Supplementary Material: Table S1. Changes in total sugar concentration (glucose + fructose) during fermentation in Control **(c)**, DAP **(d)**, and Organic **(o)** nitrogen treatments, including nonlinear regression analysis of sugar degradation kinetics and statistical comparisons of decay rates and time-specific differences.

Table S1. Changes in total sugar concentration (glucose + fructose) during fermentation for Control, DAP, and Organic nitrogen treatments. Data represent the average of three replicates per treatment ± standard deviation (SD) for each sampling day. Different letters indicate statistically significant differences among treatments for each day at $p < 0.05$.

TREATMENT	CONTROL	DAP	ORGANIC N
DAY 0	229 ± 8.74 A	229 ± 8.74 A	229 ± 8.74 A
DAY 1	223 ± 32.08 AB	217 ± 8.54 B	212 ± 5.03 A
DAY 3	176 ± 10.02 AB	183 ± 20.66 B	178 ± 10.21 A
DAY 5	139 ± 4.04 AB	136 ± 8.72 B	156 ± 4.04 A
DAY 6	131 ± 10.07 AB	114 ± 9.64 B	121 ± 7.77 A
DAY 7	100 ± 9.17 AB	95 ± 5.77 B	96 ± 12.86 A
DAY 8	71 ± 6.11 AB	72 ± 11.85 B	82 ± 10.69 A
DAY 9	68 ± 3.51 AB	58 ± 4.51 B	70 ± 2.31 A
DAY 10	46 ± 10.79 AB	36 ± 4.36 B	51 ± 11.53 A
DAY 11	32 ± 7.61 AB	33 ± 3.08 B	36 ± 7.89 A
DAY 12	28 ± 9.12 AB	27 ± 1.44 B	33 ± 10.16 A
DAY 13	19 ± 5.51 AB	13 ± 6.58 B	26 ± 7.62 A
DAY 14	15 ± 3.33 AB	5 ± 1.11 B	12 ± 2.71 A
DAY 15	12 ± 1.55 AB	3.1 ± 0.85 B	10 ± 3.66 A
DAY 16	9.9 ± 4.20 AB	2.9 ± 0.81 B	6.1 ± 2.74 A
DAY 18	6.0 ± 3.50 AB	1.8 ± 0.50 B	3.5 ± 2.08 A

Table S2. Standard physicochemical parameters of young Sauvignon Blanc wines after SO_2 addition in the control, DAP, and organic treatments. DAP: diammonium phosphate supplementation; Organic N: organic nitrogen supplementation Alcohol, acetic acid, pH, total acidity, and SO_2 were measured on a composite sample pooled from all biological replicates, while glucose + fructose values represent the mean of individual fermentation replicates.

Parameter	**Control**	**DAP**	**Organic N**
Glucose + fructose (g/L)	6.0 ± 3.50ab	1.8± 0.50a	3.5± 2.08b
Alcohol (vol.%)	13.5	13.5	13.2
Acetic acid (g/L)	0.37	0.21	0.23
pH	3.23	3.20	3.20
Total acidity (g/L, as tartaric acid)	6.1	6.2	6.3
Free SO_2 (mg/L)	14	15	14
Total SO_2 (mg/L)	72	69	67

Nonlinear Decay Analysis

Nonlinear regression was used to compare the decay behavior of three samples (c, d, and o). Three nested exponential models were fitted using nonlinear least squares (nls).

Model 1 (common curve)

measurament = pr1 · exp(−pr2 · time) + pr3

Model 2 (different decay rates)

measurament = pr1 · exp(−pr2_{sample} · time) + pr3

Model 3 (fully separate curves)

measurament = pr1_{sample} · exp(−pr2_{sample} · time) + pr3_{sample}

Model Comparison

Nested model comparisons were conducted using likelihood-based F-tests. Results are shown below:

Model Comparison		Res.Df	Res.Sum Sq	Df	Sum Sq	F	p
Model 1	141	21879	–	–	–	–	
Model 2	139	20635	2	1243.65		4.1886	0.01712
Model 3	135	20496	4	139.37	0.2295	0.92144	

Allowing sample-specific decay rates significantly improved model fit relative to the common-curve model ($F(2,139)=4.19$, $p=0.017$). However, allowing fully separate curves did not further improve fit ($F(4,135)=0.23$, $p=0.92$).

Thus, differences among samples were adequately explained by differences in decay rate alone.

Comparison of Decay Parameters

Pairwise comparisons of decay coefficients were conducted within Model 2 using Wald tests implemented as F-tests, with Holm correction applied across the three comparisons..

Comparison	Raw p	Holm-adjusted p
c vs d	0.0374	0.0748
c vs o	0.5433	0.5433
d vs o	0.00849	0.0255

The decay parameter differed significantly between samples **d** and **o** after adjustment ($p=0.025$). The difference between **c** and **d** did not remain significant after correction ($p=0.075$), and no difference was observed between **c** and **o** ($p=0.54$).

Overall, sample **d** exhibited the fastest decay, whereas samples **c** and **o** showed similar decay behavior.

Time-Specific Comparisons (1–18)

Model-estimated responses were compared across all timepoints (1–18) using nonlinear contrasts derived from Model 2:

$\hat{y}(t) = pr1 \cdot \exp(-pr2_\{sample\} \cdot t) + pr3$

Contrasts were evaluated using the delta method (msm::deltamethod) to obtain standard errors accounting for parameter covariance. T-tests were used, and Holm correction was applied within each timepoint across the three pairwise comparisons.

Full Contrast Results

Day 1

- c vs d: diff = 1.369, SE = 0.645, t = 2.12, p = 0.0354, adj p = 0.0708
- c vs o: diff = −0.379, SE = 0.621, t = −0.610, p = 0.543, adj p = 0.543
- d vs o: diff = −1.748, SE = 0.643, t = −2.72, p = 0.00742, adj p = 0.0223

Day 3

- c vs d: diff = 2.505, SE = 1.178, t = 2.13, adj p = 0.0703

- c vs o: diff = −0.695, SE = 1.140, t = −0.610, adj p = 0.543
- d vs o: diff = −3.201, SE = 1.175, t = −2.72, adj p = 0.0219

Day 5

- c vs d: diff = 3.438, SE = 1.614, t = 2.13, adj p = 0.0698
- c vs o: diff = −0.957, SE = 1.569, t = −0.610, adj p = 0.543
- d vs o: diff = −4.395, SE = 1.610, t = −2.73, adj p = 0.0215

Day 6

- c vs d: diff = 4.195, SE = 1.967, t = 2.13, adj p = 0.0694
- c vs o: diff = −1.171, SE = 1.920, t = −0.610, adj p = 0.543
- d vs o: diff = −5.365, SE = 1.962, t = −2.73, adj p = 0.0212

Day 7

- c vs d: diff = 4.797, SE = 2.247, t = 2.13, adj p = 0.0691
- c vs o: diff = −1.343, SE = 2.202, t = −0.610, adj p = 0.543
- d vs o: diff = −6.140, SE = 2.242, t = −2.74, adj p = 0.0209

Day 8

- c vs d: diff = 5.267, SE = 2.465, t = 2.14, adj p = 0.0688
- c vs o: diff = −1.479, SE = 2.424, t = −0.610, adj p = 0.543
- d vs o: diff = −6.746, SE = 2.460, t = −2.74, adj p = 0.0207

Day 9

- c vs d: diff = 5.622, SE = 2.629, t = 2.14, adj p = 0.0685
- c vs o: diff = −1.584, SE = 2.595, t = −0.610, adj p = 0.543
- d vs o: diff = −7.205, SE = 2.624, t = −2.75, adj p = 0.0205

Day 12

- c vs d: diff = 5.878, SE = 2.748, t = 2.14, adj p = 0.0683
- c vs o: diff = −1.661, SE = 2.722, t = −0.610, adj p = 0.543
- d vs o: diff = −7.539, SE = 2.744, t = −2.75, adj p = 0.0204

Day 13

- c vs d: diff = 6.051, SE = 2.828, t = 2.14, adj p = 0.0682
- c vs o: diff = −1.714, SE = 2.810, t = −0.610, adj p = 0.543
- d vs o: diff = −7.765, SE = 2.824, t = −2.75, adj p = 0.0203

Day 14–18 (pattern continues identically)

Across Days 14–18:

- c vs d: differences decrease gradually (6.15 → 5.44), adj p ≈ 0.068–0.070
- c vs o: always non-significant (adj p ≈ 0.543)
- d vs o: consistently significant (adj p ≈ 0.020–0.021)

Interpretation

Across both parameter-level and time-specific analyses:

- Differences among samples are primarily driven by variation in decay rate.
- Sample **d** consistently shows lower predicted values across time due to faster decay.
- Samples **c** and **o** follow similar trajectories and do not differ significantly at any timepoint.
- Differences between **c** and **d** are systematic but do not remain significant after multiplicity adjustment.

These results are consistent across all analytical approaches used.