

## **Biomass-derived magnetic amorphous carbon as an efficient catalyst in the conversion of fructose into 5-hydroxymethylfurfural**

Tuan Minh Dang,<sup>a,b, ‡</sup> Trinh Hao Nguyen,<sup>a,b, ‡</sup> Ha Khanh Nguyen,<sup>a,b</sup> Ha Bich Phan,<sup>a,b,c</sup> Hai  
Truong Nguyen,<sup>a,b \*</sup> and Phuong Hoang Tran<sup>a,b \*</sup>

<sup>a</sup>Department of Organic Chemistry, Faculty of Chemistry, University of Science, Ho Chi Minh  
City, Vietnam

<sup>b</sup>Vietnam National University, Ho Chi Minh City, Vietnam

<sup>c</sup>Institute of Public Health, Ho Chi Minh City, Vietnam

<sup>‡</sup> The authors contributed equally to this work.

\*Corresponding author:

Hai Truong Nguyen: phone number: +84-908-108-824; e-mail: [ngthai@hcmus.edu.vn](mailto:ngthai@hcmus.edu.vn)

Phuong Hoang Tran: phone number: +84-903-706-762; e-mail: [thphuong@hcmus.edu.vn](mailto:thphuong@hcmus.edu.vn)

## Section 1: Chemical and equipment

Iron (III) chloride ( $\geq 97\%$ ), sodium hydroxide ( $\geq 99\%$ ), hydrochloric acid (36%), oxalic acid ( $\geq 99\%$ ), *D*-glucose monohydrate ( $\geq 99\%$ ), dioxane ( $\geq 99\%$ ), methyl isobutyl ketone (MIBK) ( $\geq 99\%$ ), *D*-fructose ( $\geq 99\%$ ), dimethylformamide ( $\geq 99\%$ ) were obtained from Merck. 2,5-Diformylfuran ( $>99\%$ ), 2,5-furandicarboxylic acid ( $>99\%$ ), 5-(hydroxymethyl)furfural ( $>99\%$ ) furfural ( $>99\%$ ), levulinic acid ( $>99\%$ ), deuteriochloroform ( $>99\%$ ), dimethyl sulfoxide ( $>99\%$ ) were supplied by Sigma–Aldrich. All chemicals were utilized without any additional purification.

### Analytical techniques

The NMR spectra were obtained using a Bruker Advance 500 MHz nuclear magnetic resonance (NMR) spectrometer, with *D*-chloroform serving as the solvent. A thorough examination was carried out using Fourier transform-infrared spectroscopy (FTIR) on KBr pellets utilizing a Bruker Vertex 70 system. The reaction products were measured using a high-performance liquid chromatography system with a diode array detector at a specific wavelength. A particular type of column, called InertSustain C18, was used in the experiment to efficiently separate the different components in the reaction mixture. The temperature of the column was kept at 30 °C. A solution of methanol and sulfuric acid was utilized as the eluent, flowing at a rate of 0.7 mL.min<sup>-1</sup>.

$$\text{H\%} = (\text{The number of 5-HMF moles})/(\text{The initial number of fructose moles}) \times 100\% \quad (1)$$

## Section 2: NMR spectrum of 5-HMF

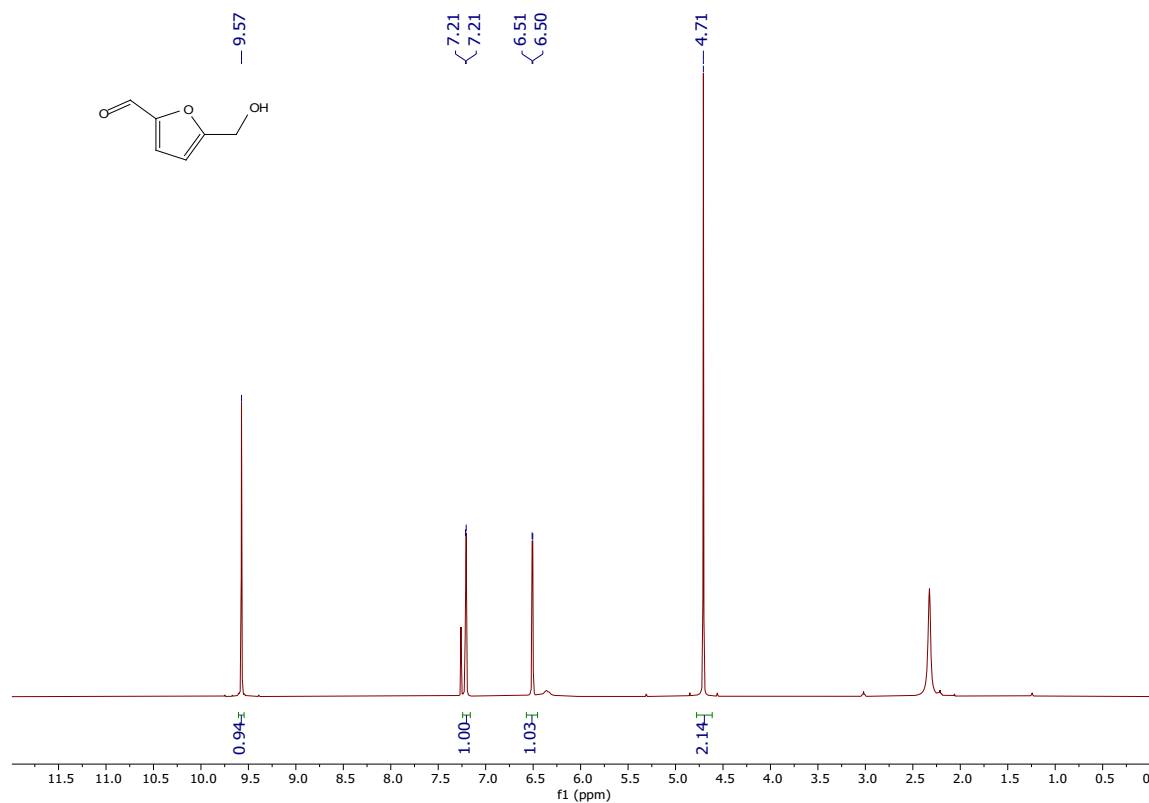


Figure S2-1. <sup>1</sup>H-NMR spectrum of HMF

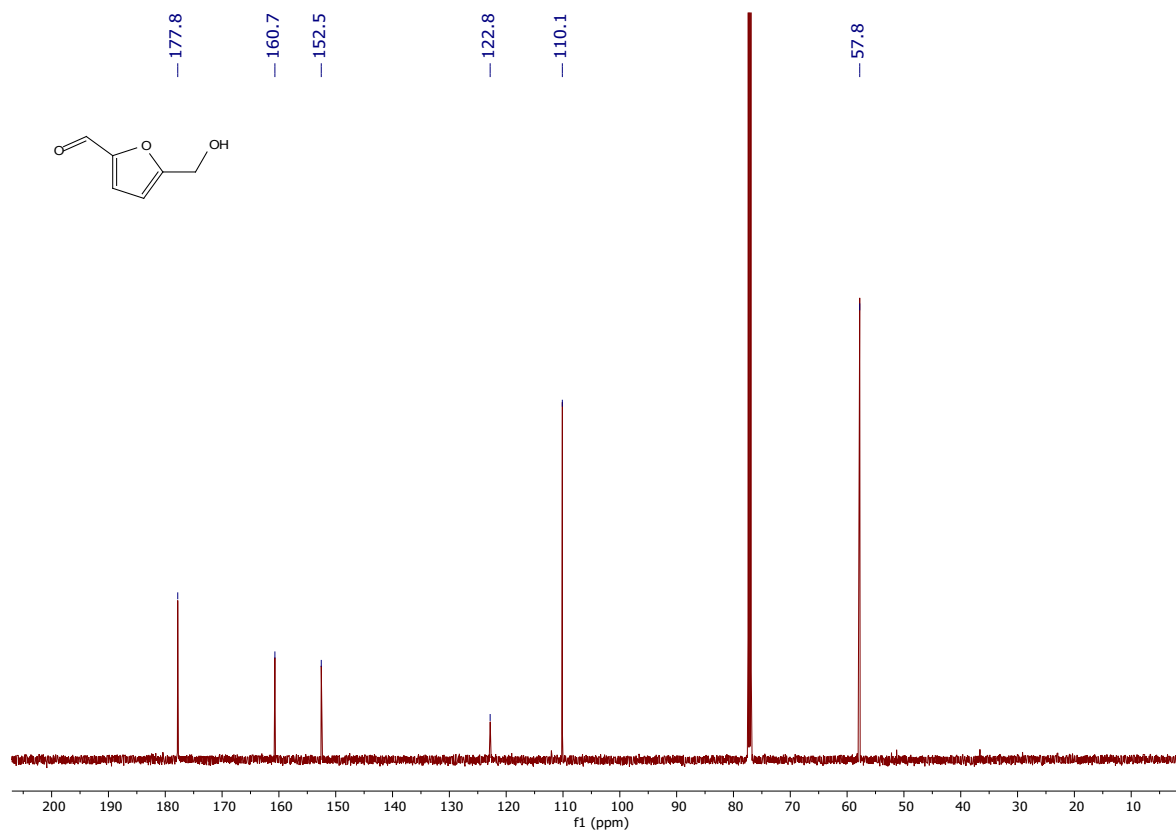
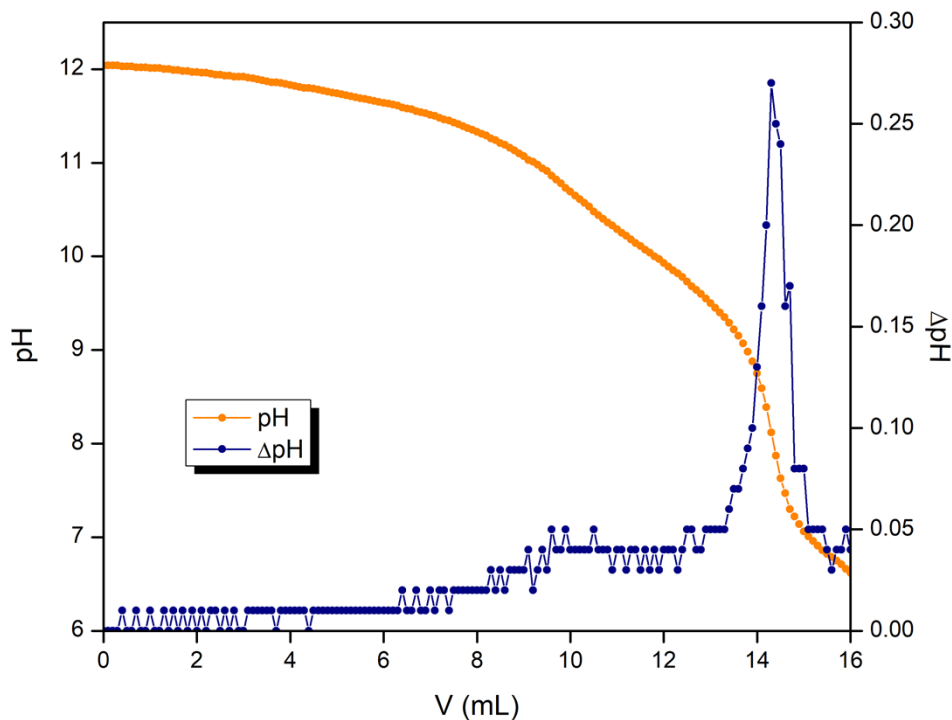
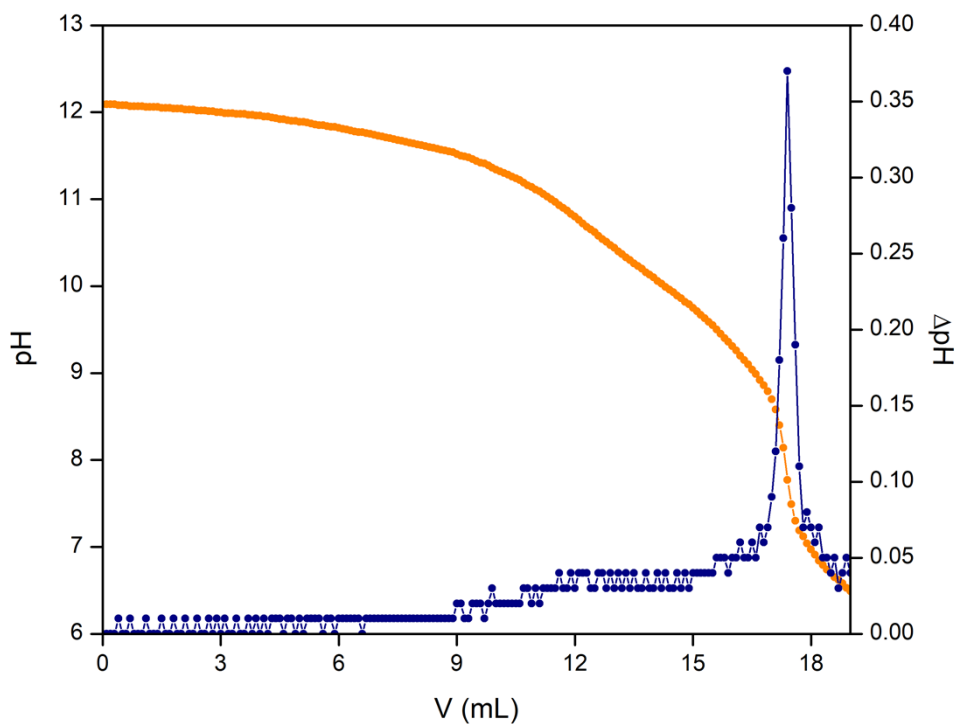


Figure S2-2. <sup>13</sup>C-NMR spectrum of HMF

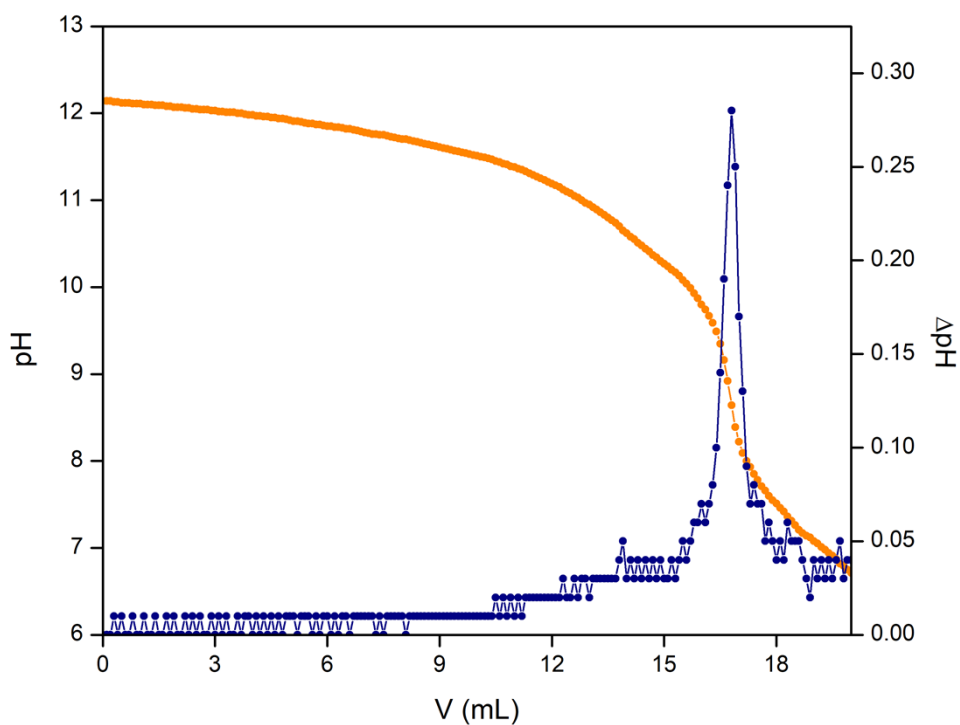
**Section 3: Titration of catalyst**



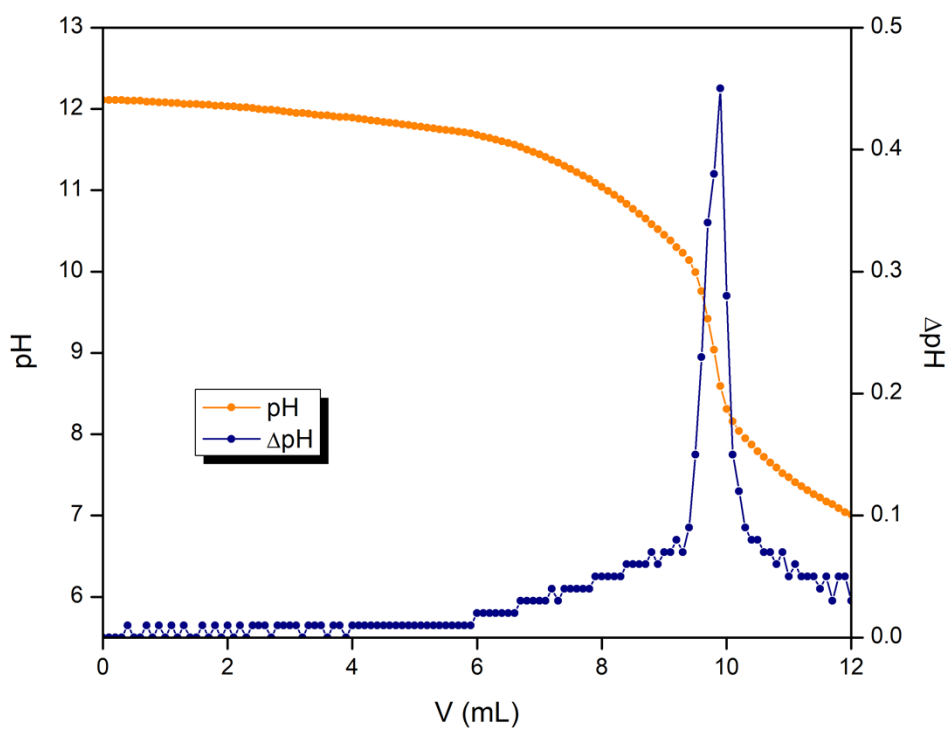
**Figure S3-1.** The titration curves of 100-4 with pH/V (orange line) and  $\Delta$ pH/V (blue line)



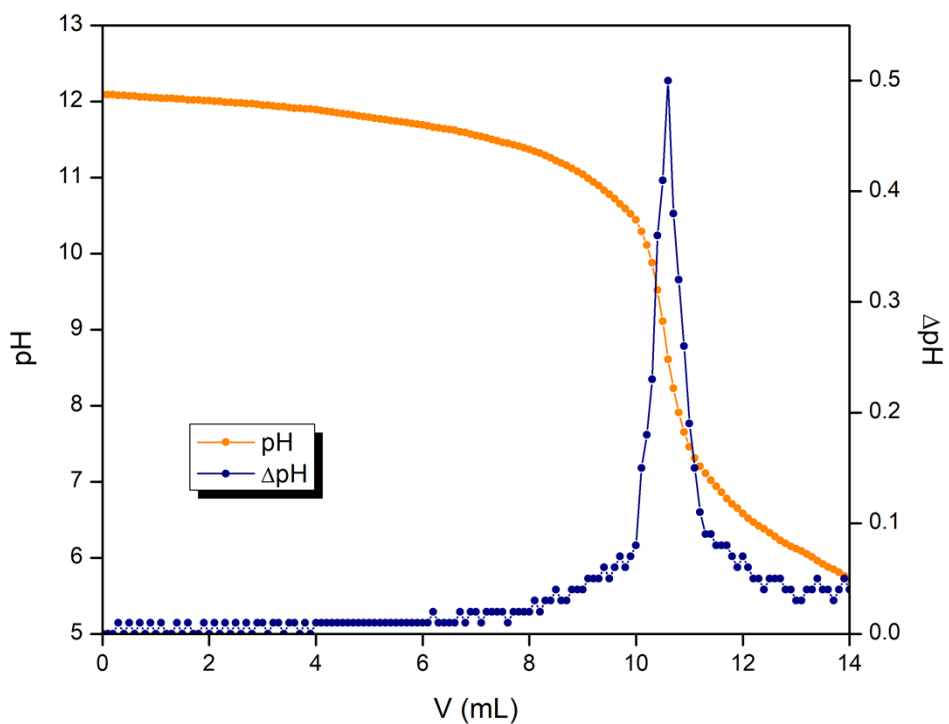
**Figure S3-2.** The titration curves of 200-4 with pH/V (orange line) and  $\Delta$ pH/V (blue line)



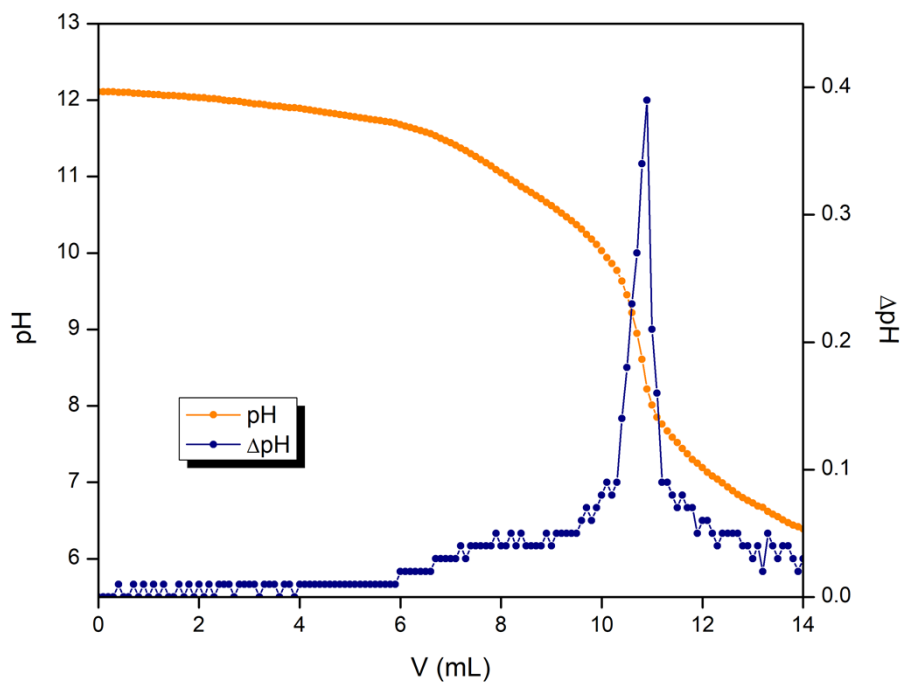
**Figure S3-3.** The titration curves of 300-4 with pH/V (orange line) and  $\Delta\text{pH}/V$  (blue line)



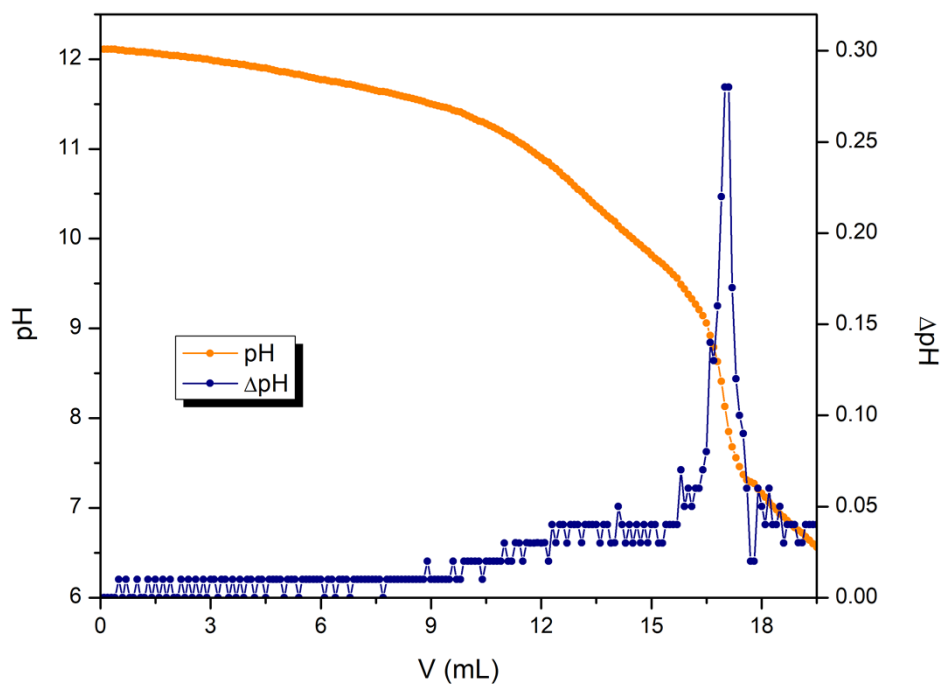
**Figure S3-4.** The titration curves of 350-4 with pH/V (orange line) and  $\Delta\text{pH}/V$  (blue line)



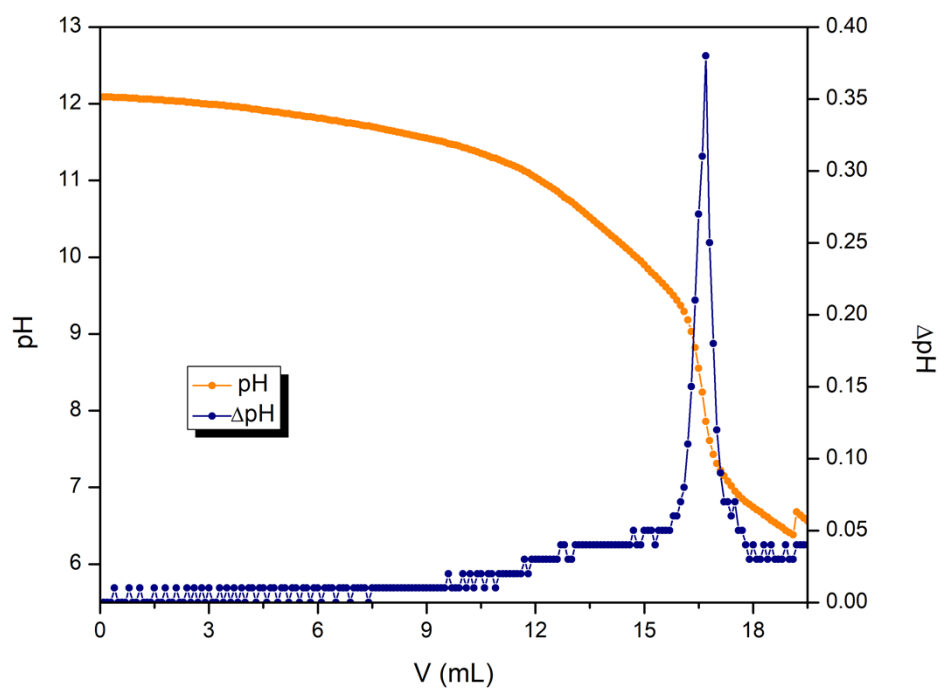
**Figure S3-5.** The titration curves of 400-4 with pH/V (orange line) and  $\Delta\text{pH}/V$  (blue line)



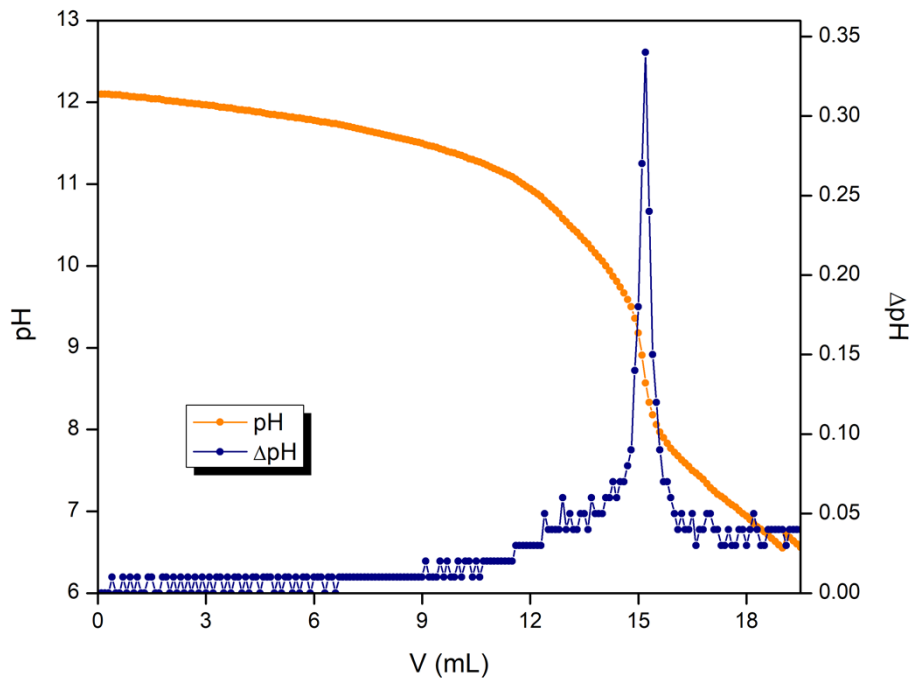
**Figure S3-6.** The titration curves of 400-4R4 with pH/V (orange line) and  $\Delta\text{pH}/V$  (blue line)



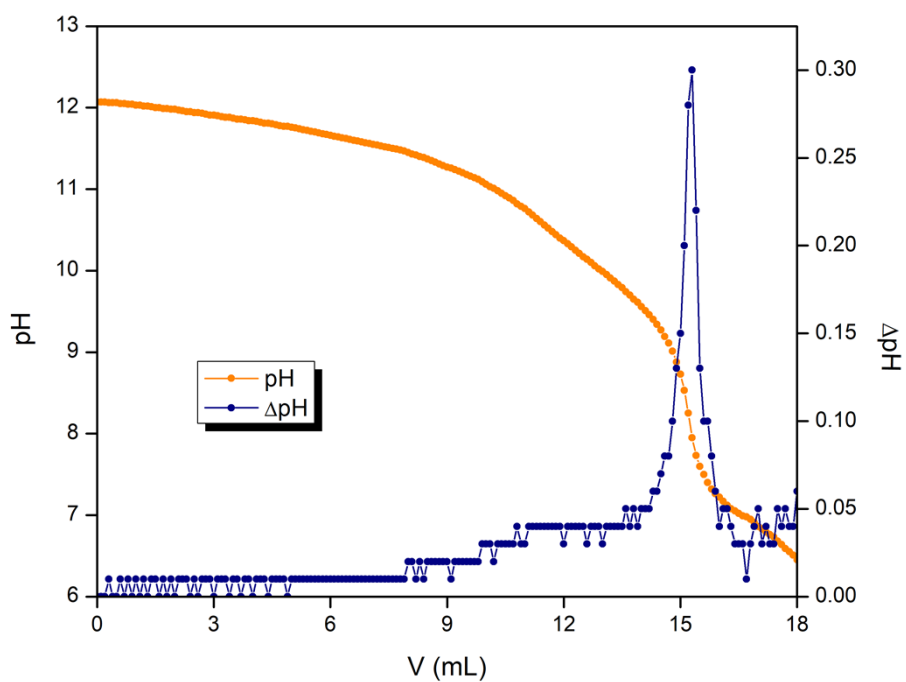
**Figure S3-7.** The titration curves of 500-1 with pH/V (orange line) and  $\Delta\text{pH}/V$  (blue line)



**Figure S3-8.** The titration curves of 500-2 with pH/V (orange line) and  $\Delta\text{pH}/V$  (blue line)

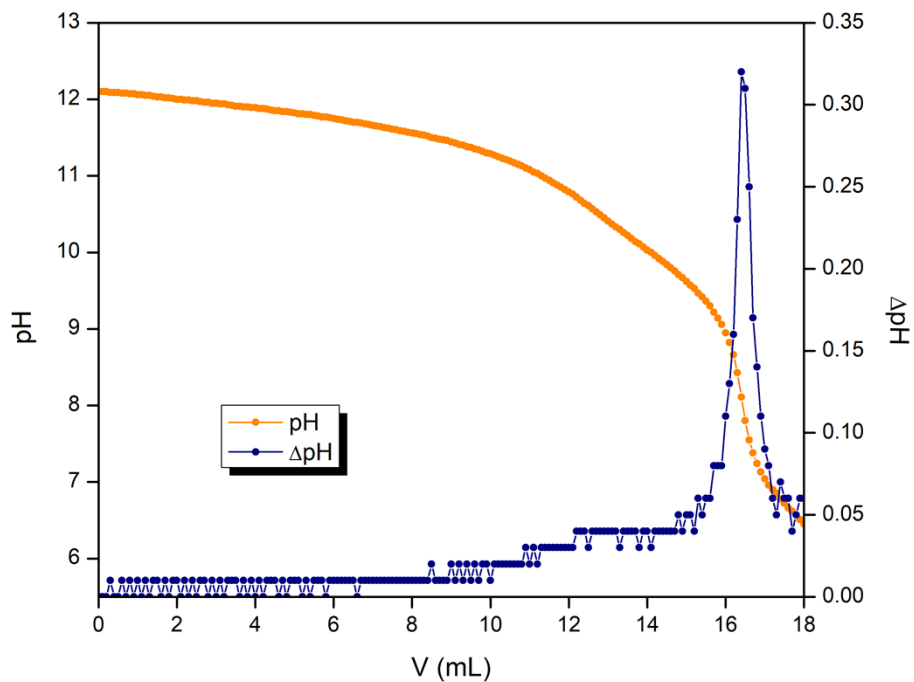


**Figure S3-9.** The titration curves of 500-3 with pH/V (orange line) and  $\Delta$ pH/V (blue line)

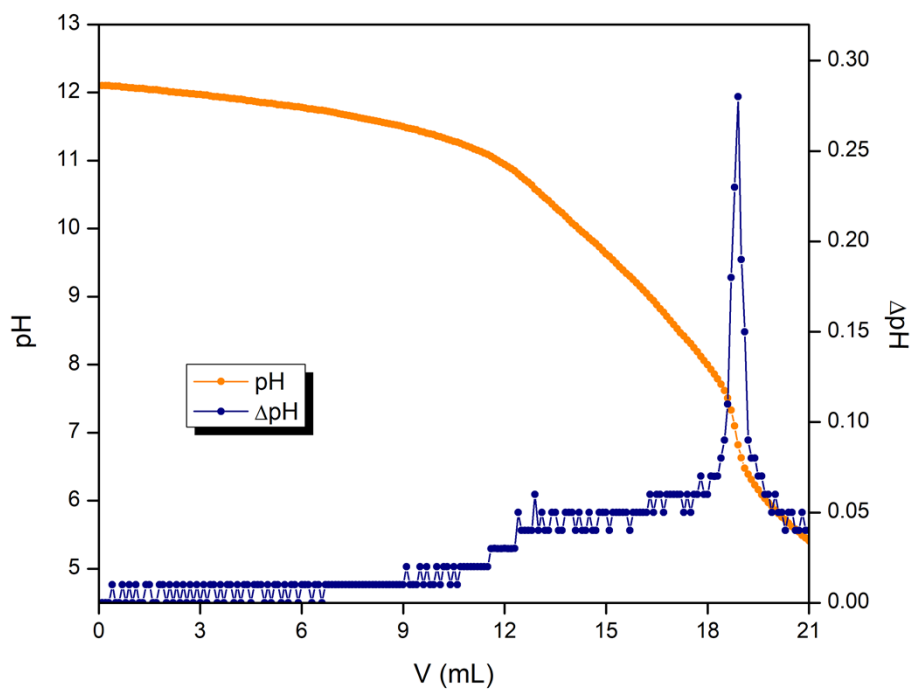


**Figure S3-10.** The titration curves of 500-4 with pH/V (orange line) and  $\Delta$ pH/V (blue line)





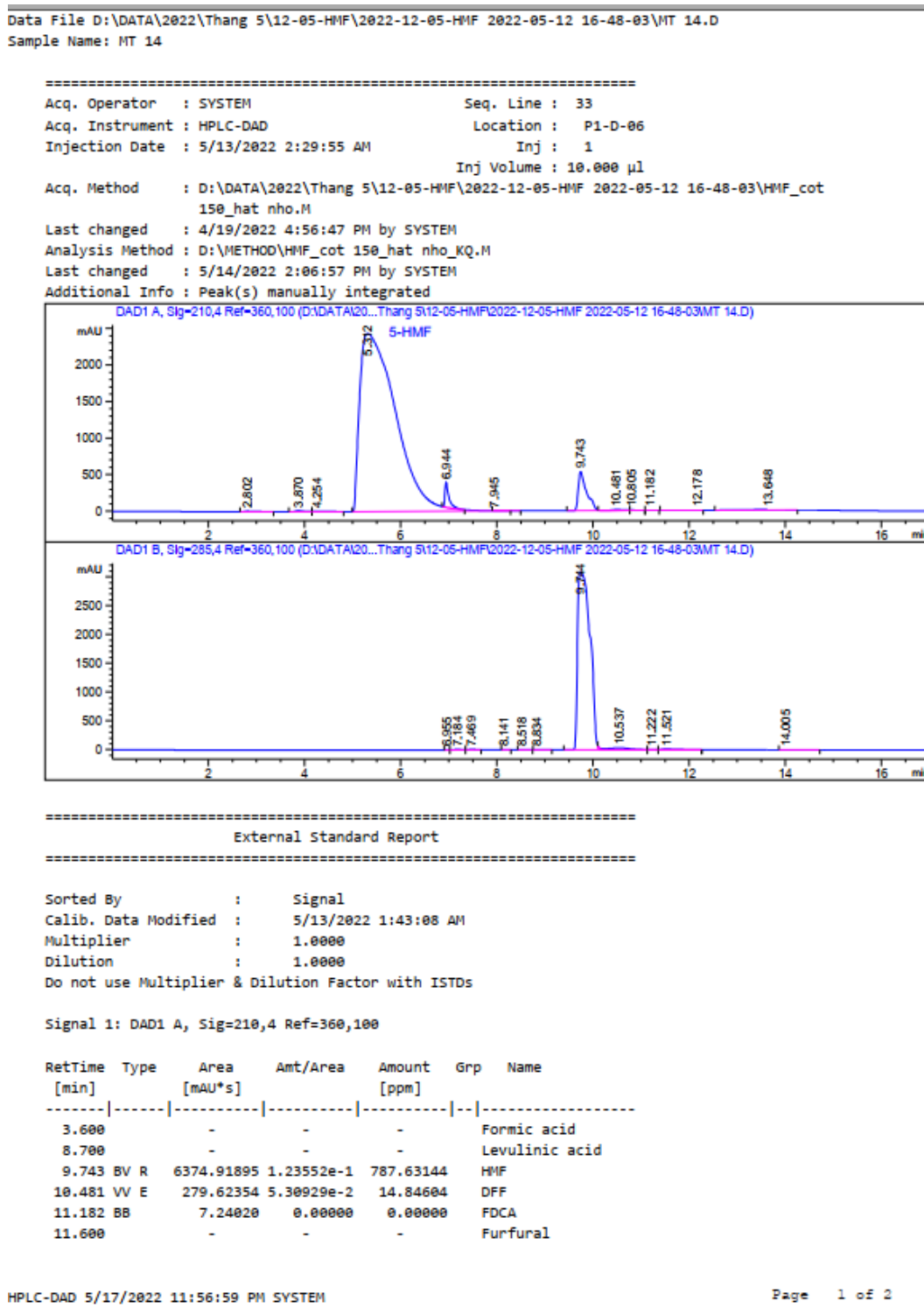
**Figure S3-11.** The titration curves of 500-5 with pH/V (orange line) and  $\Delta$ pH/V (blue line)



**Figure S3-12.** The titration curves of Blank with pH/V (orange line) and  $\Delta$ pH/V (blue line)

## Section 4: HPLC chromatography

**Figure S4-1:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 30 minutes at 120 °C.



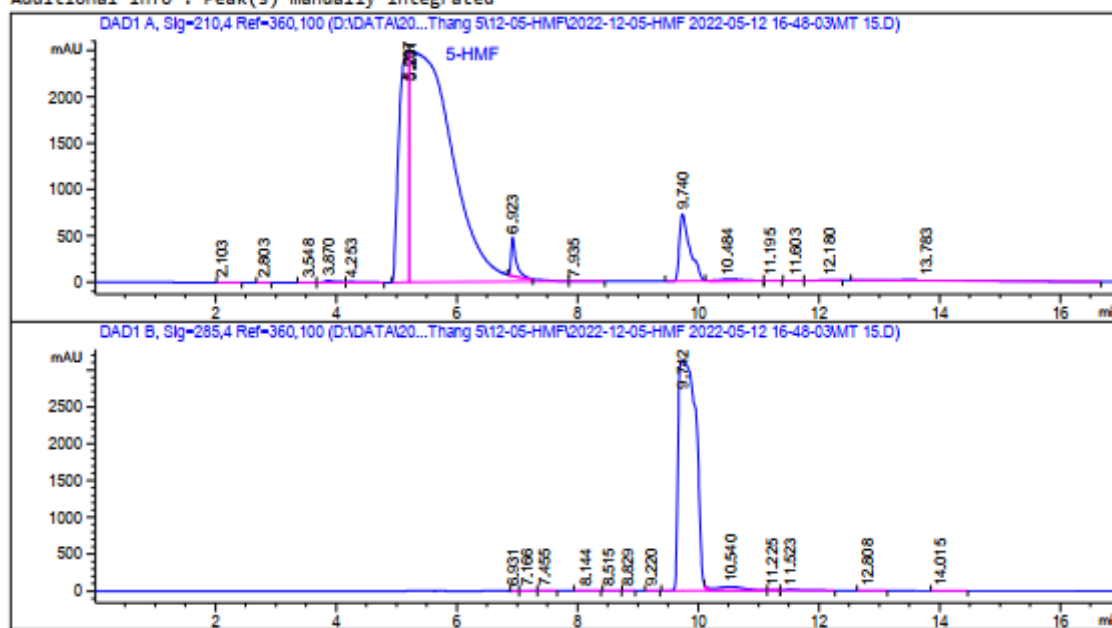


**Figure S4-2:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 1 hour at 120 °C.

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                                                    Inj Volume: 10.000 µl
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Last changed    : 5/14/2022 2:06:57 PM by SYSTEM
Additional Info : Peak(s) manually integrated
  
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External Standard Report

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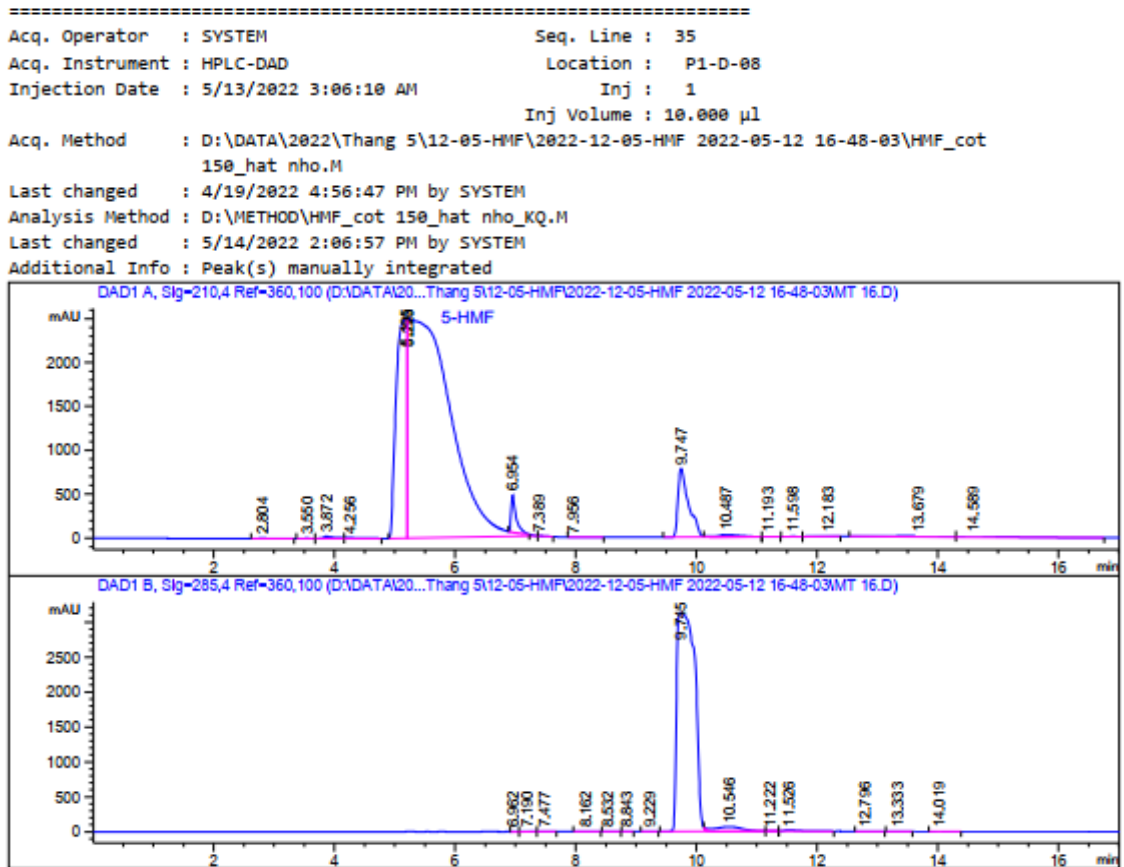
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8.700		-	-	-		Levulinic acid
9.740	BV R	8814.55078	1.23612e-1	1089.58840		HMF
10.484	VB E	514.49731	5.70333e-2	29.34348		DFF
11.195	BB	11.94851	0.00000	0.00000		FDCA
11.603	BV	23.86707	7.68687e-2	1.83463		Furfural

**Figure S4-3:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 3 hours at 120 °C.

Data File D:\DATA\2022\Thang 5\12-05-HMF\2022-12-05-HMF 2022-05-12 16-48-03\MT 16.D  
 Sample Name: MT 16



External Standard Report

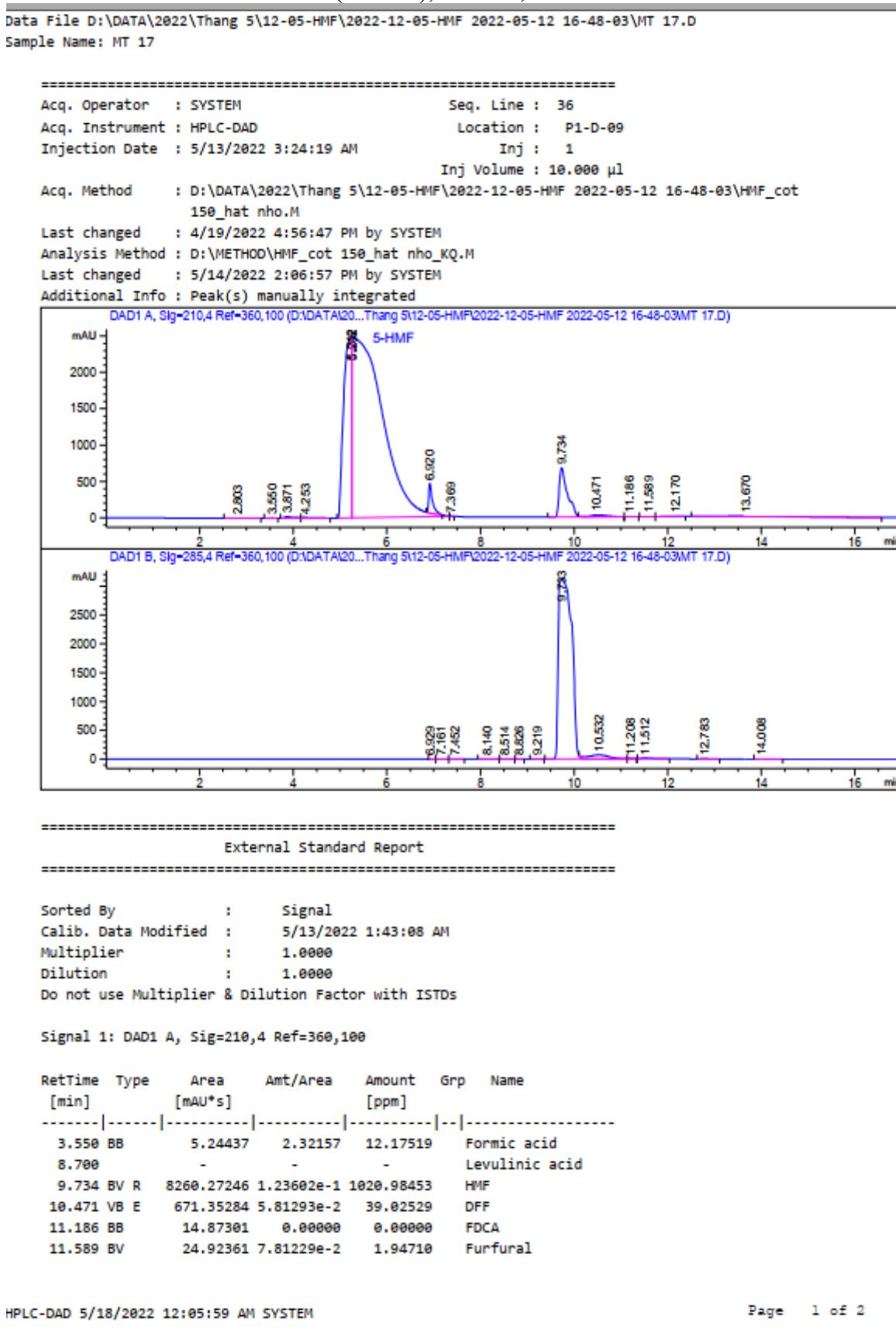
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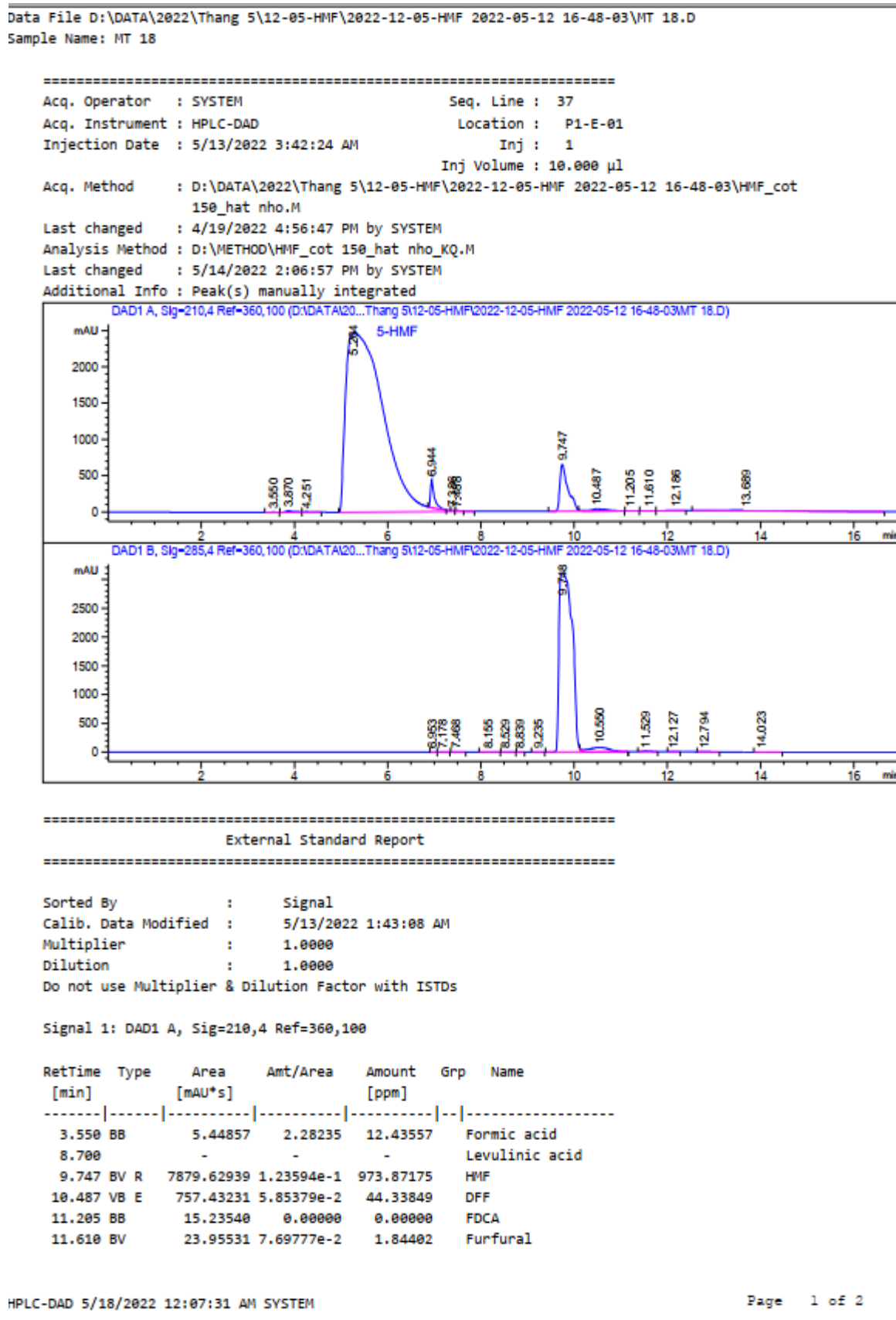
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8.700		-	-	-		Levulinic acid
9.747	BV R	9574.73145	1.23625e-1	1183.67713		HMF
10.487	VB E	637.41016	5.79379e-2	36.93020		DFF
11.193	BB	14.78250	0.00000	0.00000		FDCA
11.598	BV	30.35662	8.31934e-2	2.52547		Furfural

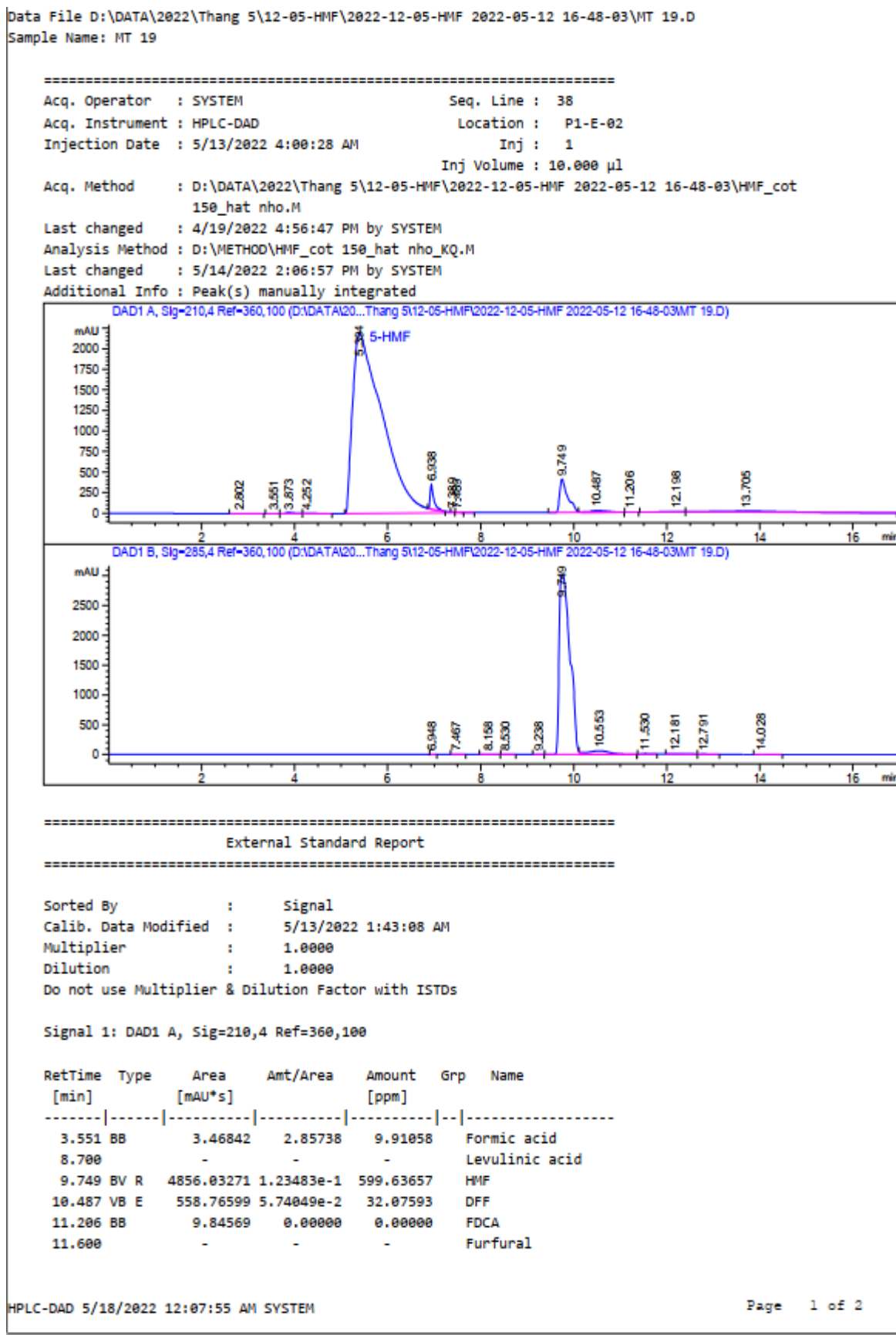
**Figure S4-4:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 6 hours at 120 °C.



**Figure S4-5:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 8 hours at 120 °C.



**Figure S4-6:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 9 hours at 120 °C.



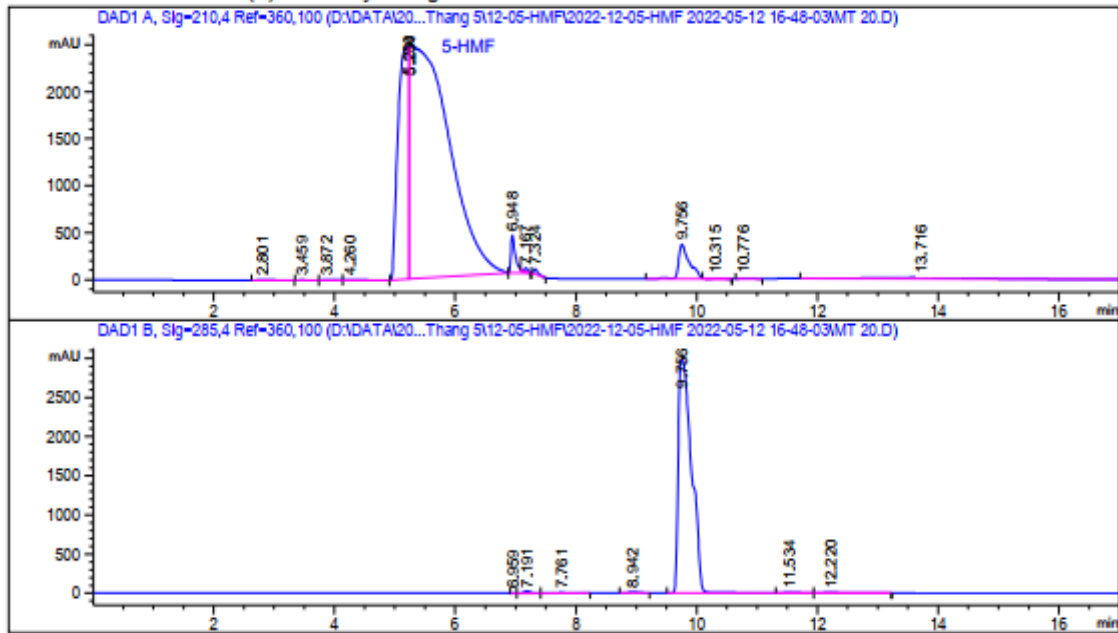


**Figure S4-7:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 10 hours at 120 °C.

Data File D:\DATA\2022\Thang 5\12-05-HMF\2022-12-05-HMF 2022-05-12 16-48-03\MT 20.D  
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External Standard Report

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Signal 1: DAD1 A, Sig=210,4 Ref=360,100

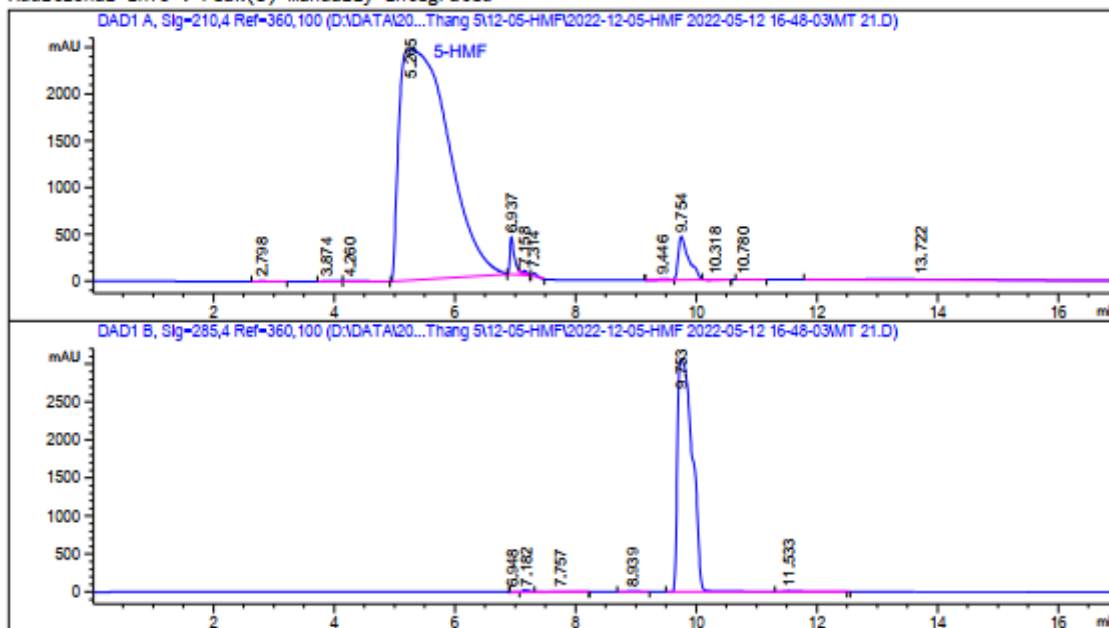
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8.700	-	-	-	-	-	Levulinic acid
9.756	VV R	4572.72998	1.23465e-1	564.57176	-	HMF
10.315	VB E	36.16873	0.00000	0.00000	-	DFF
10.776	BB	19.69633	3.91499e-2	7.71110e-1	-	FDCA
11.600	-	-	-	-	-	Furfural

**Figure S4-8:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 11 hours at 120 °C.

Data File D:\DATA\2022\Thang 5\12-05-HMF\2022-12-05-HMF 2022-05-12 16-48-03\MT 21.D  
 Sample Name: MT 21

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                                           Inj Volume: 10.000 µl
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Analysis Method : D:\METHOD\HMF_cot 150_hat_nho_KQ.M
Last changed    : 5/14/2022 2:06:57 PM by SYSTEM
Additional Info : Peak(s) manually integrated
  
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External Standard Report

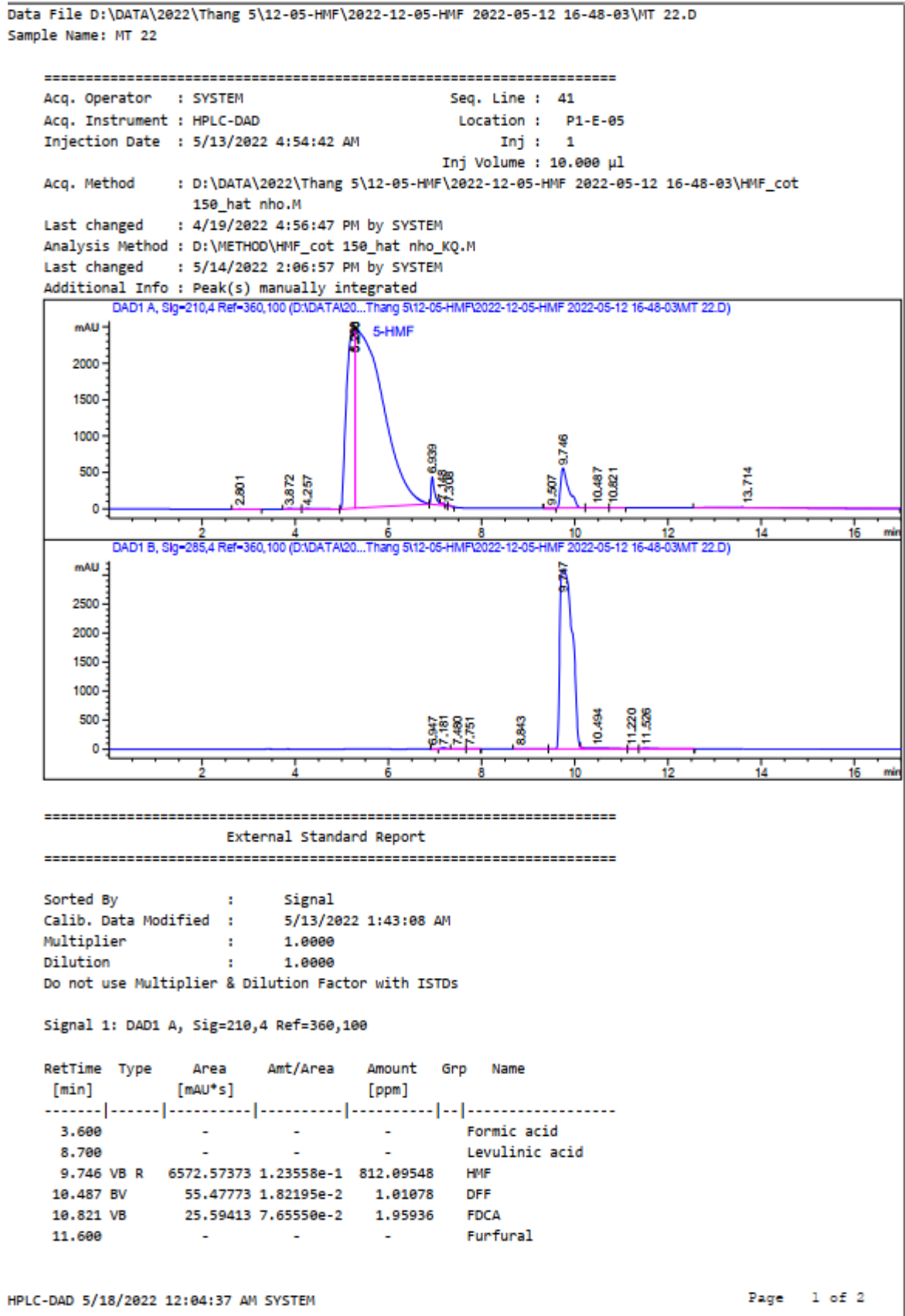
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Signal 1: DAD1 A, Sig=210,4 Ref=360,100

RetTime [min]	Type	Area [mAU*s]	Amt/Area	Amount [ppm]	Grp	Name
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8.700	-	-	-	-	-	Levulinic acid
9.754	VV R	5639.07373	1.23523e-1	696.55475	-	HMF
10.318	VB E	23.97812	0.00000	0.00000	-	DFF
10.780	BB	13.14831	0.00000	0.00000	-	FDCA
11.600	-	-	-	-	-	Furfural

**Figure S4-9:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at 120 °C.

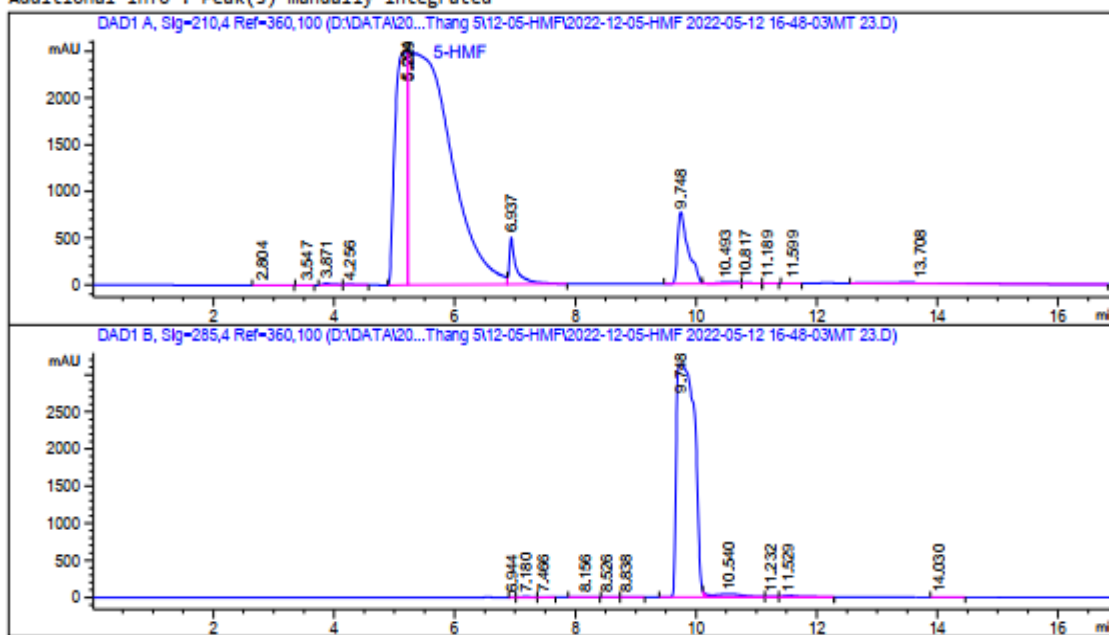


**Figure S4-10:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 13 hours at 120 °C.

Data File D:\DATA\2022\Thang 5\12-05-HMF\2022-12-05-HMF 2022-05-12 16-48-03\MT 23.D  
 Sample Name: MT 23

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                                                    Inj Volume: 10.000 µl
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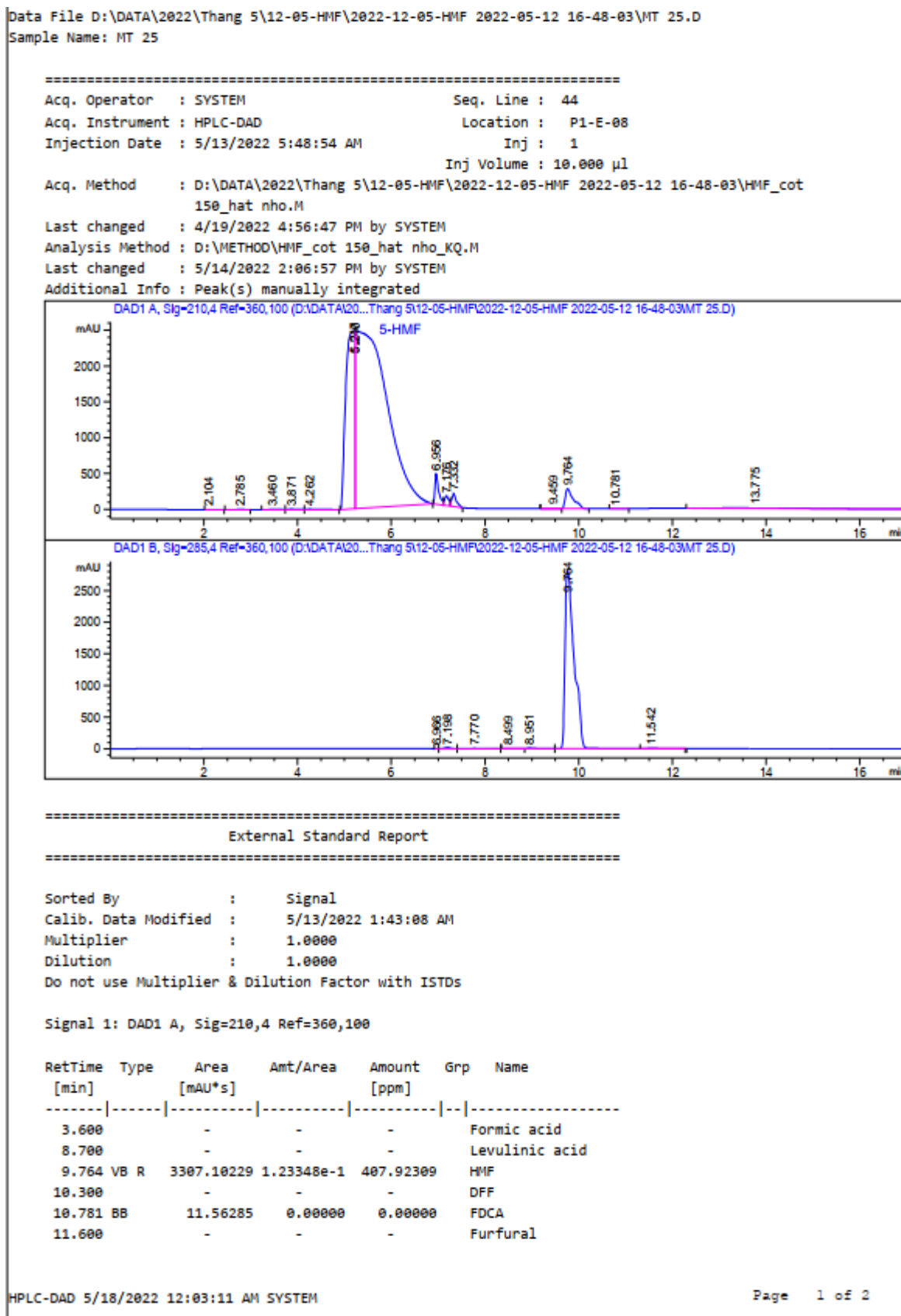
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8.700		-	-	-		Levulinic acid
9.748	BV R	9428.64746	1.23623e-1	1165.59609		HMF
10.493	VV E	317.50110	5.41227e-2	17.18401		DFF
10.817	VB E	81.47691	1.62233e-1	13.21824		FDCA
11.599	BB	16.65361	6.40537e-2	1.06673		Furfural

**Figure S4-11:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 30 minutes at 120 °C.



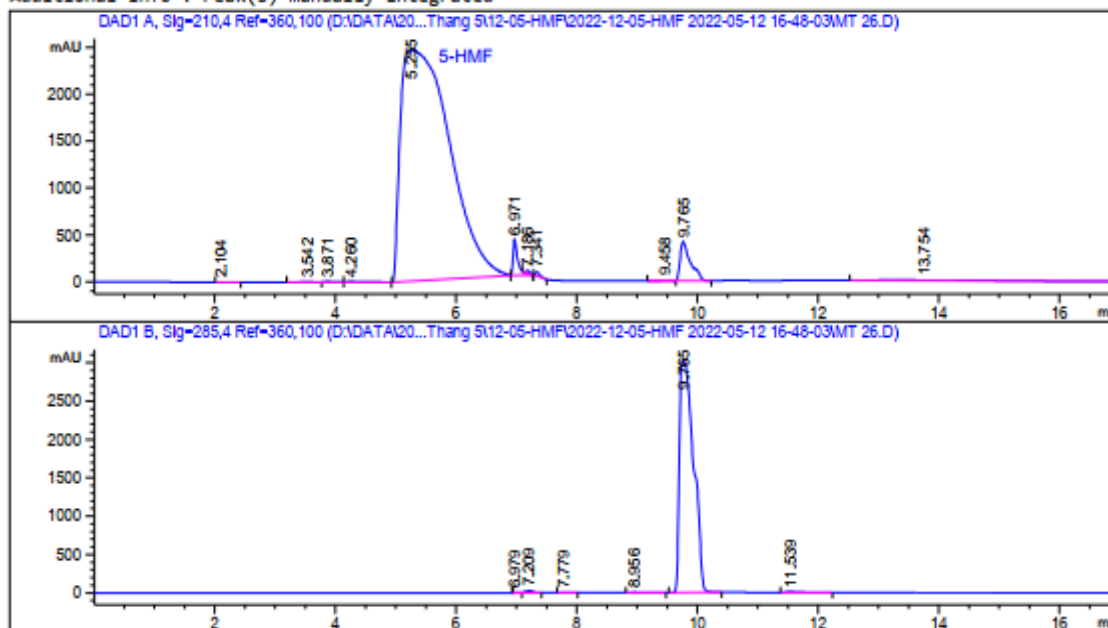
**Figure S4-12: HPLC chromatography of 5-HMF in investigating catalytic performance.**  
 Reaction conditions: Fructose (1mmol), DMSO, for 1 hour at 120 °C.

Data File D:\DATA\2022\Thang 5\12-05-HMF\2022-12-05-HMF 2022-05-12 16-48-03\MT 26.D

Sample Name: MT 26

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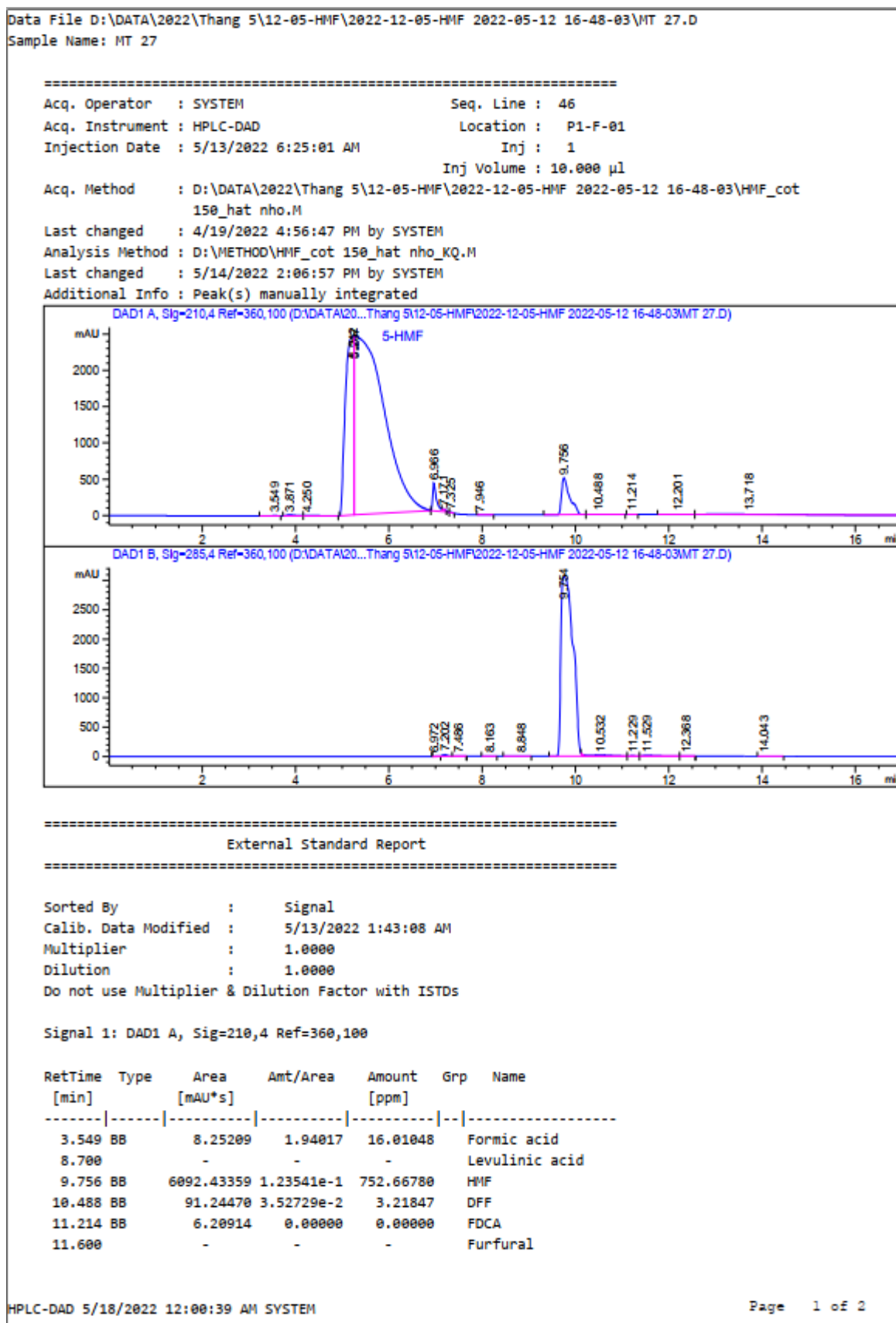
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8.700		-	-	-		Levulinic acid
9.765	VB R	4957.31104	1.23489e-1	612.17194		HMF
10.300		-	-	-		DFF
11.000		-	-	-		FDCA
11.600		-	-	-		Furfural

**Figure S4-13:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 3 hours at 120 °C.



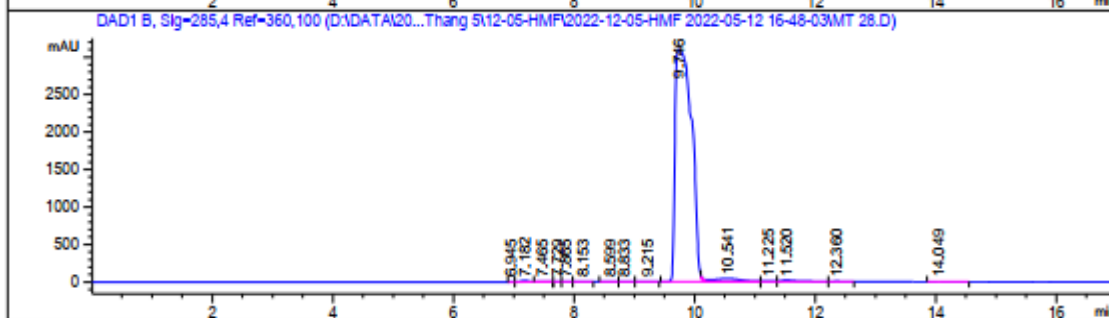
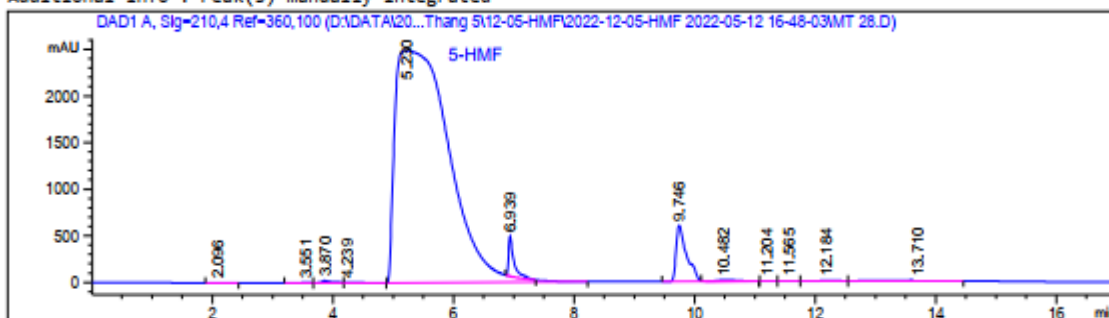


**Figure S4-14:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 6 hours at 120 °C.

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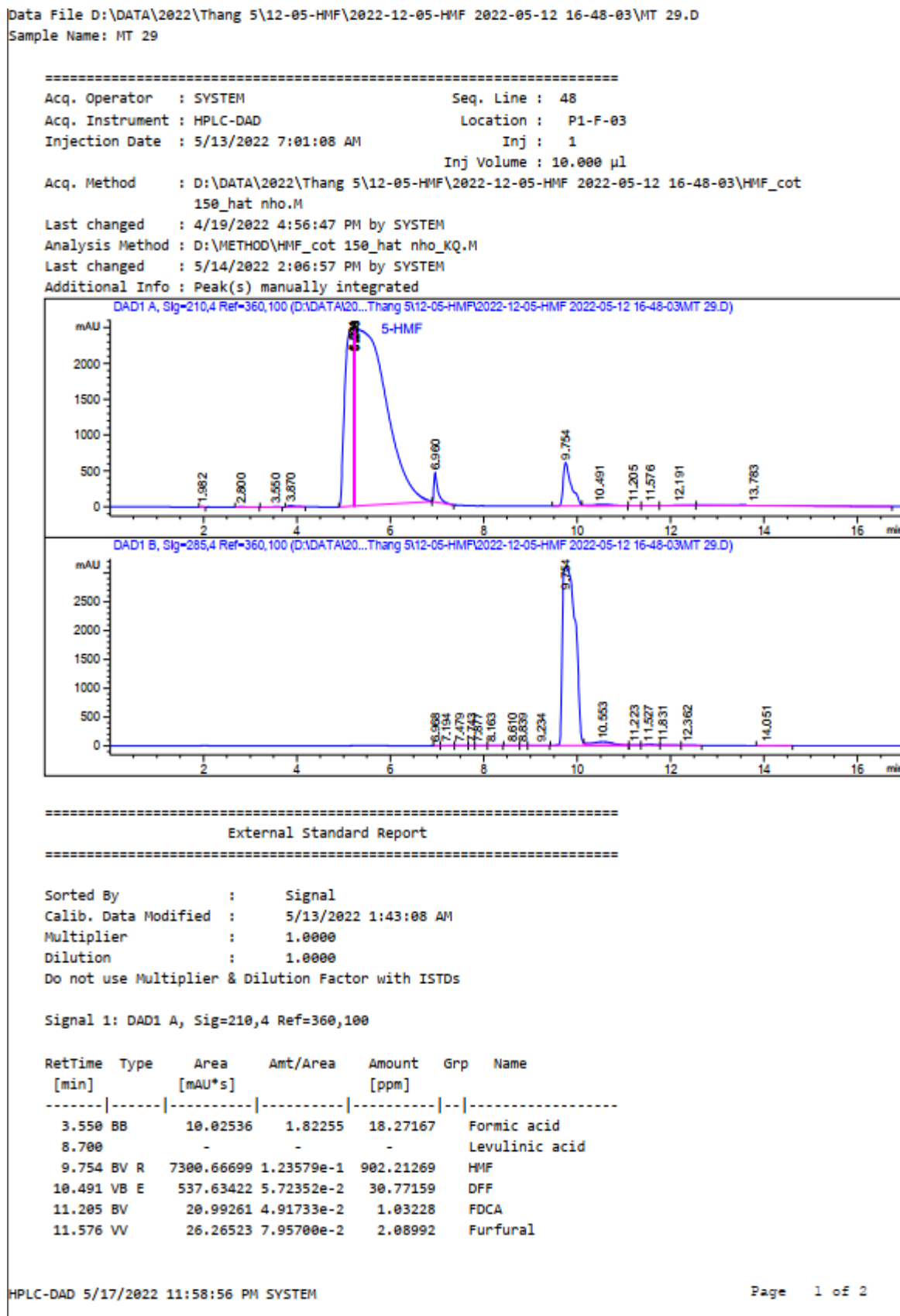
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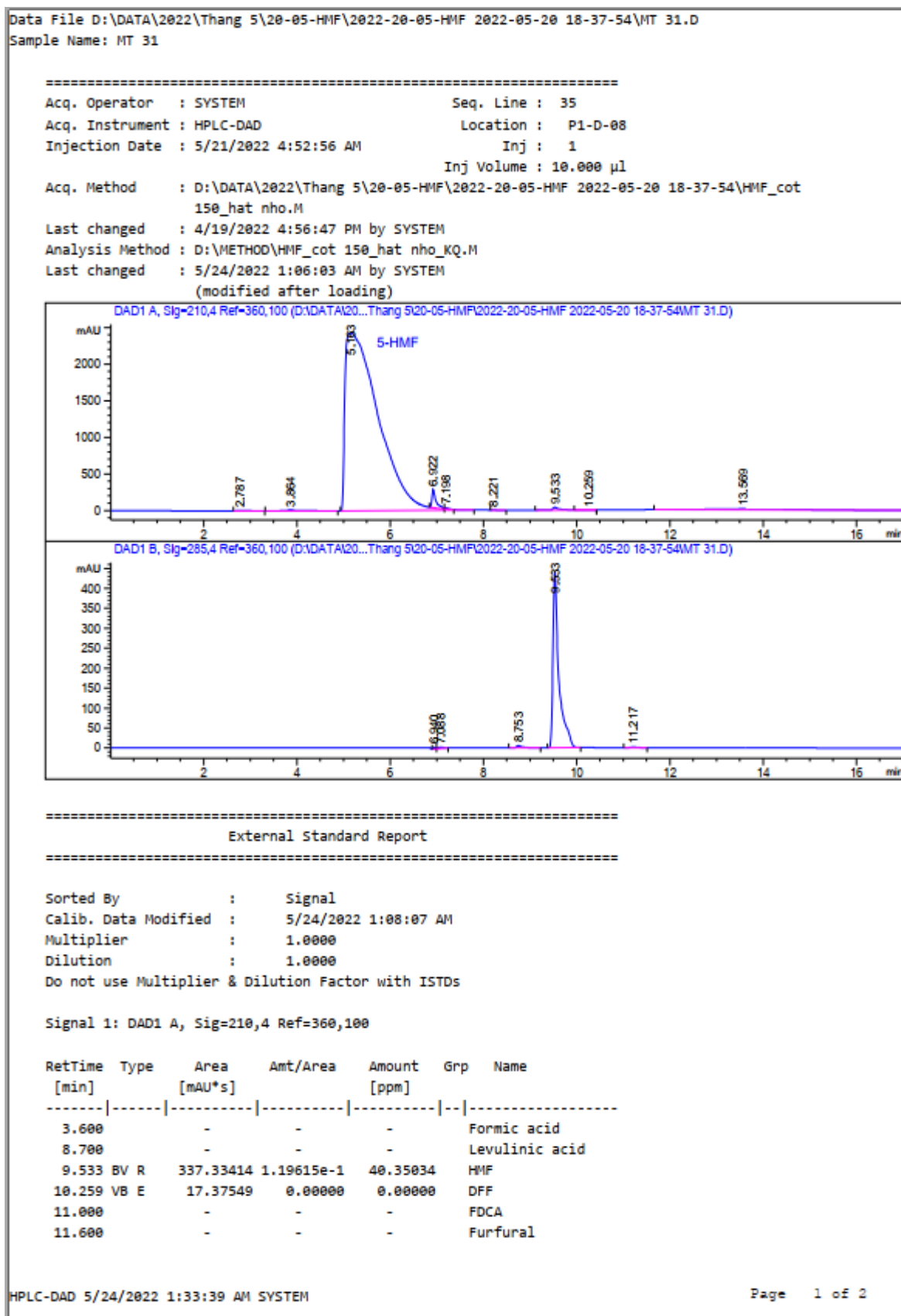
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8.700		-	-	-		Levulinic acid
9.746	BV R	7276.29932	1.23579e-1	899.19667		HMF
10.482	VB E	349.71902	5.48230e-2	19.17264		DFF
11.204	BV	25.83689	7.77287e-2	2.00827		FOCA
11.565	VV	39.98608	8.87952e-2	3.55057		Furfural



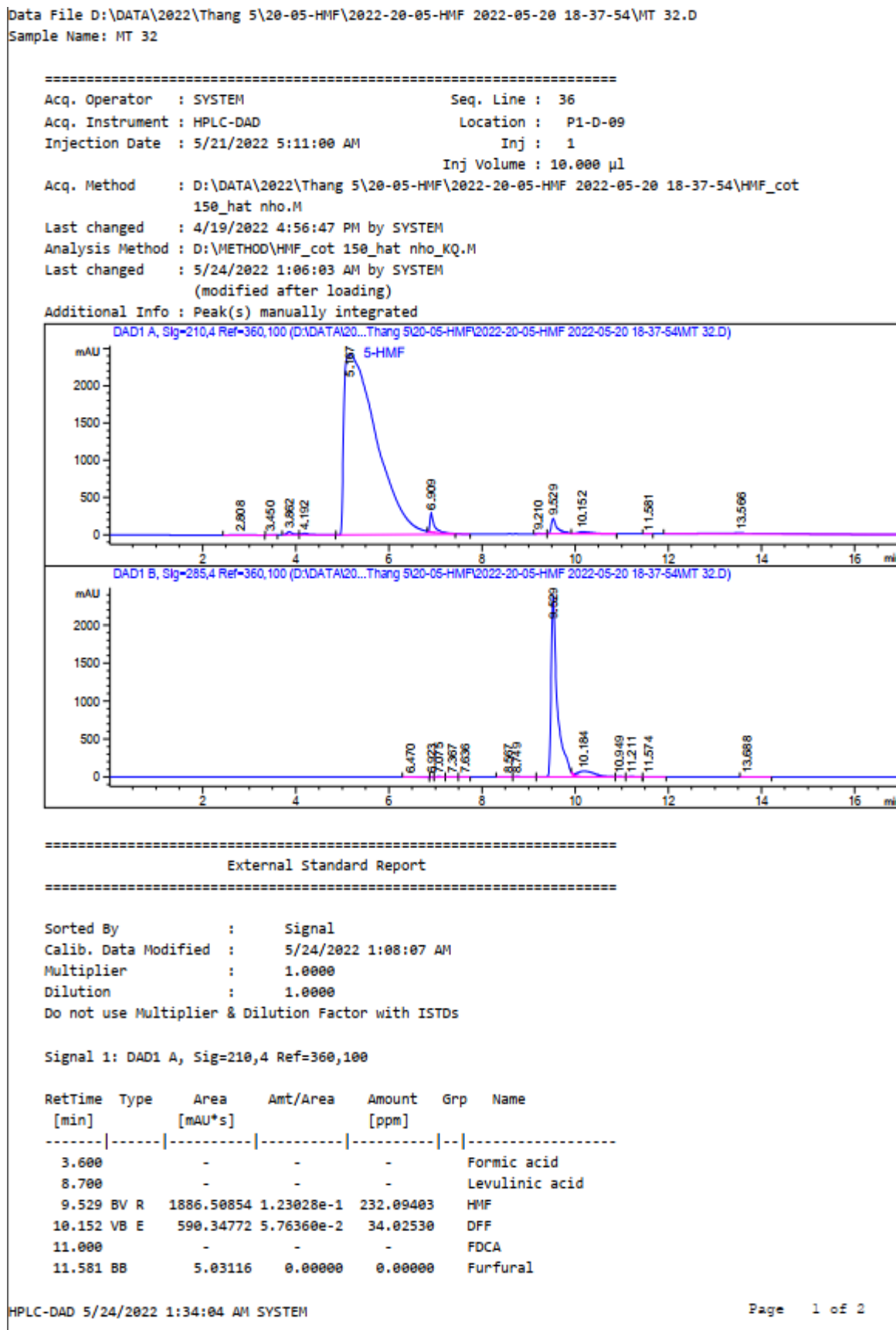
**Figure S4-15:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 8 hours at 120 °C.



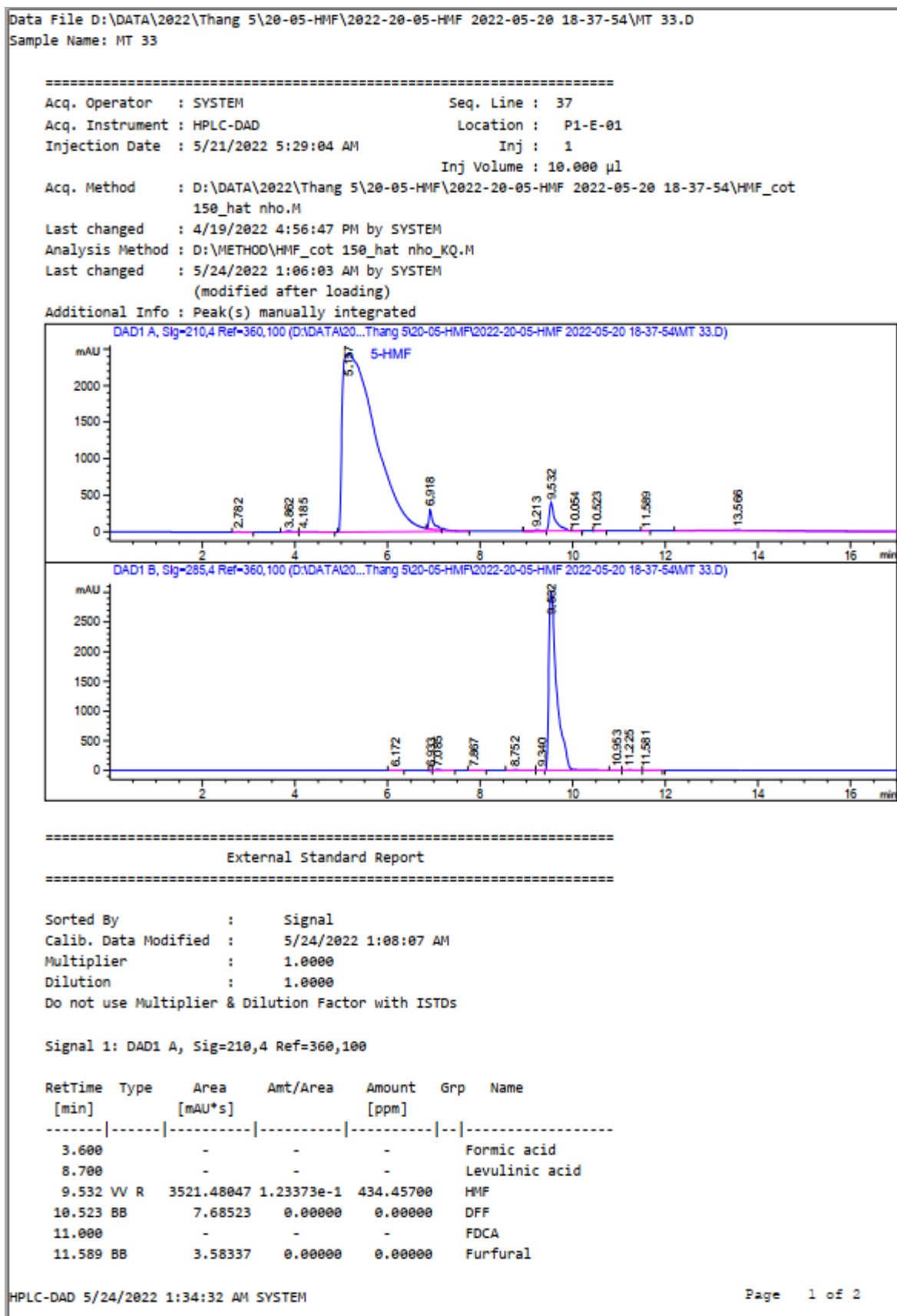
**Figure S4-16:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 9 hours at 120 °C.



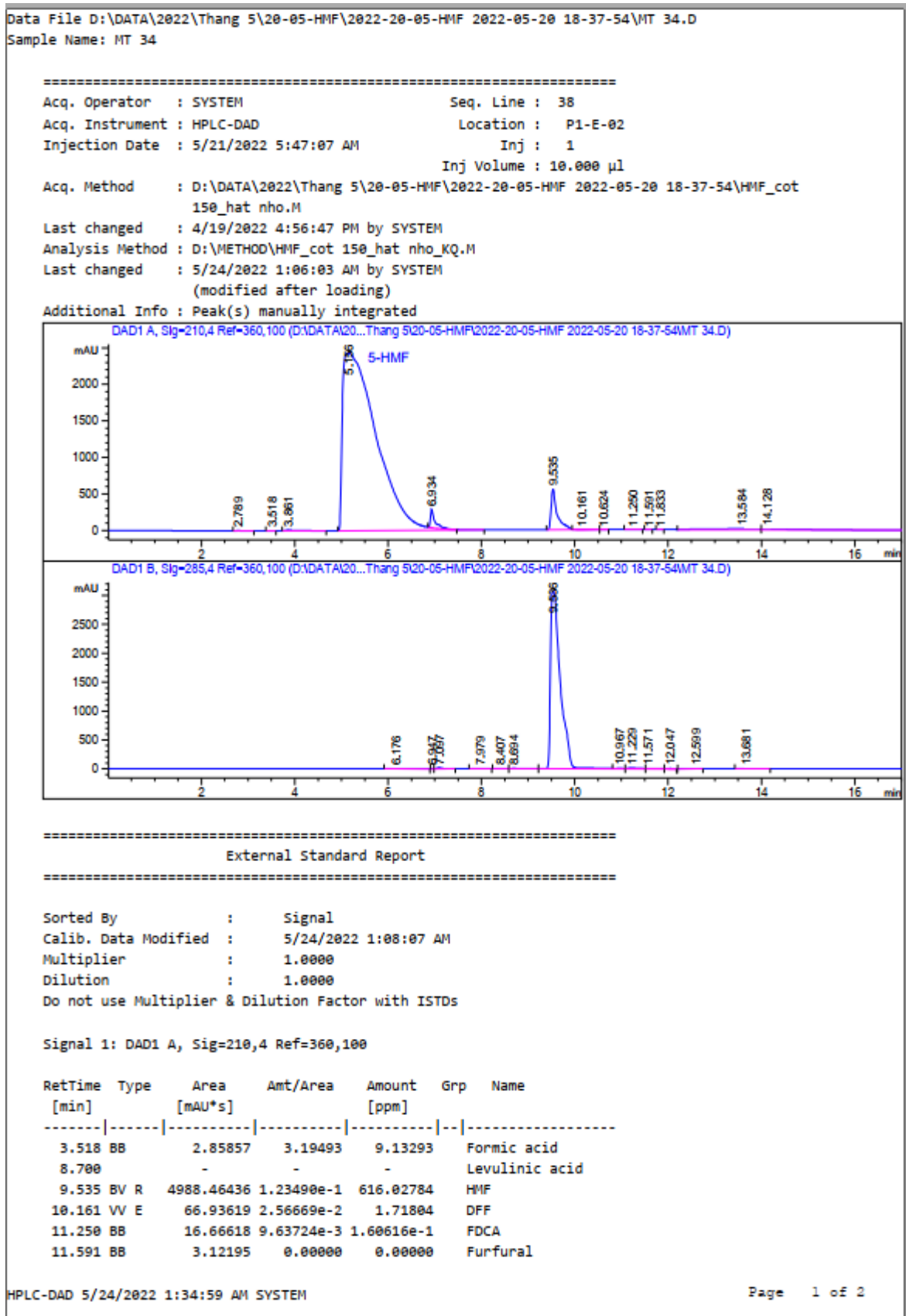
**Figure S4-17:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 10 hours at 120 °C.



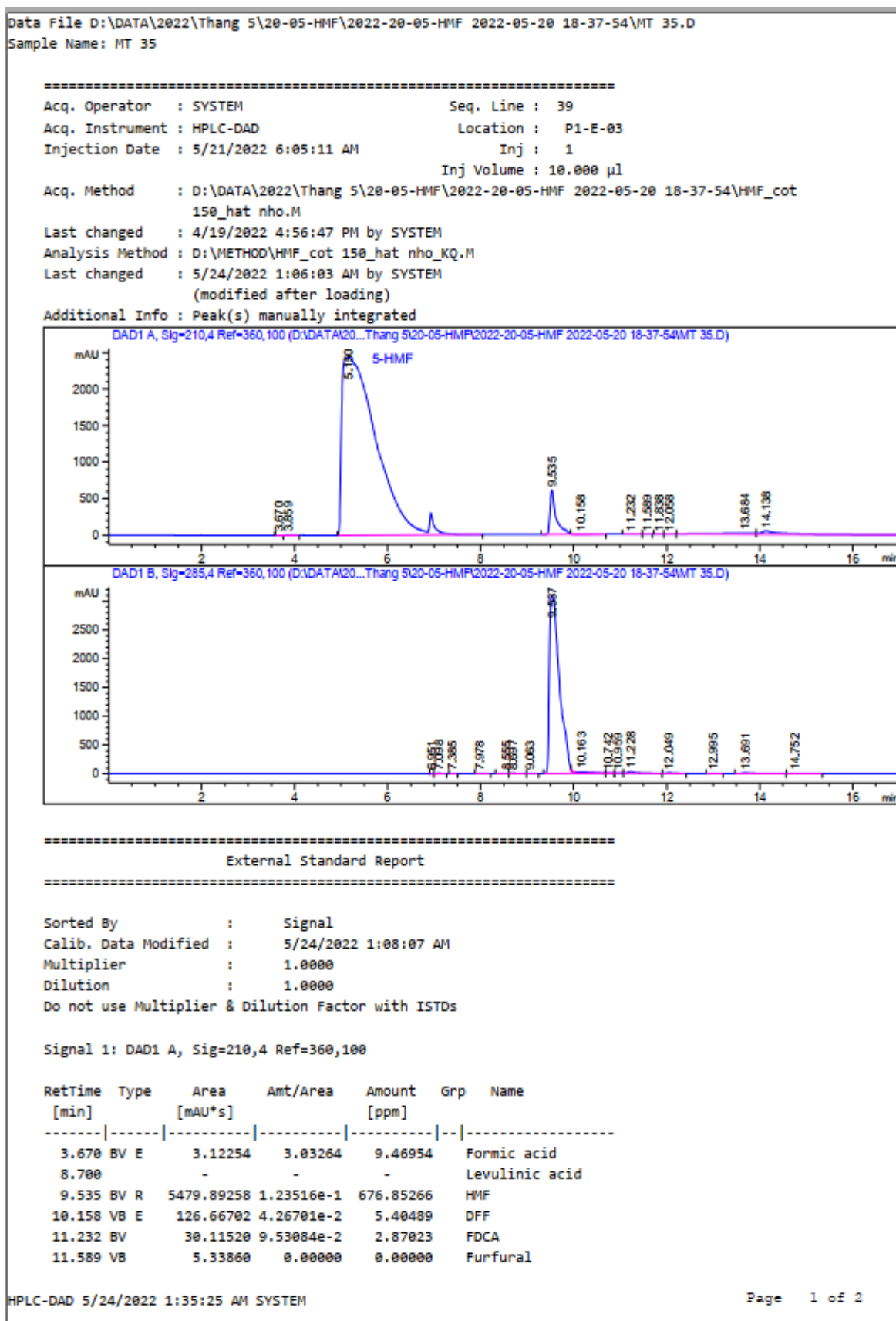
**Figure S4-18:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 11 hours at 120 °C.



**Figure S4-19:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at 120 °C.



**Figure S4-20:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 13 hours at 120 °C.

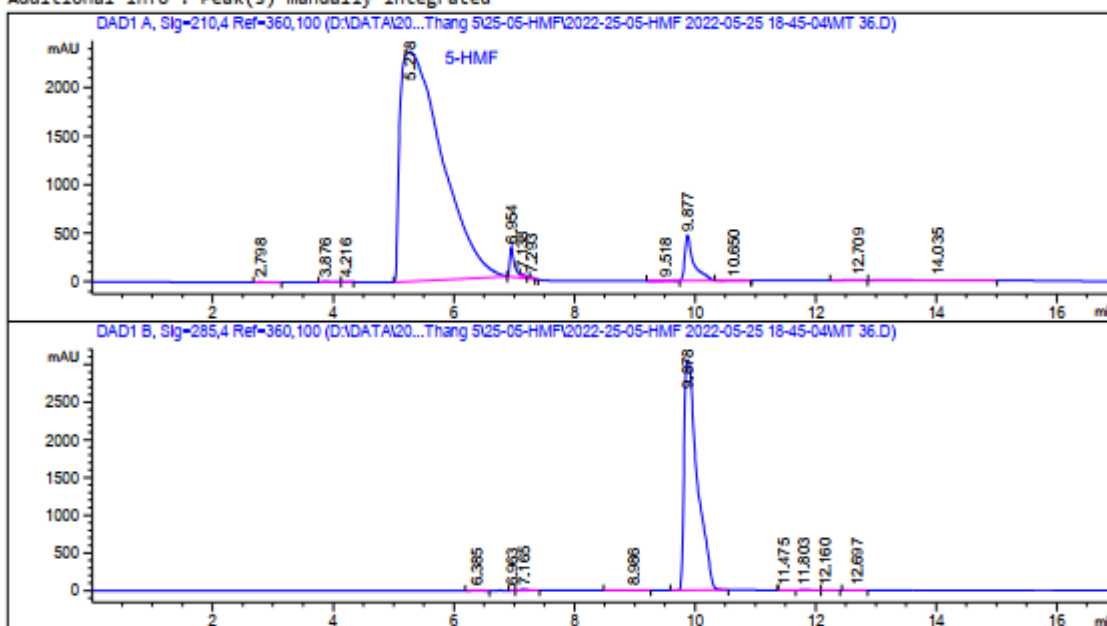


**Figure S4-21:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 30 minutes at 120 °C.

Data File D:\DATA\2022\Thang 5\25-05-HMF\2022-25-05-HMF 2022-05-25 18-45-04\MT 36.D  
 Sample Name: MT 36

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                                                Inj Volume: 10.000 µl
Acq. Method     : D:\DATA\2022\Thang 5\25-05-HMF\2022-25-05-HMF 2022-05-25 18-45-04\HMF_cot
                                                150_hat_nho.M
Last changed    : 4/19/2022 4:56:47 PM by SYSTEM
Analysis Method : D:\METHOD\HMF_cot 150_hat_nho_KQ.M
Last changed    : 5/26/2022 6:42:39 AM by SYSTEM
                (modified after loading)
Additional Info : Peak(s) manually integrated
  
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External Standard Report

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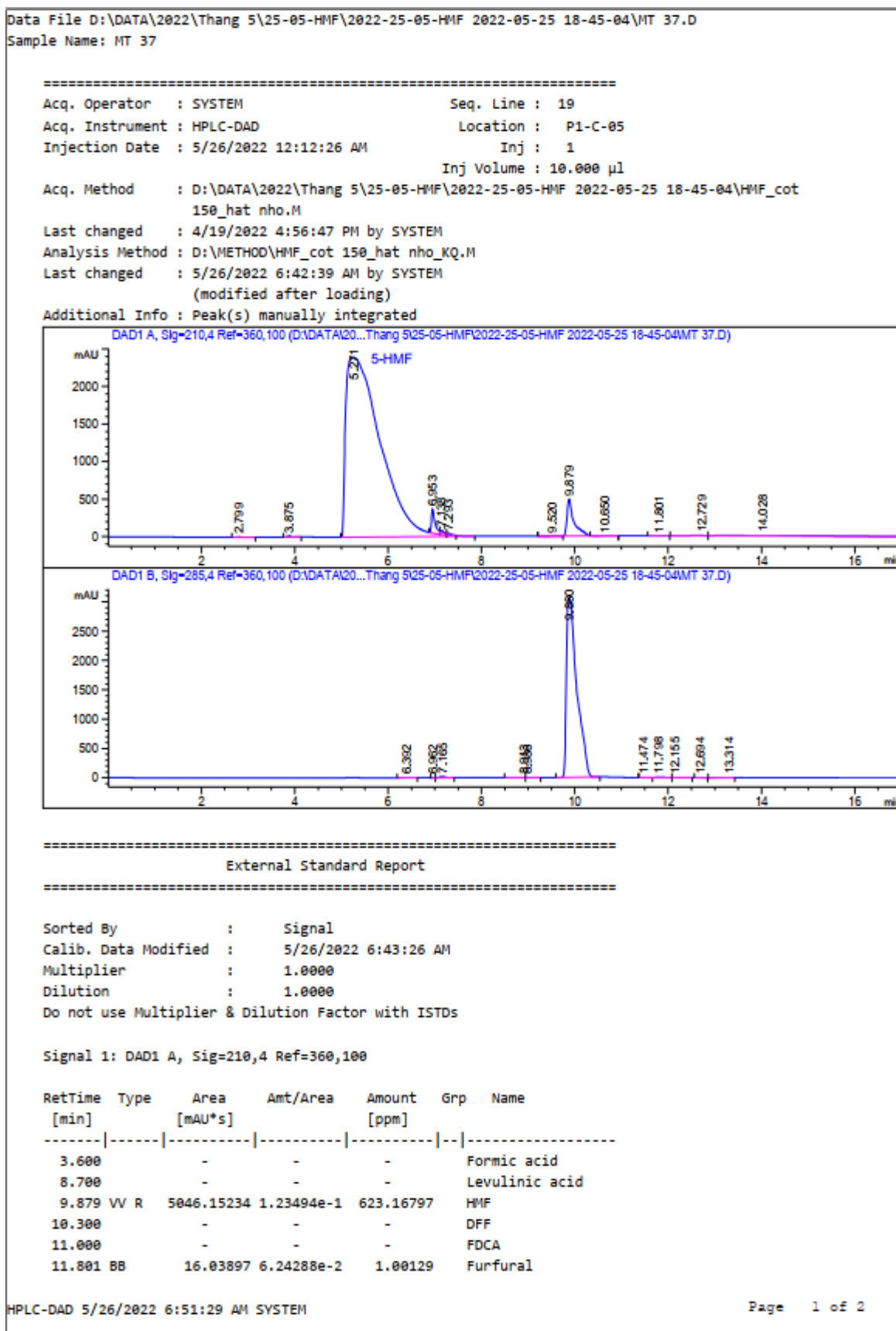
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Dilution       : 1.0000
Do not use Multiplier & Dilution Factor with ISTDs
  
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Signal 1: DAD1 A, Sig=210,4 Ref=360,100

RetTime [min]	Type	Area [mAU*s]	Amt/Area	Amount [ppm]	Grp	Name
3.600	-	-	-	-	-	Formic acid
8.700	-	-	-	-	-	Levulinic acid
9.877	VV R	4823.13281	1.23481e-1	595.56450	-	HMF
10.300	-	-	-	-	-	DFP
11.000	-	-	-	-	-	FDCA
11.600	-	-	-	-	-	Furfural

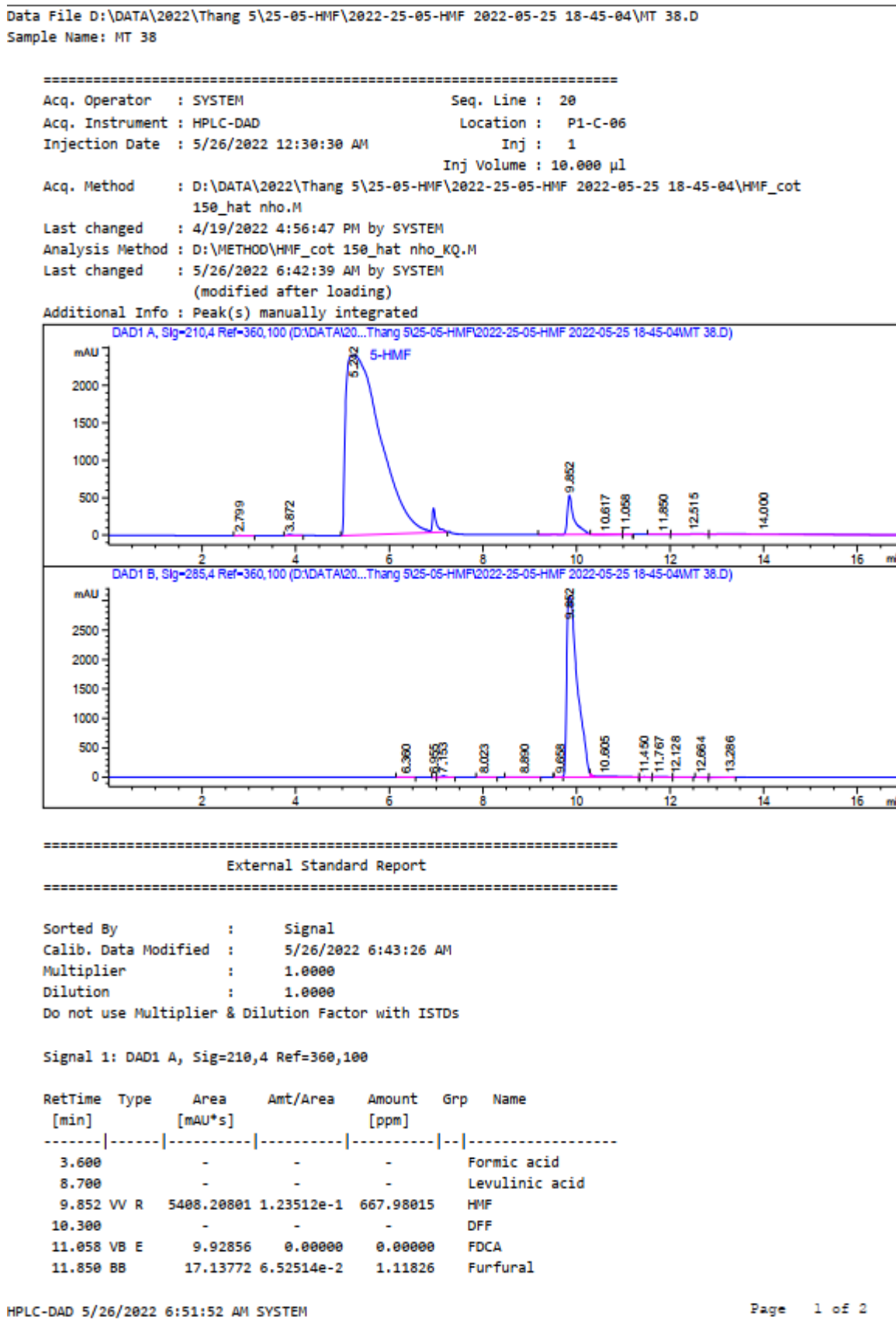


**Figure S4-22:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 1 hour at 120 °C.

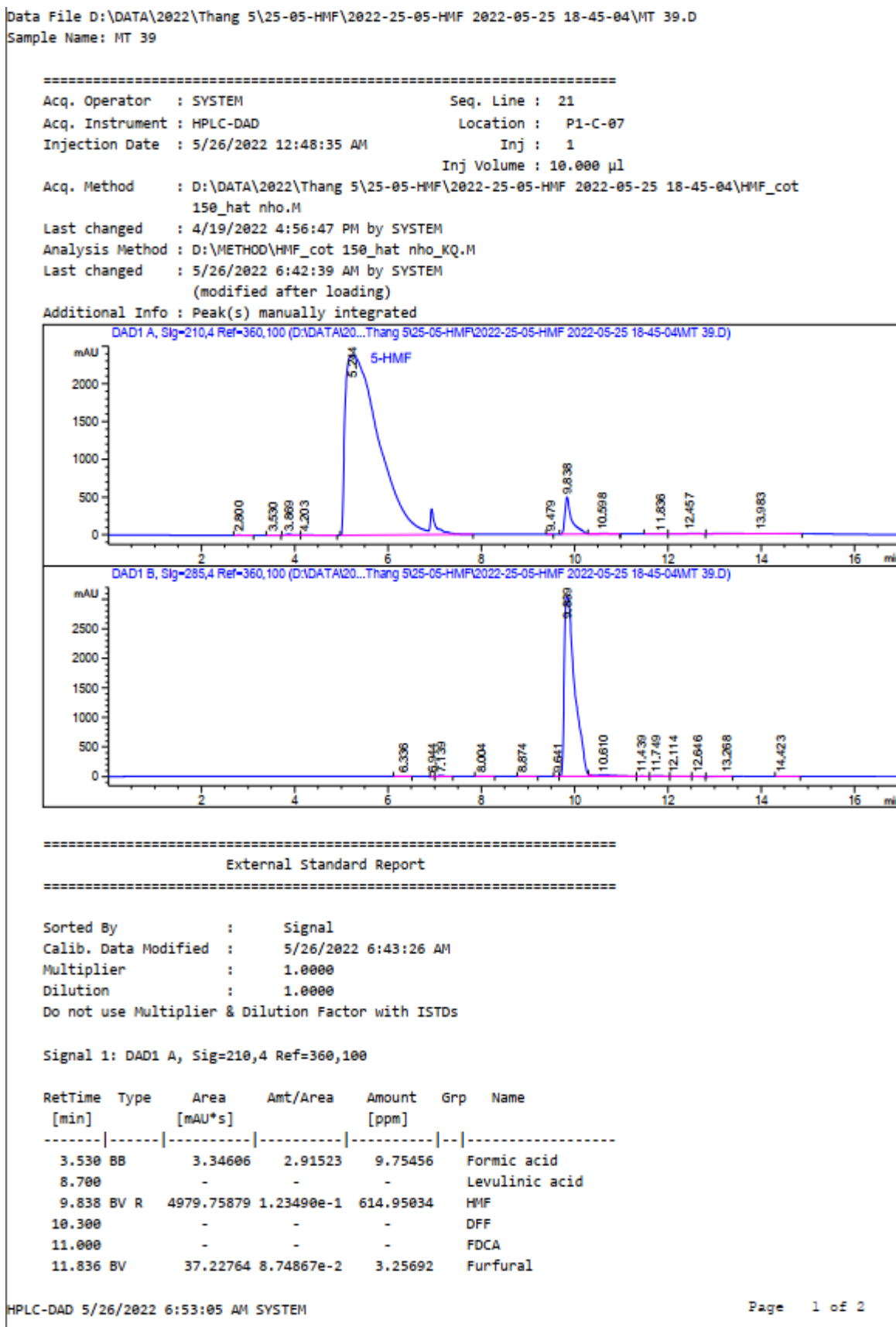




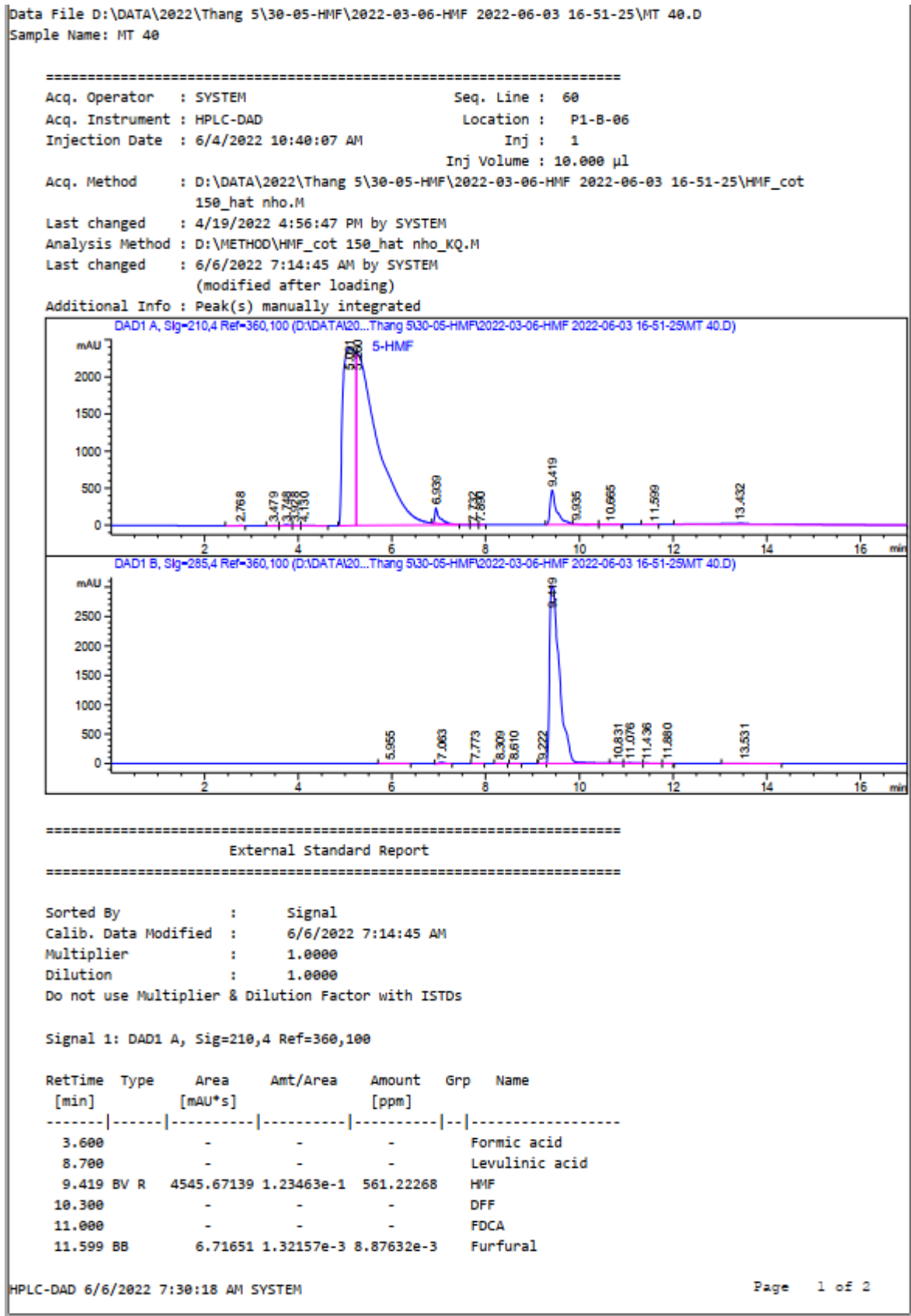
**Figure S4-23:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 3 hours at 120 °C.



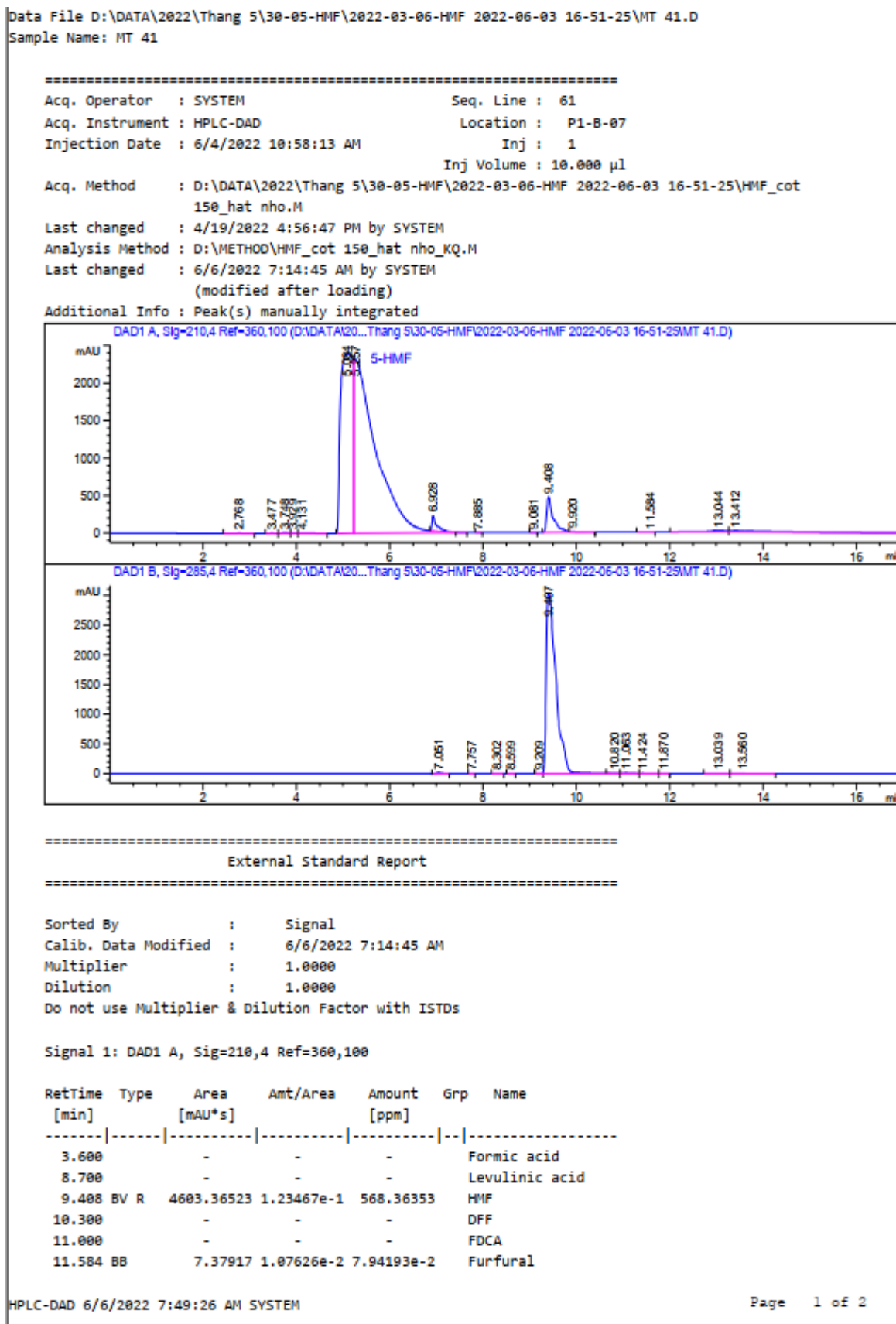
**Figure S4-24:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 6 hours at 120 °C.



**Figure S4-25:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 8 hours at 120 °C.



**Figure S4-26:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 9 hours at 120 °C.

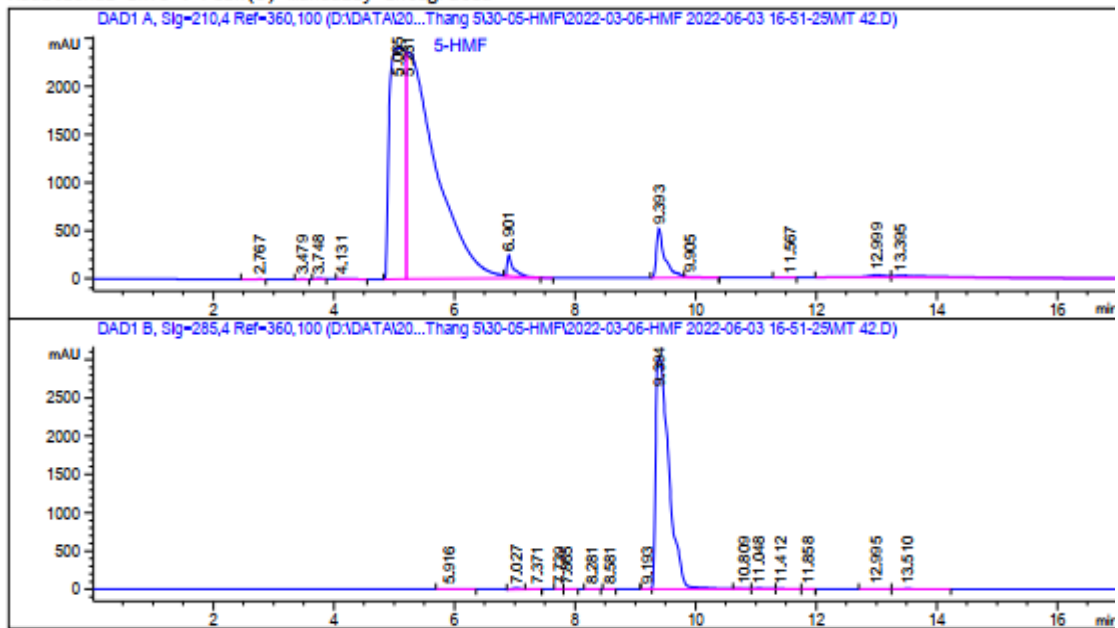


**Figure S4-27:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 10 hours at 120 °C.

Data File D:\DATA\2022\Thang 5\30-05-HMF\2022-03-06-HMF 2022-06-03 16-51-25\MT 42.D  
 Sample Name: MT 42

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Acq. Instrument : HPLC-DAD                    Location  : P1-B-08
Injection Date  : 6/4/2022 11:16:19 AM       Inj       :    1
                                           Inj Volume: 10.000 µl
Acq. Method     : D:\DATA\2022\Thang 5\30-05-HMF\2022-03-06-HMF 2022-06-03 16-51-25\HMF_cot
150_hat_nho.M
Last changed    : 4/19/2022 4:56:47 PM by SYSTEM
Analysis Method : D:\METHOD\HMF_cot_150_hat_nho_KQ.M
Last changed    : 6/6/2022 7:14:45 AM by SYSTEM
                (modified after loading)
Additional Info  : Peak(s) manually integrated
  
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External Standard Report

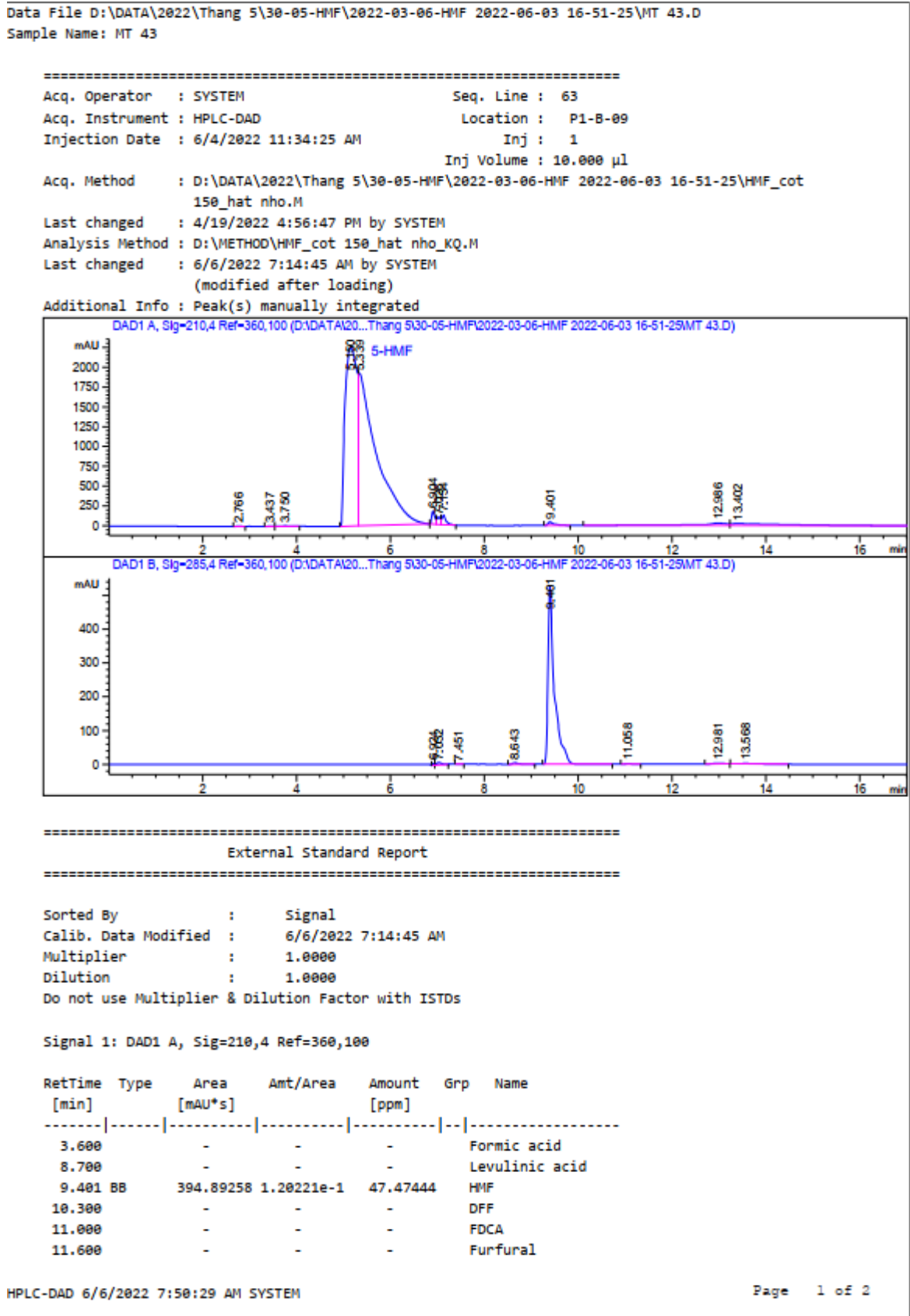
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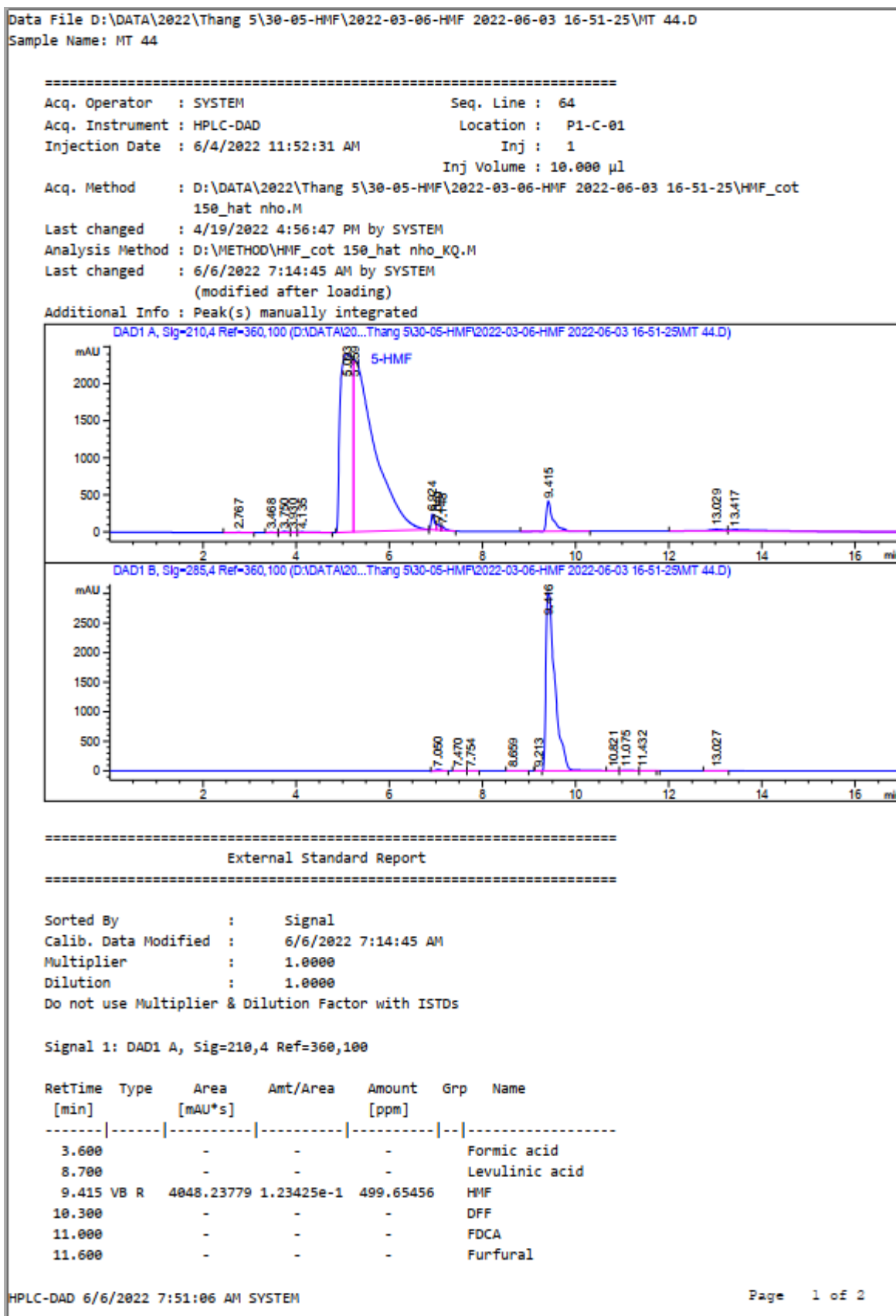
Signal 1: DAD1 A, Sig=210,4 Ref=360,100

RetTime [min]	Type	Area [mAU*s]	Amt/Area	Amount [ppm]	Grp	Name
3.600	-	-	-	-	-	Formic acid
8.700	-	-	-	-	-	Levulinic acid
9.393	BV R	4995.88672	1.23491e-1	616.94652	-	HMF
10.300	-	-	-	-	-	DFF
11.000	-	-	-	-	-	FDCA
11.567	BB	10.03618	3.60964e-2	3.62270e-1	-	Furfural

**Figure S4-28:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 11 hours at 120 °C.



**Figure S4-29:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at 120 °C.





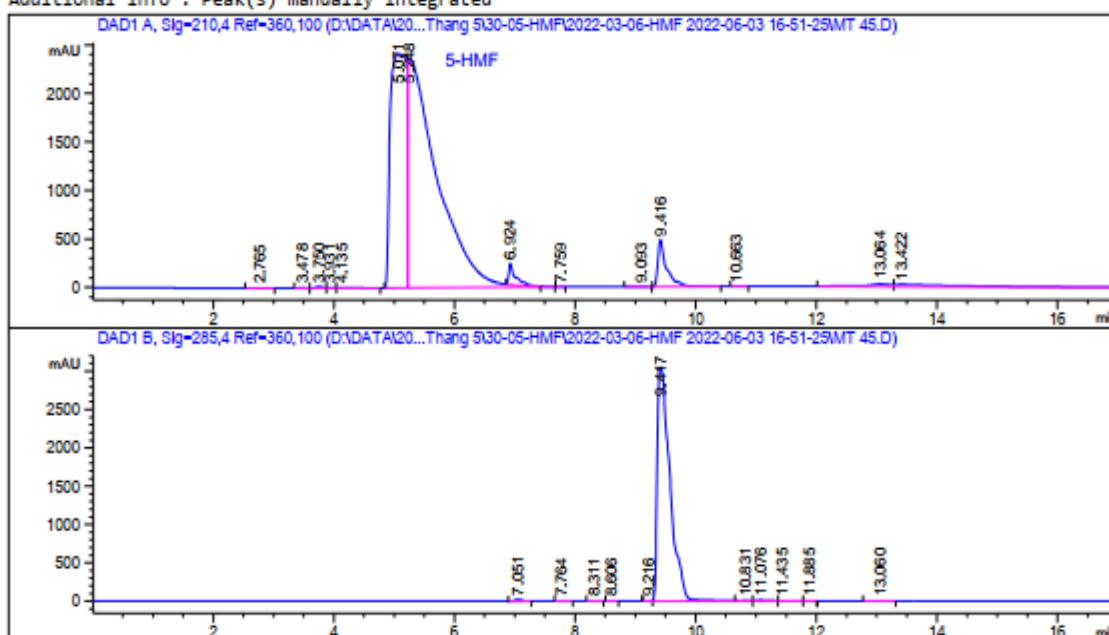
**Figure S4-30:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 13 hours at 120 °C.

Data File D:\DATA\2022\Thang 5\30-05-HMF\2022-03-06-HMF 2022-06-03 16-51-25\MT 45.D  
 Sample Name: MT 45

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Acq. Instrument : HPLC-DAD                   Location  : P1-C-02
Injection Date  : 6/4/2022 12:10:35 PM      Inj       : 1
                                           Inj Volume: 10.000 µl

Acq. Method     : D:\DATA\2022\Thang 5\30-05-HMF\2022-03-06-HMF 2022-06-03 16-51-25\HMF_cot
                  150_hat_nho.M
Last changed    : 4/19/2022 4:56:47 PM by SYSTEM
Analysis Method : D:\METHOD\HMF_cot_150_hat_nho_KQ.M
Last changed    : 6/6/2022 7:14:45 AM by SYSTEM
                  (modified after loading)
Additional Info  : Peak(s) manually integrated
  
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External Standard Report

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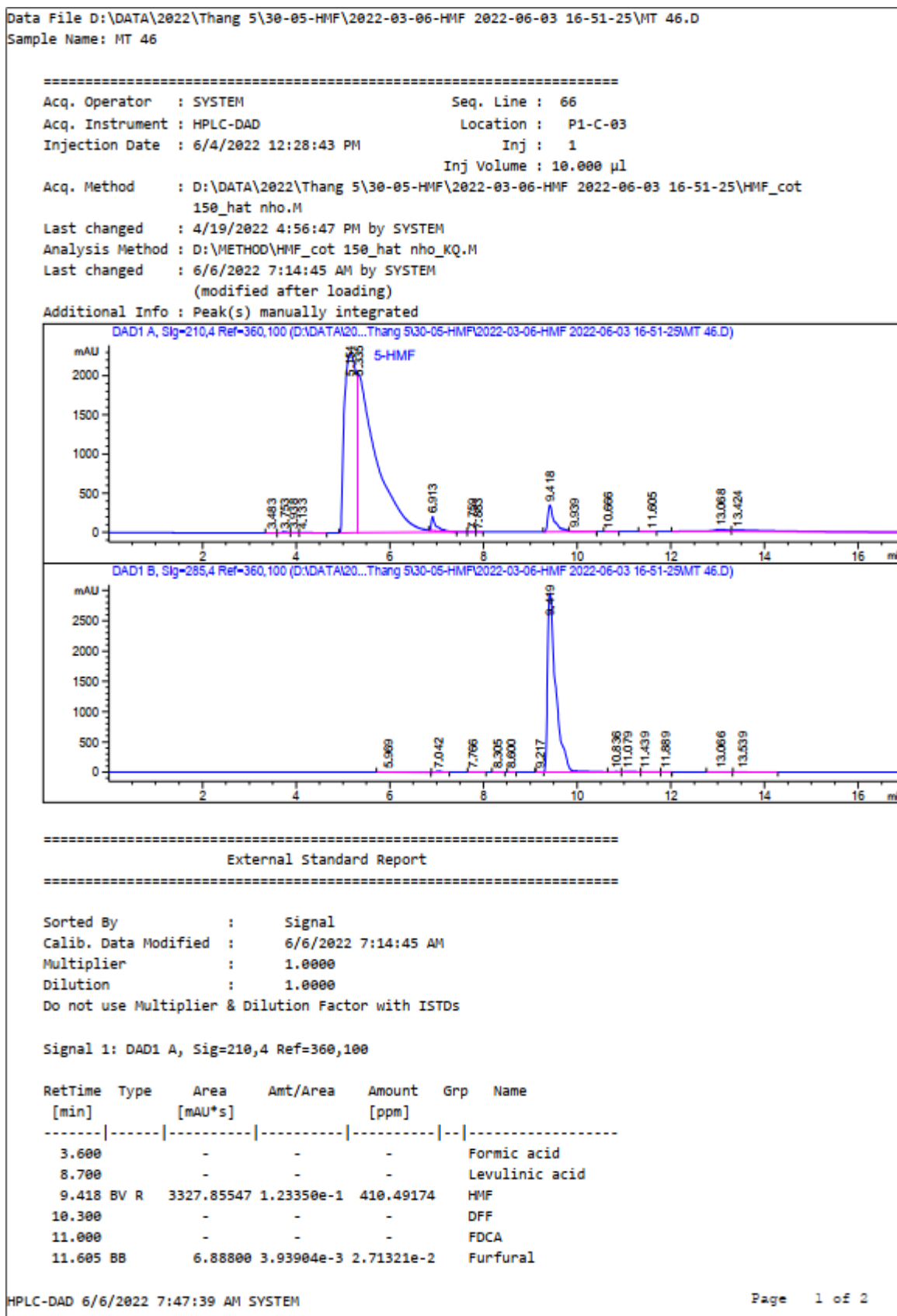
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Calib. Data Modified : 6/6/2022 7:14:45 AM
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Dilution      : 1.0000
Do not use Multiplier & Dilution Factor with ISTDs
  
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Signal 1: DAD1 A, Sig=210,4 Ref=360,100

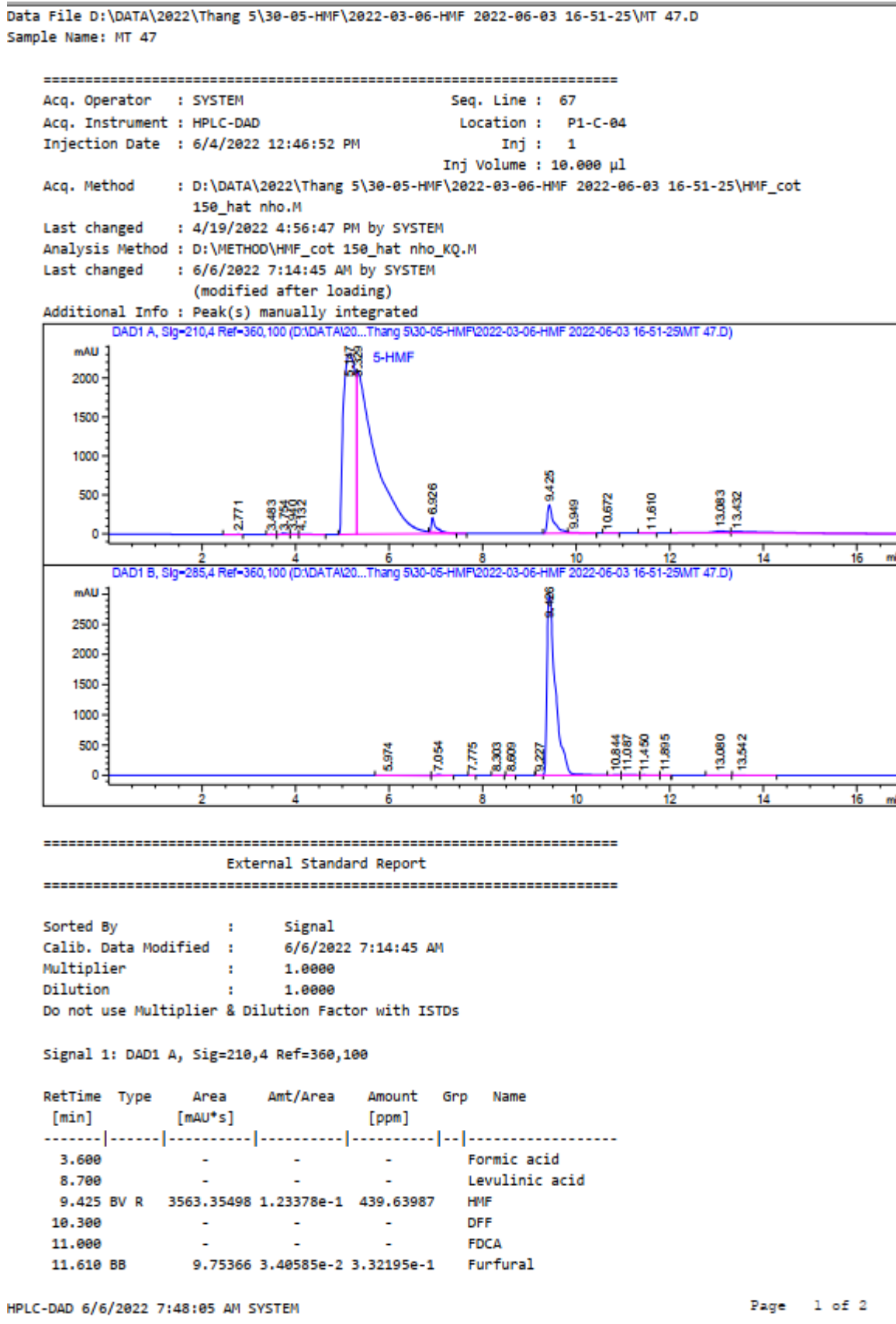
RetTime [min]	Type	Area [mAU*s]	Amt/Area	Amount [ppm]	Grp	Name
3.600	-	-	-	-	-	Formic acid
8.700	-	-	-	-	-	Levulinic acid
9.416	BB	4766.39893	1.23477e-1	588.54246	-	HMF
10.300	-	-	-	-	-	DFF
11.000	-	-	-	-	-	FDCA
11.600	-	-	-	-	-	Furfural



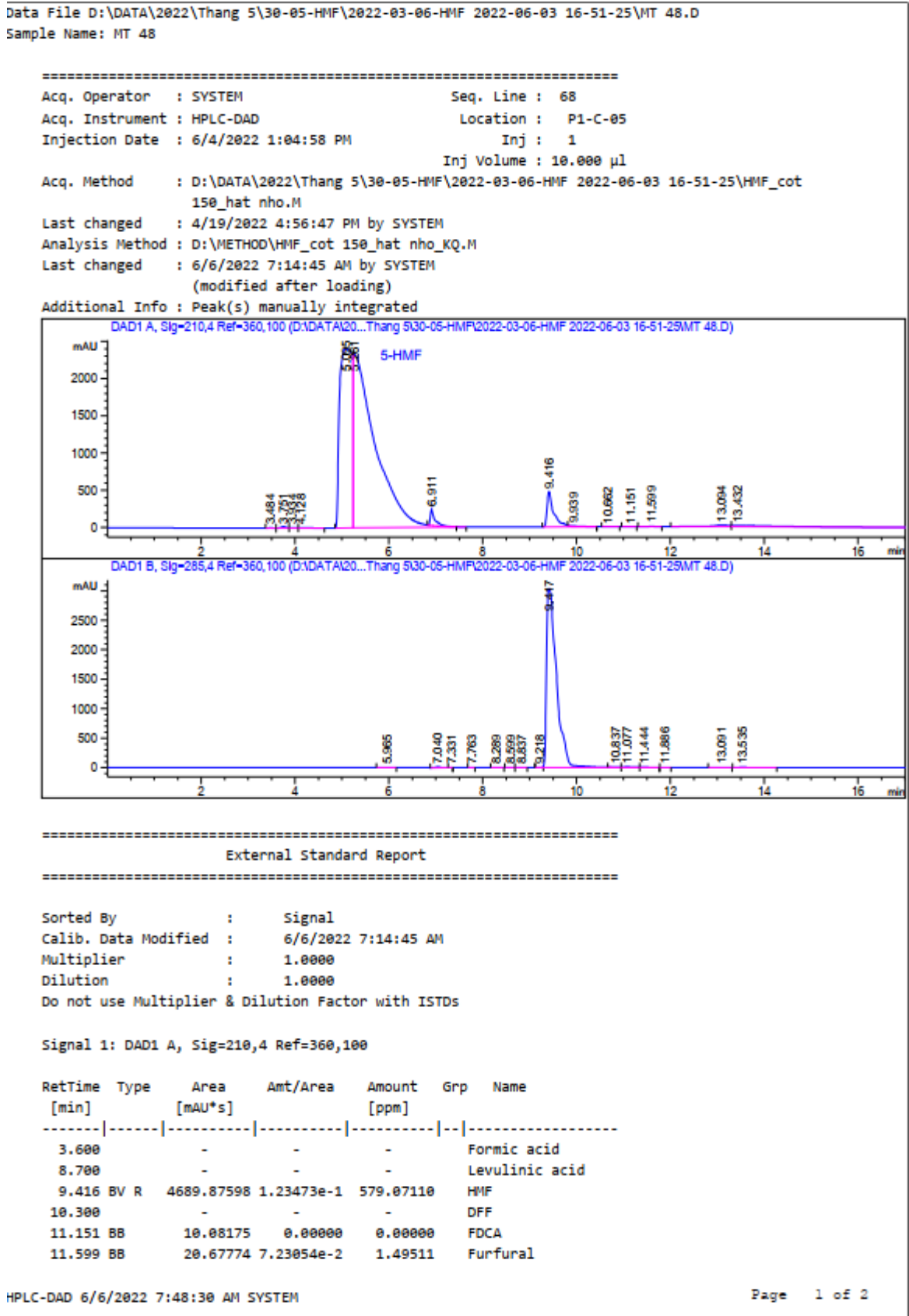
**Figure S4-31:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at room temperature.



**Figure S4-32:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at 40 °C.



**Figure S4-33:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at 60 °C.

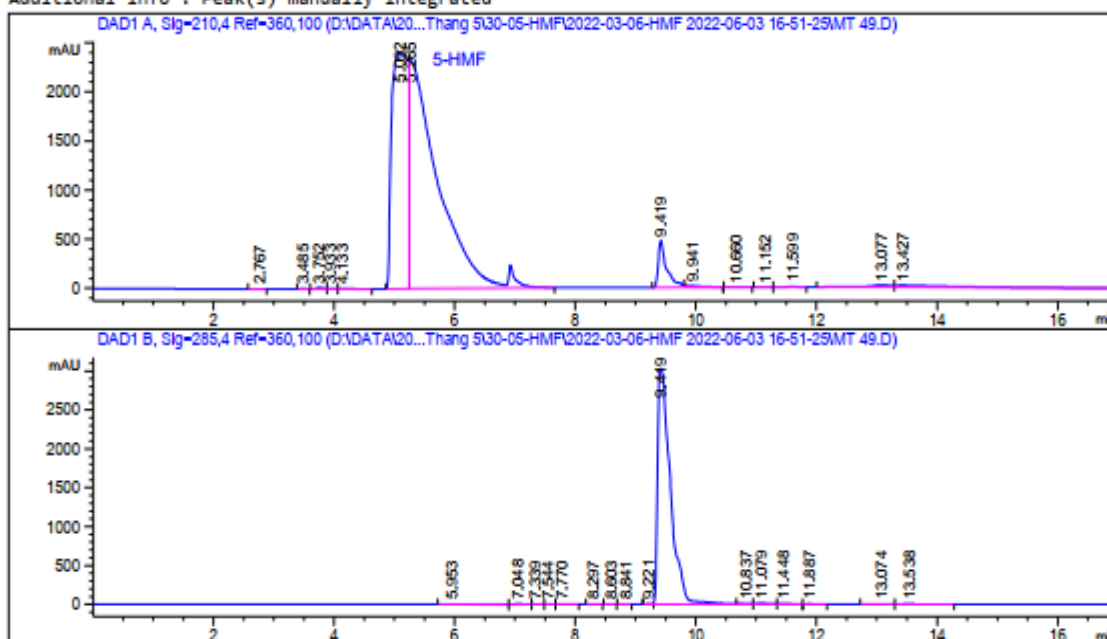


**Figure S4-34:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at 80 °C.

Data File D:\DATA\2022\Thang 5\30-05-HMF\2022-03-06-HMF 2022-06-03 16-51-25\MT 49.D  
 Sample Name: MT 49

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                                           Inj Volume: 10.000 µl
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                  150_hat_nho.M
Last changed    : 4/19/2022 4:56:47 PM by SYSTEM
Analysis Method : D:\METHOD\HMF_cot 150_hat_nho_KQ.M
Last changed    : 6/6/2022 7:14:45 AM by SYSTEM
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Additional Info  : Peak(s) manually integrated
  
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Signal 1: DAD1 A, Sig=210,4 Ref=360,100

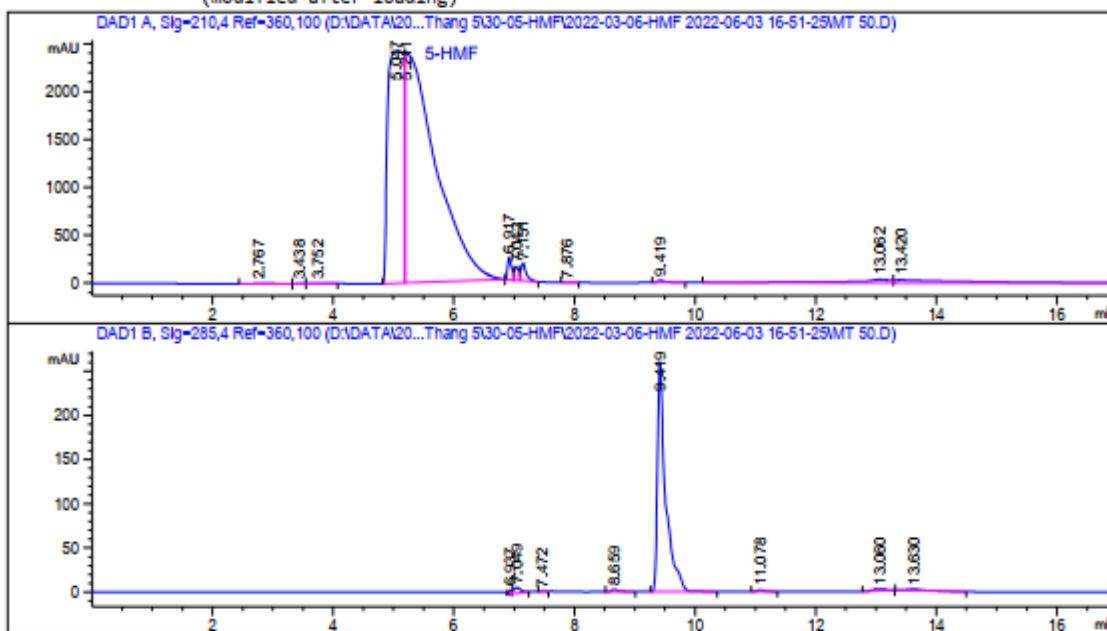
RetTime [min]	Type	Area [mAU*s]	Amt/Area	Amount [ppm]	Grp	Name
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8.700	-	-	-	-	-	Levulinic acid
9.419	BV R	4690.57861	1.23473e-1	579.15806	-	HMF
10.300	-	-	-	-	-	DFF
11.152	BV	12.56385	0.00000	0.00000	-	FDCA
11.599	VB	29.78968	8.27507e-2	2.46512	-	Furfural

**Figure S4-35:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at 100 °C.

Data File D:\DATA\2022\Thang 5\30-05-HMF\2022-03-06-HMF 2022-06-03 16-51-25\MT 50.D  
 Sample Name: MT 50

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Injection Date  : 6/4/2022 1:41:11 PM        Inj       :    1
                                           Inj Volume: 10.000 µl
Acq. Method     : D:\DATA\2022\Thang 5\30-05-HMF\2022-03-06-HMF 2022-06-03 16-51-25\HMF_cot
                                           150_hat_nho.M
Last changed    : 4/19/2022 4:56:47 PM by SYSTEM
Analysis Method : D:\METHOD\HMF_cot 150_hat_nho_KQ.M
Last changed    : 6/6/2022 7:14:45 AM by SYSTEM
                (modified after loading)
  
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External Standard Report

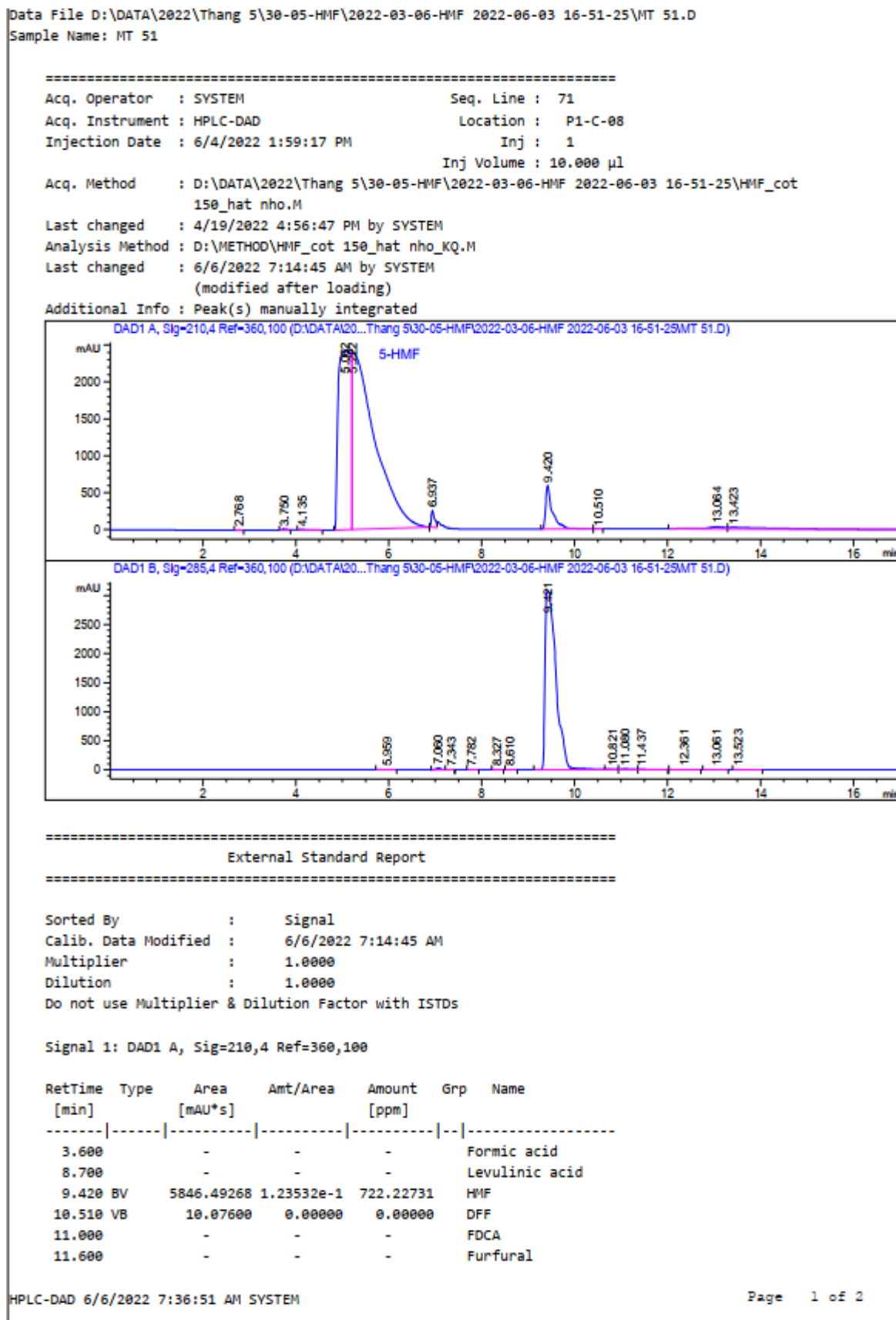
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Dilution       : 1.0000
Do not use Multiplier & Dilution Factor with ISTDs
  
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Signal 1: DAD1 A, Sig=210,4 Ref=360,100

RetTime [min]	Type	Area [mAU*s]	Amt/Area	Amount [ppm]	Grp	Name
3.600	-	-	-	-	-	Formic acid
8.700	-	-	-	-	-	Levulinic acid
9.419	BB	189.97421	1.16391e-1	22.11138	-	HMF
10.300	-	-	-	-	-	DFF
11.000	-	-	-	-	-	FDCA
11.600	-	-	-	-	-	Furfural

**Figure S4-36:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at 120 °C.

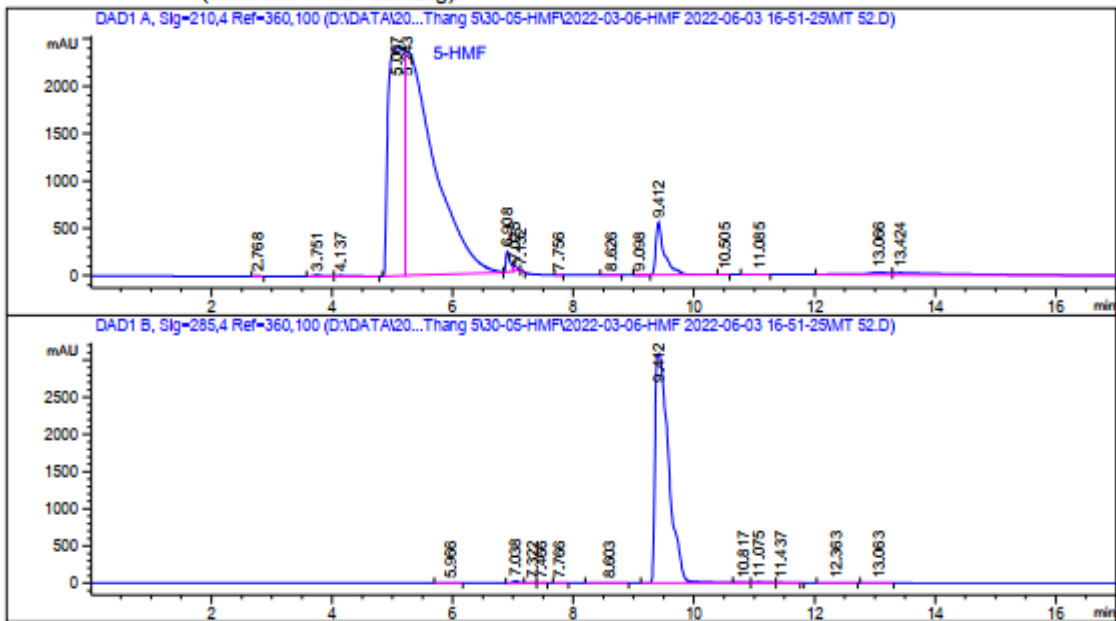


**Figure S4-37:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at 140 °C.

Data File D:\DATA\2022\Thang 5\30-05-HMF\2022-03-06-HMF 2022-06-03 16-51-25\MT 52.D  
 Sample Name: MT 52

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Injection Date  : 6/4/2022 2:17:23 PM         Inj       : 1
                                           Inj Volume: 10.000 µl
Acq. Method     : D:\DATA\2022\Thang 5\30-05-HMF\2022-03-06-HMF 2022-06-03 16-51-25\HMF_cot
                                           150_hat_nho.M
Last changed    : 4/19/2022 4:56:47 PM by SYSTEM
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External Standard Report

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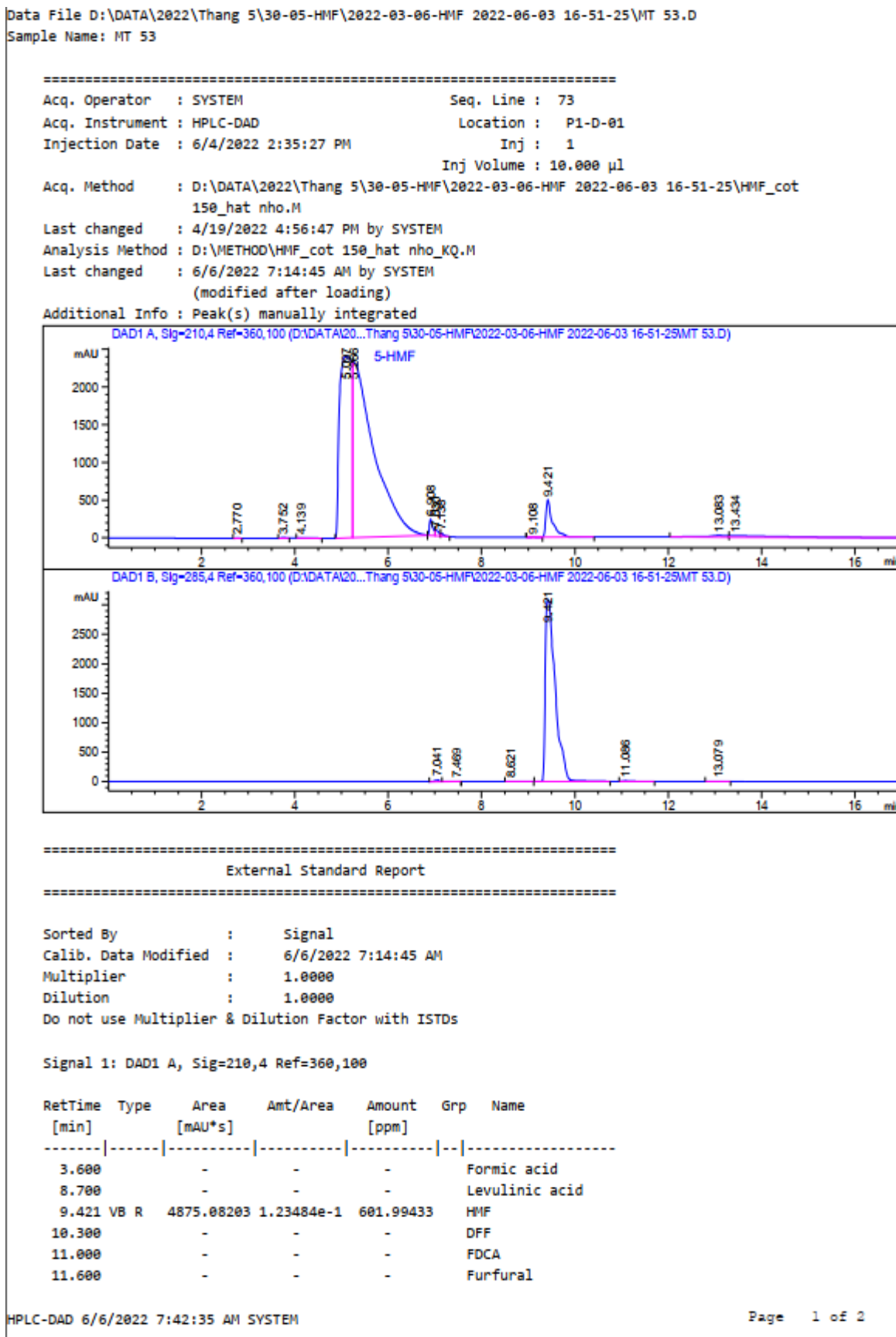
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Dilution       : 1.0000
Do not use Multiplier & Dilution Factor with ISTDs
  
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Signal 1: DAD1 A, Sig=210,4 Ref=360,100

RetTime [min]	Type	Area [mAU*s]	Amt/Area	Amount [ppm]	Grp	Name
3.600		-	-	-		Formic acid
8.626	BB	7.06291	4.22650	29.85140		Levulinic acid
9.412	VV R	5403.11621	1.23512e-1	667.34993		HMF
10.505	VB E	3.83288	0.00000	0.00000		DFF
11.085	BB	8.85389	0.00000	0.00000		FDCA
11.600		-	-	-		Furfural

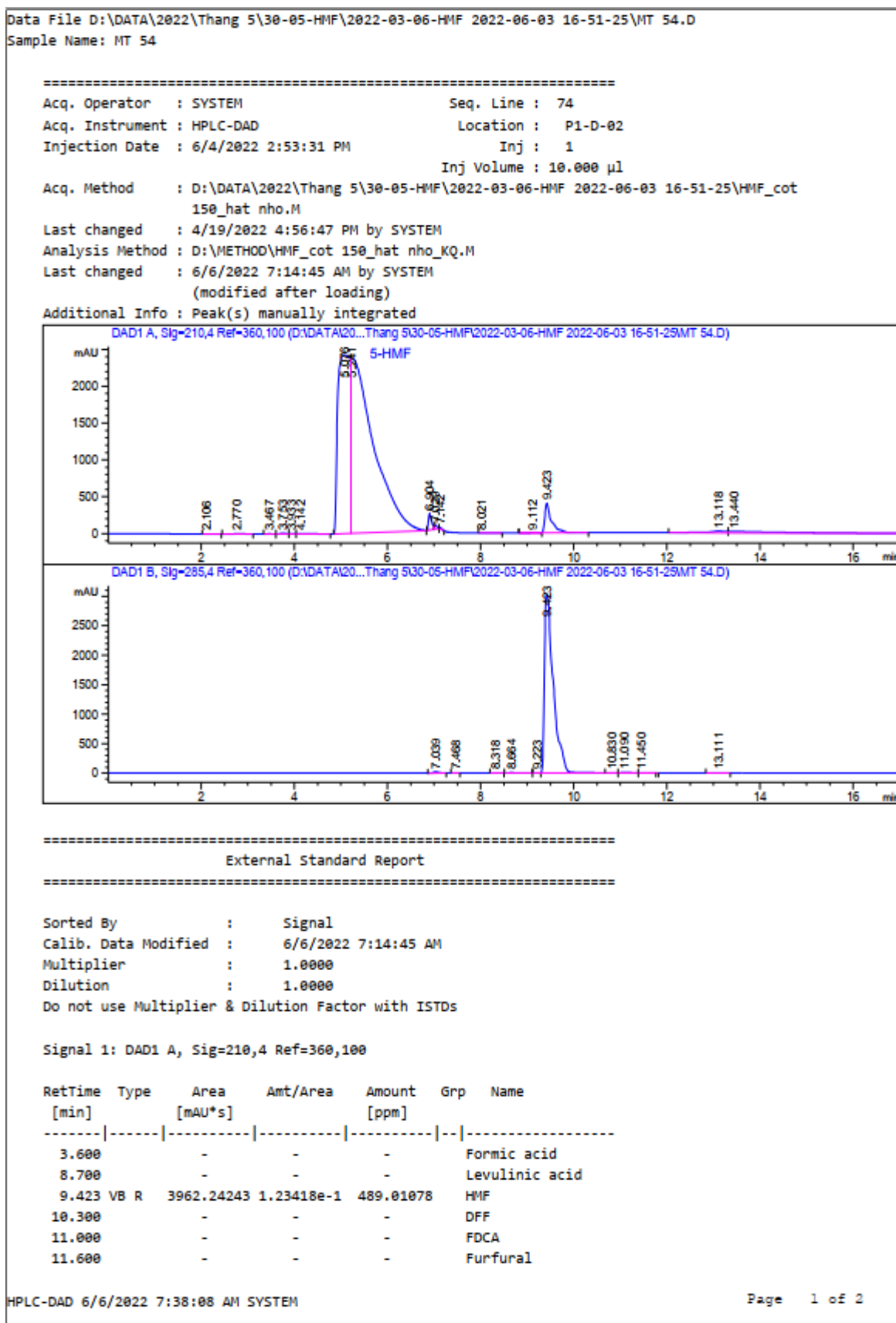


**Figure S4-38:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at 40 °C.

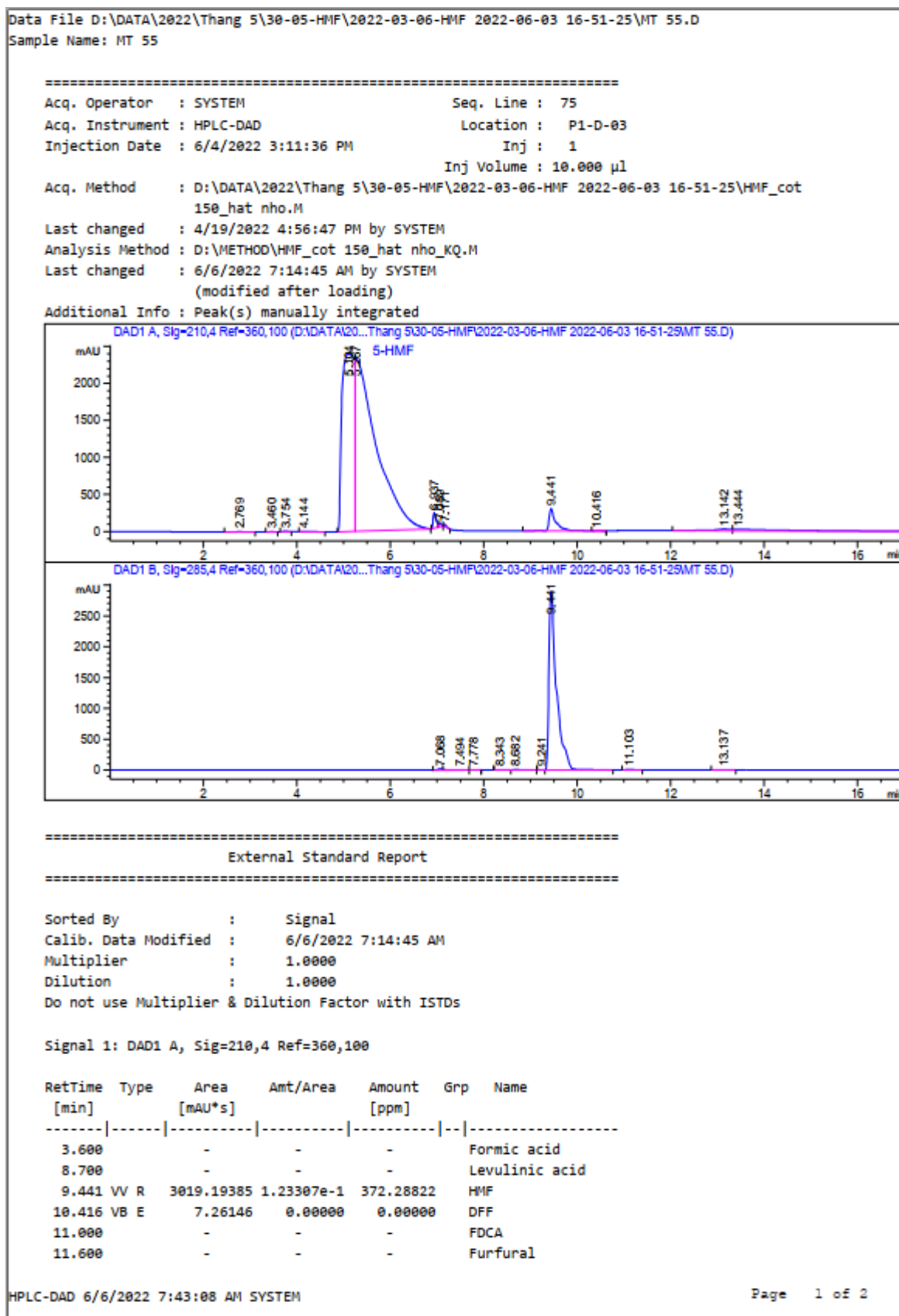




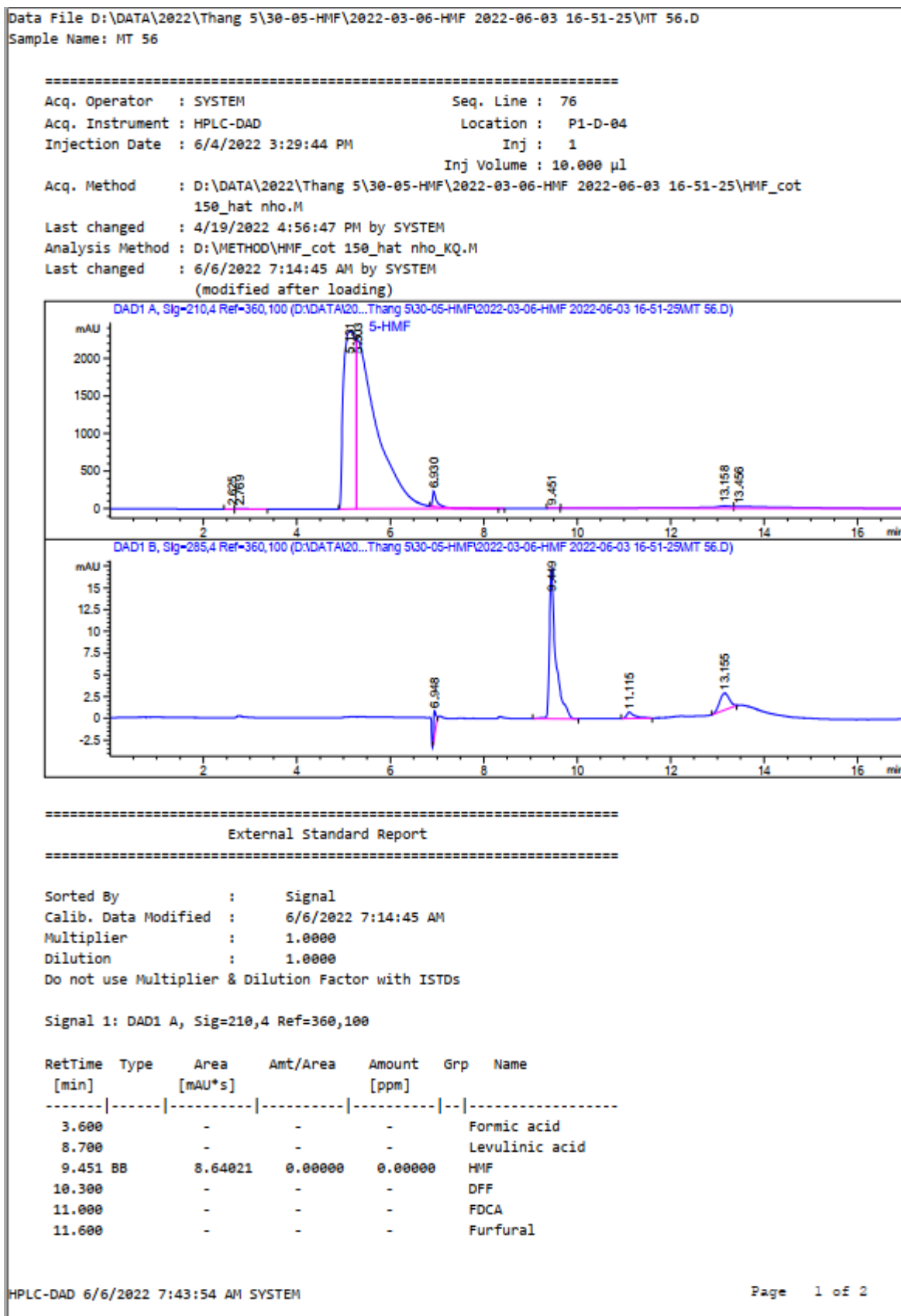
**Figure S4-39:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at 60 °C.



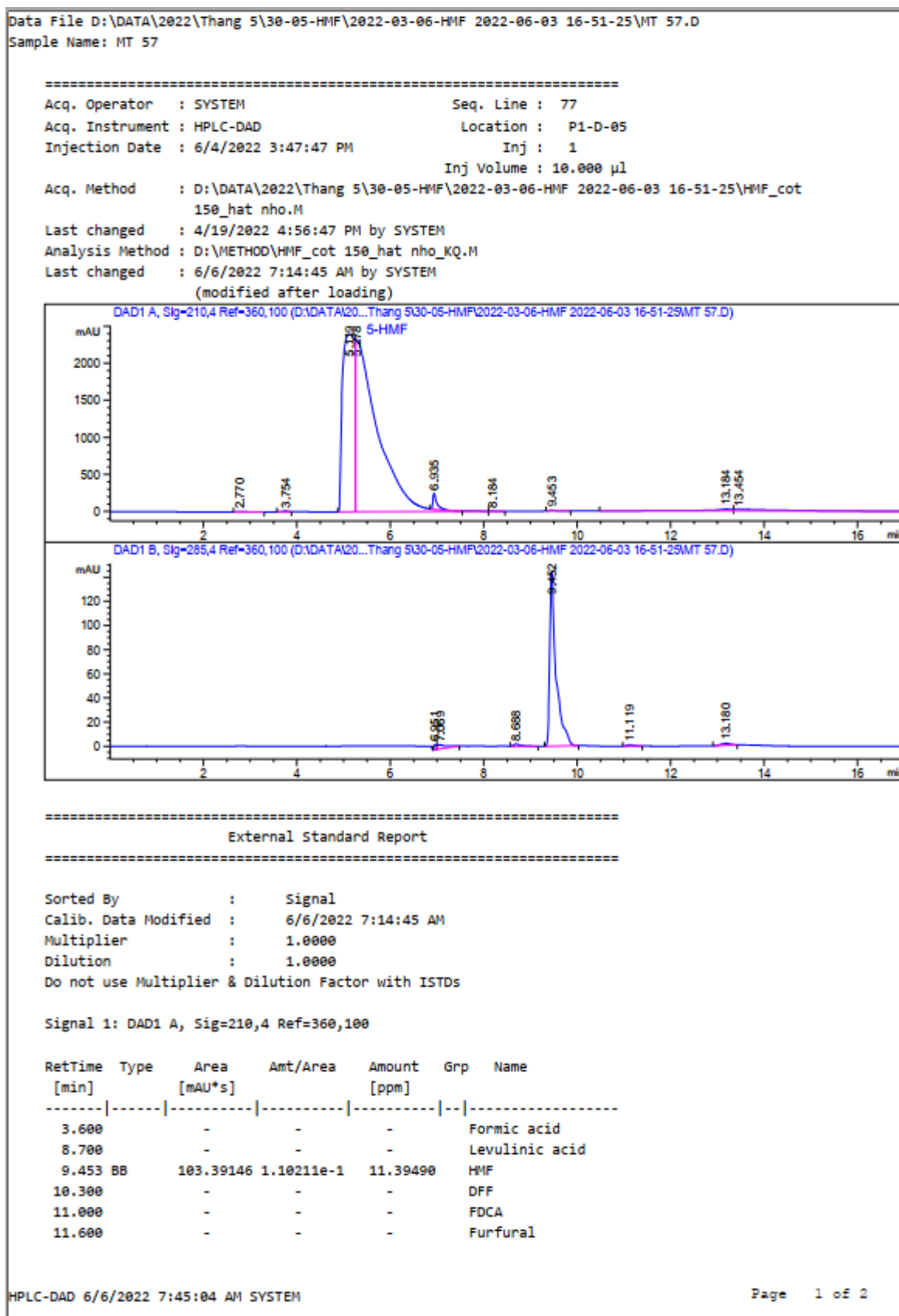
**Figure S4-40:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at 80 °C.



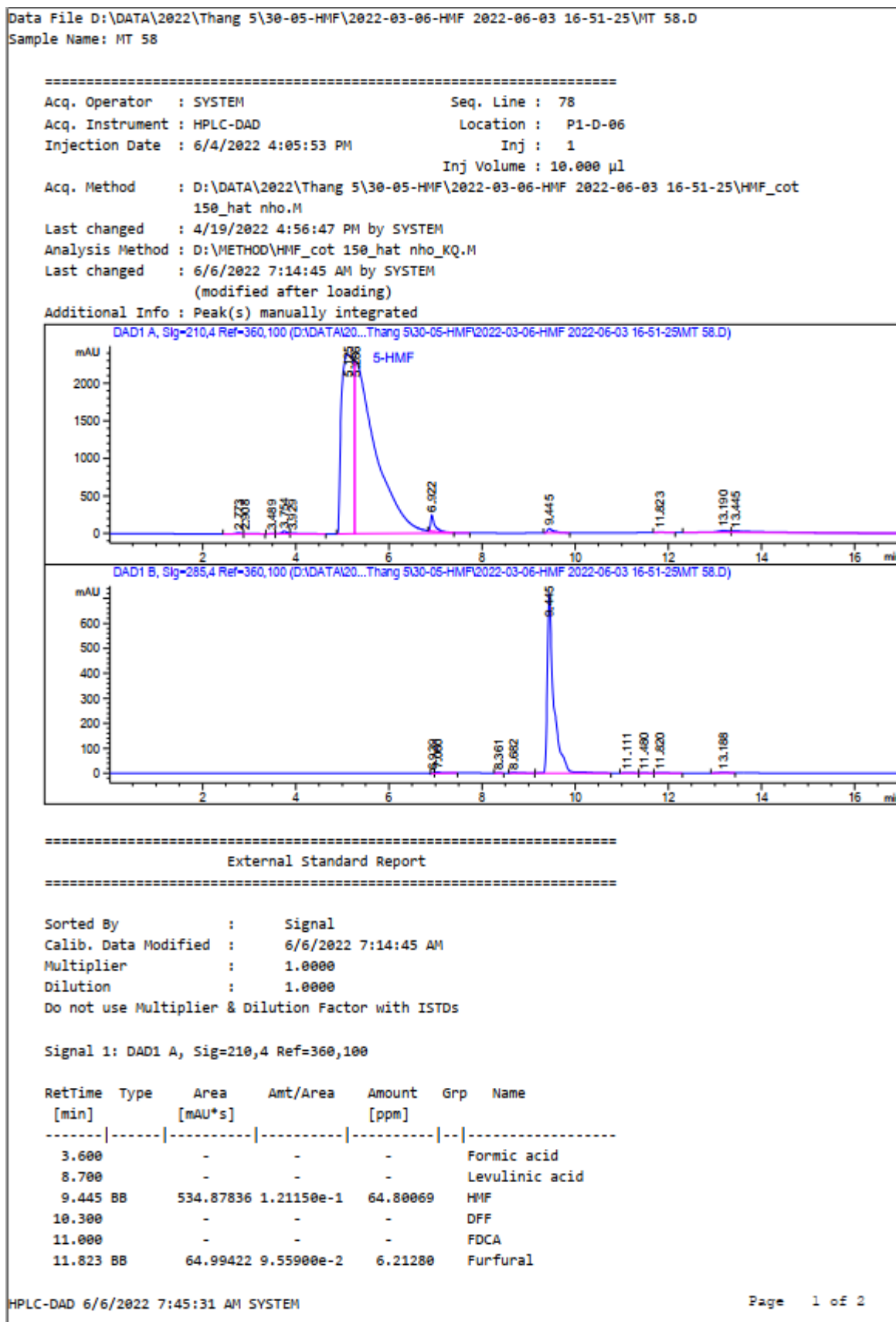
**Figure S4-41:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at 100 °C.



**Figure S4-42:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at 120 °C.



**Figure S4-43:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 12 hours at 140 °C.

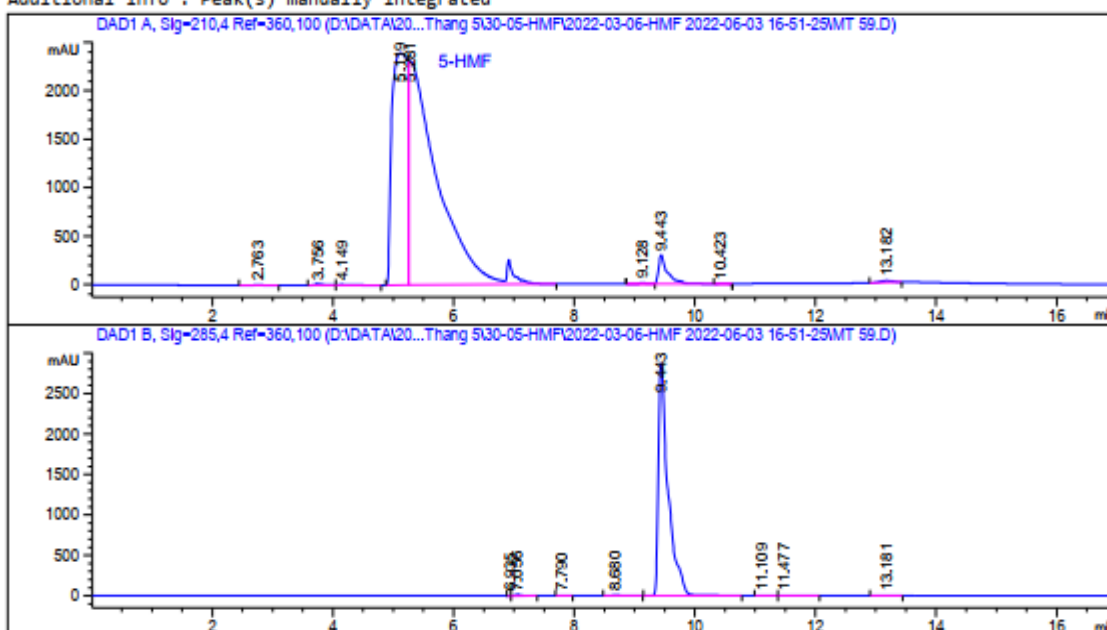


**Figure S4-44:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 3 hours at 120 °C.

Data File D:\DATA\2022\Thang 5\30-05-HMF\2022-03-06-HMF 2022-06-03 16-51-25\MT 59.D  
 Sample Name: MT 59

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                                           Inj Volume: 10.000 µl
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                                           150_hat_nho.M
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Additional Info  : Peak(s) manually integrated
  
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Dilution       : 1.0000
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Signal 1: DAD1 A, Sig=210,4 Ref=360,100

RetTime [min]	Type	Area [mAU*s]	Amt/Area	Amount [ppm]	Grp	Name
3.600	-	-	-	-	-	Formic acid
8.700	-	-	-	-	-	Levulinic acid
9.443	VV R	2976.97827	1.23301e-1	367.06313	-	HMF
10.423	VB E	10.87321	0.00000	0.00000	-	DFF
11.000	-	-	-	-	-	FDCA
11.600	-	-	-	-	-	Furfural

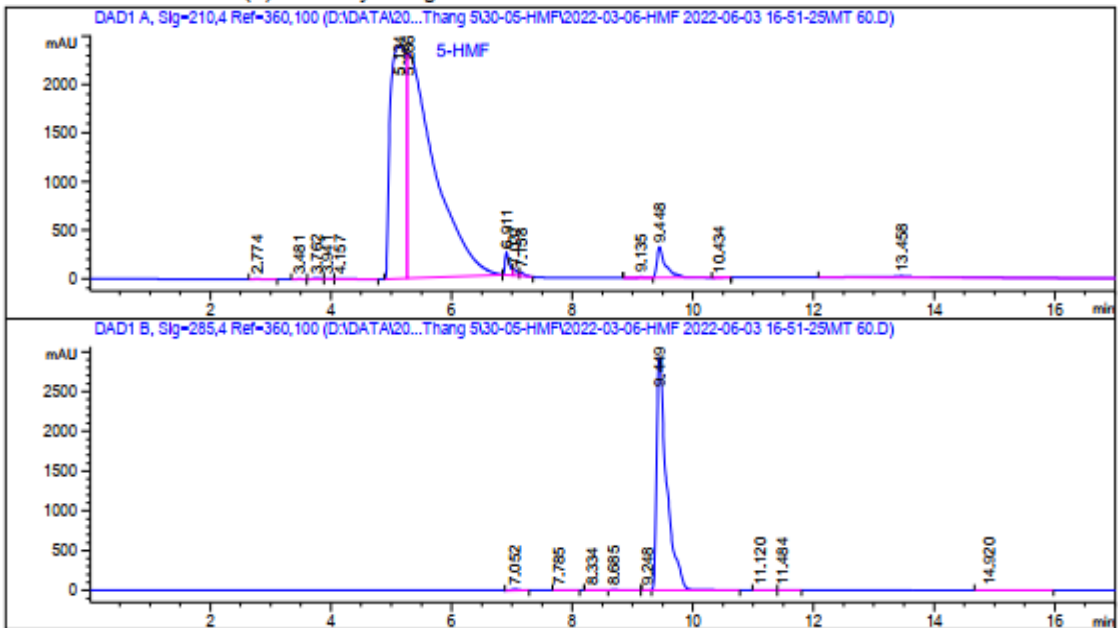
**Figure S4-45:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 3 hours at 120 °C.

Data File D:\DATA\2022\Thang 5\30-05-HMF\2022-03-06-HMF 2022-06-03 16-51-25\MT 60.D  
 Sample Name: MT 60

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Injection Date  : 6/4/2022 4:42:13 PM        Inj       :    1
                                           Inj Volume: 10.000 µl

Acq. Method    : D:\DATA\2022\Thang 5\30-05-HMF\2022-03-06-HMF 2022-06-03 16-51-25\HMF_cot
                150_hat_nho.M
Last changed   : 4/19/2022 4:56:47 PM by SYSTEM
Analysis Method: D:\METHOD\HMF_cot_150_hat_nho_KQ.M
Last changed   : 6/6/2022 7:14:45 AM by SYSTEM
                (modified after loading)
Additional Info : Peak(s) manually integrated
  
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Dilution       : 1.0000
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Signal 1: DAD1 A, Sig=210,4 Ref=360,100

RetTime [min]	Type	Area [mAU*s]	Amt/Area	Amount [ppm]	Grp	Name
3.600	-	-	-	-	-	Formic acid
8.700	-	-	-	-	-	Levulinic acid
9.448	VV R	3141.55298	1.23325e-1	387.43279	-	HMF
10.434	VB E	8.76682	0.00000	0.00000	-	DFF
11.000	-	-	-	-	-	FDCA
11.600	-	-	-	-	-	Furfural

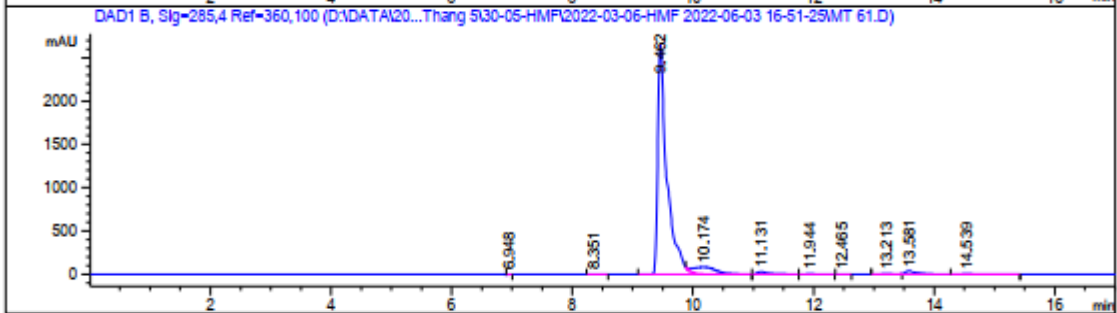
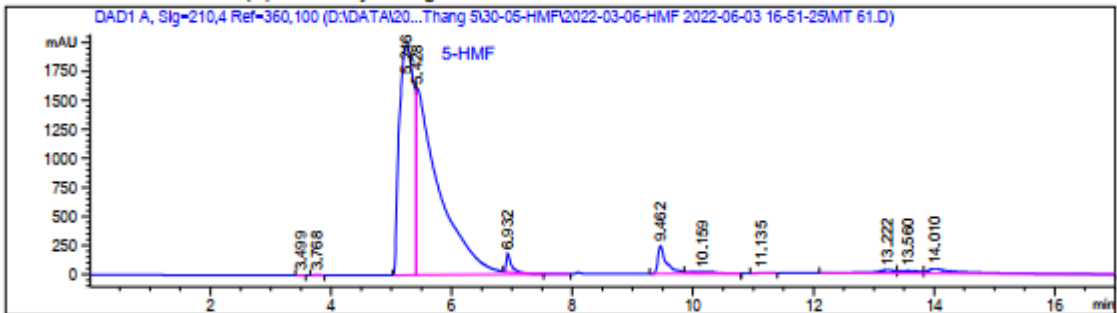


**Figure S4-46:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 3 hours at 120 °C.

Data File D:\DATA\2022\Thang 5\30-05-HMF\2022-03-06-HMF 2022-06-03 16-51-25\MT 61.D  
 Sample Name: MT 61

```

=====
Acq. Operator   : SYSTEM                      Seq. Line : 81
Acq. Instrument : HPLC-DAD                   Location  : P1-D-09
Injection Date  : 6/4/2022 5:00:36 PM       Inj       : 1
                                           Inj Volume: 10.000 µl
Acq. Method    : D:\DATA\2022\Thang 5\30-05-HMF\2022-03-06-HMF 2022-06-03 16-51-25\HMF_cot
                                           150_hat_nho.M
Last changed   : 4/19/2022 4:56:47 PM by SYSTEM
Analysis Method: D:\METHOD\HMF_cot 150_hat_nho_KQ.M
Last changed   : 6/6/2022 7:14:45 AM by SYSTEM
                                           (modified after loading)
Additional Info : Peak(s) manually integrated
  
```



External Standard Report

```

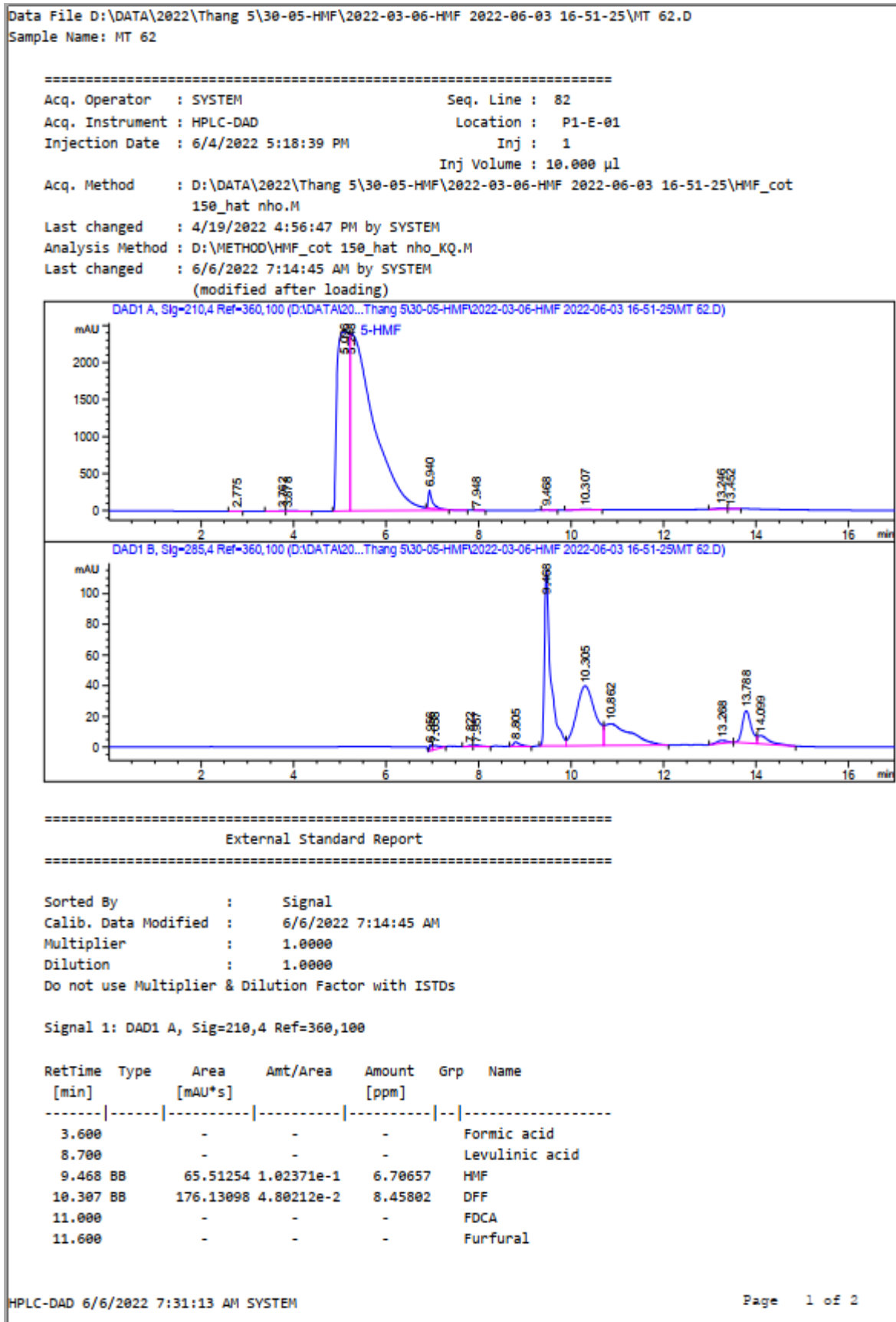
Sorted By      : Signal
Calib. Data Modified : 6/6/2022 7:14:45 AM
Multiplier     : 1.0000
Dilution      : 1.0000
Do not use Multiplier & Dilution Factor with ISTDs
  
```

Signal 1: DAD1 A, Sig=210,4 Ref=360,100

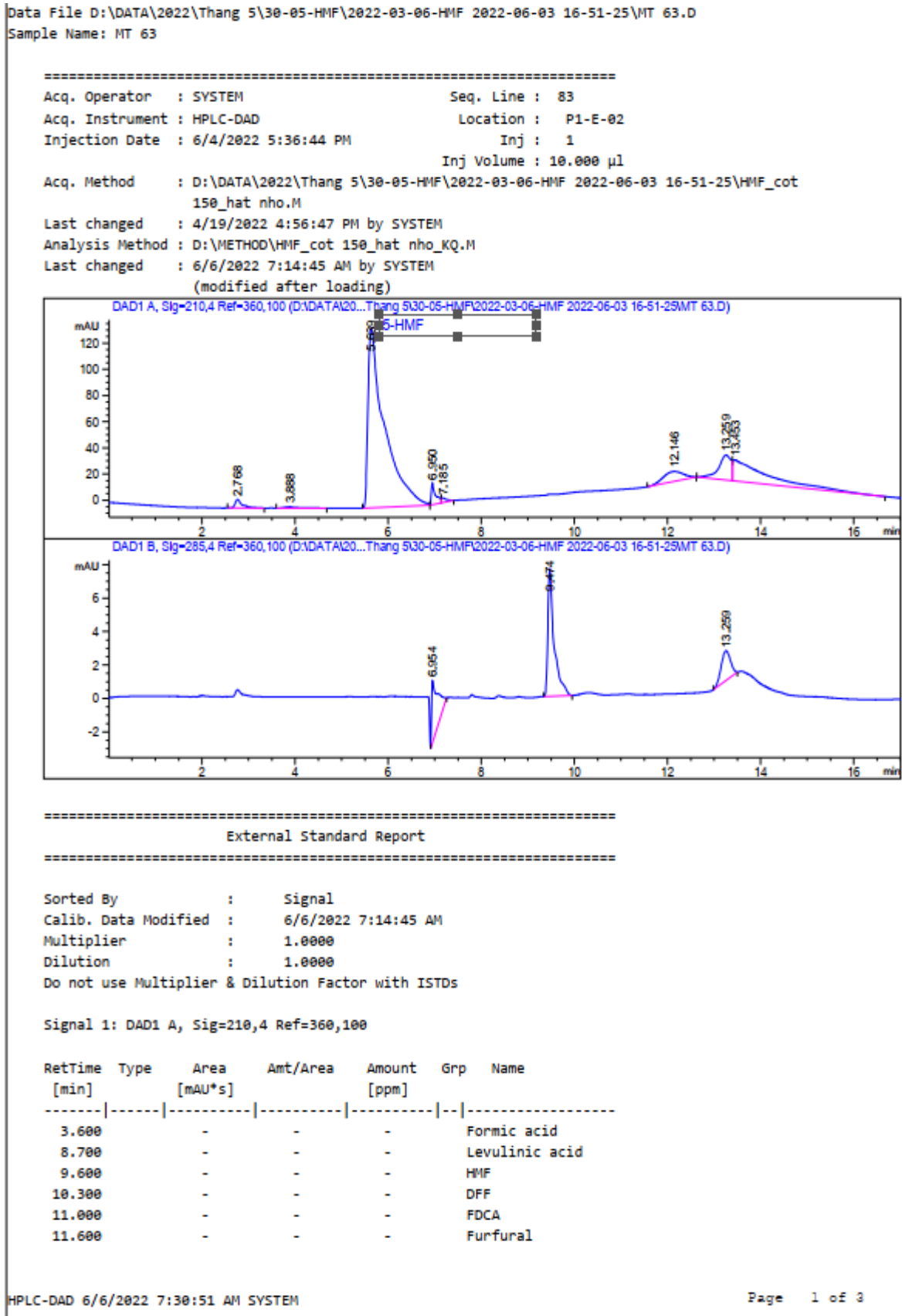
RetTime [min]	Type	Area [mAU*s]	Amt/Area	Amount [ppm]	Grp	Name
3.600	-	-	-	-	-	Formic acid
8.700	-	-	-	-	-	Levulinic acid
9.462	BV R	2490.86475	1.23209e-1	306.89612	-	HMF
10.159	VB E	388.66235	5.55145e-2	21.57639	-	DFF
11.135	BB	33.04062	1.04708e-1	3.45963	-	FDCA
11.600	-	-	-	-	-	Furfural



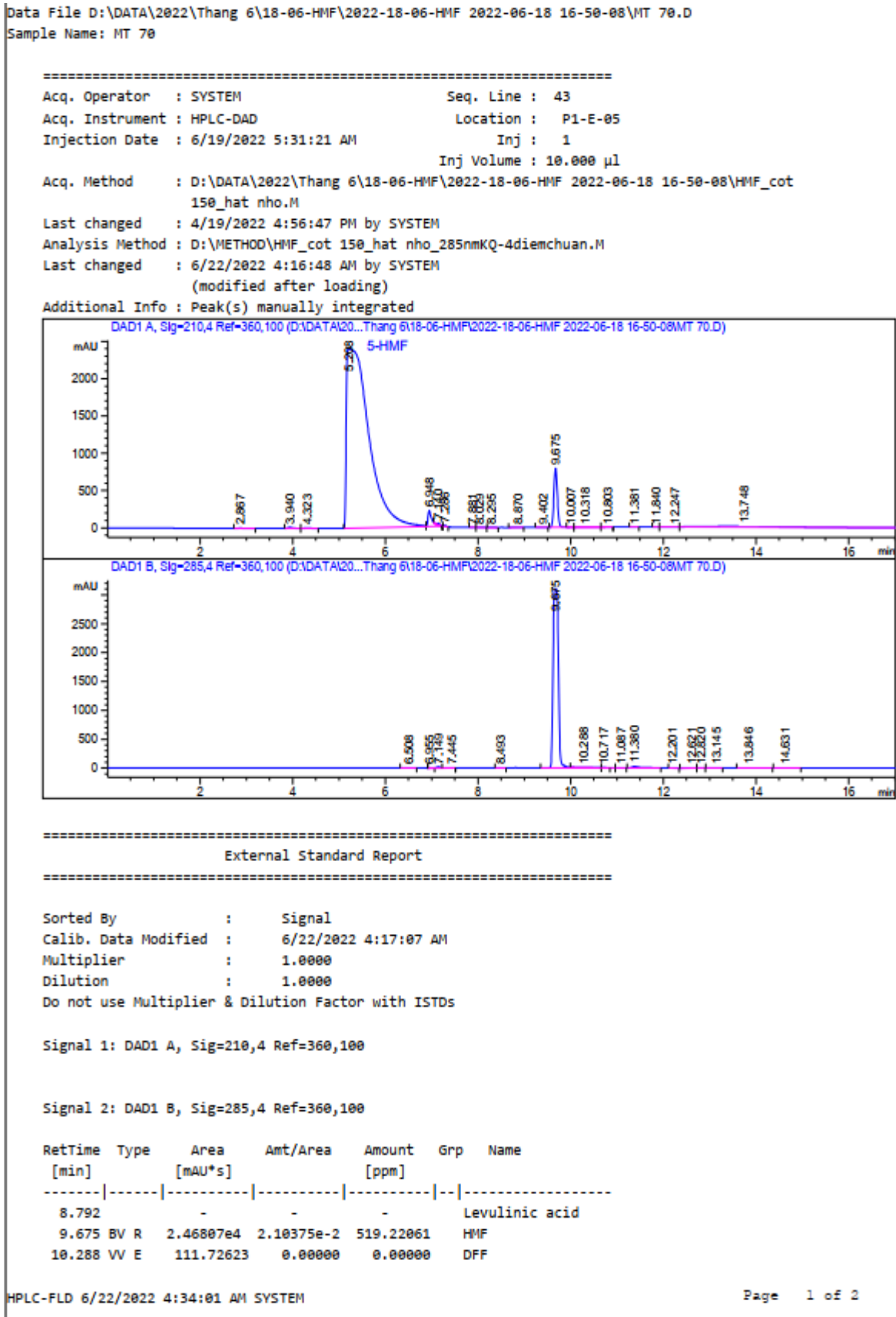
**Figure S4-47:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 3 hours at 120 °C.



**Figure S4-48:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 3 hours at 120 °C.



**Figure S4-49:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 3 hours at 120 °C.



**Figure S4-50:** HPLC chromatography of 5-HMF in investigating catalytic performance. Reaction conditions: Fructose (1mmol), DMSO, for 3 hours at 120 °C.

