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Underlying factors to consider in improving energy yield from biomass source through yeast use on high-pressure homogenizer (hph)

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ABSTRACT

Pioneering the works of Brookman (1975), Middelberg et al. (1992a, 1992b) and Kleinig and Middelberg (1996), on cell disruption of yeast through HPH (high pressure homogenizer), the underlying factors in improving energy yield from biomass source has to be considered. This has become a global issue for scientists, researchers and policy makers as the energy demand has grown over the years due to the growing population. As cleaner energy has become highly needed for save environment and protection of the climate hence shifting away from the utilization of fossil fuels will be of higher priority.

In this paper, these factors will be highlighted and discussed herein as well as other parameters that influence the energy production efficiency from the high-pressure homogenizer (HPH) through using yeast as a biomass source. The HPH for consideration in this study is the GYB40-10S; this has a pressure of up to 100 MPa with two stage homogenizing valves pressure. This is adjustable so as to produce superfine, homogeneous, stable liquid–liquid or solid–liquid under multiple actions of cavitation effect and high speed impact. And also shear through the adjustable homogenizing pressure valve in the conditions of high pressure and thereby making the material compatible after homogenization.

1. Introduction

Energy as the prime mover of economic growth, its search therefore as renewable energy sources in the 21st century has become the key challenge to stimulate a more sustainable energy development for the future [1]. It is one of the most important fundamental elements for human development and even survival [2]. Yeast as one of biomass substrates has increasingly played a dominant role in the production of energy. The continuous production and development of this biomass for energy have been improved on ever since but have also been hampered by the some factors during the production processes. This has made the full potential never to have been achieved till moment. Many studies undertaken from different countries have been recently considering expanding their biofuel production using indigenous resources in order to achieve lower GHGgreenhouse gas (greenhouse gas) emissions [3,4]. Yeast as an energy producing substrate have been able to meet this target and in the recent advances Xiong et al. [5] have been able to show that some microbial species such as; yeast, fungi and microalgae can be used as potential sources for biodiesel as they can biosynthesise and store large amounts of fatty acids in their biomass. Nigam and Singh [6] demonstrated that yeast's ability to grow well on pretreated lignocellulosic biomass could efficiently enhance the lipid accumulation hence providing a promising option for the production of economically and environmentally sound microbial oil from agricultural residues. From previous research [7], have reported that besides microalgae, many yeasts and fungi species are able to generate and accumulate lipids in their cells. In achieving this breakthrough of liberating the contents within the cell wall of yeast biomass; high-pressure homogenizer was applied in the cell wall disruption at high enough pressure and temperature over number of passes as repeated

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cycles. In yeast like in other biomasses; Tedesco et al. [8] in their studies analysed the different types of pretreatments performed on various substrates and then considered milling as the most used mechanical technique. This accordingly they discussed in their paper that cell walls and lignin component disruption treatments are needed to enhance the hydrolytic phase and the overall biodegradability of lignocellulosics during an anaerobic digestion process. Similarly [9,10], showed pretreatment as a requirement in the alteration of the biomass macroscopic and microscopic size and structure as well as its submicroscopic chemical composition and structure so as to have the hydrolysis of carbohydrate fraction to monomeric sugars to be more achieved rapidly and with greater yields.

Renewable energy use of biomass source constitute the homogenization of yeast under high pressure homogenizer (HPH) and should not be undermined as an energy producing substrate, this in fact, is of great consideration in this study, due to the high content of protein retained within the product and therefore qualifies it as a major and suitable biomass for biogas production. Yeast single cell protein showed molasses which is derived from sugarcane processing as the major raw material for its production [11]. As a result of this; Reed and Nagodawithana [12] have explained that the yeast generated from the biorefinery process has a protein content as high as 50% making it much superior to other co-products from 1G bioethanol production that have been conventionally employed in cattle feed. This in other words, was classed as an energy and protein substitute for grass and with a high protein content containing 31% carbohydrate and lipid as a biomass [12]. Cheirsilp et al. [13] pushed further the frontier of yeast importance by characteristically highlighting it to produce high amount of lipid contents similar to that of vegetable oil as well as having a high growth rate and thus can be cultured in a single medium with low cost substrate. Yeast suitability for biogas production has been stemmed from the fact that it has lower water and higher protein content. Hammerschmidt et al. [14] have explained that several types of waste biomass and fresh plants available for the production of energy and fuels as not suitable for common pyrolysis processes due to their high water content (>70%). For the process to be classical the biomass has to be dried; and this has been considered as energy and time consuming step [14]. Apart from the fact that yeast uses in human's lives are numerous; such as in the industry for brewery, pharmaceutical, food and now, energy production. Yeast as oleaginous microorganisms has an advantage over bacteria, moulds and algae due to its unicellular nature as it is having a relatively high growth rate and accumulates lipid rapidly in discrete lipid bodies [15]. Saenge et al. [16] found and concluded that the produced lipid can be used as a feedstock for biodiesel production and when compared with other vegetable oils and animal fats Li and Wang [17] showed yeast lipid production having many advantages, such as; short life cycle, requiring little labour to grow, easy to scale up as well as relatively independent of special requirements for place, season and climate.

In fact, biomass-based energy sources are potentially carbon dioxide neutral and recycle the same carbon atoms hence bioenergy is termed renewable energy made from plant-derived organic matter which are collectively recognized as biomass [18]. It is therefore important to recognize this fact that developing this biomass energy will largely be dependable on the development of the renewable energy industry as a whole, as it is driven by similar energy, environmental, political, social and technological considerations [19]. The aim of this study was to determine the underlying factors in improving energy yield through using yeast in high-pressure homogenizer and through the conducted study, some significance of these parameters are presented which determines the energy yield after homogenization.

2. Background

The disruption of yeast through high pressure homogenizer (HPH) has all been previously dealt with by Refs. [20–23] using the different parameters in their analysis [20] studied the antimicrobial effects and suggested it as dependent on the rate and magnitude of pressure drop [24–26] proposed high pressure homogenizer as an effective alternative to the pasteurization of milk and whole liquid eggs. Donsì et al. [27] highlighted pressure and temperature as mainly influencing the effectiveness of homogenization for microbial inactivation among the process parameter and contrarily, considered temperature effects to be necessarily taken into account in HPH since upon homogenization, the rise in temperature is observed in the fluid downstream of the valve. Floury et al. [28] therefore attributes this to the viscous stress that have been caused by the high velocity of the fluid flow which is then impinging on the ceramic valve of the homogenizer, leading to the dissipation of a significant fraction of the mechanical energy as heat in the fluid. Considering pressure, temperature and number of passes (cycle) as the main parameters that affect fluid flow in HPH, Diels and Michiels [29] reiterated the level of microbial inactivation caused by the application of high-pressure homogenization increases with the pressure level which is similar with the HHP (high hydrostatic pressure) processes. Other underlying factors of considerable importance which have also been analyzed; authors have suggested a correlation between cell wall structure and high-pressure resistance between the microorganisms and HPH. This indicates that high-pressure homogenization kills vegetative bacteria mainly through mechanical destruction of the cell integrity, caused by the spatial pressure and velocity gradients, turbulence, impingement [30,31] and cavitation [32,33].

Disruption of yeast or other microbial organisms is a key step towards the isolation and purification of many biotechnological products that are present in the interior of cells of the cell walls of micro-organisms [34] and it was reported in the concept presented by Clarke et al. [35] as example of breaking the walls of yeast cells. These were found to be between 5 and 10 microns in sizes and not limited to just yeast but also applicable to other unicellular micro-organisms of different sizes. During homogenization, cell disruption is accounted for as a result of the non-specific tearing apart of the cell wall which is determined by the physical interaction with the valve slit of the homogenizer, in a balance between the destructive fluid-dynamic stresses and the cells' physical strength [27]. This therefore results in the complete deformation of the cell wall and the protein contents are then liberated. Concerning the oil yield from microalgae after pretreatment, it is considered higher than other terrestrial biomass with much lower costs than electrolysis of water Amaro et al. [36] but still considerable lower or equivalently as that of yeast. This when compared with second generation biofuels, microalgal fuels have a much higher yield; 30–100 times more energy per hectare can be produced by microalgae if compared with terrestrial oil crops [37].

Yeast dominant role as a biomass substrate in renewable energy production cannot be over exaggerated. Ref. [6] previously claimed that its ability to grow well on pretreated lignocellulosic biomass could provide a promising option for the energy production. And factors to consider, biogas yield from yeast homogenization under HPH has been regarded highly favourable under high pressure and above room temperature. This is because thermochemical biomass conversion involves processes which require much more extreme temperatures and pressures than those found in biochemical conversion systems [6]. Though as ascertained, Farias et al. [38] pushed further that certain essential characteristics differentiate thermochemical process from biochemical process, this includes the flexibility in feedstock that can be accommodated with