Mash, Beans, Viscosity and Power in Electric Pressure Cookers

Mash, Beans, Viscosity and Power in Electric Pressure Cookers

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Working Paper for Comment

Disclaimer – This was an early draft released for discussion among the MECS team and those working on the Global Leap testing, and was originally not intended for publication. However, the information contained has proven useful for partners and collaborators and we now wish to place it on our website for wider use. (June 2021). It remains a working paper for comment.

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1 Introduction

When I visited China (before Christmas so before virus), I met with Mr Gao, lead designer of Midea. Midea are of course one of the leading manufactures of EPCs.

We asked them if they would consider manufacturing a 600W version of the 6 litre EPC. Our understanding was that most 6 litre (or more) versions are 1 kW or more, and that 3 litre versions are produced at around 700W.

Mr Gao had two pushbacks.

His first was that the flow of steam through the safety valve would be insufficient to shut the valve.

If this was the case, there was a simple solution, to have the valve shut at the start of the process. The build up of pressure would therefore be in a closed environment. The valve is for safety, to prevent the top being opened under pressure. To start with it shut would not change this aspect as long as the only way to open the valve was by the internal space not being under pressure, as is the case now in all EPCs.

However, the second pushback was that with low power and a significant amount of cooking material, a 600W device would create a situation where the top and bottom of the material were at different temperatures and were cooking for a different period of time (potentially affecting the taste across the whole).

This pushback seemed reasonable and so we have undertaken some experiments to test this hypothesis

You will see that when the beans are mashed into a dense block, temperature differentials do occur. So Mr Gao was right to say that there **could** be a temperature differential, but we don't believe this is a function of power, more of the density of the material. Such an effect can occur in any EPC that has a compacted dense mass with limited convectional flow. You will see that we conclude that the 'density' of the material is what is important rather than the volume of material per se, or the power of the heating element.

2 Method

The device in question was an Instant Pot IP Lux rated at 1kW. A Bronson 3000 variac was used to lower the mains voltage applied to the device to simulate a 600W EPC. Note while the power axis in the following charts shows 620W consumption, approximately 20W was lost to the variac.

The following graphs show temperature profiles monitored by two ibutton type temperature sensors. One was located at the top of the beans, placed in a stand so that it remained submerged in the beans (blue line), and the other was placed at the bottom, inside the pot (yellow line).

The green line represents the power drawn by the variac and shows the device switching on and off.

We used kidney beans as the cooking material since they were readily available. The same beans were cooked four times. This created four cooking conditions, each with increasing viscosity of the cooking material.

The EPC programme that labelled 'Soup' and extended from the recommended 30 minutes to 60 minutes.

3 Findings

3.1 First cook (600W)

Figure 1 shows results from 3.5kg of kidney beans undergoing their first cook (i.e. pre-soaked raw beans) at 600W. The chart shows the temperature rising steadily during the heating up phase of the cooking programme, then fluctuating moderately as the power cycles on and off during the cooking phase of the programme.

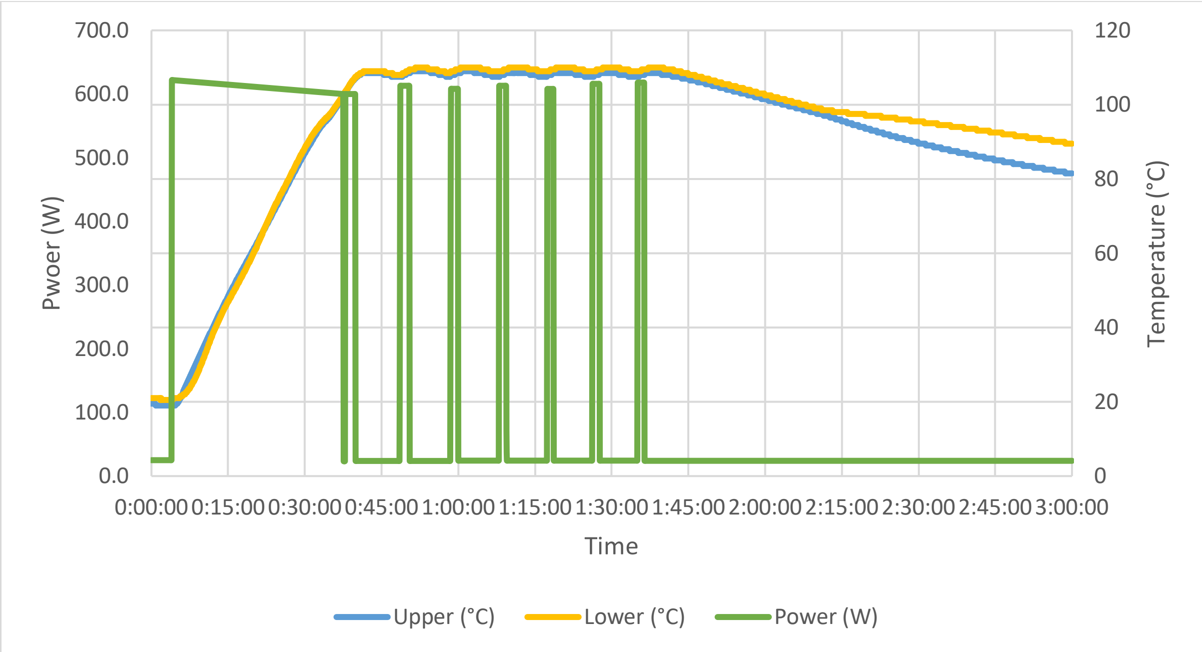

Figure 1 Temperature and power profiles - first cook

Total energy used (MJ)	1.7
Total energy usage (kWh)	0.5

The points of note are

a) There is no substantial temperature difference
b) The 600W takes longer than 1kW, but that is expected
c) The beans at top and bottom were cooked to the same texture (a subjective test)

3.2 Second cook (600W)

Figure 2 shows the same beans having cooled and then cooked for a second time. Before cooking, the beans were compressed or mashed, such that each bean integrity was broken. This decreased the gap between beans, making a much more viscous cooking material, which lowered the possibility of convection flow of fluids.

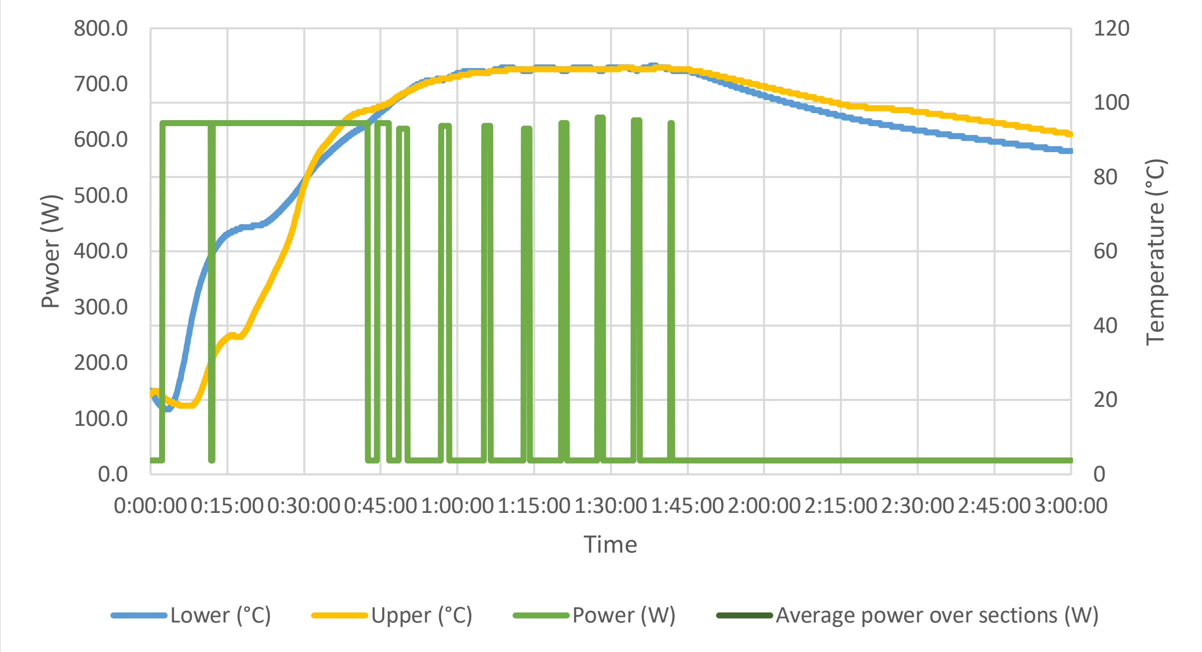

Figure 2 Temperature and power profiles – second cook

Total energy used (MJ)	1.9
Total energy usage (kWh)	0.5

Under these conditions, a temperature differential was more evident during the heating phase. The lower sensor increased ahead of the upper, although the upper at one point overtakes the lower. We hypothesise that this may be due to a build up of steam held back by the mass, which then breaks through in a bubble, putting steam into the upper chamber, although the upper sensor is still submerged in the top layer of beans. (This is speculation – the unit is sealed and no visual data can be taken – not sure how to test this hypothesis?).

However, importantly we see here the temperature sensors on the pressure cooker beginning to do their job. They are designed to stop the bottom burning, and we can see that at about 40 mins, they switch the unit off. Fortunately, there is enough thermal mass for the beans to continue to heat up, and the valve shuts. The unit continues with intermittent heating to rise to pressure, and then the pressure phase is continued as designated.

The points of note are

a) There is some temperature difference (top to bottom) during the heating phase, but it is absent during the pressure phase.
b) The 600W takes longer than 1kW, but that is expected
c) The beans at top and bottom were pre- cooked so it was not possible to check for any taste differential.

3.3 Third cook (600W)

Figure 3 shows the same beans having cooled and then cooked for a third time. By this time the beans were compressed or mashed forming pretty much a solid block, similar to mash potato or ugali. There was no possibility of convection flow of fluids.

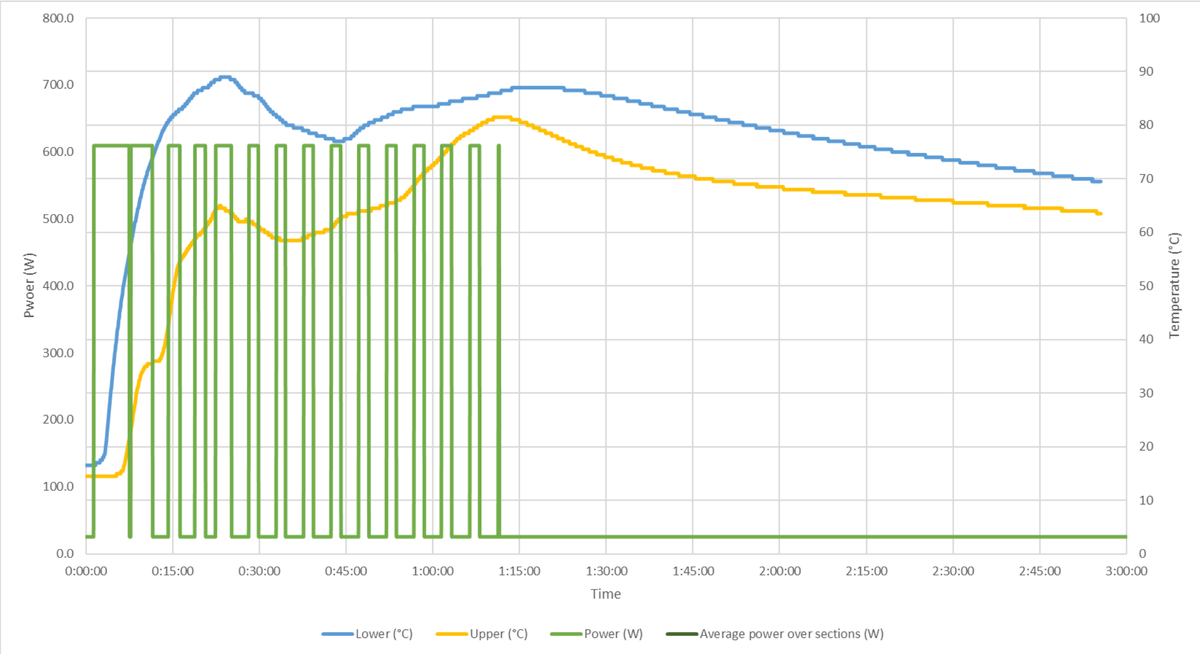

Figure 3 Temperature and power profiles – third cook

Total energy used (MJ)	1.2
Total energy usage (kWh)	0.3

Under these conditions, a temperature differential was more evident during the heating phase. The unit never reaches pressure (the test was repeated with the valve closed) and the built in thermostat of the unit senses the bottom being burnt and switches off the power. With the intermittent heating, the unit never reaches pressure. The base of the 'mash' was slightly burnt, although as stated, the thermostat switched it off to prevent too much burning.

It should be noted that this test used 200Wh less energy than the previous tests because while it singed the bottom, it didn't really cook the food.

3.4 Fourth cook (1.2kW)

The power is not shown in Figure 4, but a fourth cooking of the cooled beans was made with the pressure cooker delivering 1.2kW (using the variac to increase the voltage to 260V).

The figure shows that the temperature differential persists, and there is an inability of the unit to reach pressure.

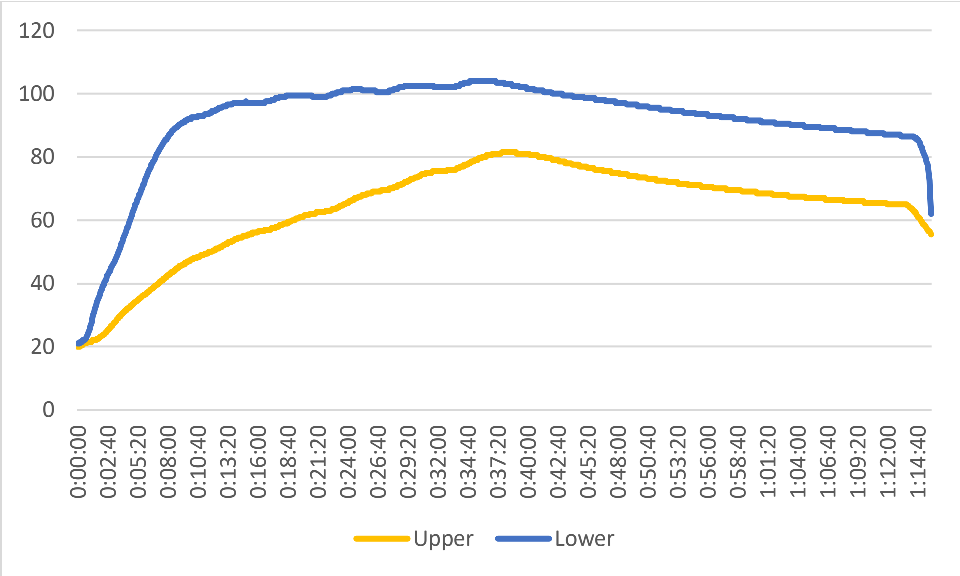

Figure 4 Temperature profiles – fourth cook

The thermal mass does not allow the heat to transfer through the bean mash at a sufficient rate, meaning that the bottom burns (but for the switch offs) while the top does not reach cooking temperature. Indeed close inspection of the temperatures shows that the bottom is at 102 deg C at some points.

4 Conclusion

Dense cooking material does indeed confuse the EPC.

However, this is not necessarily a question of heating element power, but of the flow of fluids.

We conclude that any very dense or viscous material that does not demonstrate fluid properties when heated at the bottom will create a temperature differential during the heating up phase, and potentially fail to pressurise not so much because of the power rating per se but because the absence of heating energy from the EPC which when sensing the bottom is over heating, switches itself off, and the poor heat transfer suggests the water is not driven off as steam creating the pressurisation..

It will perhaps therefore be an important part of any test procedure to document the pressure cooker pan temperatures at which the device switches itself off, and indeed whether it allows the cooking material on the bottom to burn.

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