OC-42: Design of a New Bifrequential 20/500 kHz Ultrasonic Reactor for the Depolymerisation of Starch-Based Waste into Reducing Sugars

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The design of a lab-prototype enabling a simultaneous dual low and high ultrasonic irradiation will be presented in this work. This prototype has been specifically designed to explore the feasibility to depolymerise industrial starch-based waste into reducing sugars in strong acidic medium to afford reducing sugars, whose can be later on fermented into high bio-alcohols.

Introduction

All over the world, the rapid increase of energy demand during the last decades generates a rise of the environmental pollution. This situation is devastating for our society all the more important that we are very dependent on non renewable energy resources such as oil, gas or coal. This is especially true for transport, whether road, sea or air, using almost only oil. Our society became aware of the mistakes done in the last decades by being focussed on one non-renewable resource. Since the rise of the major concern about the worsened health of our planet, several alternatives have been explored in R&D and are now under intense development to answer to the already programmed depletion of world oil stocks. Among, the use of biomass to produce clean biofuels is probably one of the most promising alternatives. However, it is also known that the use of edible biomass may raise ethic issues but also may impact on the agricultural land and food prices. Non-edible biomasses should thus be selected to avoid harsh competition between food and biofuels production.

The main goal of our research is the conversion of biomass into reducing sugars and their latter transformation into higher alcohol biofuels. The raw material used in our research is a non-edible industrial waste, potato peel, provided by a company producing ready-cooked vacuum potatoes for professional catering. This Finnish company, Jepuan Peruna Oy, is generating up to 20 tons per day in 2010 of potato peels. This waste is mainly composed of water (67%) and starch and a total hydrolysis revealed that up to 88% could be valorised into reducing sugars. So far, up to 90% of this industrial waste is transported, via conventional transportation fuels, to cattle and pigs farms. The remaining 10% is also transported to a waste dump for fertilizer and soil fertilizer. The high value-added of this waste suggests us that it could be used as a feedstock for biofuel production.

Preliminary study

At first, we compared the use of low and high frequency ultrasound in strong acidic aqueous medium to develop a clean and rapid way to depolymerise this industrial waste into reducing sugars. For that, three kind of starting starch-based materials were selected: a pure commercially available starch, used as reference (i.e. Granule), the raw waste as out from the Jepuan Peruna Oy Company (i.e. Crude) and the latter which has been dried and ground prior to depolymerisation reaction (i.e. Ground). The below figure 1 displays the reducing sugars conversions obtained for the three different starting starch-based materials under both mechanical stirring and ultrasound when used singly.

These preliminary results show that, whatever the incident ultrasonic frequency and the nature and the starting starch-based material, obtained depolymerisation rates are higher than under mechanical stirring. However, several technical hurdles have to be overcome to improve the process. At first, the strong acidic medium avoids the direct immersion of an ultrasonic probe into the medium, forcing us to use an indirect mode at low frequency, i.e. an ultrasonic bath. At second, the raw material always affords the lowest rates while the industrial depolymerization process would be less expensive using this raw material compared to the other two starting materials approached. This reflects the complexity of the industrial matrix towards the two other materials where the starch grains are trapped and agglomerated into the waste as it will be shown by SEM pictures.

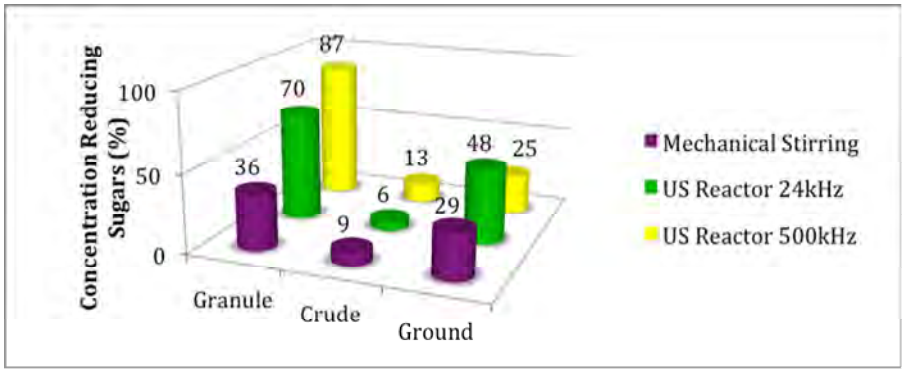
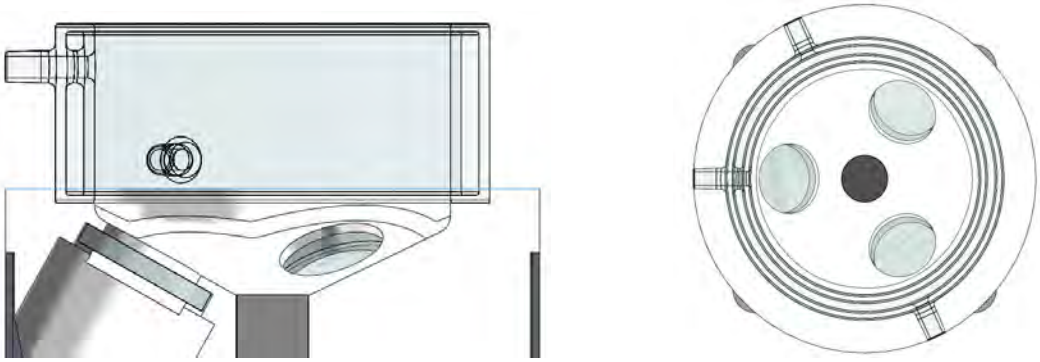


Figure 1: Depolymerisation of three starch-based materials under mechanical stirring, low and high frequency ultrasound (2h, 60°C, 3wt%, water/H_2SO_4 3M)

Dual low/high ultrasonic frequencies reactor

To overcome these limitations, a lab-prototype allowing the combination of low and high ultrasonic frequencies has been designed enabling simultaneously physical effects brought up by low frequency ultrasound to release trapped starch grains from the complex matrix and chemical effects brought up by high frequency ultrasound to help the overall depolymerisation process. Pictures of the prototype are given here below, picture 1:



Picture 1: Drawing of an ultrasonic device prototype combining low and high frequencies for the depolymerisation process.

In addition, to allow a direct immersion of an ultrasonic probe into the strong acidic medium, two solutions have been explored. On the one hand; a PTFE protective coating has been applied to the probe to avoid corrosion and on the second hand; a probe extension in Inconel© alloy has been made. The preliminary results obtained with this prototype on the depolymerisation process with the three approached starch-based materials will be presented.

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