CHAPTER 2

# Bio-Based Alkyl Levulinate Derived from Biomass via Thermo-Catalytic Alcoholysis Process

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## 2.1 INTRODUCTION

As a sustainable approach to replace the current applications of conventional fuels-based feedstock, the momentum of research work towards the conversion of renewable resources into chemicals and fuels are rapidly increasing. The emphasis on sustainable solutions within the chemicals and fuels industry are due to the global population growth and the pressing demand for the energy, whereby excessive consumption of such resources has been found to cause various environmental issues (i.e., greenhouse effects, increase carbon foot print and climate change) as well as the depletions of the fossil fuels reserves (Dookheh et al., 2021). Sarker et al. (2021) reported that, the concentration of anthropogenic carbon dioxide, $CO_2$ in the atmosphere is at an alarming rate resulting from the excessive exploitation of fossil fuels. This is supported by energy consumption per capita which shows an upswing trend and is projected to grow in tandem with the increase in world population from current number of 7.2 billion to 8 billion by 2030 (Nanda et al., 2015). As such, the domination of fossil fuels for energy production and consumption (approximately 87%)

remained persistent in the global energy market (Tian et al., 2021). Therefore, with the aim of these non-renewable energy's security, the focus and utilization for the sustainable energy resources such as biomass is the major concerned and challenges among academician and industrial circles within the past decades.

Biomass is defined as any biological materials including animals, plants, and their derivative wastes. Biomass resources can be broadly classified as lignocellulosic forestry residues (wood chips, barks, sawdust), agricultural residues (oil palm wastes, cornstalk, maize straws) and biosolids (pulp and paper sludge, sewage sludge, municipal and industrial waste sludge). They are widely considered as a renewable and abundance resource. Other than the lignocellulosic biomass, organic materials derived from Municipal Solid Waste (MSW) such as kitchen waste, dried household food waste together with fruit and vegetables scraps are also being utilized for the production of liquid biofuel (di Bitonto et al., 2018). Similarly, carbohydrate derived-material from microalgal cell (i.e., *chlorella sp.* and *nannochloropsisgaditana*) are also reported as alternative bio-based products feedstocks (Kim et al., 2017). The conversion of these sustainable resources can be achieved in a one step process under acidic catalytic condition to produce not only biofuel but also other types of bio-based chemicals due to the present of lipids and carbohydrates in both microalgal and MSW compositions. Notwithstanding, to scale up the production and commercialization of microalgal-based fuel is still considered too ambitious in view of the cultivation and downstream processing required high energy consumption that induce high operation cost.

The utilization of biomass as an alternative resource is a promising approach towards minimizing the dependency on the conventional fuels. Moreover, it is reported that biomass can potentially reduce the greenhouse emissions by balancing the biomass production and its application in the future (Wang et al., 2018). Even though biomass potential as sustainable feedstocks is well known and documented, yet it is still a challenge to develop cost effective, pollution free, and efficient biomass conversion technologies. Over the years, various technological methods have been discovered, tested, and employed for biomass conversion with varying degree of success. Common biomass conversion technologies targeting diverse bio-based chemicals and biofuels via thermochemical and biochemical approaches are illustrated in Figure 2.1.

Lignocellulosic biomass is the largest natural carbon resource available on earth (Jiang et al., 2021). The source of lignocellulosic biomass includes grasses, woody materials, agriculture wastes and forestry wastes (i.e., bark, tree tops, and sawdust) (Souza et al., 2021). Depending on the type of the biomass, the lignocellulosic components range from 40-50% cellulose, 20-30% hemicellulose, and 10-30% lignin. The advantages associated with the utilization of this non-fossil carbon resource are well established. This includes minimization of the waste generated from forestry and agriculture sectors, the cost of feedstocks as well as improving the overall solid waste management scheme.

During lignocellulosic biomass conversion, glucose and xylose sugars are the main products derived from the acid hydrolysis of cellulose and hemicellulose. These sugars have been used as feedstocks for various bio-based chemicals and liquid transportation biofuels production. Biodiesel (Nata et al., 2017), bioethanol (Leo, 2018), furfural (Jiang et al., 2021), 5-hydroxymethylfurfural (Wang & Chen, 2018), levulinic acid (Antonetti et al., 2016), and alkyl levulinate (Tian et al., 2021) are among the examples of products obtained using these sugars.