Cleaner Engineering and Technology 2 (2021) 100080

Contents lists available at ScienceDirect

Cleaner Engineering and Technology

journal homepage: www.journals.elsevier.com/cleaner-engineering-and-technology

# Pyrolysis, kinetics, and structural analyses of agricultural residues in Egypt: For future assessment of their energy potential

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ARTICLE INFO

*Keywords:*
Agricultural residue
Biomass
Pyrolysis
TGA
Kinetics
Energy

ABSTRACT

Agricultural residues receive significant attention worldwide as a sustainable and green energy source. The accurate assessment of agricultural residues' energy potential depends on physicochemical properties that change with location and climate. Several studies provide an imprecise estimation of agricultural residues' energy potential in Egypt based on characteristics in literature from other sites. This study investigates the physicochemical properties, pyrolysis, and kinetics of seven types of agricultural residues, namely corn stalks, switchgrass, okra stems along with ficus, camphor, desert olive, and blueberry tree woodchips sampled from several locations in Egypt. The thermogravimetric, differential thermal, proximate, ultimate, lignocellulosic constituents, kinetics, crystallinity, and microstructure analyses are used to characterize the biomass. Kinetic parameters were determined by applying Coats-Redfern and Direct-Arrhenius approaches. The results revealed that woody residues have higher volatile matters, energy contents, hemicellulose, and lignin with lower ash, moisture, and cellulose than herbaceous residues. The activation energies of woody residues are lower than that of switchgrass and okra stems but higher than Cornstalks. The tested residues are bulk with nonuniform crystal structures, and their usages require further processing. The woody residues have promising properties. This study facilitates the accurate assessment of the agricultural residues' energy potential in Egypt.

## 1. Introduction

The world has limited fossil fuel resources with the possibility of conventional resource depletion during the next few decades (Mishra and Mohanty, 2018). Egypt is one of the most abundant natural gas (NG) and oil producers in Africa and the East Mediterranean. However, the country's oil consumption transcends its production rate, as reflected in Fig. 1(a), and the major national challenge is to satisfy increasing oil consumption and reduce the difference between production and consumption (U.S. Energy Information Administration, 2018). Natural gas and oil are the primary sources of Egypt's energy needs with a fraction of 45% and 51%, respectively, which corresponds to a total of 96% of the total energy demands in 2016, as presented in Fig. 1(b). Renewable energy makes about 2.2% of the total energy production, mainly from solar and wind energies, as reported by the Ministry of Electricity and Renewable Energy in 2019. Although Egypt is one of the largest NG producers in Africa, the country remains to import NG in 2015 as a result of escalating consumption and reduced production, as indicated in Fig. 1(c) and (d) by U.S. Energy Information Administration (2018). However, recent NG discoveries have recovered the balance between production and consumption in the short term, and Egypt reached self-sufficiency in natural gas by 2021. Additionally, the Egyptian initiative (Egypt vision 2030) set several sustainable development goals. One of these goals is related to energy and target reducing the dependence on conventional energy resources and increasing renewable energy use. Biomass and waste-to-energy technologies are some of the targeted renewable energies.

Biomass is an alternative energy source that may reduce fossil fuel dependence (Wang et al., 2016). The combustion, pyrolysis, or upgrading (torrefaction) of biomass with and without catalytic additives are various ways to use biomass as an alternative energy source (Safar et al., 2019).

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https://doi.org/10.1016/j.clet.2021.100080
Received 1 February 2021; Received in revised form 4 March 2021; Accepted 21 March 2021