Supplemental information

Development of a sensor for selective detection of manganese in aqueous

media by using grapefruit peel pectin-decorated silver nanoparticles


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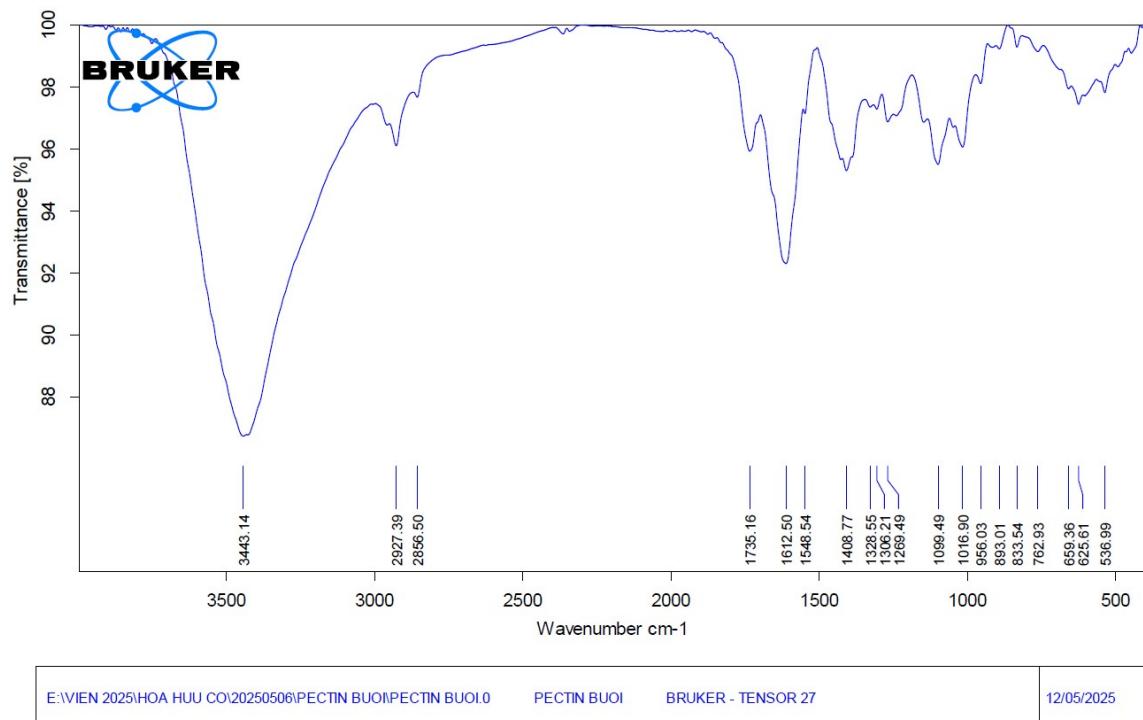
Figure S1: The FTIR spectrum of grapefruit pectin.
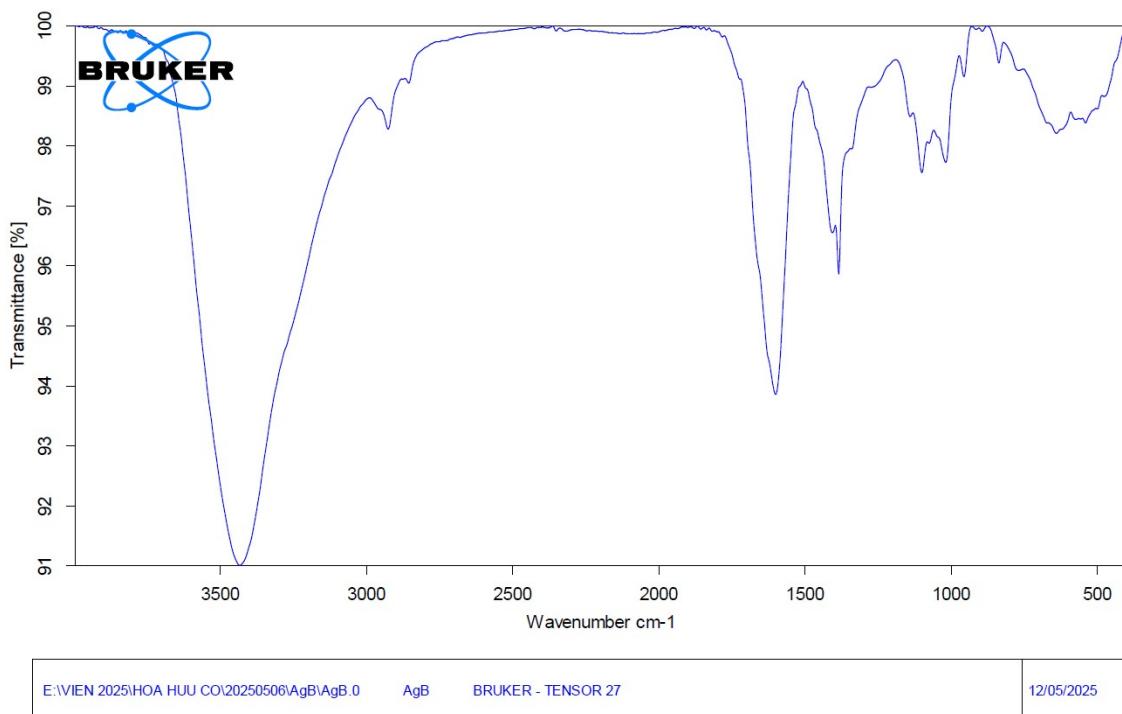
Figure S2: The FTIR of pectin-decorated silver nanoparticles.
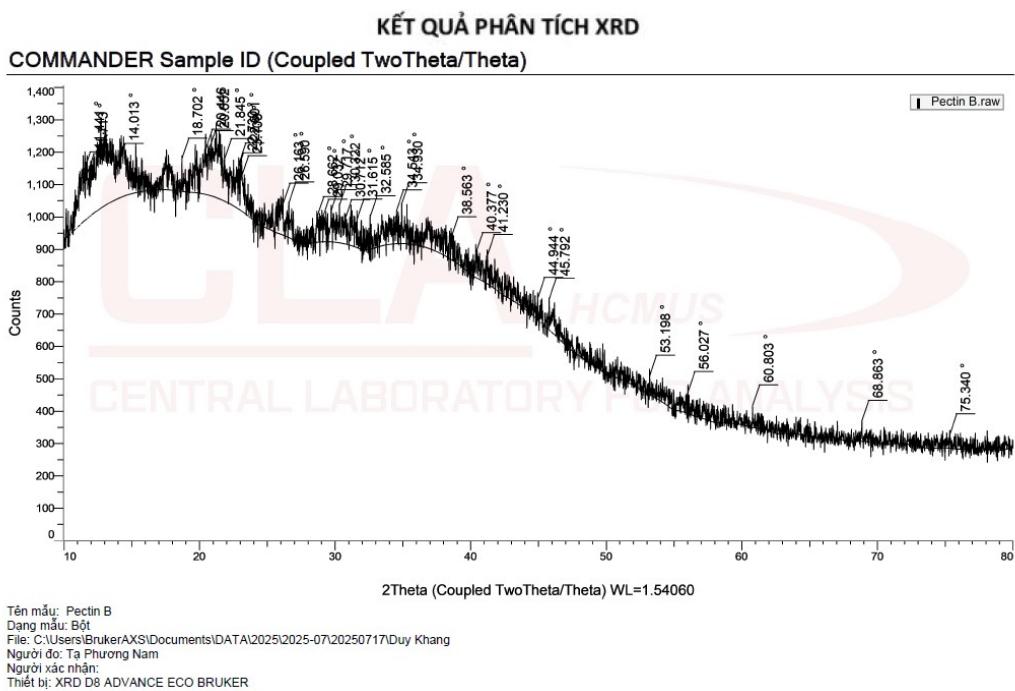
Figure S3: The XRD diffractogram of grapefruit pectin.
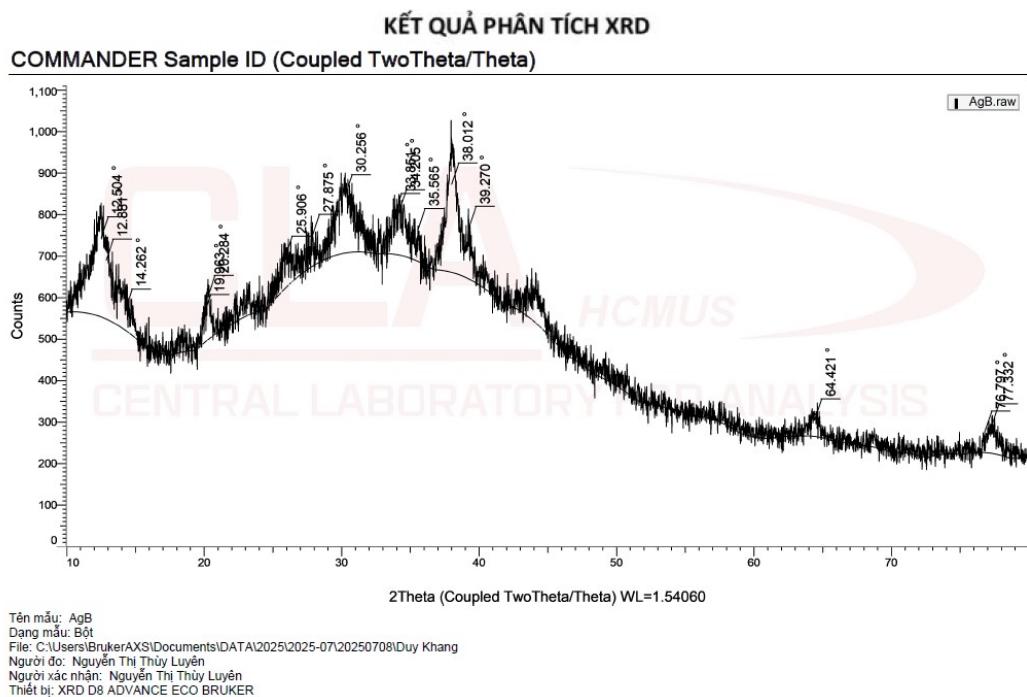
Figure S4: The XRD diffractogram of pectin-decorated silver nanoparticles.

ZTS1240 - Report - Size

Malvern Panalytical

Name	Mean	Standard Deviation	RSD	Minimum	Maximum
Z-Average (nm)	248.3	91.17	36.71	163.5	344.8
Polydispersity Index (PI)	0.2448	0.04913	20.07	0.2132	0.3014
Intercept	0.8547	0.0304	3.557	0.8285	0.888
Derived Mean Count Rate (kcps)	4822	718.2	14.89	4104	5540
Cuvette Position (mm)	4.64	0	0	4.64	4.64
Number Of Size Runs	30	0	0	30	30
Run Retention (%)	99.05	1.65	1.665	97.14	100
In Range (%)	81.11	0.5338	0.6581	80.6	81.66
Fit Error	0.04153	0.01855	44.68	0.02214	0.05912
Detector Angle (°)	173	0	0	173	173

Text Box

ZTS1240 - Verification Criteria

Parameter	Typical Mean Value	Minimum Mean Value	Maximum Mean Value	Criteria
Z-Average (nm):	300	288	328	Pass/Fail
Polydispersity Index (PI):	<0.1	0.0	0.15	Pass/Fail
Run Retention (%):	>90%	N/A	N/A	Indicative

Figure S5: The size of the pectin-decorated silver nanoparticles.

Statistics Table

Name	Mean	Standard Deviation	RSD	Minimum	Maximum
Z-Average (nm)	421.4	26.1	6.193	398.9	450
Polydispersity Index (PI)	0.3573	0.02088	5.843	0.3383	0.3797
Intercept	0.8853	0.002032	0.2296	0.883	0.887
Derived Mean Count Rate (kcps)	1864	40.13	2.153	1822	1902
Cuvette Position (mm)	4.64	0	0	4.64	4.64
Number Of Size Runs	30	0	0	30	30
Run Retention (%)	97.94	1.803	1.841	96.67	100
In Range (%)	69.42	3.371	4.856	66.55	73.13
Fit Error	0.04584	0.002087	4.553	0.04343	0.04718
Detector Angle (°)	173	0	0	173	173

Text Box

ZTS1240 - Verification Criteria

Parameter	Typical Mean Value	Minimum Mean Value	Maximum Mean Value	Criteria
Z-Average (nm):	300	288	328	Pass/Fail
Polydispersity Index (PI):	<0.1	0.0	0.15	Pass/Fail
Run Retention (%):	>90%	N/A	N/A	Indicative

Figure S6: The size of AgGPe after encountering manganese ions in aqueous solution.

Sample Name: ZT - AgB
Project Name: QUY
Date and Time: Saturday, August 16, 2025 5:35:14 PM

Type: Zeta
Cell Name: DTS1070
Material Name: Ag
Material RI: 0.14
Material Absorption: 3.99

Result Source: Instrument
Temperature (°C): 25
Dispersant Name: Water
Dispersant RI: 1.33
Dispersant Viscosity (cP): 0.887
Dispersant Dielectric Constant: 78.5

Zeta Potential Distribution

Phase Plot

Frequency Shift

Statistics Table

Name	Mean	Standard Deviation	RSD	Minimum	Maximum
Zeta Potential (mV)	-34.26	0.74	2.16	-34.95	-33.48
Zeta Deviation (mV)	16.36	5.939	36.3	12.5	23.2
Conductivity (mS/cm)	0.03865	0	0	0.03865	0.03865
Quality Factor	2.555	0.729	28.54	1.943	3.361
Number Of Zeta Runs	12	0	0	12	12
Mean Count Rate (kcps)	380.8	0	0	380.8	380.8
Reference Beam Count Rate (kcps)	2712	0	0	2712	2712
Effective Voltage (V)	149.2	0.003517	0.002357	149.2	149.2
Measured Current (mA)	0.08459	0.0003206	0.379	0.08429	0.08493
Wall Zeta Potential (mV)	-29.62	0.6511	2.199	-30.02	-28.86
Attenuator	8	0	0	8	8

Figure S7: The zeta measurement of pectin-decorated silver nanoparticles.

Sample Name: ZT - AgB Mn1
Project Name: QUY
Date and Time: Saturday, August 16, 2025 5:47:28 PM

Type:	Zeta	**Result Source:**	Instrument
Cell Name:	DTS1070	**Temperature (°C):**	25
Material Name:	Ag	**Dispersant Name:**	Water
Material RI:	0.14	**Dispersant RI:**	1.33
Material Absorption:	3.99	**Dispersant Viscosity (cP):**	0.887
		Dispersant Dielectric Constant:	78.5

Zeta Potential Distribution

Phase Plot

Frequency Shift

Statistics Table

| Name	Mean	Standard Deviation	RSD	Minimum	Maximum
Zeta Potential (mV)	-19.5	4.811	24.67	-25.03	-16.3
Zeta Deviation (mV)	16.32	10.67	65.37	6.155	27.43
Conductivity (mS/cm)	0.007666	0.0002598	3.389	0.007516	0.007966
Quality Factor	1.194	0.0867	7.262	1.097	1.263
Number Of Zeta Runs	12	0	0	12	12
Mean Count Rate (kcps)	269.7	14.71	5.453	261.2	286.6
Reference Beam Count Rate (kcps)	2724	84.67	3.109	2626	2773
Effective Voltage (V)	149.2	0.002527	0.001694	149.2	149.2
Measured Current (mA)	0.01675	0.0003677	2.196	0.01638	0.01711
Wall Zeta Potential (mV)	-6.166	2.407	39.03	-8.232	-3.523
Attenuator	8	0	0	8	8

Figure S8: The zeta of AgGPe after encountering manganese ions in aqueous solution.