*International Journal of Environment, Agriculture and Biotechnology*
*Vol-11, Issue-4; Jul-Aug, 2026*
*Peer-Reviewed International Journal*
*Journal Home Page Available:* https://ijeab.com/
*Journal DOI:* 10.22161/ijeab

# Reaction Parameter Optimization for Sustainable Hydroxymethylfurfural Production from Tanzanian Sugarcane Bagasse

Frank Telesphore Beichumila

Department of Water Resources Management, Water Institute, Tanzania.
Email: fbeichumila@gmail.com

Received: 18 Jun 2026; Received in revised form: 14 Jul 2026; Accepted: 21 Jul 2026; Available online: 28 Jul 2026


***Abstract***— *Hydroxymethylfurfural (HMF) is an important biomass-derived platform chemical with extensive applications in the production of biofuels, polymers, pharmaceuticals, and other value-added chemicals. The growing demand for sustainable alternatives to petroleum-based chemicals has stimulated interest in the conversion of lignocellulosic biomass into HMF. In this study, the reaction parameters for the production of HMF from Tanzanian sugarcane bagasse were optimized under pressurized conditions using a high-pressure reactor. Sugarcane bagasse (25 g) was hydrolyzed under varying reaction temperatures, sulfuric acid concentrations, and reaction times. A total of 27 hydrolysis experiments were conducted in a non-stirred SS-304 pressure reactor. The hydrolysis reactions were carried out using sulfuric acid concentrations ranging from 0.5 to 1.5 M, temperatures between 180 and 200 °C, and reaction times of 10 to 20 minutes. The concentration of HMF produced under different reaction conditions was determined using UV–Visible spectrophotometry based on a calibration curve. The results demonstrated that HMF yield was significantly influenced by the interactive effects of acid concentration, reaction temperature, and reaction time. The optimum reaction conditions were found to be 1.0 M sulfuric acid, a reaction temperature of 190 °C, and a reaction time of 15 minutes, yielding a maximum HMF concentration of 4.519 mg mL$^{-1}$. These findings indicate that Tanzanian sugarcane bagasse is a promising low-cost and renewable feedstock for HMF production and highlight the importance of process optimization in maximizing product yield. The study contributes to the development of sustainable biorefinery technologies for the valorization of agro-industrial waste in Tanzania.*

***Keywords***— ***Biorefinery, Hydrolysis, Hydroxymethylfurfural (HMF), Lignocellulosic biomass, Sugarcane bagasse.***

## I. INTRODUCTION

### I.1 Background of the problem

The rapid growth of industrialization and agricultural processing activities has resulted in the generation of large quantities of solid wastes worldwide. Improper disposal and management of these wastes have become major environmental concerns due to their adverse effects on ecosystems and human health. Consequently, increasing attention has been directed toward the development of sustainable technologies that can convert industrial and agricultural wastes into value-added products. At the same time, the depletion of fossil fuel reserves and growing environmental concerns associated with petroleum-based chemical production have intensified the search for renewable and environmentally friendly feedstocks for the manufacture of industrial chemicals. In this context, lignocellulosic biomass has emerged as one of the most promising renewable resources for the production of bio-based chemicals and fuels due to its abundance, low cost, and non-food competitive nature (Hayes et al., 1999).

Among the different lignocellulosic biomass resources, sugarcane bagasse is one of the most abundant agro-

industrial residues produced during the processing of sugarcane. Following the extraction of juice, substantial quantities of bagasse are generated as a residual by-product. While some of this material is used as a fuel source for energy production within sugar mills, a significant portion remains underutilized or is disposed of through open burning, leading to the loss of a potentially valuable biomass resource. Owing to its high content of cellulose, hemicellulose, and lignin, sugarcane bagasse is considered a promising feedstock for biorefinery processes. With suitable conversion methods, it can be transformed into a variety of value-added products, including cellulose-based materials, levulinic acid, citric acid, lignin-derived chemicals, and hydroxymethylfurfural (HMF) (Allen, 2017).

Hydroxymethylfurfural is one of the most important platform chemicals that can be derived from biomass. It has attracted considerable interest due to its wide range of applications in the production of polymers, biofuel additives, pharmaceuticals, and other value-added chemicals (Fachri et al., 2015; Wang et al., 2018).

Nevertheless, the utilization of sugars and starches as raw materials poses both economic and sustainability concerns, as they directly compete with food supplies and can contribute to higher production expenses.

The conversion of sugarcane bagasse into hydroxymethylfurfural (HMF) offers a sustainable route for producing bio-based chemicals. As an abundant and low-cost agricultural by-product, bagasse does not compete with food resources or require additional farmland. Its utilization for HMF production promotes waste valorization, supports the circular bioeconomy, and helps reduce environmental impacts associated with biomass disposal and open-field burning.

Tanzania generates substantial quantities of sugarcane bagasse from its sugar industries; however, much of this biomass is either burned or inefficiently used for low-value energy generation, limiting its economic potential and contributing to environmental concerns. Despite its promise as a renewable feedstock, the lack of efficient conversion technologies has restricted its utilization for producing high-value chemicals such as hydroxymethylfurfural (HMF). Since HMF yield is strongly influenced by factors including reaction temperature, reaction time, catalyst concentration, solvent composition, and biomass loading, optimization of these parameters is essential for improving process efficiency and economic viability. Therefore, this study aims to optimize the production of HMF from Tanzanian sugarcane bagasse. The results are expected to support the development of sustainable biorefinery technologies, enhance the utilization of agro-industrial residues, reduce environmental pollution, and promote economic growth and industrial development, particularly in rural sugar-producing regions.

**1.2 Hydroxylmethyl furfural**

5-(Hydroxymethyl) furfural (5-HMF) is an organic compound formed through the dehydration of certain sugars. Structurally, the molecule contains a furan ring and includes both aldehyde and alcohol functional groups. Its IUPAC name is 5-(hydroxymethyl)-2-furaldehyde. (Ghaderi et al., 2015).

HMF, or 5-hydroxymethyl- 2-furaldehyde, is a water-soluble heterocyclic organic compound derivative from sugars. It is obtained from furan compound and has three function groups furan ring, aldehyde and alcohol. A little amounts of this compound are naturally found in fresh sugar-containing foods including animal product like milk, honey, fruit juices, spirits, and bread (Agustina et al., 2013).

***1.3 Chemistry of HMF***

Furfural, also referred to as the “sleeping beauty bio-renewable chemical,” is used as a precursor for producing various chemicals in biofuel and biochemical production as renewable materials. Due to its versatility, furfural is widely applied in the manufacture of industrial chemicals and solvents. It and its derivatives are extensively utilized in a variety of applications, including fungicides and nematicides, transportation fuels, gasoline additives, lubricants, resins, decolorizing agents, jet fuel blending components, pharmaceuticals, insect repellents, bio-plastics, and as flavor enhancers in food and beverages.(Eseyin & Steele, 2015).

The structure of HMF contains a furan ring, a primary hydroxyl group and a formyl group. The rich chemistry attributes of HMF provide possibilities of many potential transformations targeting these structural motifs. Shown in Figure two are potential downstream products that can be synthesized using HMF as starting material (Cañas et al., 2017).

Hydroxymethylfurfural (HMF) possesses a unique chemical structure that makes it an important intermediate for the synthesis of various valuable chemicals. It is a heterocyclic furan compound containing a hydroxymethyl group at the 5-position and an aldehyde group at the 2-position. This bifunctional structure allows HMF to undergo oxidation or reduction reactions, forming either dicarboxylic acids or diols, which are important precursors for industrial commodities. In addition, its furan ring enables hydrogenation processes that convert HMF into fuel-related products. Furthermore, HMF serves as a structural basis for several biologically active molecules

with pharmaceutical applications due to its heterocyclic nature. (Wang, 2014).

### 1.4 Challenge in the production of hydroxymethyl furfural from sugarcane bagasse (non-edible lignocellulosic biomasses)

Hydroxymethylfurfural (HMF) can be produced from both edible biomass and non-edible lignocellulosic materials; however, greater emphasis is placed on using non-edible sources to avoid competition with food supplies. Non-edible lignocellulosic biomass is mainly composed of cellulose (38–50%), hemicellulose (23–32%), and lignin (15–25%). Despite its availability, the direct conversion of this biomass into HMF has not yet become efficient or economically viable. Only in the past decade have studies increasingly focused on the direct transformation of lignocellulosic biomass into HMF.

According to (Mcaloon et al., 2000), Prior to producing products such as HMF from lignocellulosic biomass, the removal or pretreatment of lignocellulose can help eliminate several capital-intensive steps, including the procurement of raw materials, which ultimately leads to a reduction in overall capital costs.

Although lignocellulosic biomass has a huge reserve of bio-refineries its recalcitrant structure is set to work are the major source in biofuel production. The resilience of lignocellulosic materials is due to their composition and physicochemical matrix (Hashmi, 2016).

Lignocellulosic biomass is rich in cellulose, which makes up more than half of its composition and is commonly converted into glucose as a key intermediate for producing various chemicals. Through acid-catalyzed and catalytic processes, glucose can be transformed into a wide range of valuable products such as 5-HMF, furfural, organic acids, and other sugars (Herbst & Janiak, 2016). However, current production technologies are still associated with high costs and complex, labor-intensive processes, limiting their economic feasibility. In addition, hemicellulose-derived sugars such as D-xylose represent a significant fraction of biomass carbohydrates and must also be considered in conversion processes (Limayem & Ricke, 2012).

Although lignocellulosic biomass is abundant, low-cost, and renewable, its highly resistant structure remains a major barrier to efficient conversion. This resistance is due to its dense and complex matrix of structural components that protect plant cells and hinder chemical and microbial breakdown (Limayem & Ricke, 2012). Despite these challenges, lignocellulosic waste remains a promising raw material for producing bio-based chemicals like HMF, supporting the shift away from petroleum-based resources and promoting environmental sustainability (Herbst & Janiak, 2016). Therefore, effective pretreatment and breakdown of biomass structure are essential for its efficient conversion into fuels and value-added chemicals (Cañas et al., 2017).

Sugarcane bagasse is a lignocellulosic biomass and therefore its cell wall is composed of three elements cellulose, hemicellulose and lignin. Sugar cane bagasse is mainly composed of two polysaccharidic fractions (cellulose 43.8% and hemicelluloses 28.6%) and a polyphenolic macromolecule (lignin 23.5%) ash1.3%and other components 2.8% (Saska & Gray, 2006).

According to Howard and Hons (Howard & Hons, 2017) the sugarcane bagasse is the material available in bulk , cheap and readily available. Sugarcane bagasse can therefore, be used as raw material for the production of biofuels, and platform chemical. This in turn will increase the value of this waste from sugar industry.

Due to the structure of sugarcane bagasse, which remains after sugar extraction and is composed of hemicellulose, lignin, and cellulose, the use of chemical agents and high temperature is required to break down its complex structure. This process helps to convert sugarcane bagasse into various valuable chemicals such as HMF and other compounds derived from this agricultural waste.

## II. METHODOLOGY

### 2.1 SAMPLE COLLECTION

The sugarcane bagasse (15kg) was collected from Kilombero in Morogoro region, packed in plastic bags and then transported to the University of Dodoma.

### 2.2 Sample preparation

Sugarcane bagasse was washed thoroughly with tap water to remove adhering mud, sand, and other impurities. Approximately 25 g of bagasse was immersed in a plastic bucket filled with water and allowed to settle for 8 h. The washing process was repeated three times to ensure complete removal of surface contaminants. The cleaned bagasse was first air-dried under sunlight for 16 h and subsequently oven-dried at **50°C** for 48 h until a constant weight was attained.

The dried bagasse was ground into a fine powder and sieved to obtain a particle size of **75 µm** using standard sieves at the Geological Survey of Tanzania (GST). The prepared bagasse powder was then subjected to acid hydrolysis for the production of hydroxymethylfurfural (HMF) under different hydrolysis conditions.

The hydrolysis procedure was carried out as follows:

1. Hydrolysis: Twenty-five grams (25 g) of the prepared sugarcane bagasse powder was mixed

with 375 mL of sulphuric acid solution at the desired concentration (0.5, 1.0, or 1.5 M), corresponding to a solid-to-liquid ratio of 1:15 (w/v).

2. Reaction: The reaction mixture was transferred into a high-pressure reactor and heated at the selected reaction temperature (180, 190, or 200°C) for the predetermined reaction time (10, 15, or 20 min).
3. Filtration: At the end of the reaction, the reactor was allowed to cool to room temperature. The hydrolysate was then filtered through a muslin cloth to separate the liquid hydrolysate from the residual solid material.
4. Sample clarification: A 25 mL aliquot of the filtrate was transferred into a clean beaker, and 1.0 g of activated charcoal was added to adsorb colored compounds, humins, and other substances that could interfere with UV–Visible spectrophotometric analysis. The mixture was gently boiled for 1 min, allowed to cool to room temperature, and then filtered through Whatman No. 1 filter paper. The clarified filtrate was collected in a clean container.
5. HMF determination: An appropriate volume (approximately 2 mL) of the clarified filtrate was transferred into a quartz cuvette, and the absorbance was measured at 286 nm using a UV–Visible spectrophotometer for HMF quantification.
6. The whole process is summarized in the figure 1:

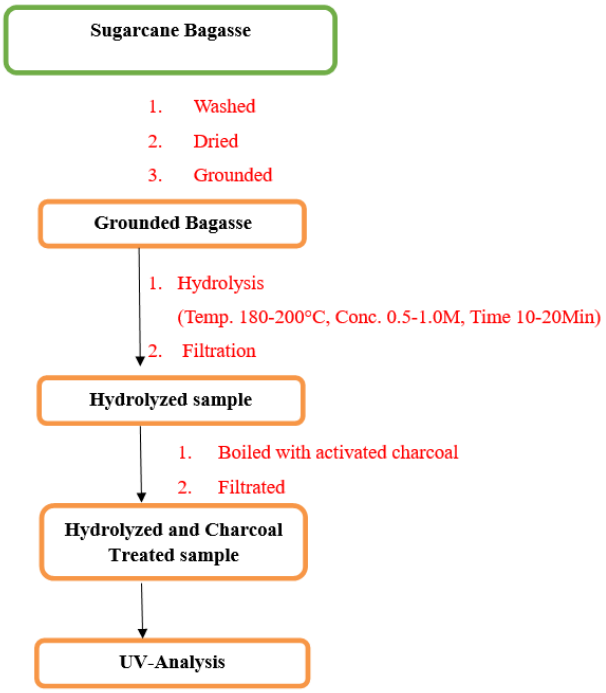


*Fig.1: Scheme of Sample Preparation and Analysis*

## III. RESULTS AND DISCUSSION

This chapter deals with the finding obtained from the experimental data from UDOM and GST together with their discussion. The optimum condition for the highest yield of HMF (mg/ml) from the hydrolysis of Tanzanian sugarcane bagasse using different concentrations of sulphuric acid, reaction time, and temperature is also discussed.

### 3.1 Optimization of the reaction's conditions on the yield of HMF

To determine the concentration of HMF in the hydrolysate a standard calibration graph is plotted using known concentration of standard HMF shown in fig **2** below:

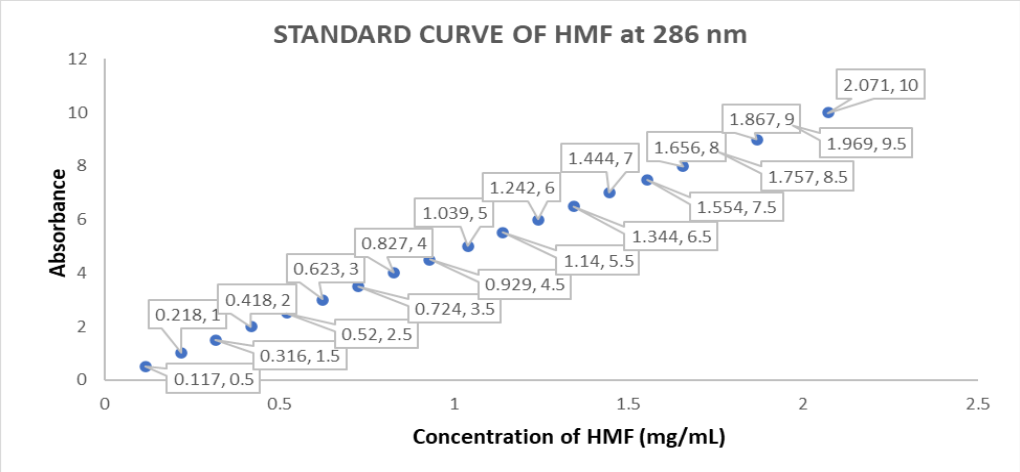


*Fig.2: Calibration graph for standard HMF at 286nm*

From the standard calibration graph the linear fit equation was used to calculate the yield at the HMF at a given Absorbance.

EQUATION

Y=0.202X +O. O34 "Equation 1"

But X=Y-0.034/0.202 "Equation 2"

Where

Y=A (absorbance)

X=concentration of HMF produced in (mg/ml).

**3.2 The effect of the reaction temperature on the yield of HMF**

This section examines how reaction temperature influences the yield of HMF from sugarcane bagasse. Along with sulphuric acid concentration and reaction time, temperature is a key factor affecting HMF production. It plays a crucial role in the conversion of cellulose from biomass into HMF during hydrolysis. In this study, sugarcane bagasse was hydrolyzed at temperatures ranging from 180°C to 200°C using different sulphuric acid concentrations and reaction times. As shown in Table 1 and Figures 3–5, the highest HMF yield was achieved at 190°C when the bagasse was treated with 1 M sulphuric acid for 15 minutes. The detailed results are presented in Table 1.

*Table 1: Effect of temperature on the yield of HMF*

| S.NO. | SAMPLE No. | TEMP (°C) | ABS 10 min | YIELD OF HMF (mg/ml) 10MIN | ABS 15 min | YIELD OF HMF (mg/ml) 15MIN | ABS 20 min | YIELD OF HMF (mg/ml) 20MIN |
|---|---|---|---|---|---|---|---|---|
| **$H_2SO_4$ [0.5]** | | | | | | | | |
| 1 | 01 | 180 | 0.531 | 2.460 | 0.538 | 2.495 | 0.243 | 1.035 |
| 2 | 02 | 190 | 0.653 | 3.089 | 0.672 | 3.158 | 0.553 | 2.529 |
| 3 | 03 | 200 | 0.432 | 1.970 | 0.602 | 2.812 | 0.113 | 0.391 |
| **$H_2SO_4$ [1.0]** | | | | | | | | |
| 4 | 02 | 180 | 0.558 | 2.594 | 0.680 | 3.198 | 0.300 | 1.317 |
| 5 | 02 | 190 | 0.781 | 3.698 | 0.947 | 4.519 | 0.692 | 3.257 |
| 6 | 02 | 200 | 0.481 | 2.213 | 0.938 | 4.475 | 0.330 | 1.465 |
| **$H_2SO_4$ [1.5]** | | | | | | | | |
| 7 | 03 | 180 | 0.176 | 0.703 | 0.342 | 1.525 | 0.162 | 0.634 |
| 8 | 03 | 190 | 0.211 | 0.905 | 0.362 | 1.624 | 0.210 | 0.871 |
| 9 | 03 | 200 | 0.164 | 0.644 | 0.172 | 0.683 | 0.069 | 0.173 |

From the graph, it is evident that the concentration of HMF increases as the reaction temperature rises from 180°C to 190°C, but decreases when the temperature exceeds 190°C. The reduction in HMF concentration between 190°C and 200°C may be attributed to the formation of char and humins during the reaction. When hydrolysis was performed using 0.5 M sulphuric acid for 10 minutes, the HMF yields were 2.460 mg/mL, 3.089 mg/mL, and 1.970 mg/mL at 180°C, 190°C, and 200°C, respectively. Increasing the reaction time to 15 minutes resulted in HMF yields of 2.495 mg/mL, 3.158 mg/mL, and 2.812 mg/mL at 180°C, 190°C, and 200°C, respectively. However, the HMF yield declined when the reaction time was extended to 20 minutes. It was also observed that HMF yield decreased at 200°C under all reaction conditions tested. This decline may be due to the conversion of HMF into by-products such as char, humins, levulinic acid, and formic acid.

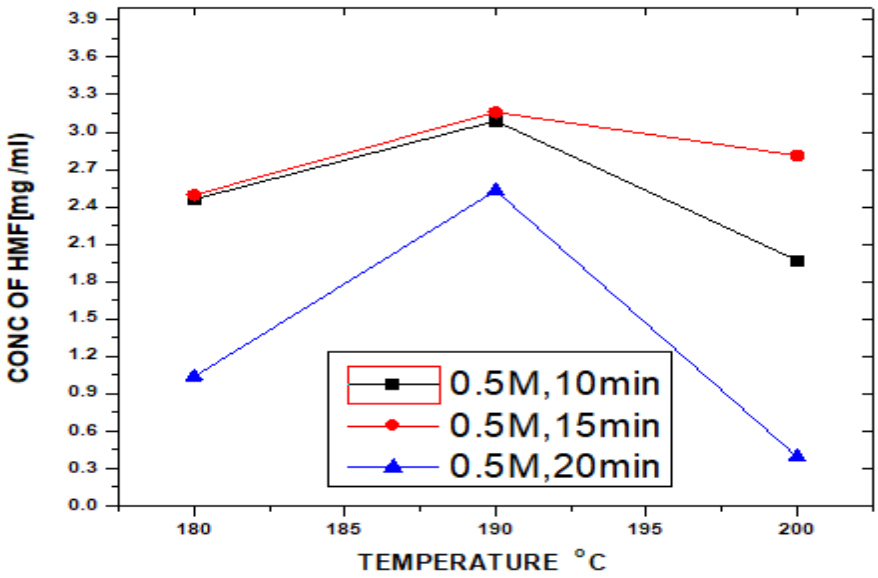


*Fig.3: Effect of temperature on the yield of HMF using 0.5M $H_2SO_4$ at different reaction time*

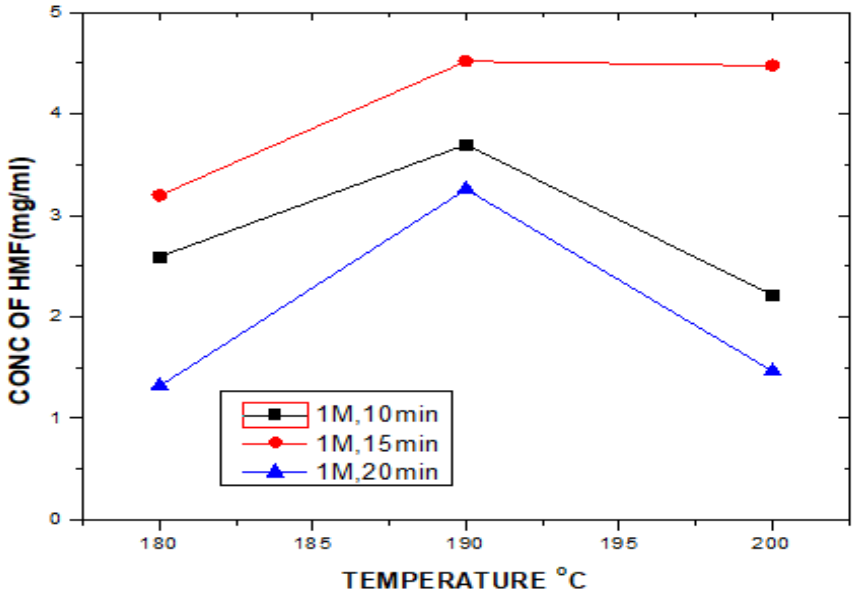


*Fig.4: Effect of temperature on the yield of HMF using 1.0M $H_2SO_4$ at different reaction time*

From the graph, it can be observed that the concentration of HMF increases as the reaction temperature rises from 180°C to 190°C, but decreases when the temperature exceeds 190°C. The reduction in HMF concentration between 190°C and 200°C may be attributed to the formation of char and humins during the reaction process. When hydrolysis was carried out using 1 M sulphuric acid for 10 minutes, the HMF yields obtained were 2.594 mg/mL, 3.698 mg/mL, and 2.213 mg/mL at 180°C, 190°C, and 200°C, respectively. Increasing the reaction time to 15 minutes resulted in higher HMF yields of 3.198 mg/mL, 4.519 mg/mL, and 4.475 mg/mL at 180°C, 190°C, and 200°C, respectively. However, the HMF yield decreased when the reaction time was extended to 20 minutes. It was also noted that HMF yield declined at 200°C across all reaction conditions tested.

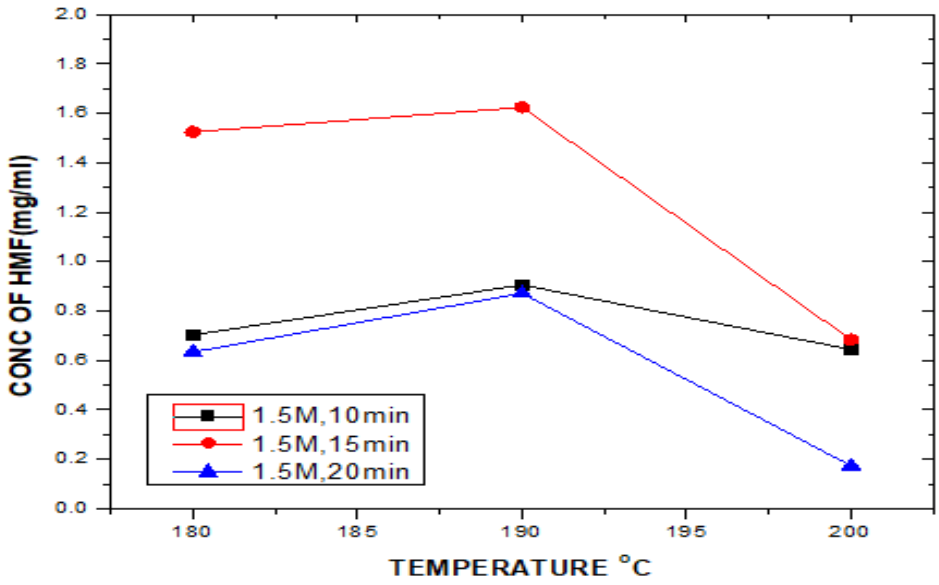


*Fig.5: Effect of temperature on the yield of HMF using 1.5M $H_2SO_4$ at different reaction time*

HMF yield increased with temperature from 180°C to 190°C and reached its maximum at 190°C. At temperatures above 190°C, the yield declined, likely because of the formation of degradation products. The highest yield for the 1.5 M sulphuric acid treatment was obtained at 190°C and 15 minutes (1.624 mg/mL), while longer reaction times and higher temperatures reduced HMF production.

3.3 The effect of concentration of hydrolyzing acid on the yield of HMF

To see the effect of concentration of the acid on the yield of HMF, the bagasse was hydrolyzed with different concentration of acid ranging from 0.5M to 1.5M at $180^0$C, $190^0$C and $200^0$C for 10, 15 and 20min respectively. The results of these investigations are shown in (Table **2** and Fig **6-8** below)

*Table 2: Effect of concentration on the yield of HMF*

| S.NO | SAMPLE No. | CONC.(M) | ABS FOR 10MIN | YIELD OF HMF (mg/ml) 10MIN | ABS FOR 15MIN | YIELD OF HMF (mg/ml) 15MIN | ABS FOR 20MIN | YIELD OF HMF (mg/ml) 20MIN |
|---|---|---|---|---|---|---|---|---|
| Temperature $180^0$C | | | | | | | | |
| **1** | **01** | **0.5** | **0.531** | **2.460** | **0.538** | **2.495** | **0.243** | **1.035** |
| **2** | **02** | **1** | **0.558** | **2.594** | **0.680** | **3.198** | **0.30** | **1.317** |
| **3** | **03** | **1.5** | **0.176** | **0.703** | **0.342** | **1.525** | **0.162** | **0.634** |
| Temperature $190^0$C | | | | | | | | |
| **4** | **04** | **0.5** | **0.658** | **3.089** | **0.672** | **3.158** | **0.553** | **2.529** |
| **5** | **05** | **1** | **0.781** | **3.689** | **0.947** | **4.519** | **0.692** | **3.257** |
| **6** | **06** | **1.5** | **0.211** | **0.905** | **0.362** | **1.624** | **0.210** | **0.871** |
| Temperature $200^0$C | | | | | | | | |
| **7** | **07** | **0.5** | **0.432** | **1.970** | **0.602** | **2.812** | **0.113** | **0.391** |
| **8** | **08** | **1** | **0.481** | **2.213** | **0.938** | **4.475** | **0.330** | **1.465** |
| **9** | **09** | **1.5** | **0.164** | **0.644** | **0.172** | **0.683** | **0.069** | **0.173** |

HMF production improved when the sulphuric acid concentration increased from 0.5 M to 1.0 M but decreased at 1.5 M. The lower yield at higher acid concentration is likely due to the formation of degradation products, including humins and char.

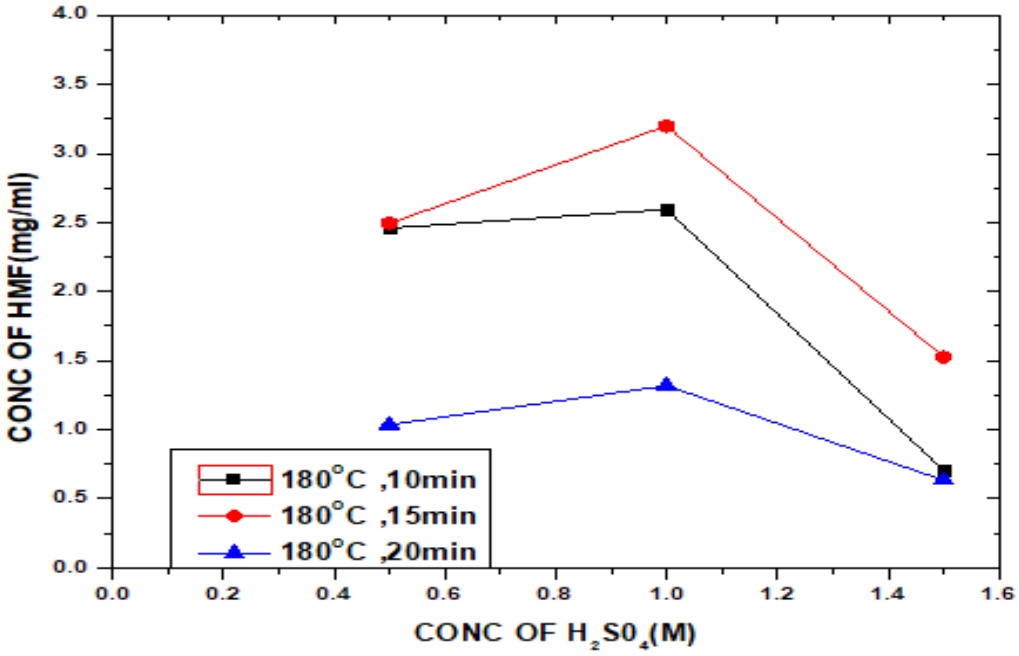


*Fig.6: Effect of concentration on the yield of HMF at 180°C for different reaction time*

As shown in fig 6, the yield of HMF increased as the concentration of the hydrolyzing acid was raised from 0.5 M to 1.0 M while keeping the other reaction parameters constant. However, a decrease in HMF yield was observed when the sulphuric acid concentration was further increased to 1.5 M. The improvement in HMF production at moderate acid concentrations can be attributed to enhanced reaction kinetics, which promote the conversion process. At the optimum sulphuric acid concentration, the frequency of effective molecular collisions increases, favoring HMF formation.

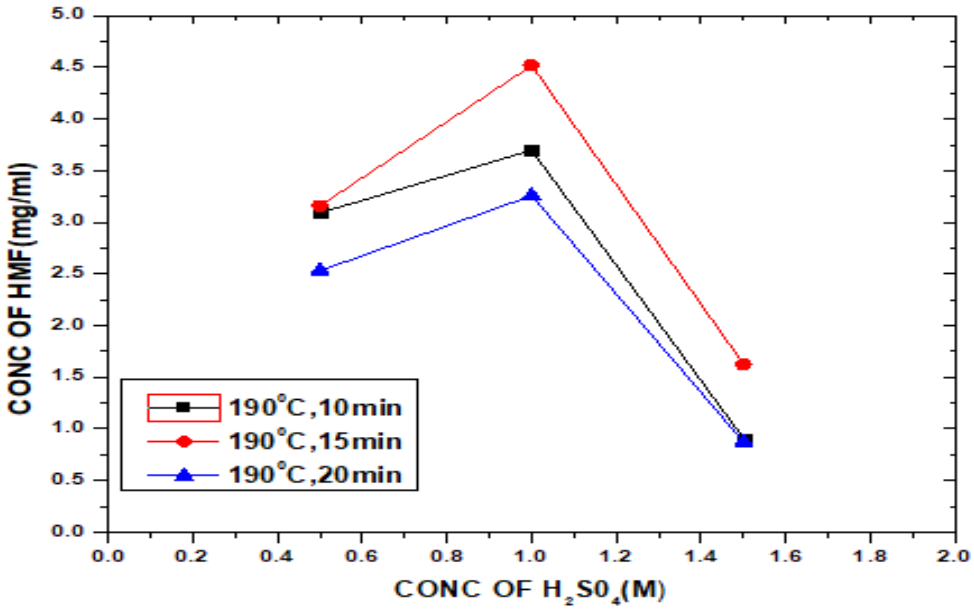


*Fig.7: Effect of concentration on the yield of HMF at 190$^0$C for different reaction time*

Fig 7 shows that the yield of HMF increased as the concentration of the hydrolyzing acid was raised from 0.5 M to 1.0 M while all other reaction conditions remained constant. However, when the sulphuric acid concentration was further increased to 1.5 M, the HMF yield declined. The increase in HMF production at moderate acid concentrations can be attributed to improved reaction kinetics, which enhance the conversion process. At the optimum sulphuric acid concentration, the frequency of effective molecular collisions increases, promoting the formation of HMF. In contrast, concentrations above the optimum level led to the degradation of HMF into by-products such as levulinic acid, formic acid, char, and humins, resulting in a lower yield.

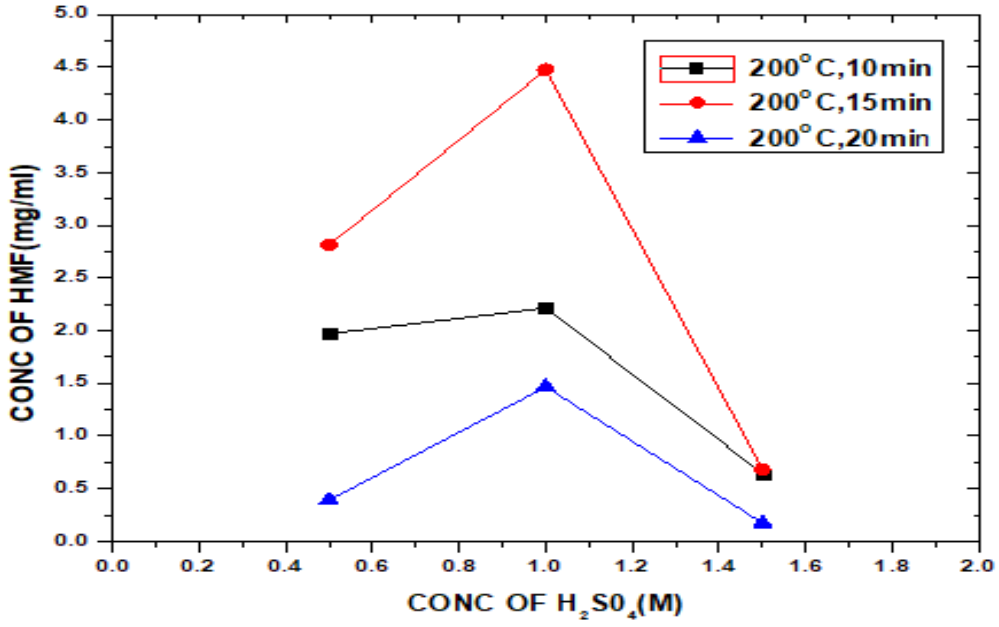


*Fig.8: Effect of concentration on the yield of HMF at 200$^0$C for different reaction time*

Fig 8 illustrates that the yield of HMF increased as the concentration of the hydrolyzing acid was increased from 0.5 M to 1.0 M while the other reaction parameters were kept constant. However, a further increase in sulphuric acid concentration to 1.5 M resulted in a reduction in HMF yield. The improvement in HMF production at moderate acid concentrations can be attributed to enhanced reaction kinetics, which facilitate the conversion process. At the optimum acid concentration, the frequency of effective collisions between reacting molecules increases, promoting the formation of HMF. Conversely, acid concentrations above the optimum level encourage the degradation of HMF into by-products such as levulinic acid, formic acid, char, and humins, leading to a decrease in yield.

### 3.4 The effect of reaction time on the yield of HMF

Reaction time is another important factor that affects the yield of HMF. The bagasse was hydrolyzed for 10, 15 and 20min with sulphuric acid of concentration ranging from 0.5M to 1.5M at 180$^0$C, 190$^0$C and 200$^0$C respectively. The results of this investigation are shown in Table **3** below.

*Table 3: Effect of reaction time on the yield of HMF*

| S.NO. | SAMPLE NO. | TIME (Min) | ABS using 0.5 M $H_2S0_4$ | YIELD OF HMF (mg/ml) $H_2S0_4$ 0.5M | ABS using 1.0 M $H_2S0_4$ | YIELD OF HMF (mg/ml) $H_2S0_4$ 1.0M | ABS using 1.5 M $H_2S0_4$ | YIELD OF HMF (mg/ml) $H_2S0_4$ 1.5M |
|---|---|---|---|---|---|---|---|---|
| **180$^0$C** | | | | | | | | |
| 1 | 01 | 10 | 0.531 | 2.460 | 0.538 | 2.495 | 0.176 | 0.703 |
| 2 | 02 | 15 | 0.558 | 2.594 | 0.680 | 3.198 | 0.342 | 1.525 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 3 | 03 | 20 | 0.243 | 1.035 | 0.300 | 1.317 | 0.162 | 0.634 |
| **190$^0$C** | | | | | | | | |
| 4 | 04 | 10 | 0.658 | 3.089 | 0.781 | 3.698 | 0.211 | 0.905 |
| 5 | 05 | 15 | 0.672 | 3.158 | 0.947 | 4.519 | 0.362 | 1.624 |
| 6 | 06 | 20 | 0.553 | 2.529 | 0.692 | 3.257 | 0.210 | 0.871 |
| **200$^0$C** | | | | | | | | |
| 7 | 07 | 10 | 0.432 | 1.970 | 0.481 | 2.213 | 0.164 | 0.644 |
| 8 | 08 | 15 | 0.602 | 2.812 | 0.938 | 4.475 | 0.172 | 0.683 |
| 9 | 09 | 20 | 0.113 | 0.391 | 0.330 | 1.465 | 0.069 | 0.173 |

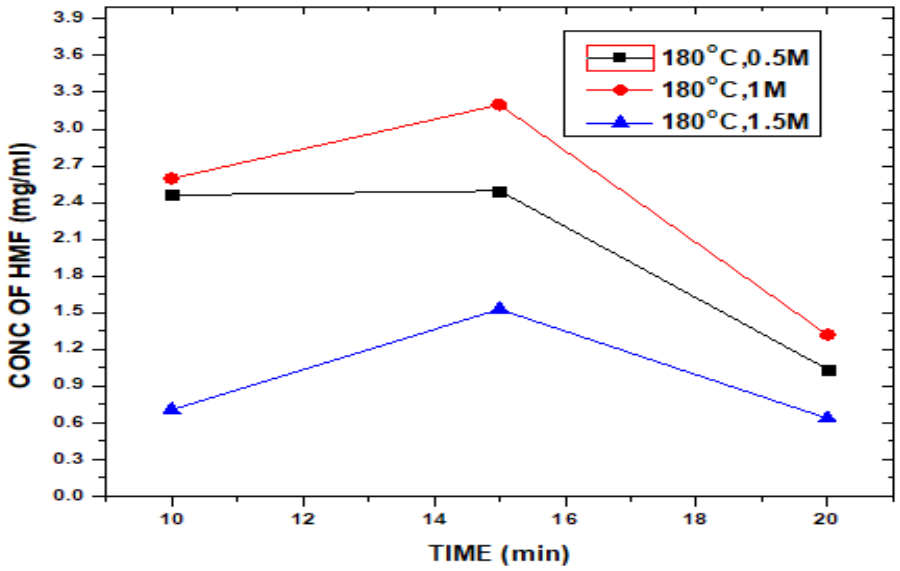


*Fig.9: Effect of reaction time on the yield of HMF at 180$^0$C using different sulphuric acid*

Fig 9 shows that the yield of HMF increased as the reaction time was extended. However, when the hydrolysis of bagasse was carried out for 20 minutes while keeping the other reaction parameters constant, a decline in HMF yield was observed. The reduced yield at longer reaction times may be attributed to the formation of by-products. Prolonged reaction duration promotes the conversion of HMF into compounds such as levulinic acid, char, and humins, thereby reducing the amount of HMF produced.

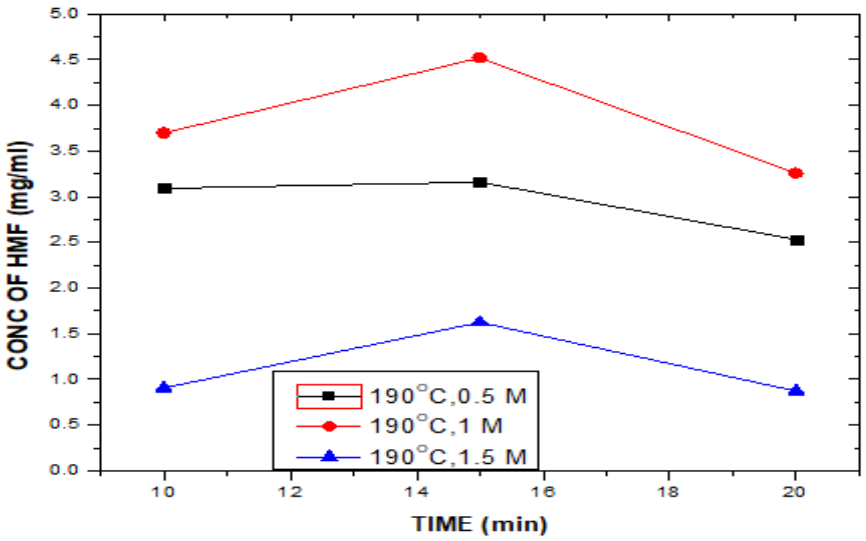


*Fig.10: Effect of reaction time on the yield of HMF at 190$^0$C using different sulphuric acid*

Fig 10 shows that the yield of HMF increases with an increase in reaction time. However, a decrease in HMF yield is observed when the hydrolysis of bagasse is extended to 20 minutes while the other parameters remain constant. The reduced yield at longer reaction times may be due to the formation of by-products. Prolonged reaction conditions promote the conversion of HMF into compounds such as levulinic acid, char, and humins, which leads to a decline in overall HMF production.

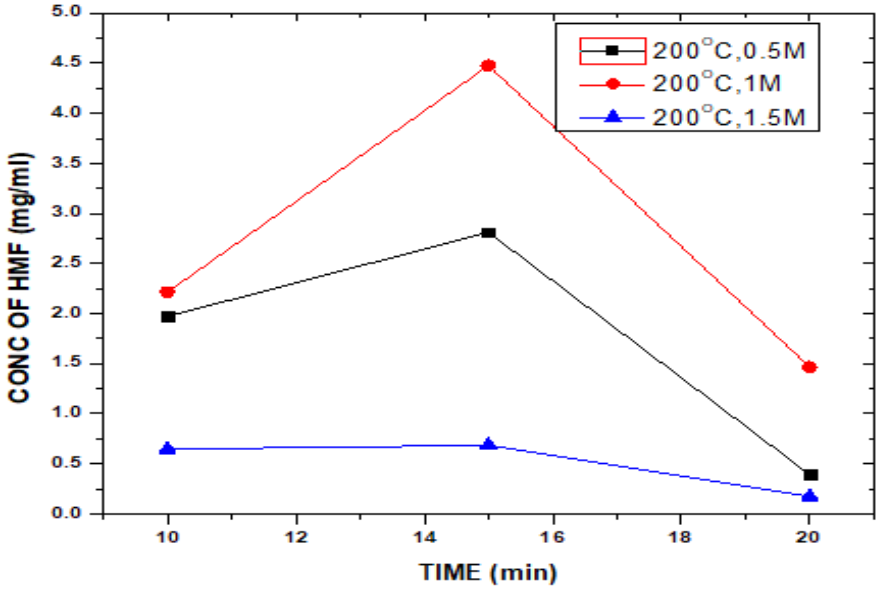


*Fig.11: Effect of reaction time on the yield of HMF at 200$^0$C using different sulphuric acid*

Fig 11 shows that the yield of HMF increases as the reaction time is extended. However, a reduction in HMF yield is observed when the hydrolysis of bagasse is carried out for 20 minutes while keeping the other conditions constant. The lower yield at longer reaction times may be attributed to the formation of by-products. Extended reaction time promotes the conversion of HMF into compounds such as levulinic acid, char, and humins, which results in decreased HMF production.

## IV. CONCLUSION

Sugarcane bagasse was hydrolyzed in a non-stirred pressure reactor designed at SIDO Dodoma and developed

in this study. The experiments were carried out using different operating conditions, including sulphuric acid concentrations (0.5 M, 1.0 M, and 1.5 M), reaction times (10, 15, and 20 minutes), and temperatures (180°C, 190°C, and 200°C).

The results demonstrated that the production of HMF is strongly influenced by the combined effect of these process parameters. The optimum conditions for HMF production from Tanzanian sugarcane bagasse were found to be 1.0 M sulphuric acid at 190°C for 15 minutes. Under these conditions, the maximum HMF yield obtained was 4.519 mg/mL.

Overall trends showed that increasing reaction time initially enhanced HMF formation; however, excessive reaction time led to a decline in yield, likely due to the degradation of HMF into secondary products. A similar pattern was observed with temperature, where HMF yield increased from 180°C to 190°C, but decreased at 200°C, suggesting thermal degradation at higher temperatures.

The concentration of sulphuric acid also played a significant role. Increasing acid concentration from 0.5 M to 1.0 M improved HMF yield, likely due to enhanced hydrolysis efficiency and improved conversion of cellulose-derived intermediates. However, further increase to 1.5 M resulted in reduced yields, which may be associated with the accelerated formation of by-products.

These findings indicate that the yield of HMF is governed not by a single parameter, but by the interactive effects of temperature, reaction time, and acid concentration. An optimum balance among these variables is essential to maximize HMF production, while avoiding excessive degradation into undesired compounds. The study highlights the importance of carefully controlled reaction conditions in biomass valorization processes for efficient conversion of sugarcane bagasse into valuable platform chemicals such as HMF.

## REFERENCES

[1] Agustina, D., Kumagai, S., Nonaka, M., & Sasaki, K. (2013). Production of 5-hydroxymethyl Furfural from Sugarcane BagasseUnder Hot Compressed Water. *Procedia Earth and Planetary Science*, *6*, 441–447. https://doi.org/10.1016/j.proeps.2013.01.058

[2] Allen, M. C. (2017). *Creating Renewable Tunable Polymers from Hydroxymethylfurfural*. http://digitalcommons.library.umaine.edu/etdhttp://digitalcommons.library.umaine.edu/etd/2751

[4] Cañas, M., García-Martín, N., & Pinedo, R. (2017). ¿Qué concepciones tienen sobre el pensamiento los docentes en formación? *Avances En Ciencias de La Educación y Del Desarrollo, 2017*, *1*, 888–894. https://doi.org/10.16309/j.cnki.issn.1007-1776.2003.03.004

[5] Eseyin, A. E., & Steele, P. H. (2015). An overview of the applications of furfural and its derivatives. *International Journal of Advanced Chemistry*, *3*(2), 42. https://doi.org/10.14419/ijac.v3i2.5048

[6] Ghaderi, F., Shadbad, M. R. S., & Hoseinzadeh, M. (2015). Effect of pH and storage temperature on 5-(Hydroxymethyl) furfural (5HMF) formation in USP syrup preparation. *Pharmaceutical Sciences*, *21*(1), 1–5. https://doi.org/10.15171/PS.2015.09

[7] Hashmi, M. (2016). Enhanced Production of Biofuel from Sugar Industry Waste By Muzna Hashmi PhD Thesis Department of Microbiology Enhanced Production of Biofuel from Sugar Industry Waste. *Quaid-i-Azam University Islamabad, Pakistan*.

[8] Hayes, D. J., Ross, P. J., Hayes, P. M. H. B., & Fitzpatrick, P. S. (1999). *The Biofine Process : Production of Levulinic Acid , Furfural and Formic Acid from Lignocellulosic Feedstocks*.

[9] Herbst, A., & Janiak, C. (2016). levulinic acid with MIL-101Cr MOF-derivatives †. *New Journal of Chemistry*, *40*, 7958–7967. https://doi.org/10.1039/C6NJ01399F

[10] Howard, J. M., & Hons, B. (2017). queensland university of catalytic conversion of sugar manufacturing by - products to 5- ( c hloromethyl ) furfural and 5-.

[11] Limayem, A., & Ricke, S. C. (2012). Lignocellulosic biomass for bioethanol production : Current perspectives , potential issues and future prospects. *Progress in Energy and Combustion Science*, *38*(4), 449–467. https://doi.org/10.1016/j.pecs.2012.03.002

[12] Mcaloon, A., Taylor, F., Yee, W., Regional, E., Ibsen, K., Wooley, R., & Biotechnology, N. (2000). Determining the Cost of Producing Ethanol from Corn Starch and Lignocellulosic Feedstocks Determining the Cost of Producing Ethanol from Corn Starch and Lignocellulosic. *National Renewable Energy Laboratory U.S. Department of Agriculture*, *October*.

[13] Saska, M., & Gray, M. (2006). Pre-treatment of sugarcane leaves and bagasse pith with lime-impregnation and steam explosion for enzymatic conversion to fermentable sugars. Michael. *Louisiana State University Agricultural Center, St. Gabriel, LA 70776.*, *70776*, 1–13.

[14] Türköz Acar, E., Helvacioğlu, S., Charehsaz, M., & Aydin, A. (2018). Determination and safety evaluation of furfural and hydroxymethylfurfural in some honey samples by using a validated hplc-dad method. *Marmara Pharmaceutical Journal*, *22*(4), 519–527. https://doi.org/10.12991/jrp.2018.93

[15] Wang, T. (2014). Catalytic conversion of glucose to 5-hydroxymethylfurfural as a potential biorenewable platform chemical. *Iowa State University Capstones, Theses and Dissertations*, 210. https://doi.org/10.1063/1.2399752

[16] Wu, H., Chen, R., Du, H., Zhang, J., Shi, L., Qin, Y., Yue, L., & Wang, J. (2019). Synthesis of activated carbon from peanut shell as dye adsorbents for wastewater treatment. *Adsorption Science and Technology*, *37*(1–2), 34–48. https://doi.org/10.1177/0263617418807856