Is it really worth my time to eat that last grain of rice?

This manuscript will endeavour to answer a question we must have asked ourselves at least several hundred times in our lives: "Is it really worth it to eat that last grain of rice on my plate?" We've probably all had it happen to us. Just getting to the end of of a delicious meal, and theres just a grain or two of rice left on the plate, so you think, "Ah, its not worth it to scrape my plate and eat that last bit of rice," and the grain gets rinsed down the drain. But is that supposition the case? Or is it actually *energetically worthwhile* to reach down with fork in hand, scrape up that last morsel of rice, and consume it? This analysis will be done in three steps. Step one: Determine how much energy, in Calories, is in a single grain of rice. Step two: Determine how much energy is required to reach down, scrape up the single piece of boiled rice, bring it to your mouth, and swallow it. Step three: Compare the two and see if its energetically worthwhile.

Step one: to determine the energy content of a single grain of rice

To determine how much energy is in a grain of rice, I used my wife's electronic baking scale to measure out 10 grams of rice. The scale has no decimal point, so I just added grains of rice until the weight ticked from 9 to 10 grams. I hope that that means that I'm as close to 10 grams as I can reasonably hope to be, using standard round-the-house gadgetry. The rice is Rooster Brand AAA Scented Jasmine Rice, from Thailand, and the nutritional information given says that 45 grams is the energetic equivalent of 160 Calories.

$$\text{Caloric Content of Rooster rice (per gram)} = \frac{\text{Energy (Cal)}}{\text{Mass (g)}} = \frac{160}{40} = 3.555 \text{ Cal/g}$$

So each gram of Rooster Rice holds 3.555 Calories. I then counted the grains of rice that I had weighed, and found that the 10 grams of rice contained exactly 517 individual grains. So, we can find the amount of Calories in each grain by the following formula.

$$\text{Grains of rice per gram} = \frac{517}{10} = 51.7 \text{ grains/g}$$

Now, we can find out how many calories are in each grain by dividing the top result by the bottom one.

$$\text{Calories per grain} = \frac{3.555 \ \frac{Cal}{g}}{51.7 \ \frac{grains}{g}} = 0.06877 \text{ Cal/grain} = 68.77 \text{ mCal/grain}$$

So, each grain of rice contains about 7/100ths of a Calorie.

Step two: Determine the energy expended in eating a single grain of rice

This part is a little trickier. I thought for a while about how to calculate how much energy used when bringing a grain of rice to your mouth. When you perform that action, your arm muscles aren't just lifting the grain of rice, they have to lift your entire forearm as well, along with the fork and the rice. So this answer (it seems to me) depends on a bunch of individual factors like how much your arm weighs, how heavy your fork is, and how efficiently your muscles burn energy, among other things. Finally, I decided to just make a bunch of assumptions about these factors, and then use straight physics to calculate how much work is done. So here goes.

First, I wanted to figure out the mass of an average forearm. The major muscles involved in lifting a fork to your mouth are located in your upper arm, and attach to your forearm, so for simplicitys sake, I assumed that you could (and would) only move your forearm when eating. If I could find the mass of an average forearm, I could calculate the amount of work done in lifting that forearm (along with a fork and a single grain of rice) up to a mouth. I decided to use my own forearm, as I'm a fairly average sized North American male. While the most accurate way to measure my forearms mass would be to cut it off and weigh it, I decided against this approach. You may cast aspersions on my scientific method but at least I still have the full use of both my arms. As an alternative, I decided to calculate my forearm's volume, and assume that it has the same density as water.

To do this, I submerged my hand and wrist, oriented vertically with my hand down, in a pitcher of water until I had displaced 500 mL (using the volume markings on the side of the pitcher). I made a mark on my forearm where the water had reached. Therefore, the volume of my hand and wrist up to that mark was exactly 500 mL. All that remained was the roughly cylindrical part of my upper forearm. I calculated the average circumference of this portion of my forearm by measuring its circumference at the point I marked, then at 2 cm intervals for the remaining 12 cm of my forearm, until the crease of my elbow. I averaged the 7 measurements as shown below.

$$\frac{[18+20+22+24+26+27+28]}{7} = 23.57 \text{ cm}$$

The volume of my upper forearm can thus be calculated as a cylinder, with height equal to 12 cm and radius as below:

$$radius = \frac{circumference}{2\pi} = \frac{23.57}{2(3.14)} = 3.7515 \text{ cm}$$

The volume is given by this equation:

$$Volume(cylinder) = Area * height = \pi * (r^2) * h = 3.14 * (3.7515)^2 * 12 = 530.57\ cm^3$$

Add this to the previously estimated volume of my hand and lower forearm, and you have the volume of my entire forearm and hand.

$$Volume(forearm) = 530.57 + 500 = 1030.57\ cm^3$$

Since Im assuming that my arm has roughly the same density as water, which has the density of 1 g/cm^3 (true only at 4 degrees Celcius, but hey, close enough), then my forearm weighs approximately 1.031 kg. One of my forks weighs 28 grams (measured using my wifes baking scale), and a single grain of rice weighs about a fiftieth of a gram, so lets round those all together and say my forearm, including fork and grain of rice, weighs about 1.06 kg.

Now for another assumption. My forearm is 36 cm long from the crease of my elbow to the knuckle of my index finger (where my index finger meets my hand, that is). I'm going to assume that my forearm, with the fork closed in my fist, has its center of mass exactly 18 cm from the crease of my elbow. In other words, Im assuming that the center of mass of my forearm is located in the middle of its linear measurement from my elbow. This is by no means necessarily correct, because the forearm is thicker nearer the elbow, but I feel that closing my hand into a fist and holding a fork in it will help balance out the center of mass assumption. Close enough for government work, anyways.

Assuming all this, I set out to determine the distance that the center of mass of my forearm would have to travel in order to deliver a grain of rice from my plate to my mouth. I simply sat in front of my table with my arm in front of me (as it would be after having scooped up a grain of rice) and measured the distance from the middle of my forearm to my mouth. That measurement was 40 cm.

I then measured the distance from the center of my forearm to my mouth when my elbow was flexed so that the fork in my fist would be next to my mouth. That distance was 23 cm, so the difference between them was 17 cm. Therefore, I reasoned that in order to bring the grain of rice up to my mouth, I moved a weight of 1.06 kg about 17 cm vertically.

Work is equal to the product of force and distance, according to the formula below.

$$Work(Joules) = force(Newtons) * distance(meters)$$

Similarly, force is equal to the product of mass and acceleration.

$$Force = mass(kg) * acceleration(m/s^2)$$

In this case, well take acceleration to be the force of gravity downwards on my forearm, which is equal to 9.8 m/s^2. Substituting these into the above formulas gives:

$$Work(Joules) = mass(kg) * acceleration(m/s^2) * distance(m) = 1.06 * 9.8 * 0.17 = 1.766 \text{ J}$$

This calculation assumes that the work done to overcome inertia in starting the lifting motion was exactly balanced (i.e. cancelled) by the work saved when efficiently letting the fork slow down as it approached my mouth. It is also ignoring the work done in scraping up the piece of rice onto the fork and in chewing/swallowing. Let's say that this last factor result in this calculated energy being doubled, to 3.532 Joules. And let's say, for the sake of argument, that the human muscle, as a machine, has about the same efficiency as a gasoline internal combustion engine, about 25%. This means we have to now quadruple the energy, to 14.128 Joules. This is equal to 0.014128 Kilojoules (or kJ for short). Since there are 4.184 kJ/Calorie, we can use the formula below to calculate the amount of Calories used to eat the grain of rice.

$$Energy(Calories) = \frac{Energy(kJ)}{\frac{kJ}{Calorie}} = \frac{0.014128}{4.184} = 0.003377 \text{ Cal} = \text{ 3.38 mCal}$$

That is, the amount of energy burned in the arm muscles when lifting a grain of rice (situated on an average sized fork on the end of an average sized forearm) is just over 3/1000ths of a Calorie.

Step three: compare the energy contained in a grain of rice with that expended in eating it

We have the following results. Energy contained in a grain of rice = **68.77 mCal**. Energy burned making the motions to eat a grain of rice = **3.38 mCal**.

So the net energy gain when lifting a single grain of rice up to your mouth and eating it is the following.

$$Energygain \ = energy\ contained\ -\ energy\ burned = 68.77 - 3.38 = 65.39 \text{ mCal}$$

Therefore, it is **very much energetically worthwhile to reach down, scrape up, and eat that last grain of rice sitting on your plate**, resulting in a net gain of over 6/100ths of a Calorie.

Another way to think of it is that you could perform the scooping, lifting, and eating motions twenty times (68.77/3.38 = 20.35), *actually succeeding in eating the grain of rice only one of those times*, and it would still be energetically worthwhile to do so.

My final disclaimer is that the above calculations only determine how much energy is expended in the muscles actually performing the necessary eating motions. It does not take into account how much energy your body is burning to keep breathing, keep your heart beating, regulate your internal metabolism, etc (i.e. your basal metabolic rate or BMR). It is likely that your BMR would consume energy at a far greater rate than solely your arm muscles would if you undertook the above exercise, and that therefore if you tried to eat only a single grain of rice per 20 attempts, you would quickly become hungry and need to eat more. However, I can save the 'how many grains of rice do I need to swallow per eating motion in order to not get hungry' calculation for another day.

Thanks for stopping by...