

## Supplementary Information

### Supplementary Material: Valorization of Rambutan Peel (*Nephelium lappaceum* L.) byproducts through Pulsed Electric Field-Assisted Green Extraction of Pectin Optimized by Response Surface Methodology

Table S 1 Combination of Treatments and Research Responses from Design Expert 13.

Run	Treatment Factor: Electric Field Strength (kV/cm)	Treatment Factor: Time (minutes)	Treatment Factor: Solvent Ratio (w/v)	Response: Yield (%)	Response: Equivalent Weight (mg)	Response: Methoxyl Content (%)	Response: Galacturonic Acid Content (%)	Response: Degree of Esterification (%)
1	15	18.409	25	3.62	769.23	7.13	63.36	63.89
2	10	15	30	3.01	769.23	7.29	64.24	64.38
3	15	10	25	3.51	714.29	7.75	68.64	64.1
4	20	5	20	3.65	769.23	7.13	63.36	63.89
5	6.59104	10	25	1.9	833.33	6.05	55.44	61.9
6	20	15	20	4	714.29	7.6	67.76	63.64
7	15	10	25	3.59	689.66	8.06	71.28	64.2
8	15	10	25	3.71	714.29	7.91	69.52	64.56
9	15	10	25	3.78	689.66	8.22	72.16	64.63
10	10	5	30	2.44	800	6.2	57.2	61.54
11	23.409	10	25	4.28	666.67	8.68	75.68	65.12
12	20	5	30	3.93	689.66	8.06	71.28	64.2
13	10	15	20	2.88	833.33	6.51	58.08	63.64
14	15	10	33.409	4.03	714.29	8.37	72.16	65.85
15	10	5	20	2.45	909.09	5.58	51.04	62.07
16	15	1.59104	25	3.05	833.33	6.05	55.44	61.9
17	20	15	30	4.3	666.67	9.15	78.32	66.29
18	15	10	25	3.7	714.29	8.06	70.4	65
19	15	10	25	3.65	689.66	8.22	72.16	64.63
20	15	10	16.591	3.77	800	7.29	63.36	65.28

Notes on Variables: Treatment Factors (Variables X1, X2, X3): These factors were optimized using RSM Central Composite Design (CCD). Electric Field Strength (A): Ranged from 10 to 20 kV/cm (excluding axial points). Time (B): Ranged from 5 to 15 minutes (excluding axial points). Solvent Ratio (C): Ranged from 1:20 to 1:30 w/v (excluding axial points). Responses: The optimization focused on five key characteristics of the pectin: Yield (Rend.): Pectin extraction yield (Rendemen). Equivalent Weight (BE): Berat Ekuivalen. Methoxyl Content (KM): Kadar Metoksil. Galacturonic Acid Content (K GalA): Kadar Asam Galakturonat. Degree of Esterification (DE): Derajat Esterifikasi. Highest Results: The highest result for Yield, Methoxyl Content, Galacturonic Acid Content, and Degree of Esterification was obtained in Run 17.

Below are the 20 corresponding tables detailing the statistical results for the five analyzed responses: Pectin Yield (Rendemen), Equivalent Weight (BE), Methoxyl Content (KM), Galacturonic Acid Content (K. GalA), and Degree of Esterification (DE).

**A. Pectin Yield Response**

**Table S 2 Fit Summary Statistics for Pectin Yield Response**

Source	Sequential p-value	Lack of Fit p-value	Adjusted R <sup>2</sup>	Predicted R <sup>2</sup>
Linear	< 0.0001	0.0081	0.823	0.7531
2FI	0.9246	0.0046	0.7897	0.649
Quadratic	< 0.0001	0.4278	0.9752	0.9375
Cubic	0.7305	0.1361	0.9692	0.1636

**Table S 3 Model Summary Statistics for Pectin Yield Response**

Source	Std. Dev	R <sup>2</sup>	Adjusted R <sup>2</sup>	Predicted R <sup>2</sup>	PRESS	
Linear	0.2704	0.851	0.823	0.7531	1.94	
2FI	0.2948	0.8561	0.7897	0.649	2.76	
Quadratic	0.1012	0.987	0.9752	0.9375	0.4906	Suggested
Suggested Cubic	0.1128	0.9903	0.9692	0.1636	6.57	(Aliased)

**Table S 4 Analysis of Variance (ANOVA) Results for Pectin Yield Response**

Source	Sum of Squares	Df	Mean Square	F-value	p-value
Model	7.75	9	0.8609	84.11	< 0.0001 (significant)
A - PEF Electric Field Strength	6.06	1	6.06	591.99	< 0.0001
B - Time	0.5256	1	0.5256	51.36	< 0.0001
C - Solvent Ratio	0.0958	1	0.0958	9.36	0.012
AB	0.0105	1	0.0105	1.03	0.3347
AC	0.0266	1	0.0266	2.6	0.1378
BC	0.0032	1	0.0032	0.3173	0.5857
A <sup>2</sup>	0.7045	1	0.7045	68.84	< 0.0001
B <sup>2</sup>	0.2597	1	0.2597	25.37	0.0005
C <sup>2</sup>	0.0614	1	0.0614	6	0.0343
Residual	0.1023	10	0.0102		
Lack of Fit	0.0555	5	0.0111	1.19	0.4278 (not significant)
Pure Error	0.0468	5	0.0094		
Cor Total	7.85	19			

Table S 5 Fit Statistics ANOVA for Pectin Yield Response

Statistic	Value
R <sup>2</sup>	0.987
Adjusted R <sup>2</sup>	0.9752
Predicted R <sup>2</sup>	0.9375
Adeq Precision	34.1521

**B. Equivalent Weight Response (Berat Ekuivalen, BE)**

Table S 6 Fit Summary Statistics for Equivalent Weight Response

Source	Sequential p-value	Lack of Fit p-value	Adjusted R <sup>2</sup>	Predicted R <sup>2</sup>	
Linear	0.0001	0.0066	0.6601	0.5927	
2FI	0.8936	0.0038	0.6003	0.3706	
Quadratic	< 0.0001	0.4955	0.9601	0.9044	Suggested
Cubic	0.3665	0.5662	0.9644	0.8114	(Aliased)

Table S 7 Model Summary Statistics for Equivalent Weight Response

Source	Std. Dev.	R <sup>2</sup>	Adjusted R <sup>2</sup>	Predicted R <sup>2</sup>	PRESS	
Linear	39.46	0.7138	0.6601	0.5927	35460.34	
2FI	42.8	0.7265	0.6003	0.3706	54798.66	
Quadratic	13.53	0.979	0.9601	0.9044	8325.9	Suggested
Cubic	12.77	0.9888	0.9644	0.8114	16421.61	(Aliased)

Table S 8 Analysis of Variance (ANOVA) Results for Equivalent Weight Response

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	85235.82	9	9470.65	51.76	< 0.0001	(significant)
A - Electric Field Strength	41420.79	1	41420.79	226.39	< 0.0001	
B - Time	6254.76	1	6254.76	34.19	0.0002	
C - Solvent Ratio	14470.2	1	14470.2	79.09	< 0.0001	
AB	102.2	1	102.2	0.5586	0.4721	
AC	264.49	1	264.49	1.45	0.2569	
BC	740.06	1	740.06	4.04	0.072	
A <sup>2</sup>	3690.82	1	3690.82	20.17	0.0012	
B <sup>2</sup>	16791.27	1	16791.27	91.77	< 0.0001	
C <sup>2</sup>	4947.57	1	4947.57	27.04	0.0004	
Residual	1829.66	10	182.97			
Lack of Fit	919.67	5	183.93	1.01	0.4955	(not significant)
Pure Error	910	5	182			
Cor Total	87065.48	19				

Table S 9 Fit Statistics ANOVA for Equivalent Weight Response

Statistic	Value
R <sup>2</sup>	0.979
Adjusted R <sup>2</sup>	0.9601
Predicted R <sup>2</sup>	0.9044
Adeq Precision	25.5093

**C. Methoxyl Content Response (Kadar Metoksil, KM)**

Table S 10 Fit Summary Statistics for Methoxyl Content Response

Source	Sequential p-value	Lack of Fit p-value	Adjusted R <sup>2</sup>	Predicted R <sup>2</sup>	
Linear	< 0.0001	0.0052	0.6726	0.5801	
2FI	0.8743	0.003	0.6173	0.3743	
Quadratic	< 0.0001	0.4948	0.9651	0.9143	Suggested
Cubic	0.3163	0.8221	0.9708	0.9643	(Aliased)

Table S 11 Model Summary Statistics for Methoxyl Content Response

Source	Std. Dev.	R <sup>2</sup>	Adjusted R <sup>2</sup>	Predicted R <sup>2</sup>	PRESS	
Linear	0.5567	0.7243	0.6726	0.5801	7.55	
2FI	0.6019	0.7381	0.6173	0.3743	11.25	
Quadratic	0.1818	0.9816	0.9651	0.9143	1.54	Suggested
Cubic	0.1663	0.9908	0.9708	0.9643	0.6427	(Aliased)

Table S 12 Analysis of Variance (ANOVA) Results for Methoxyl Content Response

Source	Sum of Squares	Mean Df Square	F-value	p-value
Model	17.65	9	1.96	59.37 < 0.0001
A - PEF Electric Field Strength	8.52	1	8.52	257.87 < 0.0001 (Significant)
B - Time	2.13	1	2.13	64.38 < 0.0001
C - Solvent Ratio	2.38	1	2.38	72 < 0.0001
AB	0.027	1	0.027	0.8181 0.387
AC	0.1472	1	0.1472	4.45 0.061
BC	0.0751	1	0.0751	2.27 0.1626
A <sup>2</sup>	0.8478	1	0.8478	25.66 0.0005
B <sup>2</sup>	3.85	1	3.85	116.39 < 0.0001
C <sup>2</sup>	0.088	1	0.088	2.66 0.1337
Residual	0.3304	10	0.033	
Lack of Fit	0.1662	5	0.0332	1.01 0.4948 (not significant)
Pure Error	0.1642	5	0.0328	
Cor Total	17.98	19		

Table S 13 Fit Statistics ANOVA for Methoxyl Content Response

Statistic	Value
R <sup>2</sup>	0.9816
Adjusted R <sup>2</sup>	0.9651
Predicted R <sup>2</sup>	0.9143
Adeq Precision	24.9265

**D. Galacturonic Acid Content Response (Kadar Asam Galakturonat, K. GalA)**

Table S 14 Fit Summary Statistics for Galacturonic Acid Content Response

Source	Sequential p-value	Lack of Fit p-value	Adjusted R <sup>2</sup>	Predicted R <sup>2</sup>	
Linear	< 0.0001	0.0064	0.6819	0.6042	
2FI	0.9583	0.0035	0.6174	0.3867	
Quadratic	< 0.0001	0.5843	0.9666	0.9247	Suggested
Cubic	0.3919	0.942	0.9693	0.9836	(Aliased)

Table S 15 Model Summary Statistics for Galacturonic Acid Content Response

Source	Std. Dev.	R <sup>2</sup>	Adjusted R <sup>2</sup>	Predicted R <sup>2</sup>	PRESS	
Linear	4.23	0.7322	0.6819	0.6042	422.65	
2FI	4.64	0.7382	0.6174	0.3867	654.95	
Quadratic	1.37	0.9824	0.9666	0.9247	80.43	Suggested
Cubic	1.31	0.9903	0.9693	0.9836	17.52	(Aliased)

Table S 16 Analysis of Variance (ANOVA) Results for Galacturonic Acid Content Response

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	1049.08	9	116.56	62.08	< 0.0001	(significant)
A - PEF Electric Field Strength	519.12	1	519.12	276.48	< 0.0001	
B - Time	110.46	1	110.46	58.83	< 0.0001	
C - Solvent Ratio	152.26	1	152.26	81.09	< 0.0001	
AB	0.8712	1	0.8712	0.464	0.5112	
AC	4.74	1	4.74	2.53	0.1431	
BC	0.8712	1	0.8712	0.464	0.5112	
A <sup>2</sup>	46.79	1	46.79	24.92	0.0005	
B <sup>2</sup>	228.26	1	228.26	121.57	< 0.0001	
C <sup>2</sup>	15.11	1	15.11	8.05	0.0176	
Residual	18.78	10	1.88			
Lack of Fit	8.45	5	1.69	0.8185	0.5843	(not significant)
Pure Error	10.33	5	2.07			
Cor Total	1067.86	19				

Table S 17 Fit Statistics ANOVA for Galacturonic Acid Content Response

Statistic	Value
R <sup>2</sup>	0.9824
Adjusted R <sup>2</sup>	0.9666
Predicted R <sup>2</sup>	0.9247
Adeq Precision	25.4886

**E. Degree of Esterification Response (Derajat Esterifikasi, DE)**

Table S 18 Fit Summary Statistics for Degree of Esterification Response

Source	Sequential p-value	Lack of Fit p-value	Adjusted R <sup>2</sup>	Predicted R <sup>2</sup>	
Linear	0.004	0.0067	0.4714	0.2266	
2FI	0.3089	0.0066	0.5017	0.2058	
Quadratic	< 0.0001	0.3763	0.9271	0.8026	Suggested
Cubic	0.4574	0.2249	0.9283	-0.406	(Aliased)

Table S 19 Model Summary Statistics for Degree of Esterification Response

Source	Std. Dev.	R <sup>2</sup>	Adjusted R <sup>2</sup>	Predicted R <sup>2</sup>	PRESS	
Linear	0.9545	0.5549	0.4714	0.2266	25.33	
2FI	0.9268	0.6591	0.5017	0.2058	26.01	
Quadratic	0.3546	0.9616	0.9271	0.8026	6.47	
Suggested Cubic	0.3515	0.9774	0.9283	-0.406	46.05	(Aliased)

Table S 20 Analysis of Variance (ANOVA) Results for Degree of Esterification Response

Source	Sum of Squares	Df	Mean Square	F-value	p-value
Model	31.49	9	3.5	27.83	< 0.0001 (significant)
A - PEF Electric Field Strength	10.18	1	10.18	80.93	< 0.0001
B - Time	6.74	1	6.74	53.57	< 0.0001
C - Solvent Ratio	1.26	1	1.26	10.03	0.01
AB	0.8259	1	0.8259	6.57	0.0282
AC	0.9437	1	0.9437	7.51	0.0208
BC	1.64	1	1.64	13.06	0.0047
A <sup>2</sup>	2.43	1	2.43	19.34	0.0013
B <sup>2</sup>	5.68	1	5.68	45.16	< 0.0001
C <sup>2</sup>	1.44	1	1.44	11.44	0.007
Residual	1.26	10	0.1257		
Lack of Fit	0.7213	5	0.1443	1.35	0.3763 (not significant)
Pure Error	0.5361	5	0.1072		
Cor Total	32.75	19			

Table S 21 Fit Statistics ANOVA for Degree of Esterification Response

Statistic	Value
R <sup>2</sup>	0.9616
Adjusted R <sup>2</sup>	0.9271
Predicted R <sup>2</sup>	0.8026
Adeq Precision	18.8412

