Electronic Supplementary Material (ESI) for Environmental Science: Advances.

Supplementary Information

Weathering of agricultural polyethylene films in cold climate regions: which parameters influence fragmentation?

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Supporting Calculations

Calculation S1. Irradiation calculation during the experiment.

An irradiance of ~35 W/m^2 from the bulbs used for the experiment would represent a total of 117,600 Wh/m^2/year:

$$20\ weeks\ \times\ 24\,\frac{h}{day}\ \times\ 7\,\frac{days}{week} =\ 3360\ h \qquad \text{Eq. S1}$$

$$35\,\frac{W}{m^2}\ \times\ 3360\ h =\ 117{,}600\,\frac{W\ h}{m^2} \qquad \text{Eq. S2}$$

Two approaches could be implemented to compare this laboratory weathering with natural weathering.

1) First, this value can be compared to the total sunlight radiation. In an official report, Hydro Quebec reported an average radiation of 3.5 – 4.2 kWh/m^2/day or 1350 kWh/m^2/year in Montreal[1].

$$\frac{117{,}600\,\frac{W\ h}{m^2}}{1{,}350{,}000\,\frac{W\ h}{m^2\ yr}} =\ 0.087\ yr\ \times\ 52\,\frac{weeks}{yr} = 4.5\ weeks \qquad \text{Eq. S3}$$

   These calculations suggest that 20 weeks of laboratory UV exposure in this experiment was roughly equivalent to 4.5 weeks of environmental UV irradiation. However, we caution that a direct comparison between laboratory irradiation and the natural sunlight is an oversimplification since the bulbs used in this type of experiments is made of monochromatic sources and could not be compared to the broad solar spectrum. It is expected that the impact of visible light on natural weathering is less than that of UV.

2) Secondly, the radiation generated in the laboratory can be compared to sunlight radiation generated in the range of 300 – 400 nm, i.e. the radiation of the laboratory experiment. This data was not found for the region of Montreal. The sunlight radiation for the range of 300 – 400 nm for a northern hemisphere region of ~52 W/m^2 at noon was obtained from B.L. Diffey (Albuquerque, New Mexico, United States at noon, July 3).[2] The laboratory radiation is then equal to 67% of the sunlight radiation for the same wavelength range. Consequently, 20 weeks of artificial weathering would be equivalent to 13.4 weeks of natural weathering in the same wavelength range. This calculation should be treated with caution. Firstly, the value obtained by B.L. Diffey is the solar radiation measured at noon and not an average value for the day. Secondly, as we did not find such values for the Montreal region, we present here those found for the Albuquerque region, which receives more sunlight than Montreal. Overall, the value of 52 W/m^2 therefore overestimates the irradiance in Montreal. Thus, in our scenario, the UV dosage generated in laboratory weathering is expected to be higher compared to the irradiance from natural weathering.

[1] Hydro Quebec, *State of knowledge and sustainability issues: Solar power*, Report ISBN: 978-2-550-83425-0, 2019. https://www.hydroquebec.com/data/developpement-durable/pdf/state-knowledge-sustainability-issues-solar-power-2018.pdf

[2] Diffey, B. L. (2002). "Sources and measurement of ultraviolet radiation." Methods **28** (1): 4-13.

Supporting Figures

Fig. S1. *Set up for the natural weathering (Nat) of the three films.*

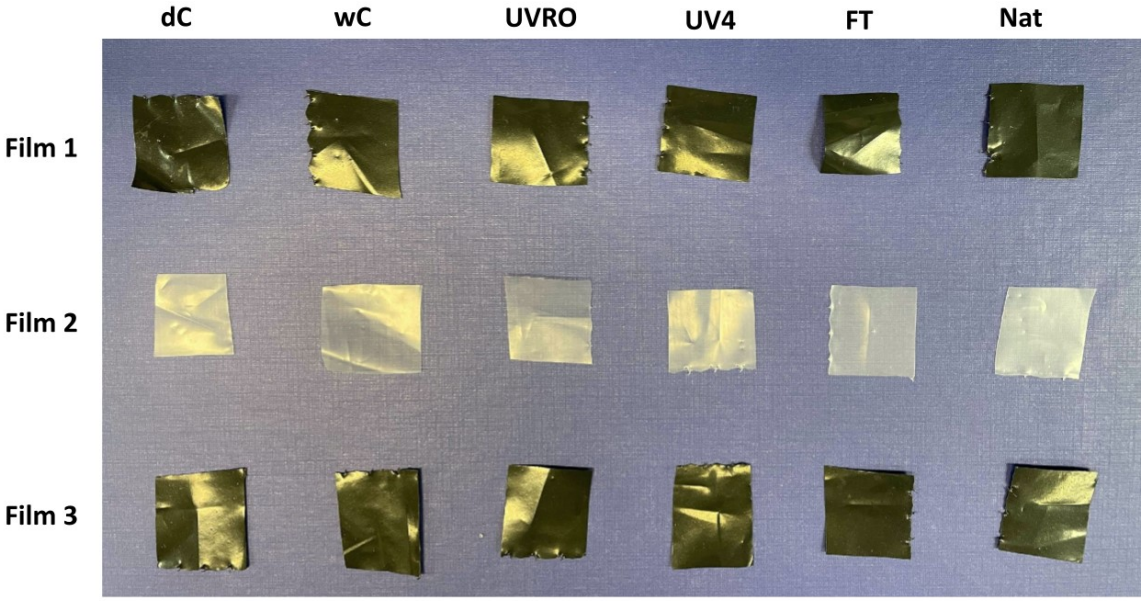

Fig. S2. *Picture of the films with different weathering processes.*

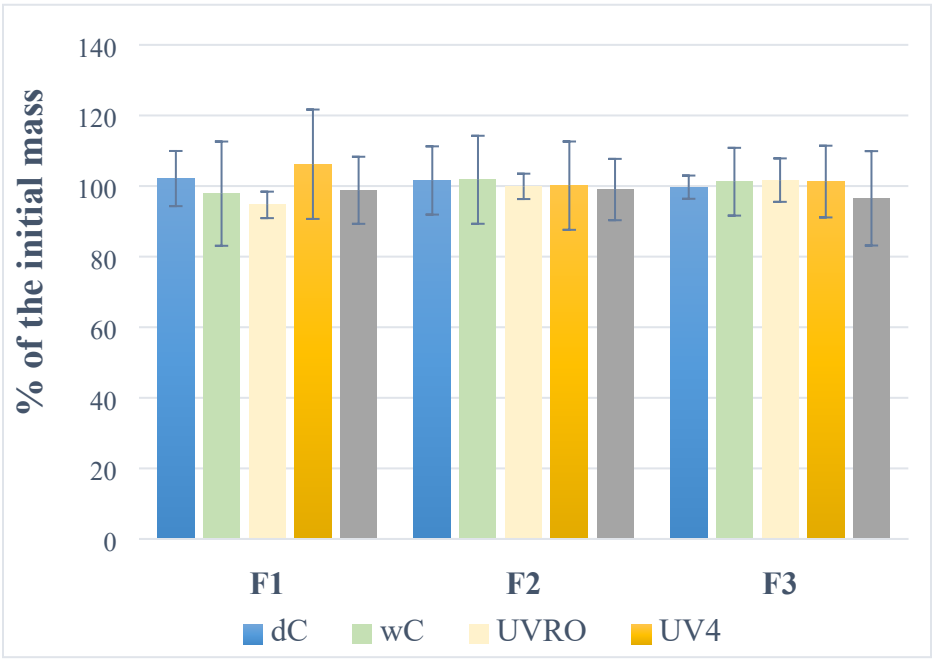

Fig. S3. *Percentage of the initial mass after the weathering procedures for the three films.*

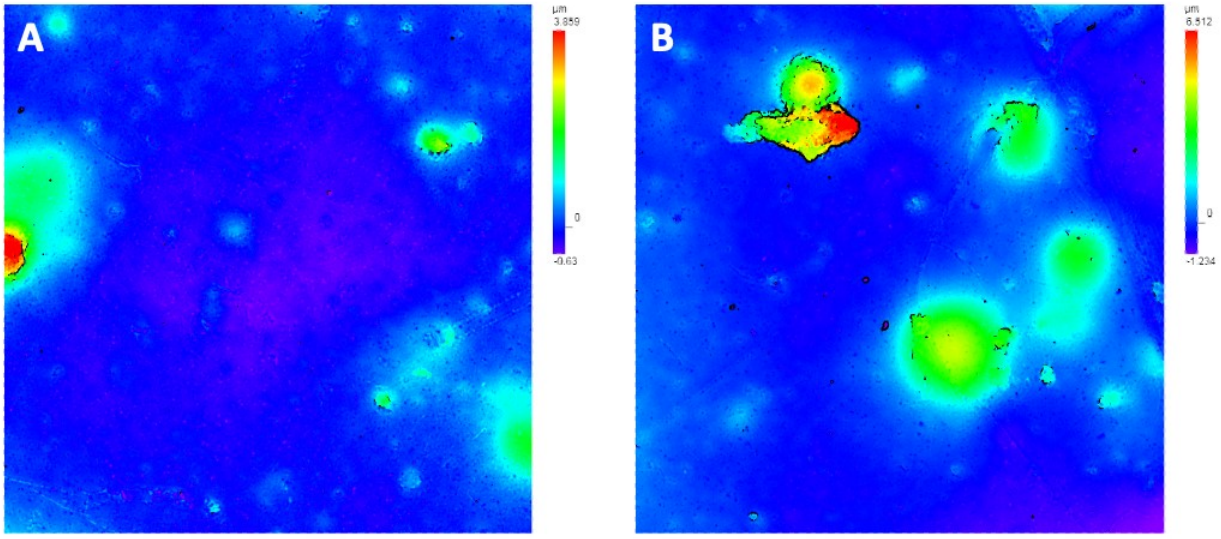

Fig. S4. *Sample images of laser confocal scanning profilometry of the surface of (A) F3dC and (B) F3wC captured with LEXT OLS5000 (Olympus, Tokyo, Japan) with a 100× objective (LMPLFLN100×, Olympus). For profilometry, a total of 18 random points were measured across three plastic squares and both sides of the films (3 measurements per side). Surface roughness was quantified as the arithmetic mean roughness (S_A) and the root mean square roughness (S_Q). Results were not significant.*

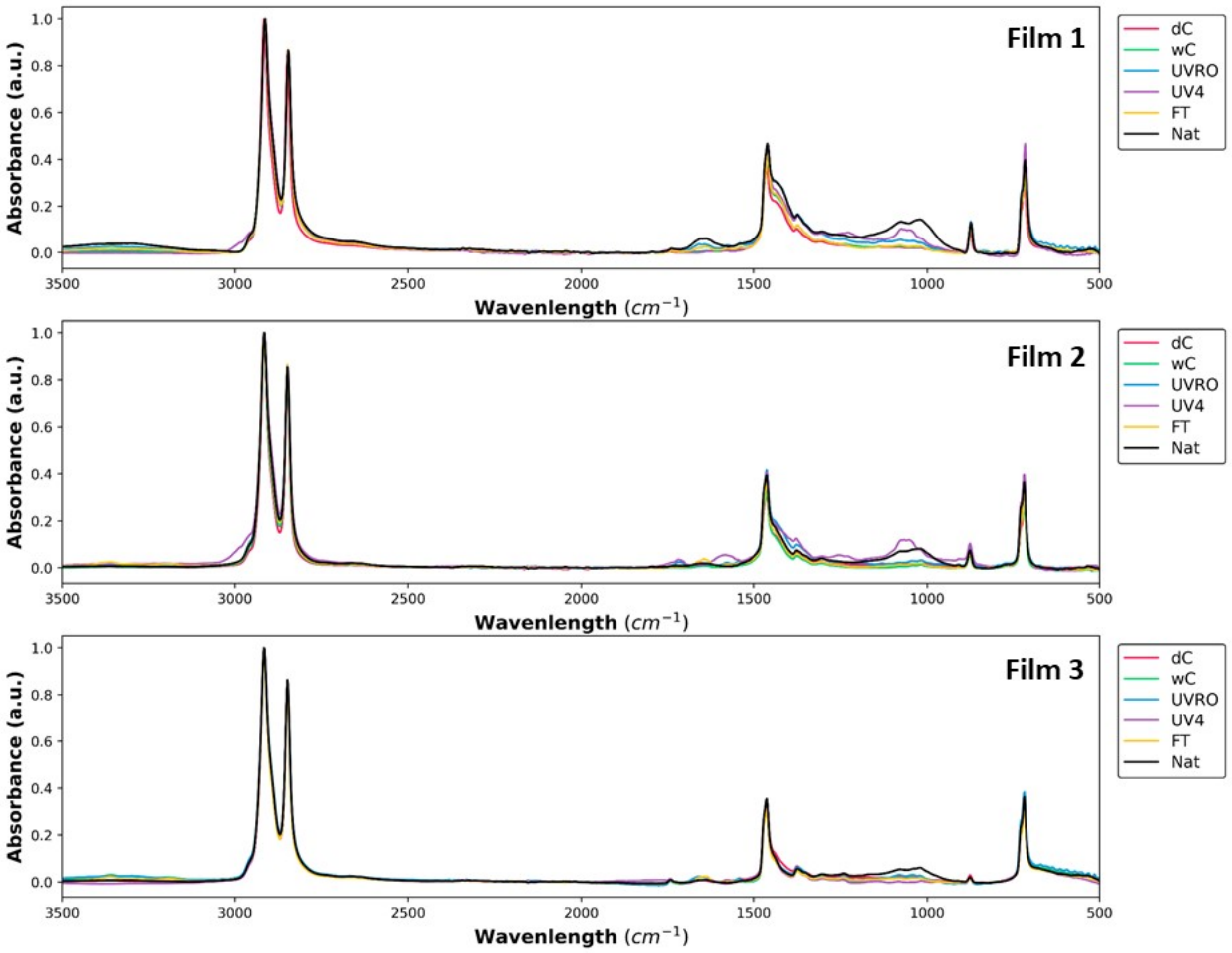

Fig. S5. *FTIR spectra of the three films after different weathering treatments.*

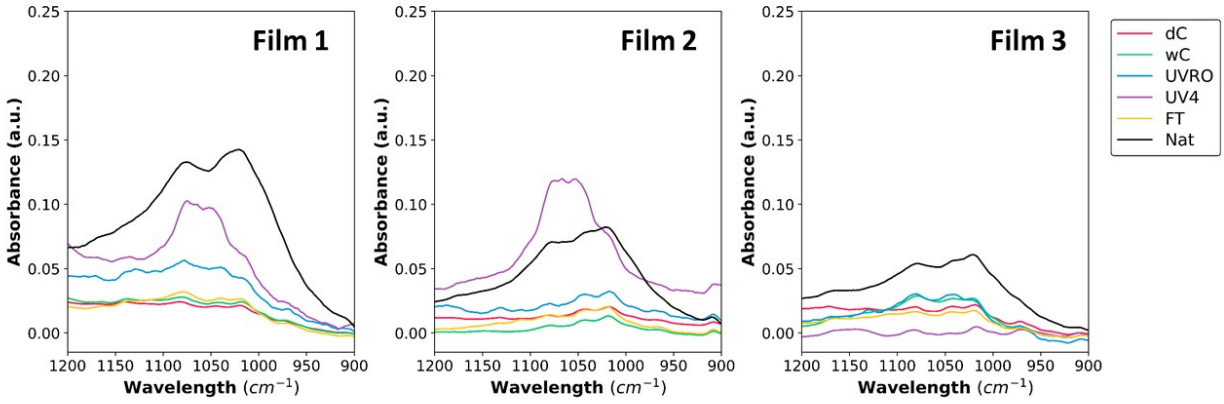

Fig. S6*. 1200-900 cm^{-1} regions of the FTIR spectra obtained for the three films after the different weathering treatments. Each spectrum is an average signal obtained from 6 spectra resulting of the analyses of points on different plastic squares.*

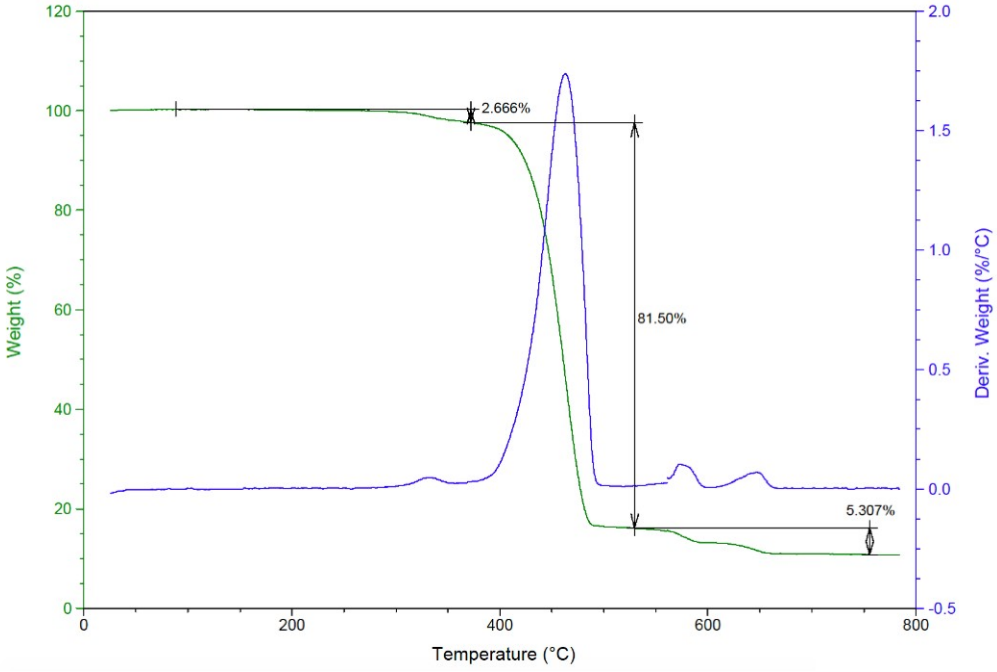

Fig. S7. *Example of curves obtained by TGA; weight loss in green, and derived weight loss in blue. The weight loss profile is integrated in three sections to obtain the volatile (2.666 %), polymer (81.50 %) and residual carbon (5.307 %) amounts.*

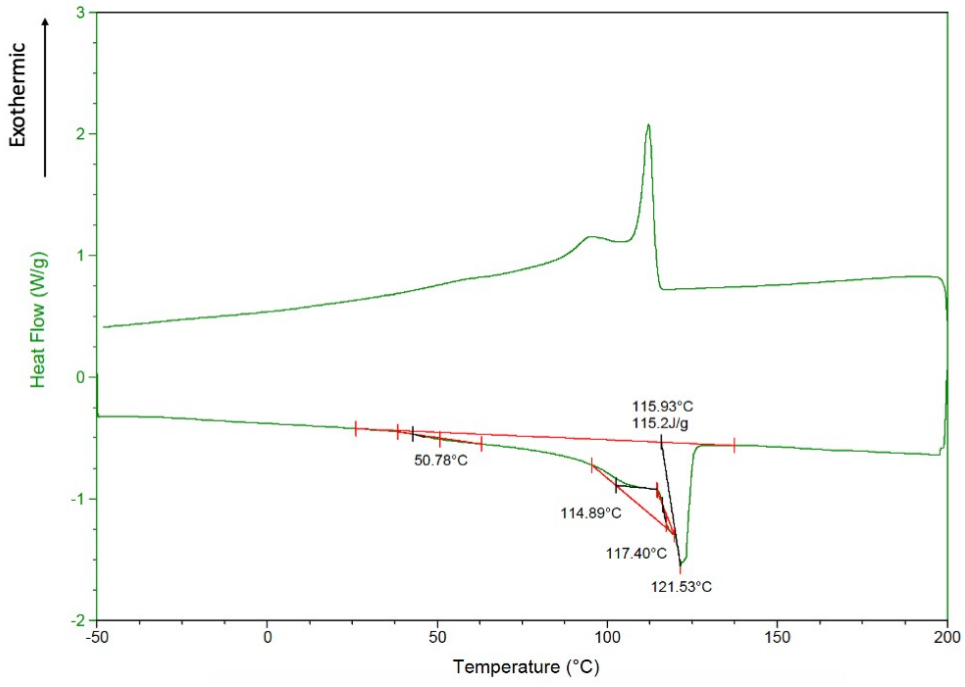

Fig. S8. *Example of melting and crystallization curves obtained by DSC. The melting peaks between 25 and 140ºC were integrated one-by-one.*

Supporting tables

Table S1. *P-values for Fig. 3A.*

Comparison	F1 *P-values*	F2 *P-values*	F3 *P-values*
dC – wC	0.107	0.789	1.000
dC – UVRO	1.000	< .001	1.000
dC – UV4	0.001	< .001	1.000
dC – FT	1.000	1.000	1.000
dC – Nat	1.000	0.185	0.018
wC – UVRO	1.000	0.069	1.000
wC – UV4	1.000	0.202	1.000
wC – FT	1.000	1.000	1.000
wC – Nat	1.000	1.000	0.280
UVRO – UV4	0.119	1.000	1.000
UVRO – FT	1.000	0.002	1.000
UVRO – Nat	1.000	0.559	0.309
UV4 – FT	0.043	0.007	1.000
UV4 – Nat	0.003	0.007	0.006
FT – Nat	1.000	0.602	0.376

Table S2. *P-values for Fig. 3B.*

Comparison	F1 *P-values*	F2 *P-values*	F3 *P-values*
dC – wC	1.000	1.000	0.002
dC – UVRO	1.000	1.000	1.000
dC – UV4	0.585	0.443	1.000
dC – FT	0.443	0.021	0.010
dC – Nat	0.021	0.768	0.989
wC – UVRO	1.000	1.000	0.046
wC – UV4	0.866	0.023	0.013
wC – FT	0.278	0.416	1.000
wC – Nat	0.011	1.000	0.262
UVRO – UV4	0.602	0.860	1.000
UVRO – FT	0.429	0.007	0.149
UVRO – Nat	0.020	0.403	1.000
UV4 – FT	0.003	< .001	0.050
UV4 – Nat	< .001	0.004	1.000
FT – Nat	1.000	1.000	0.670

Table S3. *P-values for Fig. 4.*

Comparison	F1 *P-values*	F2 *P-values*	F3 *P-values*
dC – wC	0.002	1.000	0.047
dC – UVRO	< .001	0.599	< .001
dC – UV4	< .001	0.019	0.518
dC – FT	0.002	0.859	0.030
dC – Nat	0.527	1.000	0.196
wC – UVRO	< .001	0.153	< .001
wC – UV4	1.000	0.002	< .001
wC – FT	1.000	0.170	1.000
wC – Nat	0.753	1.000	< .001
UVRO – UV4	< .001	1.000	0.001
UVRO – FT	< .001	1.000	< .001
UVRO – Nat	< .001	0.390	0.005
UV4 – FT	1.000	0.304	< .001
UV4 – Nat	0.269	0.011	1.000
FT – Nat	1.000	0.540	< .001

Table S4. *Volatile, polymer and residual carbon compositions of the control films obtained by TGA. SD: Standard deviation (n=2).*

	Volatile (% ± %SD)	Polymer (% ± %SD)	Residual carbon (% ± %SD)
F1dC	2.04 ± 1.33	93.73 ± 3.73	4.23 ± 2.40
F2dC	0.94 ± 0.16	97.21 ± 0.15	1.86 ± 0.01
F3dC	0.96 ± 0.31	96.62 ± 0.14	2.42 ± 0.16

Table S5. *Melting peaks of the control and weathered films. SD: Standard deviation (n=3). *No peak 2 was observable for this sample.*

	Peak 1 (°C ± SD)	**Peak 2 (°C ± SD)**	**Peak 3 (°C ± SD)**	**Peak 4 (°C ± SD)**
F1dC	51.86 ± 1.01	110.99 ± 4.95	116.77 ± 0.57	121.75 ± 0.55
F1wC	**59.27 ± 0.52**	*	115.77 ± 0.06	121.97 ± 0.44
F1UVRO	**52.11 ± 0.46**	107.54 ± 2.38	116.50 ± 0.02	122.39 ± 0.19
F1UV4	**60.23 ± 15.50**	93.71 ± 0.37	116.22 ± 0.26	121.85 ± 0.07
F1FT	**60.65 ± 9.61**	97.62 ± 2.07	115.90 ± 0.48	122.19 ± 0.33
F1Nat	52.41 ± 1.22	105.40 ± 0.74	115.74 ± 0.56	122.03 ± 0.19
F2dC	**54.54 ± 1.22**	103.26 ± 1.88	114.25 ± 0.71	119.79 ± 0.11
F2wC	**57.24 ± 1.09**	103.20 ± 0.47	113.33 ± 0.01	119.81 ± 0.29
F2UVRO	**62.52 ± 3.20**	105.11 ± 0.42	113.76 ± 0.14	119.66 ± 0.19
F2UV4	**60.81 ± 0.44**	104.79 ± 0.32	113.77 ± 0.24	119.61 ± 0.68
F2FT	**60.38 ± 0.94**	103.97 ± 0.14	114.08 ± 0.40	119.78 ± 0.49
F2Nat	55.77 ± 0.73	103.96 ± 0.70	114.03 ± 0.44	119.55 ± 0.38
F3dC	51.80 ± 1.45	105.29 ± 0.96	117.62 ± 1.04	122.92 ± 0.38
F3wC	**59.21 ± 0.72**	104.08 ± 0.80	116.75 ± 0.23	122.11 ± 0.15
F3UVRO	53.98 ± 0.16	**107.16 ± 0.57**	117.35 ± 0.23	123.02 ± 0.25
F3UV4	52.37 ± 1.38	104.52 ± 0.29	116.17 ± 1.35	122.44 ± 0.08
F3FT	**59.64 ± 0.30**	**106.53 ± 0.91**	117.45 ± 0.38	122.30 ± 0.26
F3Nat	**58.21 ± 5.80**	105.18 ± 1.57	117.21 ± 1.01	122.25 ± 0.20