheless, a slower flow may be even worse, in that it

may force hot gases away from the pot, prevenint efficient heat transfer all together!

3. Rounded (hemispherical) pots will be more efficient for cooking than cylindrical pots.

4. Preliminary tests on a real pots on hydrocarbon fueled fires performed by our collaborators at Rice University found a 42% decrease in boil time with a pot with radiative fins. Modern gas fuel camping stoves, such as the JetBoil, use heat transfer fins.

3.1 Why Not Consider Stoves and Skirts?

It is entirely possible that the best way to efficiently cook with gathered wood is use an iron stove, what in American English is often called a wood-burning stove. Some engineers have suggested that a pot skirt, a metal device which partially encloses a pot, might also make cooking more efficient.

We are intentionally not investigating these ideas because we believe much can be learned by considering the simpler problem of trying to design a more efficient pot. If we can develop the ability to design, simulate via CFD, and ultimately test on real gathered wood fires, this technical capacity will no dout allow us to conduct research on more complicated cooking equipment.

3.2 Why Not Consider Cost?

> Premature optimization is the root of all evil.
>
> *Donald Knuth*

Similarly, we currently give no consideration to the cost of manufacturing a pot of a particular design. Pots 3D printed in metal are so expensive that there economic use for many people is completely precluded. However, we believe that any design which is drastically more fuel-efficient than a standard pot will be mass-producible at such scale that we not consider the cost of manufacture at this early stage of research.

4 Efficiency

Defining the efficiency of a cooking pot is a matter of practical engineering, not science. The authors have invested the basic amount of fuel required under ideal conditions which could only be obtained with expensive equipment in a laboratory. For example, using pure carbon as a fuel and pure O2 as an oxidant, and operating under pressure inside the cooking pot itself, it would take only 27.15 grams of carbon to cook 12 cups of rice.[1] It is interesting to posit such efficiency as an absolute chemical limit, but it is completely impractical.

More practical is define efficiency in purely relative sense. Define a "standard pot" to be a roughly cylindrical pot (with slightly outward sloping side) that can safely contain 3 liters of water. Since fires vary so much by fuel quality, outside wind, and even the skill of the person tending the fire, we will define efficiency relative to a giving cooking context C. Let $F(C, S)$ be the mass of fuel in grams required to bring 3 liters of water to boil in a cooking context C in a standard pot S. The for a new pot design D the *relative efficiency* for a given context is $F(C, S)/F(C, D)$. A higher efficiency is better.

This definition does not include the ability of the pot to keep food warm when it is taken off the fire, which may be an important practical decision.

4.1 Defining Efficiency

The easiest to manage definition of efficiency a relative definition.

4.2 A note on absolute efficiency

4.3 Testing Strategy

Our basic strategy was to design small, 100ml "mini-pots" with a CAD program to be tested with ANSYS simulation software and to order small, affordable 3D printed steel pots based on these designs. The small tests could be tested relatively easily with simple test apparatuses.

5 Initial Test Plan

In order to test the hypotheses presented in the paper, we design pots using OpenSCAD free, fully-parametric CAD program. An experienced OpenSCAD designer will understand how to produce exportable model files without main OpenSCAD script called ParameterizedPotDesigns.scad[2]. This produces 3D models which can be imported into a CFD simulation program (OpenFOAM) or 3D printed for real testing.

Taking advantage of the fully parametric capability of OpenSCAD, we developed the OpenSCAD script so that we can produce pots in any volume, and can select a variety of features. In general, the fuel efficiency of a pot can only be measured against another pot of different design with the same capacity.

Initially we intend to begin testing with pot designs, which can be selected with the "ptype" parameter in the OpenSCAD file:

1. flatbottom
2. roundbottom$_{w}ith_{f}ins_{a}nd_{h}andles$

We have also developed a variety of lids.

Our initial plan is to test Hypothesis 1 by simulating these two pots in OpenFOAM.

6 OpenFOAM Simulations

Our basic simulation approach is to use OpenFOAM. A pot design is placed in side a cube, which has an updraft of hot air. The OpenFOAM CFD models the transfer of heat from the air to the pot. Each pot has a "contents" which represents the water, modeled as a fixed block shaped like the interior of the pot, but having water-like properties set in OpenFOAM.

The initial approach is very unlike a fire in some ways:

1. It does not include turbulence
2. It is uniformly warm across the entire space, whereas a fire is likely hottest near its center.
3. It does not model radiative heat transfer, which is likely significant.
4. Flue gases may contain a significant amount of CO2 and H2O vapor, which may have different heat transfer properties than air.

Our basic test methodology will be to compare two pot designs, one considered a control (S) and a design (D) in OpenFOAM in the same simulation hot-gased environment. We will run the simulation long enough that each has reached 95C in temperature (because we cannot model the vaporization of our contents easily.) We will then use the time for the contents of each pot to reach 95C from 25C as a stand-in for consumed fuel, and compute the relative efficiency of the new design as T_c/T_s.

7 Mini-pot Test Methodology

Mini-pots were tested for boil time over the burner of a stove using a standard clamp apparatus.

We also constructed a cardboard profile sheet and attempted to do IR imaging on this sheet to verify our understanding of the fluid flow and heat transfer [More needed here.]

7.1 Mini-pot Test Data

8 Constructing large pots

Based on the relative success of the min-pots, large, 12-cup pots were constructed and tested over propane burners.

8.1 Large Pot Test Data

9 Rounded Bottom Designs

Later the team designed a pot using the successful half-radial approach that had a rounded (hemispherical) bottom. The theory was that the Coanda effect would keep the hot gases in contact with the pot. Both Ansys simulation and mini-pot flame testing suggested this is actually true. There is some reason to believe the rounded-bottom pots may be a more efficient point in the design space than flat-bottomed pots, although they may be more difficult to manufacture.

10 Acknowledgments

A Senior capstone engineering team named Team EcoPot at Rice University in 2021 did some initial CFD simulation in Ansys Fluent and tested very small pots. They included Stephanie Ponce, Christopher Fang, San Robedee, Chinwe, Kaitlyn, and Sana.

11 Conclusions

This work demonstrates that pots with heat-exchanging fins can be more efficient than standard pots in some way. If this translates to decreased fuel consumption without inordinate additional expense or loss of durability, these pots may ease fuel gathering burdens, cook faster, and create less pollution than standard pots.

References

[1] Basic Chemistry of Sealed Combustion, 2025. [Online; accessed 25-May-2025].

[2] Parameterized Pot Designs, 2025. [Online; accessed 25-May-2025].