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# A4_12 Healthy Eating

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**Abstract**

This paper investigates the feasibility of a pedal powered oven. A crude model is constructed to look at the energy required to heat and maintain a temperature of 200°C. It is found that approximately 27 people would be required to negate the heat lost by the oven through conduction during the cooking period.The calories burnt for a 20 minute cooking period for each person pedalling is found to be approximately 294kcal.

## Introduction

Food has always been an important part of life, it being necessary for our survival. With recent reports that obesity levels are rising things such as what we eat and how much exercise we do are becoming more important to people. This paper proposes a new idea that could combine both of these tasks thus revolutionising our concept of healthy eating. We look at the feasibility of powering an oven with human generated power using a bicycle and dynamo to convert the mechanical power generated to heat via a resistive heater.

## Energy Requirements

In order to test the feasibility of our proposed idea we must first calculate the energy required to cook our meal. We will use a simple model for our oven that consists of an enamel cube with length ($x$) 0.75m, as most ovens have a window, so that you can check on the progress of the cooking process, we will model one of our faces as glass. Enamel is used as many ovens have a thin layer to reduce heat loss due to its low thermal conductivity. In order to calculate the energy required to heat our oven up to the required temperature we will use the following relationship,

$$Q = mc\Delta T, \tag{1}$$

where $m$ is the mass, $c$ is the specific heat of the medium being heated and $\Delta T$ is the change in temperature. In our calculations we will assume that the air inside the oven begins at room temperature (20°C) and will be raised to 200°C, this gives a $\Delta T$ of 180°C. The mass of the air will be given by $\rho x^3$, where $x$ is the length of the sides of our cube and $\rho$ is the density of air, 1.205kgm$^{-3}$ [1]. The specific heat of air is 1.005kJkg$^{-1}$ [1]. If we substitute these values into Eq.1 we can get an energy required to heat our oven.

$$\begin{aligned} Q &= \rho x^3 c\Delta T \\ &= 1.205 \times 0.75^3 \times 1.005 \times 10^3 \times 180 = 92.0\text{kJ}. \end{aligned} \tag{2}$$

Once up to temperature, the oven will lose heat via conduction through the walls. The total surface area of Enamel is 5 faces $\times\ 0.75^2 = 2.81\text{m}^2$ and the surface area of the glass is 1 face $\times\ 0.75^2 = 0.563\text{m}^2$. The thermal conductivities for enamel and glass are 0.81 [2] and 0.8 Wm$^{-1}$K$^{-1}$ [3] respectively. We shall assume a thickness of 0.1m for the walls of our oven. Using these numbers, if we apply the following relationship,

$$I = -kA\frac{\Delta T}{\Delta t}, \tag{3}$$

we can obtain a value for the heat lost due to conduction. Where $I$ is the heat change, $k$ is the thermal conductivity, $A$ is the total area, $\Delta T$ is the difference in temperature and $\Delta t$ is the thickness of the material. As we are using two different materials we need to sum two versions of this relation to get the total heat lost. Once our values are substituted in we get the following result,

$$\begin{aligned} I_{Total} &= -0.81 \times 2.81\frac{180}{0.1} - 0.8 \times 0.563\frac{180}{0.1} \\ &= -4.91\text{kW}. \end{aligned} \tag{4}$$

We can see that once the oven is up to temperature, the rate of heat loss will be 4.91kW. We can convert this to degrees per second by calculating the energy required to change our mass of air by 1°. This can be done using Eq.1, rearranging and calculating gives us 1.21 kJ per degree. Our oven's heat loss equates to 1° per s.

## Discussion

Having calculated the energy required to heat our oven and also the heat lost through conduction we can analyse the feasibility of whether a human powered oven would be possible. A study done on 15 participants of the Tour de France show that power output while cycling can vary between around 218-234W for professional athletes [4]. This averages out to a power output of 226W. Using a dynamo to convert the mechanical power of cycling into electricity we can expect a upper limit of efficiency of around 80% [5]. To convert the electrical energy into heat, this paper proposes the use of resistive heating as this has an efficiency very close to 100% [6]. If we apply these efficiency limits we find that the work converted to heat, will be 180W per person. With this efficiency we can calculate the amount of people required to provide enough power to negate the heat lost. This can be found by doing a simple calculation,

$$\frac{4.91\text{kW}}{180\text{W}} = 27.2 \text{ people.} \tag{5}$$

Assuming that no heat is lost during the warm up process it would take,

$$\frac{92.0\text{kJ}}{180\text{W}} = 511\text{s} = 8.52 \text{ minutes,} \tag{6}$$

to heat the oven to 200°. As 1 joule is 0.239 calories [3], we can convert the energy expended to cook the food to the calorific content the food provides. A typical 100g portion of oven chips provide 158kcals of energy [7] while taking 20 minutes to cook at 200° [8]. To heat the oven and then maintain the temperature required, power would need to be generated for the warm up time, calculated in Eq.6, and the cooking time. Giving a total time of 28.5 minutes. The energy required to achieve this would be,

$$180\text{W} \times 60\text{s} \times 28.5 \text{ minutes} = 308\text{kJ.} \tag{7}$$

The energy required for a human to output at the required power level is governed by muscle efficiency. When cycling this efficiency has been found to be 25% [9]. This means that the energy consumed by each person assisting in the cooking process is,

$$\frac{308\text{kJ}}{0.25} = 1.23\text{MJ} = 294\text{kcal.} \tag{8}$$

**Conclusion**

We can see that under the assumptions made by this paper an oven powered by humans pedaling is not really a feasible idea due to the number of people required, but it is found that if pedal powered, the energy burnt would be greater than that contained by the food. The model lacks feasibility due to the large number of people required to power the oven. This impracticality is further exacerbated by the crudeness of the model as it is assumed no heat loss during the initial warming of the oven as well as neglecting the heat absorbed by the food during cooking. If further investigation was done into how the energy required scaled with the amount of food being cooked, it may be more feasible that a large group meal could be cooked. This increase of food available for the people powering the oven would result in a more feasible system due to the improved ratio between people and food prepared. This could display a potential for the idea providing the additional energy required could be minimised by optimising the oven design or extra exertion by the current population.

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