Physical Properties and Biodegradability of PVA/DNA Blend Films

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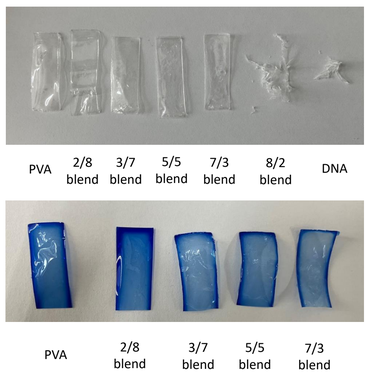
Introduction & Purposes

- PVA(Polyvinyl Alcohol) is widely used in many ways, including the plastic industry, industrial textiles, and medical materials. However, biological decomposition is not easy, it can cause environmental pollution.
- In our study, we blend DNA with PVA to make biomass plastic that can reduce environmental pollution.
- To confirm the plastic properties are maintained, compare and analyze the stress and strain according to the mixing ratio of DNA and PVA.
- To find out the biodegradability of DNA/PVA blend film, we measure and anaylze the time of decomposition, the rate of decomposition, and the change of concentration during decomposition.

Experiment

DNA/ PVA blend film



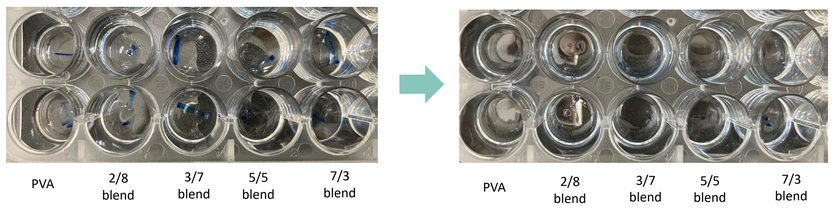
- 8/2 blends and DNA were not made in the form of film

  → PVA, 2/8, 3/7, 5/5, and 7/3 choose

- To check DNA/PVA FILM decomposition visually

  → PVA is dyed with Remazol Brilliant Blue R

Decomposition of DNA/PVA blend film



Time of 10 mm^3 film to dissolve (solvent : water+ DNase Ⅰ + DNase Ⅰ Buffer)

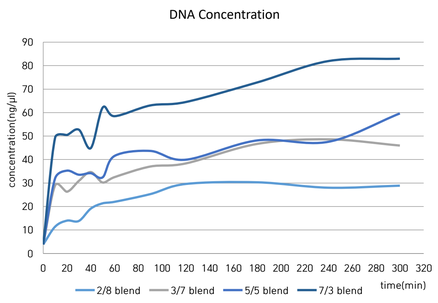
	2/8 blend	3/7 blend	5/5 blend	7/3 blend	PVA
Time [min]	15	19	16	26	30

Results & Discussion

Biodegradability

DNA Concentration [ng/μl]

Time [min]	2/8 blend	3/7 blend	5/5 blend	7/3 blend
0	3.87	3.87	3.87	3.87
10	11.4	29.0	32.0	49.3
20	14.0	26.3	35.3	50.5
30	13.9	30.9	33.6	52.7
40	19.1	34.7	34.2	44.9
50	21.4	30.2	32.5	62.1
60	22.0	32.5	41.6	58.5
90	25.3	37.0	43.7	63.0
120	29.6	38.3	40.0	64.5
180	30.3	46.6	48.2	72.8
240	28.0	48.6	47.6	81.9
300	28.9	45.9	59.7	82.9

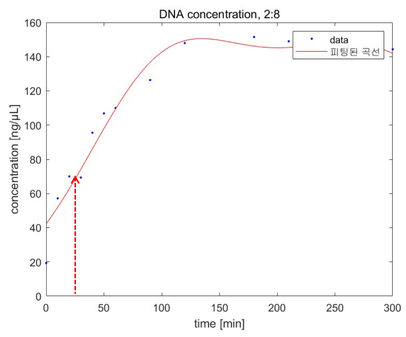


<Theoretically DNA final concentration>

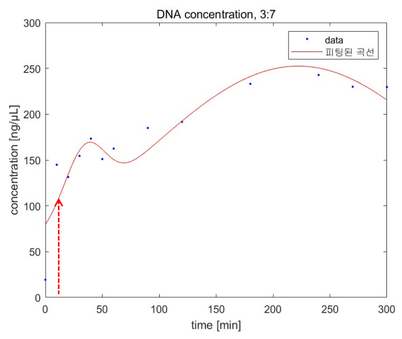
DNA/PVA blend ratio	Concentration [ng/μL]
2/8	67.6
3/7	109
5/5	213
7/3	361

Experimental DNA concentration

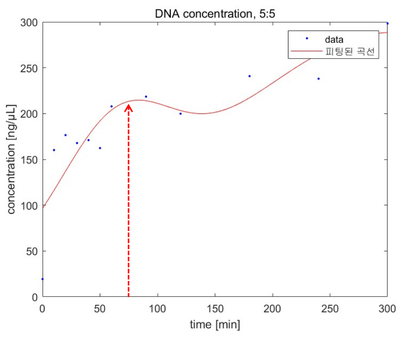
Time [min]	Concentration [ng/μL]
0	19.3
10	57.2
20	70.0
30	69.3
40	95.5
50	107
60	110
90	126
120	148
180	152
240	140
300	144



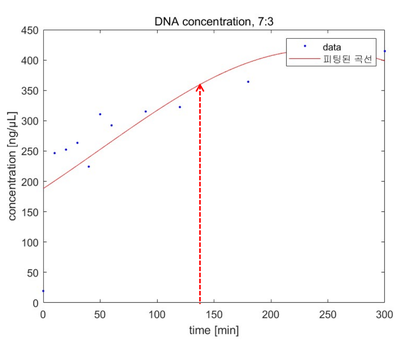
Time [min]	Concentration [ng/μL]
0	19.3
10	145
20	132
30	155
40	173
50	151
60	163
90	185
120	192
180	233
240	243
300	230



Time [min]	Concentration [ng/μL]
0	19.3
10	160
20	177
30	168
40	171
50	162
60	208
90	219
120	200
180	241
240	238
300	298

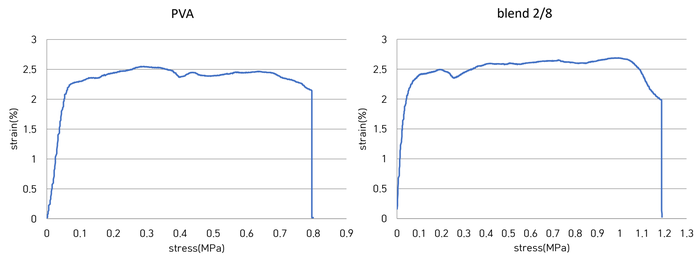


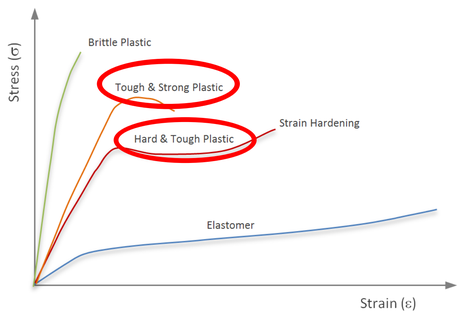
Time [min]	Concentration [ng/μL]
0	19.3
10	247
20	252
30	264
40	224
50	311
60	292
90	315
120	323
180	364
240	410
300	415



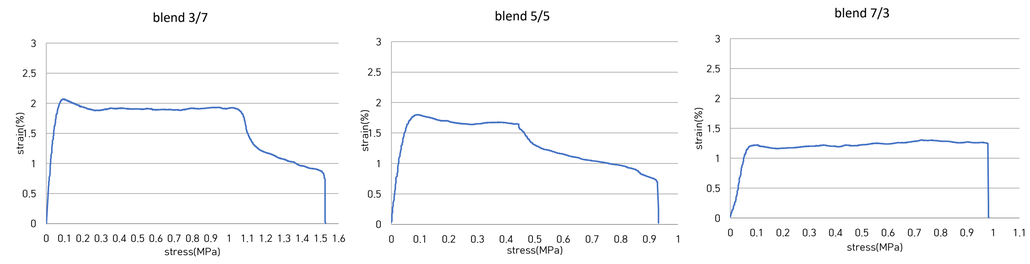
Stress-strain curve of DNA/PVA blend

Tough & strong plastic

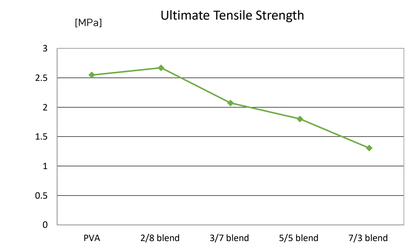


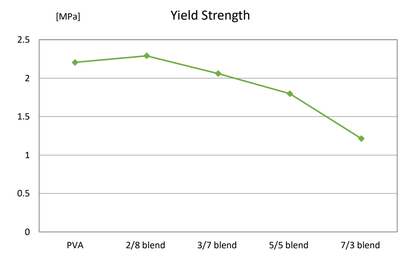


Hard & Tough plastic



Physical Properties

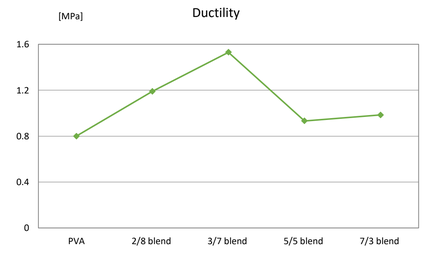


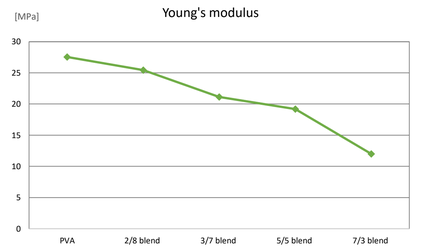


	PVA	2/8 blend	3/7 blend	5/5 blend	7/3 blend
Ultimate Tensile Strength $[MPa]$	2.55	2.67	2.07	1.80	1.31

	PVA	2/8 blend	3/7 blend	5/5 blend	7/3 blend
Yield Strength $[MPa]$	2.20	2.29	2.06	1.80	1.21

- DNA blend ratio increases → ultimate tensile strength & yield strength decrease.
  → physical properties of plastic is getting worse.

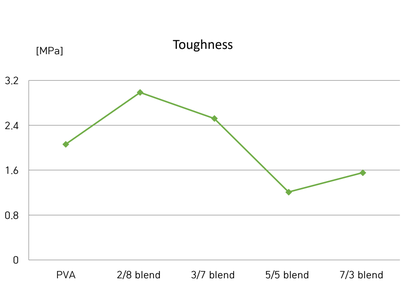




	PVA	2/8 blend	3/7 blend	5/5 blend	7/3 blend
Ductility $[MPa]$	0.800	1.19	1.53	0.932	0.984

	PVA	2/8 blend	3/7 blend	5/5 blend	7/3 blend
Young's modulus $[MPa]$	27.6	25.4	21.1	19.2	12.0

- Ductility is maximum at 3/7 blend.
- DNA blend ratio increases → Young's modulus decreases.



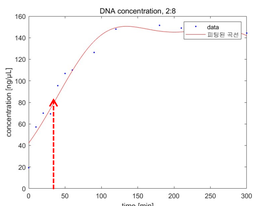
	PVA	2/8 blend	3/7 blend	5/5 blend	7/3 blend
Resilience $[MPa]$	0.0545	0.115	0.119	0.112	0.0586

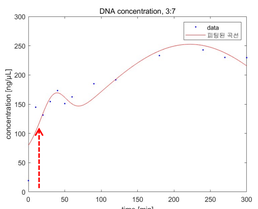
	PVA	2/8 blend	3/7 blend	5/5 blend	7/3 blend
Toughness $[MPa]$	2.06	2.99	2.52	1.21	1.56

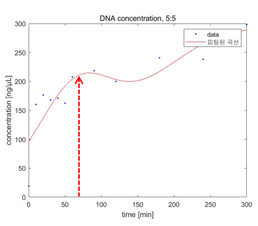
- Resilience is maximum at 3/7 blend.
- 2/8 and 3/7 have higher toughness than PVA.

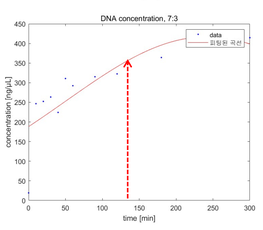
Conclusion

Biodegradability









<Theoretically DNA final concentration>

DNA/PVA blend ratio	Concentration [ng/μL]
2/8	67.6
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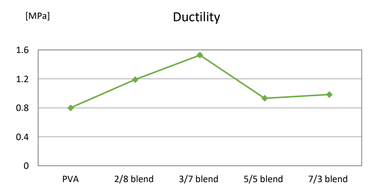
5/5	213
7/3	361

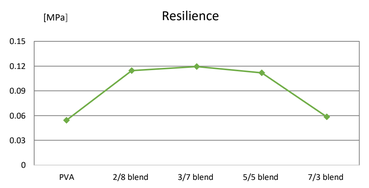
DNA/PVA blend ratio	2/8 blend	3/7 blend	5/5 blend	7/3 blend
Time [min]	24.2	11.9	74.3	138

- The shortest time for making $10mm^3$ film to reach the theoretically DNA final concentration

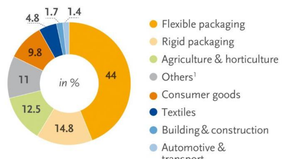
  → 3/7 blend is the best!

Physical Properties





Biodegradable plastics (by market segment) 2017



- The most commonly bioplastic usage is flexible packing.
- Conductivity and resiliency are important

  → 3/7 blend is the best!

Reference

[1] Yamada, M., Kawamura, M. & Yamada, T. Preparation of bioplastic consisting of salmon milt DNA. *Sci Rep* 12, 7423 (2022).
[2] C. Miehe, S. Goektepe and J. Mendez Diez, *Int. J. Of Solids and Structures*, Vol. 46, 1, pages 181-202 (2009)
[3] Davis, Joseph R. Tensile testing. Ohio: ASM International, 2004.