

# The chemistry and technology of furfural and its Full PDF

The Chemistry and Technology of Furfural and its Many By-Products Some Reactions of Furfural and Furan Furfural Manufacturing Guide Conversion and Assimilation of Furfural and 5-(hydroxymethyl)furfural by *Pseudomonas Putida* KT2440 The Formation of Furfural and Hydroxymethylfurfural in Model Solutions and Port-style Wines Furfural and Its Derivatives ... The Vapor Phase Catalytic Reduction of Furfural and of Furfuryl Alcohol The Application of Furfural and Its Derivatives to the Manufacture of Plastics Furfural (furfuraldehyde) and Some of Its Derivatives Some Derivatives of Furfural and Their Antiseptic Actions The Catalytic Reduction of Furfural and Derivatives Furoylation of Cellulose The Catalytic Reduction of Furfural and Derivates Condensation Reactions of Furfural and Its Derivatives ... Studies of Brønsted/Lewis Acid-Catalyzed Dehydration of Xylose to Furfural and Simultaneous Separation of Furfural by Pervaporation Furfural and Hydrogen Production from Raw Biomass Integrating Chemical and Electrochemical Methods Identification of Furfural and Other Members of the Same Series in Dark Apricots The Catalytic Reduction of Furfural and Derivatives The Antiseptic Action of Furfural and Some Derivatives of Furfural Against *Bacillus Typhosus* and *Staphylococcus Aureus* Researches on the Simultaneous Production of Furfural and High Alpha Pulp from Hard Wood The Chemistry and Technology of Furfural Production in Modern Lignocellulose-feedstock Biorefineries Synthesis of Furfural and Solketal Methacrylate Derivatives and Their Use as Monomers for the Production of New Bio-based Sustainable Polymers and Polymer Composites The Estimation of Pentoses and Pentosans Aspen Simulation of Furfural and Hydroxymethylfurfural Production from Biomass Production of Furfural and an Activated Char from Bagasse ... Preparation of Furfural and Oxalic Acid from Cottonseed Hulls The Free Energy of Furfural and Some of Its Derivatives ... Furfural Rational Design of Bifunctional Catalysts for the Conversion of Furfural Into Chemicals of Industrial Interest Selected Properties of 2-furaldehyde Bulletin Interaction of Furfural and Thiocarbamide The Condensation of Furfural and Urea New Compounds of Furfural Method for Manufacture and Concentration of Furfural Furfural and Some of Its Derivatives ... Furfural Furfural and Some of Its Derivatives ... The Estimation of Pentoses and Pentosans

**The Chemistry and Technology of Furfural and its Many By-Products** 2000-02-09 this book is a world first since the furfural industry has been traditionally secretive to the point of appearing shrouded in clouds of mystery even renowned encyclopedic works have published but scant and often erroneous information on the subject striking a healthy balance between theory and practice the book leads the reader from reaction mechanisms and kinetics to the technology of making furfural by various old and new processes using conventional raw materials or sulfite waste liquor detailed discussions of means of increasing the yield are of great chemical and technological interest as well as of immense economic importance from furfural proper the treatise shifts to the fascinating field of wanted and unwanted by products ranging from largely unutilized carboxylic acids to troublesome impurities such as 5 methyl furfural and 2 furyl methyl ketone and then to extremely valuable serendipitous flavor compounds such as diacetyl and 2 3 pentanedione a wide variety of derivatives are discussed considerable space is devoted to polytetrahydrofuran an important building block of stretchable synthetic fibers while furan resins from both furfural and furfuryl alcohol are given the attention commensurate with their industrial importance notable supplementary chapters cover the in line measurement of furfural the treatment of furfural waste water and various aspects of corrosion a chapter on the applications of furfural elaborates not only traditional uses in extracting petroleum and vegetable oils but also the sensational discovery that furfural is a highly effective indirect nematocide without becoming toxic it changes the microflora of the soil by stimulating bacteria antagonistic to nematodes thereby reducing the nematode population to zero at an unprecedented low price it is believed that this application will be the principal outlet for furfural in the future a comprehensive list of physical properties some never published before make the book an indispensable companion for producers users and researchers alike

*Some Reactions of Furfural and Furan* 1930 there is a wide consensus that furfural a renewable commodity currently obtained from lignocellulosic agro residues with a production volume of around 300 kton per year is a key feedstock for leveraging lignocellulosic residues in future biorefineries several chemicals are already being manufactured from furfural due to its advantageous production cost furthermore a vast number of others are also technically viable to produce from oil this book compiles the vast existing information into relevant stages of transformations of furfural as renewable chemicals biofuels and bioresins focusing on the relevant chemical and engineering aspects of processes to obtain them including reactors and catalysis it offers essential information for improving the economic and environmental viability of current commercial applications and upcoming future applications it should be of particular interests to graduate and advanced undergraduate students as well as engineers and academic researchers alike who are working in the field

Furfural 2018-06-18 the sugar dehydration products furfural and 5 hydroxymethyl furfural hmf are commonly formed during high temperature processing of lignocellulose most often in thermochemical pretreatment liquefaction or pyrolysis typically these two aldehydes are considered major inhibitors in microbial conversion processes many microbes can convert these compounds to their less toxic dead end alcohol counterparts furfuryl alcohol and 5 hydroxymethyl furfuryl alcohol recently the genes responsible for aerobic catabolism of furfural and hmf were discovered in *Cupriavidus basilensis* hmf14 to enable complete conversion of these compounds to the tca cycle intermediate 2 oxo glutarate in this work we engineer the robust soil microbe *Pseudomonas putida* kt2440 to utilize furfural and hmf as sole carbon and energy sources via complete genomic integration of the 12 kb hmf gene cluster previously reported from *Burkholderia phytofirmans* the common intermediate 2 furoic acid is shown to be a bottleneck for both furfural and hmf metabolism when cultured on biomass hydrolysate containing representative amounts of furfural and hmf from dilute acid pretreatment the engineered strain outperforms the wild type microbe in terms of reduced lag time and enhanced growth rates due to catabolism of furfural and hmf overall this study demonstrates that an approach for biological conversion of furfural and hmf relative to the typical production of dead end alcohols enables both enhanced carbon conversion and substantially improves tolerance to hydrolysate inhibitors furthermore

this approach should find general utility both in emerging aerobic processes for the production of fuels and chemicals from biomass derived sugars and in the biological conversion of high temperature biomass streams from liquefaction or pyrolysis where furfural and hmf are much more abundant than in biomass hydrolysates from pretreatment

**Manufacturing Guide** 1974 in the spring of 1919 the eastman kodak laboratories suggested to the chemistry department of the missouri school of mines and metallurgy that experiments on small scale production of furfural be undertaken after a series of experiments a small amount of this product was made and a report was given before the american chemical society at st louis in april 1920 the furfural prepared at the missouri school of mines and metallurgy was sold to the eastman kodak laboratories within recent years very little experimental work has been done on furfural it commands a high price as only small amounts are found on the market the object of this work is to prepare a few compounds of furfural and to study their commercial possibilities introduction leaf 3

**Conversion and Assimilation of Furfural and 5-(hydroxymethyl)furfural by Pseudomonas Putida KT2440** 2017 a major component of lignocellulosic biomass is hemicellulose a polysaccharide composed of monomeric sugars principally xylose xylose can be dehydrated most often in aqueous solution using brønsted acid catalysts to form furfural which can be further reacted to produce fuels lubricants polymers solvents and pharmaceutical precursors furfural production can also be enhanced by using lewis acid catalysts which promote the formation of xylulose an isomer of xylose which more readily dehydrates to form furfural with either type of catalyst side reactions consume furfural to produce a group of soluble and insoluble products known as humins humins formation has been stymied by extracting furfural as it is produced this is done on the industrial scale with steam stripping but researchers have also explored the use of liquid liquid extraction lle by an organic solvent typically 2 1 organic aqueous volume ratio for the same purpose both extraction methods increase furfural yield but dilute the product phase which raises the cost of furfural production a new method e g pervaporation must be developed to increase furfural yield and concentrate furfural in the product simultaneously pervaporation is a membrane based process in which a liquid mixture is placed in contact with the feed side of the membrane while a vapor is located on the permeate side a vacuum is used to reduce the partial pressure and therefore the fugacity of components in the permeate which provides the driving force for mass transfer pervaporation is most often used to separate water from concentrated ethanol solutions but may also be used to remove organics selectively e g furfural from aqueous solutions membranes used for such applications are typically made of polydimethylsiloxane pdms but researchers have also used the pdms containing triblock copolymer poly styrene block dimethylsiloxane block styrene sds pervaporation with a furfural selective membrane may be used to extract furfural as it is produced and concentrate it rather than dilute it as steam stripping and lle do the objective of this investigation was to assess pervaporation as a method to extract furfural during its production this was done by designing and constructing membrane reactors comparing them to lle assisted reactors through experiments and simulations and studying how lewis acid catalysts can improve reaction and pervaporation compatibility and lead to the formation of novel products the feasibility of pervaporation as a means for in situ furfural extraction was studied in comparison to lle and a reaction without extraction during batch mode furfural production both lle and pervaporation with a commercial pdms membrane were found to improve furfural yield over the reaction without extraction but pervaporation with pdms yielded a product phase that was 6 6x as concentrated as that obtained with lle additionally switching the pdms membrane with an sds membrane resulted in similar furfural yields but the product with sds was 10x as concentrated as the lle product furthermore the amount of furfural extracted was qualitatively different for lle and pervaporation assisted reactions lle was limited to 85 the equilibrium distribution of furfural among the organic and aqueous whereas the amount of furfural extracted by pervaporation increased monotonically over time reaching as high as 67 during experiments the reaction pervaporation system was simulated in order to identify the full extent of the benefits of

reaction with pervaporation in the simulations water lost from the reactor due to removal by pervaporation was replenished at the equivalent rate the simulations revealed that as the reaction approached complete xylose conversion both the pdms and sds membranes led to product concentrations greater than was possible with lle while extracting nearly all 98 of the furfural formed ultimately pervaporation with the sds membrane could produce a product phase with 33 greater furfural yield than that achievable by lle the membrane reactor design was revised to permit continuous pervaporation assisted reaction in both batch and continuous mode operation with both reaction and pervaporation occurring at the same temperature batch mode reactions were fed water while continuous mode reactions were fed an aqueous xylose solution the reactions took place at a relatively low temperature of 90 c catalyzed by chromium iii chloride crcl<sub>3</sub> which contributed both brønsted and lewis acidity batch mode reactions with varying rates of pervaporation revealed that furfural extraction had no effect on furfural yield under these conditions but a moderate pervaporation rate did lead to an order of magnitude increase in furfural concentration relative to that obtained without pervaporation pervaporation was also found to retain all of the crcl<sub>3</sub> inside the reactor demonstrating a simple way to separate product from homogeneous catalyst this enabled continuous furfural production with only an initial charge of catalyst in which an aqueous xylose solution was fed to the reactor while a furfural water vapor was permeated from the reactor the furfural permeability of the sds membrane decreased over time during the course of reactions carried out at 90 c due likely to interactions of soluble humins with the membrane experiments with the cross linked pdms membrane demonstrated that cross linking of the membrane can inhibit this behavior and result in a much more stable furfural permeability additionally cross linking could lead to greater membrane thermal stability permitting the pervaporation assisted reaction at higher temperatures which would benefit the chemistry by allowing extraction to have an impact on furfural yield pervaporation assisted furfural production with crcl<sub>3</sub> and sulfuric acid at 130 c was then simulated reaction rate constants were measured at this temperature but in the absence of pervaporation pervaporation data collected at lower temperatures were extrapolated to represent a hypothetical membrane that could operate at 130 c simulations of batch mode reactions demonstrated that increasing the membrane area to reactor volume ratio would lead to higher furfural yield and more furfural extracted but also reduce the permeate furfural concentration demonstrating a tradeoff between furfural production and concentration simulations of continuous mode reactions showed that furfural concentration and selectivity were maximized at an intermediate value of a 0.17 cm<sup>1</sup> conversely furfural production rate increased nearly linearly with a indicating that the optimal value of a depends on process economics and not just technical considerations the lewis acidity of crcl<sub>3</sub> was beneficial for reducing reaction temperature within the membrane stability limits but lewis acids such as the sn containing zeolite sn bea have been shown to convert sugars i e xylose and glucose at a rate greater than the rate of formation of identified products suggesting that additional unidentified products are formed through extensive analytical chemistry these products were determined to be hydroxyl rich carboxylic acids and furanone esters that form by structural isomerization of the sugars followed by dehydration and constitute as much as 45 of the yield these side produced acids and esters may find use as monomers for the synthesis of biodegradable polyesters which are often used for sutures bone prostheses and controlled drug delivery this work demonstrates that lewis acid catalysts are not only useful for bridging the gap between pervaporation membrane limits and furfural production temperatures but also for the formation of additional value added chemicals

*The Formation of Furfural and Hydroxymethylfurfural in Model Solutions and Port-style Wines* 1991 furfural is the most promising product among the high value products obtained from hemicellulose fraction of native biomass since furfural is broadly used in multiple areas such as plastics pharmaceuticals pesticides and the production of non petroleum chemicals and fuels hydrogen is considered as the cleanest energy in the world because the combustion product of hydrogen is only water thus hydrogen has been considered as a promising alternative to substitute conventional fossil fuels first in order to increase the furfural yield with appropriate metal chloride catalysts the hydrolysis of hemicellulose oxidation of corncob

and xylose and humins formation via the condensation of furfural with intermediates were investigated as possible factors for inhibiting furfural production at 90 and 170 c respectively the results show that the hydrolysis of hemicellulose is not a factor for inhibiting furfural production at 170 c while humins formation is oxidation of corncob and xylose are factors for inhibiting furfural production at 90 and 170 c it was observed that some metal ions e g fe3 cu2 could be reduced during furfural production a novel method for predicting the best catalyst for furfural production based on the fundamental chemical properties of metal ions e g lewis acid strengths oxidizing properties and solubility products of the corresponding hydroxides was developed the proposed method explains why alcl3 is the best catalyst for furfural production among fecl3 fecl2 alcl3 and cucl2 second furfural production from corncob and pure hydrogen evolution from the corresponding waste furfural residue were first achieved and reported via tandem chemical and electrochemical methods the operating conditions for furfural production were optimized with alcl3 catalyst in a cyclopentyl methyl ether cpme water biphasic system the highest furfural yield of 85 was achieved from raw corncob with intermediate volume 40 ml of reaction solvent which is higher than values obtained in the literature using raw biomass substrate and metal chloride catalysts under similar reaction conditions

**Furfural and Its Derivatives ...** 1925 biomass field liquefaction is a concept where green biomass is chemically treated to produce organic liquids using small scale equipment in the field if liquefaction occurs as the crop is harvested the energy requirements for growing the biomass can be charged to the crop as if the biomass were left in the field the energy in the organic liquid product is available at the expense of the energy required by the process a simplified process was simulated using aspen to assess the energy production feasibility acid catalyzed liquefaction of cellulose and hemicellulose solids produces furfural and hydroxymethylfurfural hmf the simulation assumed furfural from xylans and hmf from hexosans were the only organic products reaction rate was regressed from published data complete physical properties were estimated for hmf using group contribution methods marrero pardillo critical properties benson ideal gas heat capacity and standard heat of formation unifac vapor liquid liquid equilibrium two figures of merit were determined over a range of process temperatures residence times and feed compositions xylan hexosan and a mixture representative of corn stover maximum energy recovery ratio was nearly 2.3 and represents the ratio of combustion energy in the organic liquid product minus energy required for the reactor to biomass feed combustion energy this value occurred at short residence time desirable for field liquefaction the product to process energy ratio is the ratio of the combustion energy in the organic liquid product to the process energy requirements the 9.1 maximum occurred with low temperature and high conversion long residence time the value was greater than 7.1 for high temperature and conversion short residence time which compares favorably with the enzymatic ethanol biomass reported value of 2.61 1 abstract page iii

The Vapor Phase Catalytic Reduction of Furfural and of Furfuryl Alcohol 1949 biomass is a renewable and clean resource and great interest is devoted to its conversion into fuels and fine chemicals in particular furfural emerges as a key platform molecule in this view it is an urgent need to develop eco efficient and intensified processes affording the conversion of furfural into added value chemicals in a minimum number of steps in this phd thesis we engineered single reactor tandem reactions where furfural is transformed into target chemicals in a one pot fashion without separation of reaction intermediates to this aim multifunctional catalysts showing high activity selectivity and reusability are required as a first example we conceived a single reactor tandem process for the aldol condensation crotonization reaction between furfural and methyl isobutyl ketone mibk followed by hydrogenation with molecular h2 two robust bifunctional catalysts were developed and optimized based on pd hpsapo 5 with hierarchical porosity and brønsted acidity and pd al2o3 with lewis acidity the catalysts exhibited high yield to thf derivatives and were reusable in multiple steps without decrease of catalytic activity as a second example we conceived a single reactor tandem process for the benzoin condensation of furfural to

furoin followed by reductive amination of the as generated furoin with  $\text{NH}_3$  and molecular  $\text{H}_2$  a high yield of 2-amino-1,2-difuran-2-yl-ethanol could be obtained over combined silica supported benzimidazole and  $\text{RuAl}_2\text{O}_3$

The Application of Furfural and Its Derivatives to the Manufacture of Plastics 1930 there is a wide consensus that furfural a renewable commodity currently obtained from lignocellulosic agro residues with a production volume of around 300 kton per year is a key feedstock for leveraging lignocellulosic residues in future biorefineries several chemicals are already being manufactured from furfural due to its advantageous production cost furthermore a vast number of others are also technically viable to produce from oil this book compiles the vast existing information into relevant stages of transformations of furfural as renewable chemicals biofuels and bioresins focusing on the relevant chemical and engineering aspects of processes to obtain them including reactors and catalysis it offers essential information for improving the economic and environmental viability of current commercial applications and upcoming future applications it should be of particular interests to graduate and advanced undergraduate students as well as engineers and academic researchers alike who are working in the field

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