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Synthesis of 1-((2-carbamoylguanidino)(furan-2-ylmethyl)urea via Biomass-Based Furfural.

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Abstract: *This study reports the synthesis of 1-((2-carbamoylguanidino)(furan-2-ylmethyl)urea by coupling purified furfural with urea to afford the compound 1-((2-carbamoylguanidino)(furan-2-ylmethyl)urea, with a much -improved yield and definite structural affirmation. The compound was characterized by GC-MS, IR, ^{1}H-NMR, ^{13}C-NMR, ^{1}H-^{1}H COSY, HSQC, and DEPT. The assigned structures agree with the spectral data obtained.*

Keywords: Furfural, Urea, 1-((2-carbamoylguanidino)(furan-2-ylmethyl)urea,

Introduction

Synthesis of an organic compound from renewable resources has attracted the attention of many research workers because of the environmental issues associated with petrochemicals. Furfural, which is one of such products, is a biomass-based agricultural by-product [1] and is obtained by hydrolysis and dehydration of pentose carbohydrates contained in lignocellulose [2]. It is a chemical that is potentially relevant in organic synthesis due to its cheapness and bio-availability [2,3]. Furfural has gained attention as a potential chemical for organic synthesis since its derivatives have outlets in chemical and pharmaceutical industries[4,5,6]. It has also served as a precursor in the synthesis of the following [7], furfurymaleic acid [8], 5-(3-nitrophenyl)-4-(2-furyl)-3-buten-2-one [9], nitrofurazone [10], etc. Urea is another interesting renewable organic compound with the chemical formula $CO(NH_2)_2$ [11]. It is a colourless, odourless solid, highly soluble in water and practically non-toxic, it is neither acidic nor alkaline when dissolved in water [12]. The rationale for this study is to explore the use of chemicals from natural sources in organic synthesis since they are bio-degradable [13]. 1-((2-carbamoylguanidino)(furan-2-ylmethyl)urea has been previously synthesised [14,15] but in relatively low yields and questionable product structure due to inadequate structural data. It is a precursor in the synthesis of complexes. The present work reports the coupling of furfural to urea, with an improved yield and sufficient spectroscopic data to affirm the structure of the product.

Materials and Methods

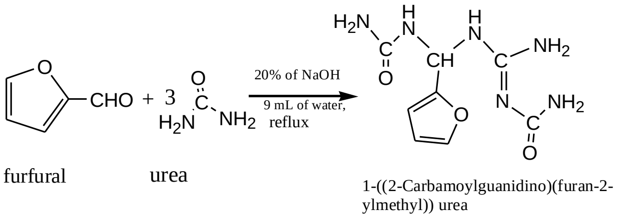
FTIR 8400S Fourier Transform Infrared spectrophotometer was used to identify the functional groups, Gas Chromatography/Mass Spectrometer-QP2010 PLUS SHIMADZU was used for molecular formula/mass identification, Nuclear Magnetic Resonance(Agilent-NMR-VNMRS400) was used for structural elucidation, Vacuum Pump (TKS-70), for vacuum distillation of furfural and Digital Melting Point Electrothermal IA9300X1, for melting point determination. Furfural was bought from a chemical store and purified by vacuum distillation. Other chemicals such as urea, ethanol, and sodium hydroxide were of Analar grade and used without further purification. Thin layer chromatography (TLC) was carried out using a Merck pre-coated silica gel plate (10x10 cm); the Rf value was obtained using solvent mixture of n-hexane and ethyl acetate in a ratio of 2:3. The chromatogram was visualized using an ultraviolet lamp at 256 nm.

Synthesis of 1-((2-Carbamoylguanidino)(furan-2-ylmethyl)) urea

The furfural used in this study was bought from chemical store. The deteriorated furfural was purified by vacuum distillation at the temperature of 65^0 C to 80^0 C. The procedure adopted in the synthesis of 1-((2-Carbamoylguanidino)(furan-2-ylmethyl)urea was earlier reported by Idoko and Emmanuel [14,15]. The purified furfural (40 mL, 0.48 mol), urea (40 g, 0.63 mol) and distilled water (9 mL) were placed in a flat-bottomed flask (250 mL) and the mixture heated in a water bath at a temperature of 60^0 C for 1 hour, 40 minutes with vigorous stirring. Thereafter, NaOH (2 mL of 20% of solution) was added and the heating continued for 20 minutes. The mixture was cooled in an ice bath and the resulting brown precipitate filtered, washed with n-hexane, recrystallized from methanol and the crystal dried in an oven at 50^0 C.

Results and Discussions

The reaction equation for the synthesis of 1-((2-Carbamoylguanidino)(furan-2-ylmethyl)) urea is shown in scheme 1.



Scheme 1: Synthesis of 1-((2-Carbamoylguanidino)(furan-2-ylmethyl))urea

From Scheme 1, furfural is coupled with urea molecule to form 1-((2-Carbamoylguanidino)(furan-2-ylmethyl)) urea. Thin layer chromatography analysis of the product with a solvent system of hexane and ethylacetate in a ratio of 2:3 gave rf value of 0.74. The melting point determination of the recrystallized product was in the range of 108^0 C- 110^0 C. The percentage yield of the product synthesized was 60%, this was higher than the product yield of 40% by Emmanuel [15]. The product was characterized using spectroscopic data from IR, ^{1}H-NMR, ^{13}C-NMR, ^{1}H-^{1}H COSY, SQC, HMBC, DEPT and GC-MS analyses. The summary of IR, ^{1}H-NMR, and ^{13}C-NMR data analyses are shown in Table 1

Table 1: IR, ^{1}H-NMR and ^{13}CNMR Data of the Synthesised 1-((2-Carbamoylguanidino) (furan-2-ylmethyl)) urea.

Components of compound	IR (cm^{-1})	^{1}HNMR (ppm)	^{13}CNMR (ppm)	Remark
Furan	1458.23	7.6, 6.30, 6.5	154.75, 142.43, 110.7, 106.12	Obtained from furfural
$>C=N-$	1532.87	-------------	158.52	Imine group
$-CONH_2$	1666.55	5.6	160.15	Carbamoyl group
$-NH_2$	3464.27	2.4-2.5	------------	Amine group
$-\overset{H}{\underset{\vert}{C}}-$	2885.60	6.23	50.60	Methine group
DMSO	---------	3.5	40	H&^{13}C Solvent

The IR data analysis of the product identified the presence of imine group (1532.87cm^{-1}), a carbamoyl group (1666.55 cm^{-1}) and methine (2885.23 cm^{-1}). This IR data analysis is in line with Idoko and Emmanuel [14,15]. The ^{1}H-NMR analysis of the product in DMSO showed multiplet peaks in the range (δ) 6.54-7.53 ppm which corresponds to the furan ring. The peak at 6.23 ppm is due to the proton around the methine group while the peak in the 5.6 ppm is assigned to proton around carbamoyl group. ^{13}C-NMR data analysis indicates the presence of carbon from furan (106.12-154.75 ppm), imine (158.52 ppm), carbamoyl group (160.15ppm) and methane (50.6 ppm). The proton NMR data analysis showed in Idoko and Emmanuel [14, 15] was in line with the proton NMR data analysis of this research work. ^{1}Hnmr and IR are not enough data for structure elucidation. In this report, IR, ^{1}H, ^{13}C NMR, GC-MS, 1H-1H COSY, SQC, HMBC and DEPT confirmatory data, were used for complete structure elucidation.

The spectral data are shown in Table 2, Figs.1 and 2,

Table 2:^{1}H-^{1}H COSY NMR Spectrum interpretation of (1-((2-Carbamoylguanidino)(furan-2-ylmethyl)) urea)

2.5														##
3.5													##	
5.5												##		
6.0											##			
6.05										##				
6.1					√6				##					
6.2								##						
6.3		√4			√5		##							
6.4						##								
6.5					##		√3		√2					
6.7				##										
6.8			##											
7.6		##					√1							
8.0	##													
	8.0	7.6	6.8	6.7	6.5	6.4	6.3	6.2	6.1	6.05	6.0	5.5	3.5	2.5

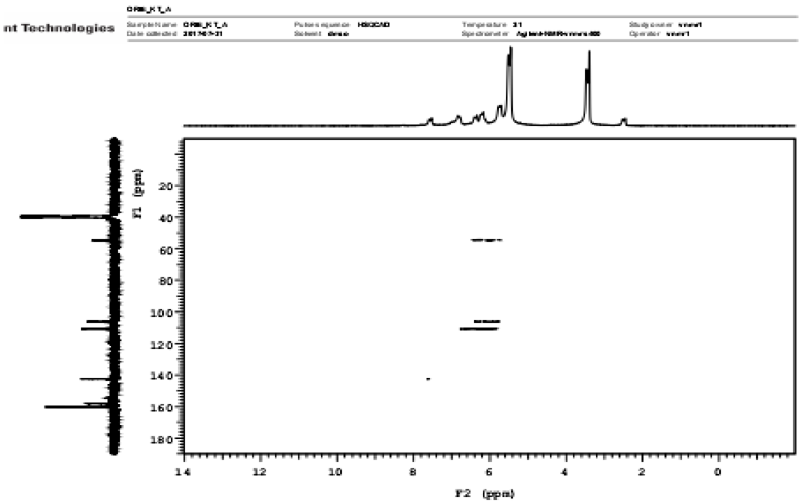


Fig.1: HSQC Spectrum of (1-((2-Carbamoylguanidino)(furan-2-ylmethyl)) urea

Table 2 is an extrapolated data from ^{1}H- ^{1}H COSY NMR spectrum investigation and fig.1 is the HSQC spectrum of the synthesized compound. A comparison of the extrapolated data of ^{1}H- ^{1}H COSY NMR spectrum and data obtained from Heteronuclear Single Quantum Correlation and Heteronuclear Multiple Bond Correlation indicate that, the peaks at 6.3 ppm, 6.5 ppm, and 7.6 ppm correspond to furan ring which is obtained from furfural, the peak at the chemical shift of 6.1 ppm indicates the presence of methine, while the peaks in the range of 5.4-5.7 ppm correspond to hydrogen protons of nitrogen attached to carbonyl (imides) and the peak 2.5 ppm belong to imines' proton. More also, these peaks correspond to carbon-proton correlation of HSQC spectrum in Fig.1, except those protons that are not attached to carbon (peaks with the chemical shift of 2.5 ppm, 5.7 ppm) and those of them that lack proton (i.e. carbonyl and imine carbon) that are indicated in ^{13}C NMR spectrum whose data is shown in Table 1.

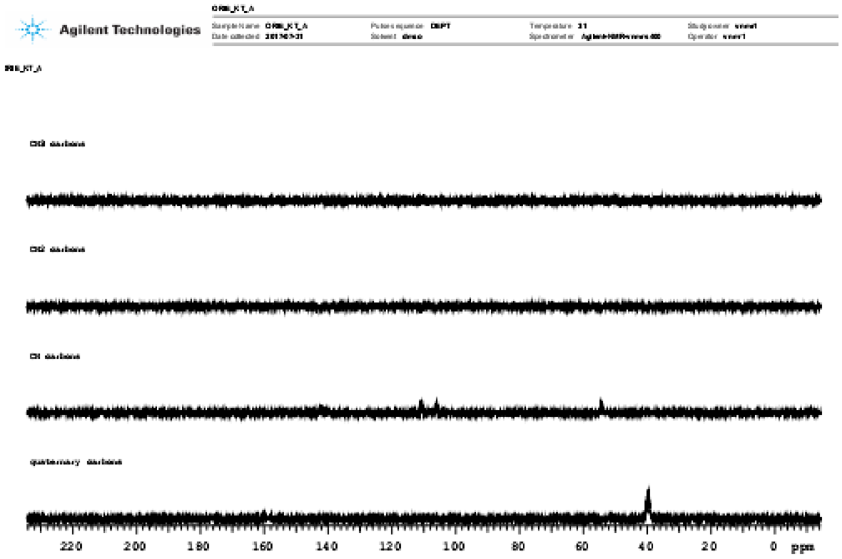


Fig. 2: DEPT Spectrum of (1-((2-Carbamoylguanidino)(furan-2-ylmethyl)) urea

Distortionless Enhancement polarization Transfer (DEPT) spectrum shown in Fig.2, confirms the presence of various categories of carbon in the synthesized compound. From Table 1, the carbon-13 chemical shift of 172.733 ppm, 160.182 ppm, 154.744 ppm, 142.428 ppm, 110.797 ppm, 106.118 ppm, and 54.548 ppm confirm the presence of carbonyl, a carbamoyl group, a furan ring, and a methine. But the DEPT spectrum confirms only the presence of tertiary and primary carbons. The primary carbon is obtained from DMSO solvent used for the analysis and the tertiary carbon is got from furan and methine. Fig.2 also confirmed the absence of methylene in the structure of the synthesized compound.

Conclusion

This research work, therefore, reports the synthesis of 1-((2-carbamoylguanidino)(furan-2-ylmethyl) urea by coupling furfural with urea, gave an improved yield and definite structural affirmation. The result confirmed a higher percentage yield of 60%, against an earlier yield of 40%. The combined spectral data from IR, ^{1}H-NMR, ^{13}C-NMR, ^{1}H-^{1}H COSY, HSQC, HMBC, DEPT and GC-MS confirmed product structure as against IR and ^{1}H-NMR only that were used in the early study. This work is an improvement on the earlier work based on the higher yield and complete spectral data for structure confirmation.

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