International Journal of Science and Technology Research Archive

ISSN: 0799-6632 (Online)

Journal homepage: https://sciresjournals.com/ijstra/

(Research Article)

Investigation of the influence of catalysts on the production of furfural and its derivatives from the leaves of *Psidum guajava* (Myrtaceae)

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International Journal of Science and Technology Research Archive, 2022, 02(01), 033–036

Publication history: Received on 30 November 2021; revised on 14 January 2022; accepted on 16 January 2022

Article DOI: https://doi.org/10.53771/ijstra.2022.2.1.0058

Abstract

Furfural and its derivatives have been found to have the potential to replace petroleum products in the production of industrial chemicals since they offer cost effective and environmentally friendly approach for sustainable development. Dried pulverized leaves of *Psidum guajava* were treated with NaOH, ZnO and CaO for production of furfural and its derivatives. About 75 g of the pulverized leaves were treated with 150 ml 3% solution using the catalysts at 100°C for 30 minutes. GC-MS chromatogram revealed the production of furanmethanol, hydroxymethyl furfural and methyl furfural. The findings from this study calls for the need to engage plant biomass in the production of useful chemicals as agro-wastes are promising alternatives to fossil fuels.

Keywords: Catalyst; Furfural Derivatives; *Psidum guajava;* Investigation

1 Introduction

Recently there is an increasing interest in the production of biochemicals from plant biomass sources as they have of late occupied pivotal role in replacing petrochemicals. The desire to provide the chemical industry with new tools to transform biomass into chemicals in a 360-degree sustainable way is a challenge for modern scientists [1]. Biomasses can be considered a renewable resource because they can be replenished over a relatively short timescale and they are essentially limitless in supply [2]. The use of plant based biomass for industrial revolution lead to less energy consumption and less CO_2 emissions as well as avoid the pretreatment steps that are required in preparing purified bio-based feedstock's. Plants contain cellulose, hemicellulose and lignin as the major chemical components of which cellulose is chiefly composed of hexoses whose decomposition results in glucose, fructose and other simple sugars [3]. Likewise, hemicellulose is a polymer of hexoses and pentoses whose decomposition yields hexoses and pentoses. The hydrolysis of the pentoses yield furfural and its derivatives [3].

Furfural is an important biodegradable biomass-based high-value chemical with numerous applications [3-5]. Furfural (Figure 1) is the only compound of the furan series that can be directly obtained from biomass at industrial scale [6]. While it is widely used directly as a solvent and a fungicide, it is most commonly converted into pharmaceuticals, chemicals and biopolymers, many of which are used as substitutes for petrochemical-derived analogs [7,8]. The use of biomass to synthesize biochemicals and biofuels has become very important due to the renewability, sustainability and biodegradability of their sources [9]. Carbon-based catalysts are attractive since the carbon supports are low-cost materials with high surface area and good thermal stability and they are easily modified with functional groups [10]. These carbon surfaces not only contains groups with heteroatoms, such as oxygen, can act as anchoring sites for metal particles and generate high metal dispersion but also enables Brønsted acidity which further promote xylose conversion to furfural [11].

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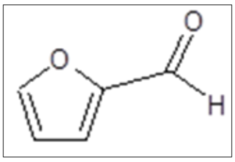

Figure 1 Furfural

Furfural is among the several products that can be obtained from biopolymeric wastes. Due to the presence of an aldehyde group and a conjugated system of double bonds, furfural can undergo several reactions, allowing the production of a range of value-added products [12].

Psidium guajava is a large dicotyledonous shrub, or small evergreen tree, generally 3-10 m high, many branches; stems crooked, bark light to reddish brown, thin, smooth, continuously flaking; root system generally superficial and very extensive, frequently extending well beyond the canopy, there are some deep roots but no distinct taproot. Leaves opposite, simple; stipules absent, petiole short, 3-10 mm long; blade oblong to elliptic, 5-15 x 4-6 cm, apex obtuse to bluntly acuminate, base rounded to subcuneate, margins entire, somewhat thick and leathery, dull grey to yellow-green above, slightly downy below, veins prominent, gland dotted. The fresh and dried leaves of the plant are shown in Figure 2 (a and b).

A **B**

Figure 2 (a) Fresh and (b) Dried Leaves of *Psidum guajava*

In view of the importance of furfural and its derivatives which are found cheaply and abundant in biomass, this study investigated the production of furfural and its derivatives from dried leaves of *Psidum guajava* over four different catalysts.

1.1 Experimental Methodology

1.1.1 Chemicals/Reagents

The analytical grade reagents used are sodium hydroxide, zinc oxide and magnesium oxide.

1.1.2 Sample Collection, Authentication and Preparation

Fresh and matured *P. guajava* leaves were collected in June 2021 from a forest in Ojo Local Government Area of Lagos State Nigeria.The leaves was identified and authenticated by a renowned taxonomist. The plant was carefully washed with water to remove earthy material, air-dried before they were reduced to fine powder with the aid of an electric milling machine.

1.1.3 Preparation of Furfural and Its Derivatives

The procedure outlined by Magaji and Ibrahim, [13] was adopted. 75 g of the pulverized *P. guajava* leaves was added to 150 mL 3% NaOH solution. The mixture was placed on a magnetic stirrer and heated to 100^{o}C for 30 minutes. The extract was filtered via Whatmann No 1 filter paper. The resulting filtrate was freeze dried and weighed. The same procedure was carried out using the zinc oxide and magnesium oxide catalysts respectively. 0.30 g of the dried samples was weighed and transferred to a GC-MS vial for GC-MS analysis to ascertain the formation and composition of the produced furfural and its derivatives.

2 Results and discussion

The results of the composition of the major components in the samples as revealed by the GC-MS chromatogram is seen in Table 1.

Table 1 Phytoconstituents revealed by the GC-MS Chromatogram

S/N	Phytoconstituents	Catalysts		
		NaOH	ZnO	MgO
1	1-Decen-3-yne	+	+	+
2	3-Cyclohexen-1,3-diol	+	+	+
3	1-Undecen-3-yne	+	+	+
4	B-D-Glucopyranose	+	+	+
5	Dodecanoic acid	+	+	+
6	Ethinamate	+	+	+
7	Creosol	+	+	+
8	1,2-Benzenediol	+	+	+
9	5-HMF	+***	+**	+*
10	Levoglucosenone	+	+	+
11	2-Furanmethanol	+**	+***	+*
12	Phytol	+	+	+
13	Tetradecanoic acid	+	+	+
14	5-methyl furfural	-	-	+
15	Pentadecanoic acid	+	+	+

Key: (+) = Presence; (-) = Absent; *** > ** > * (Order of abunmdance); NaOH = Sodium hydroxide; ZnO = Zinc oxide; MgO = Magnesium oxide; HMF = Hydroxymethylfurfural

Catalyst is one of the chief parameters in furfural production process as it speeds up the rate of the reaction. The results represented in table 1 above shows that two furfural derivatives (5-HMF and 2-furanmethanol) were produced from the investigated catalysts while 5-methyl furfural (5-methyl-2-furan carboxaldehyde) was only produced when magnesium oxide catalyst was used. The order of the produced furfural derivatives among the three catalysts are: 5-HMF: NaOH > ZnO > MgO and 2-furanmethanol: ZnO > NaOH > MgO. This result showed that magnesium oxide is best catalyst among the other investigated catalysts in the production of more furfural derivatives. The results of this study agree with the report of Nyong *et al*. [14] which suggests that catalysts increase the net rate of furfural formation without significantly altering the maximum yield as well as that of Nyong *et al*. [15] that concluded that furfural yield is dependent upon the amount of xylose decomposed in acidified solutions containing metallic catalysts. They both postulated that the presence of catalysts accelerates the rate of furfural production and has no adverse effects on yield. Metallic salts like TiO_2, $ZnCl_2$, $AlCl_3$ among others have been reported as enhancers in the production of furfural as they may act as lewis acids promoting the reaction or may stabilize intermediates in the hydrolysis of pentosans [16,17].

3 Conclusion

The findings of this study concludes that the pulverized dried leaves of *Psidum guajava* successfully produced three furfural derivatives (5-HMF, 2-furanmethanol and 5-methyl-2-furan carboxaldehyde) when NaOH, ZnO and MgO catalysts were used. In effect, plant biomass are potential source for furfural derivative production hence should be explored as a cost effective and environmentally friendly approach for sustainable development.

Compliance with ethical standards

Acknowledgments

The authors appreciate the technical assistance of Mr Adesina Kehinde for running the spectra.

Disclosure of conflict of interest

The authors declare that there is no conflict of interest.

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