Supplementary Information for

Anthocyanin-Based Intelligent Food Packaging Films Reinforced with Ginger Pseudostem Cellulose Fibers: A Sustainable Approach for Real-Time Freshness Monitoring of Perishable Foods

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Table S1. Investigation of ethanol concentration for anthocyanin extraction.

No.	Ethanol concentration* (%)	Solid-to-solvent ratio (w/v)	Ultrasonication time (min)
1	20	1:25	15
2	40	1:25	15
3	60	1:25	15
4	80	1:25	15

* The ethanol concentration was investigated to determine the optimal conditions for anthocyanin extraction. Other parameters, such as the solid-to-solvent ratio and ultrasonication time, were kept constant.

Table S2. Investigation of the solid-to-solvent ratio in anthocyanin extraction.

No.	Ethanol concentration (%)	Solid-to-solvent ratio* (w/v)	Ultrasonication time (min)
1	60	1:15	15
2	60	1:20	15
3	60	1:25	15
4	60	1:30	15

* The solid-to-solvent ratio was investigated to determine the optimal conditions for anthocyanin extraction. Other parameters, such as ethanol concentration and ultrasonic treatment time, were kept constant.

Table S3. Investigation of the anthocyanin extraction time

No.	Ethanol concentration (%)	Solid-to-solvent ratio (w/v)	Ultrasonication time* (min)
1	60	1:25	5
2	60	1:25	15
3	60	1:25	30
4	60	1:25	45

* Ultrasonication time was investigated to determine the optimal conditions for anthocyanin extraction, while parameters such as ethanol concentration and solid-to-solvent ratio were kept constant.

Table S4. One-way ANOVA table of ethanol concentration on total anthocyanin content.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	0.425	3	0.142	207.385	6.4×10^{-8}
Within groups	0.005	8	0.001		
Total	0.430	11			

At $p < 0.05$, the mean values are significantly different.

Table S5. One-way ANOVA table of the material-to-solvent ratio on total anthocyanin content.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	0.019	3	0.006	15.686	0.001
Within groups	0.003	8	0.0004		
Total	0.022	11			

At $p < 0.05$, the mean values are significantly different.

Table S6. One-way ANOVA table of ultrasound time on total anthocyanin content.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	0.087	3	0.029	28.904	0.0001
Within groups	0.008	8	0.001		
Total	0.095	11			

At $p < 0.05$, the mean values are significantly different.

Table S7. One-way ANOVA table for the tensile strength of PVA and PA films.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	126.954	1	126.954	13.104	0.022
Within groups	38.753	4	9.688		
Total	165.707	5			

At $p < 0.05$, the mean values are significantly different.

Table S8. One-way ANOVA table for the tensile strength of PA film and PA film reinforced with different cellulose fiber contents.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	24.976	3	8.325	0.779	0.538
Within groups	85.472	8	10.684		
Total	110.448	11			

At $p > 0.05$, the mean values are not significantly different.

Table S9. One-way ANOVA table for the elongation at break of PVA and PA film.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	11742.765	1	11742.765	96.291	6.046×10^{-4}
Within groups	487.803	4	121.951		
Total	12230.567	5			

At $p < 0.05$, the mean values are significantly different.

Table S10. One-way ANOVA table for the elongation at break of PA film and PA film reinforced with different cellulose fiber contents.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	5126.041	3	1708.680	4.349	0.043
Within groups	3143.206	8	392.901		
Total	8269.246	11			

At $p < 0.05$, the mean values are significantly different.

Table S11. One-way ANOVA table for the Young's modulus of PVA and PA films.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	78.567	1	78.567	0.250	0.643
Within groups	1258.084	4	314.521		
Total	1336.651	5			

At $p > 0.05$, the mean values are not significantly different.

Table S12. One-way ANOVA table for the Young's modulus of PA film and PA film reinforced with different cellulose fiber contents.

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Between groups	118.315	3	39.438	0.367	0.779
Within groups	860.497	8	107.562		
Total	978.812	11			

At $p > 0.05$, the mean values are not significantly different.

Dynamic light scattering (DLS) analysis. The average diameter distribution of cellulose fibers dispersed in aqueous suspension was determined by dynamic light scattering technique using a Malvern Panalytical Zetasizer Pro instrument. Prior to analysis, the samples were diluted to a concentration of approximately 0.1 wt% with deionized (DI) water and ultrasonicated for 30 min to improve the dispersion of the cellulose fibers.

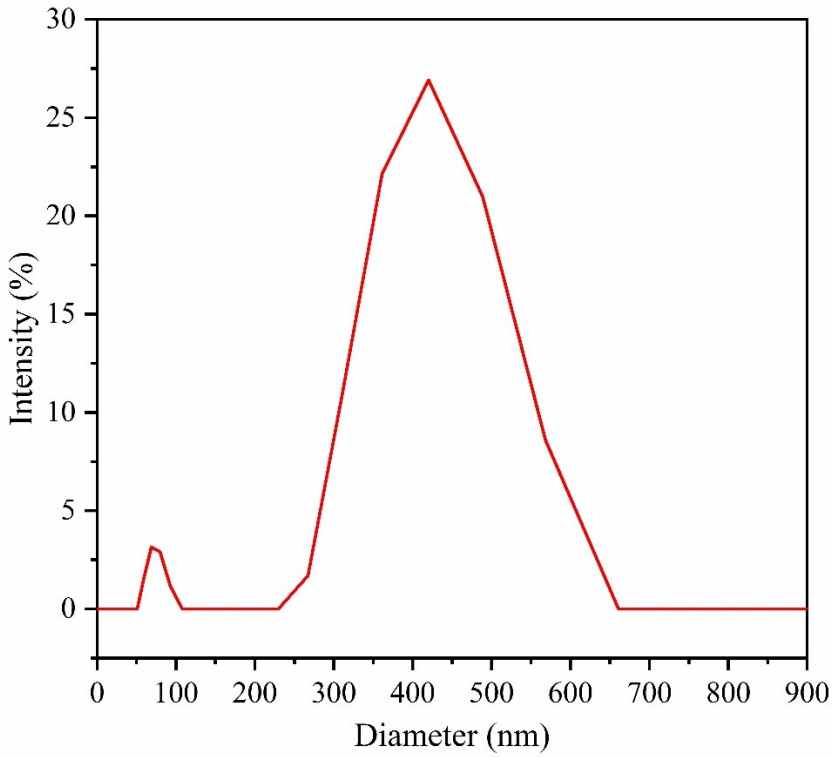

Figure S1. Cellulose fibers diameter distribution determined by DLS analysis.