SUPPLEMENTARY DATA
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SUPPLEMENTARY DATA

Table S1. Detailed composition of the sensory standards used during the Pivot© Profile training and formal evaluation sessions of Nebbiolo wines.

Sensory attribute	Standard composition
Bitterness	0.2 g caffeine (Sigma-Aldrich, Sigma-Aldrich Co., St. Louis, MO, USA)
Acidity	1.2 g/L tartaric acid (Fisher Scientific, Thermo Fisher Scientific, Waltham, MA, USA)
Astringency	0.8 g/L tannic acid (Sigma-Aldrich, Sigma-Aldrich Co., St. Louis, MO, USA)
Color saturation	Definition provided to panelists as "Total amount of color regardless of the hue"
Purple Hue	2023 Syrah, Spanish Springs, Cal Poly Research
All taste and mouthfeel standards were prepared in 400 mL of Vietti 2021 Nebbiolo, Langhe, Italy.	

Table S2. Detailed composition of the sensory standards used during the Time Intensity training sessions of Nebbiolo wines.

Sensory attribute	Standard composition
"Red fruit" low intensity	0.25 mL cherry extract bubly drops (Sodastream, Purchase, NY, USA) + 0.5 mL strawberry extract bubly drops (Sodastream, Purchase, NY, USA) + 0.25 mL blackberry extract bubly drops (Sodastream, Purchase, NY, USA)
"Red fruit" high intensity	0.25 mL cherry extract bubly drops (Sodastream, Purchase, NY, USA) + 0.75 mL strawberry extract bubly drops (Sodastream, Purchase, NY, USA) + 0.5 mL blackberry extract bubly drops (Sodastream, Purchase, NY, USA)
Standards were prepared in blend of all four Nebbiolo treatments (25:25:25:25).	

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Table S3. Average number of days to complete malolactic fermentation for Nebbiolo and Tannat wines.

Varietal	Treatment	Days to complete MLF
Nebbiolo	Control	14
	Lachancea	24
	IE	14
Tannat	Control	21
	Lachancea	51
	IE	21

Table S4. Two-way ANOVA showing treatment effects and varietal × treatment interactions of selected phenolic compounds.

Timepoint	Treatment	Anthocyanins (mg/L Mv-3-G)	Polymeric pigments (AU @ 520 nm)	Tannins (mg/L CE)	Total phenolics (mg/L CE)
Bottling	Control	343.6 b	1.27 b	766.9 b	1641.7 b
	MLFB	396.9 a	1.47 a	914.7 a	1731.2 a
	Lachancea	360.2 b	1.11 c	548.4 c	1266.8 c
	IE	339.0 b	1.32 b	909.1 a	1817.2 a
	p-value	**0.000**	**<0.0001**	**<0.0001**	**<0.0001**
	Varietal × Treatment				
	p-value	**0.000**	**0.002**	**0.000**	**0.019**
Accelerated aging	Control	199.7 ab	1.78 bc	616.6 b	1638.9 b
	MLFB	222.1 a	2.36 a	736.7 a	1724.0 a
	Lachancea	197.1 ab	1.72 c	430.7 c	1245.7 c
	IE	182.4 b	1.92 b	728.1 a	1767.6 a
	p-value	**0.032**	**<0.0001**	**<0.0001**	**<0.0001**
	Varietal × Treatment				
	p-value	**0.005**	**0.000**	**0.002**	**0.002**

** Bold values indicate significant differences between treatments for the Fisher (LSD) test and $p < 0.05$.*

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Table S5. Anthocyanin and anthocyanin-derived pigments of Nebbiolo and Tannat wines.

Varietal	Timepoint	Treatment	Malvidin-3-glucoside (mg/L)	Petunidin-3-glucoside (mg/L Mv-3-glu)	Peonidin-3-glucoside (mg/L Mv-3-glu)	Delphinidin-3-glucoside (mg/L Mv-3-glu)	Cyanidin-3-glucoside (mg/L Mv-3-glu)	Acylated anthocyanins (mg/L Mv-3-glu)	Polymeric pigments & vitisins (mg/L Mv-3-glu)
Nebbiolo	Bottling	Control	35.7 b	1.9 bc	12.6 b	1.0 b	0.8 b	4.0 a	0.1 b
		MLFB	36.9 b	2.5 a	12.1 b	1.4 ab	0.8 b	3.5 a	0.4 a
		Lachancea	43.6 a	1.8 c	26.0 a	1.6 a	2.1 a	4.2 a	0.0 b
		IE	37.3 b	2.3 ab	11.7 b	1.2 ab	0.7 b	3.5 a	0.4 a
		p-value	**0.040**	**0.012**	**<0.0001**	0.134	**<0.0001**	0.255	**0.001**
	Accelerated aging	Control	14.6 a	1.3 ab	4.3 b	0.8 b	0.7 b	1.2 a	0.0
		MLFB	10.2 b	1.1 b	3.4 b	0.6 b	0.6 b	0.6 ab	0.0
		Lachancea	14.6 a	1.4 a	8.3 a	1.0 a	1.5 a	1.1 ab	0.0
		IE	11.9 b	1.2 ab	3.9 b	0.6 b	0.7 b	0.5 b	0.0
		p-value	**0.014**	0.133	**0.000**	**0.027**	**<0.0001**	0.101	
Tannat	Bottling	Control	203.3 b	16.0 b	0.0 c	6.1 c	0.0 a	96.4 c	13.4 c
		MLFB	245.2 a	16.8 b	1.3 b	6.6 c	0.0 a	116.5 a	18.2 a
		Lachancea	209.3 b	18.1 b	3.2 a	8.2 b	0.2 a	105.1 b	14.4 b
		IE	205.1 b	21.5 a	2.5 ab	9.7 a	0.2 a	101.5 b	15.4 b
		p-value	**<0.0001**	**0.004**	**0.001**	**0.002**	0.593	**<0.0001**	**<0.0001**
	Accelerated aging	Control	97.8 a	9.0 a	1.5 a	3.9 ab	0.0 b	14.4 a	40.8 a
		MLFB	93.9 ab	7.6 b	1.6 a	3.2 b	0.0 b	14.3 a	44.0 a
		Lachancea	89.8 ab	8.5 ab	2.0 a	4.1 a	0.1 b	14.0 a	32.2 b
		IE	83.4 b	9.4 a	1.7 a	4.2 a	0.4 a	12.4 a	35.4 b
		p-value	0.148	0.073	0.268	**0.041**	**0.010**	0.272	**0.001**

** Bold values indicate significant differences between treatments for the Fisher (LSD) test and p < 0.05*

Table S6. Flavonols of Nebbiolo and Tannat wines.

Varietal	Timepoint	Treatment	Quercetin derivatives (mg/L Qct-3-glu)	Non-quercetin derivatives (mg/L Qct-3-glu)
Nebbiolo	3 Months bottle aging	Control	17.4 a	5.2 a
		MLFB	17.8 a	5.4 a
		Lachancea	19.1 a	5.5 a
		IE	18.6 a	5.4 a
		p-value	0.580	0.400
	Accelerated aging	Control	17.3 a	5.4 ab
		MLFB	17.1 a	5.5 ab
		Lachancea	16.4 a	5.1 b
		IE	18.2 a	5.8 a
		p-value	0.380	0.111
Tannat	3 Months bottle aging	Control	9.9 b	17.8 c
		MLFB	11.1 a	21.0 a
		Lachancea	9.2 b	17.9 bc
		IE	11.0 a	20.1 ab
		p-value	**0.012**	**0.020**
	Accelerated aging	Control	9.8 c	17.2 b
		MLFB	11.6 a	20.5 a
		Lachancea	9.7 c	17.6 b
		IE	10.6 b	18.6 b
		p-value	**0.002**	**0.008**

** Bold values indicate significant differences between treatments for the Fisher (LSD) test and $p < 0.05$.*

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Table S7. Monomeric flavan-3-ols of Nebbiolo and Tannat wines.

Varietal	Timepoint	Treatment	Epigallocatechin (mg/L catechin)	Catechin (mg/L)	Epicatechin (mg/L catechin)	Epicatechin gallate (mg/L catechin)	Dimers (mg/L catechin)	Trimers (mg/L catechin)	Sulfonated tannins (mg/L catechin)	Total (mg/L catechin)
Nebbiolo	3 Months bottle aging	Control	0.44 a	21.8 a	16.1 a	0.10 a	18.9 a	2.8 a	0.81 a	60.9 a
		MLFB	0.41 a	17.6 b	13.5 b	0.10 a	12.1 c	2.0 b	0.48 b	46.2 b
		Lachancea	0.42 a	18.7 b	14.3 ab	0.08 b	13.5 bc	2.0 b	0.52 b	49.6 b
		IE	0.46 a	19.4 ab	14.2 ab	0.10 ab	16.5 ab	2.8 a	0.51 b	53.9 ab
		p-value	0.788	0.051	0.141	**0.046**	**0.014**	**0.007**	**0.010**	**0.015**
	Accelerated aging	Control	0.44 ab	18.7 a	12.5 a	0.07 a	11.9 b	2.2 ab	11.60 a	57.4 a
		MLFB	0.43 ab	13.9 b	9.3 b	0.07 a	10.5 b	2.0 bc	4.71 b	40.9 b
		Lachancea	0.40 b	16.5 ab	11.1 ab	0.07 a	11.5 b	1.8 c	5.54 ab	46.9 ab
		IE	0.51 a	17.1 ab	9.5 b	0.07 a	14.4 a	2.4 a	8.24 ab	52.2 a
		p-value	0.143	0.060	**0.032**	0.938	**0.010**	**0.009**	0.146	**0.036**
Tannat	3 Months bottle aging	Control	0.26 ab	5.3 a	4.5 a	0.03 a	13.2 a	1.5 a	0.17 b	25.0 a
		MLFB	0.23 bc	6.3 a	2.9 b	0.03 a	11.7 b	1.5 a	0.21 a	22.8 a
		Lachancea	0.20 c	6.4 a	3.0 b	0.03 a	13.0 a	1.3 a	0.17 b	24.2 a
		IE	0.28 a	6.3 a	3.9 a	0.03 a	12.0 b	1.4 a	0.16 b	24.1 a
		p-value	**0.007**	0.830	**0.005**	0.821	**0.022**	0.352	**0.001**	0.671
	Accelerated aging	Control	0.25 a	8.9 a	4.6 a	0.04 a	16.2 a	2.2 a	1.99 b	34.2 a
		MLFB	0.22 ab	8.2 a	3.5 b	0.05 a	13.7 ab	1.9 ab	3.81 a	31.4 ab
		Lachancea	0.20 b	8.3 a	3.5 b	0.04 a	13.1 b	1.7 b	1.47 b	28.3 b
		IE	0.24 a	7.3 a	4.2 ab	0.04 a	15.7 a	2.2 a	1.46 b	31.1 ab
		p-value	**0.033**	0.551	0.059	0.535	0.072	**0.024**	**0.048**	0.162

** Bold values indicate significant differences between treatments for the Fisher (LSD) test and $p < 0.05$.*

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Table S8. Two-way ANOVA showing treatment effects and varietal × treatment interactions for monomeric flavan-3-ols after 3 months bottle aging and following accelerated aging.

Timepoint	Treatment	Epigallocatechin (mg/L catechin)	Catechin (mg/L)	Epicatechin (mg/L catechin)	Epicatechin gallate (mg/L catechin)	Dimers (mg/L catechin)	Trimers (mg/L catechin)	Sulfonated tannins (mg/L catechin)
3 Months bottle aging	Control	0.35 ab	13.6 a	10.3 a	0.07 a	16.0 a	2.2 a	0.49 a
	MLFB	0.32 ab	11.9 a	8.2 b	0.08 a	11.9 c	1.7 b	0.35 b
	Lachancea	0.31 b	12.6 a	8.6 b	0.05 b	13.3 bc	1.7 b	0.35 b
	IE	0.37 a	12.8 a	9.0 b	0.07 ab	14.3 ab	2.1 a	0.33 b
	p-value	0.105	0.399	**0.007**	**0.036**	**0.002**	**0.001**	**0.003**
				Varietal × Treatment				
	p-value	0.826	0.063	0.615	**0.030**	**0.011**	**0.008**	**0.002**
Accelerated aging	Control	0.34 ab	13.8 a	8.6 a	0.05 a	14.1 a	2.2 a	6.79 a
	MLFB	0.32 b	11.1 b	6.4 b	0.06 a	12.1 b	2.0 b	4.26 ab
	Lachancea	0.30 b	12.4 ab	7.3 b	0.06 a	12.3 b	1.8 c	3.51 b
	IE	0.38 a	12.2 ab	6.8 b	0.06 a	15.1 a	2.3 a	4.85 ab
	p-value	**0.025**	0.058	**0.005**	0.719	**0.002**	**0.000**	0.186
				Varietal × Treatment				
	p-value	0.333	0.128	0.056	0.946	0.177	0.704	0.053

** Bold values indicate significant differences between treatments for the Fisher (LSD) test and p < 0.05.*

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Table S9. Odor activity values (concentration/odor detection threshold) of Nebbiolo and Tannat wines.

Varietal	Timepoint	Treatment	Ethyl butyrate	Ethyl isovalerate	Isoamyl acetate	Ethyl hexanoate	Ethyl *n*-octanoate	β-ionone	Nerolidol (trans)
Nebbiolo	3 Months bottle aging	Control	27 a	7 a	116 ab	59 a	123 a	11 a	0.8 a
		MLFB	30 a	7 a	128 a	66 a	140 a	11 a	0.8 a
		Lachancea	10 c	3 c	58 c	18 b	22 b	8 b	0.5 b
		IE	19 b	5 b	97 b	61 a	147 a	10 a	0.5 b
		p-value	**<0.0001**	**<0.0001**	**0.001**	**<0.0001**	**<0.0001**	**0.002**	**0.000**
	Accelerated aging	Control	21 a	9 b	80 a	47 a	140 a	12 a	15 a
		MLFB	25 a	13 a	88 a	57 a	165 a	12 a	13 ab
		Lachancea	8 b	5 c	43 b	17 b	28 b	9 a	11 b
		IE	23 a	14 a	73 a	56 a	174 a	11 a	12 ab
		p-value	**0.000**	**0.000**	**0.015**	**0.000**	**0.000**	0.230	0.103
Tannat	3 Months bottle aging	Control	23 a	10 b	108 a	42 a	63 a	6 a	1.3 a
		MLFB	19 a	12 b	104 ab	34 a	46 a	4 a	1.2 a
		Lachancea	15 b	7 c	67 c	22 b	17 b	8 a	1.1 a
		IE	19 a	16 a	79 bc	36 a	55 a	6 a	1.5 a
		p-value	**0.013**	**0.001**	**0.018**	**0.009**	**0.006**	0.234	0.191
	Accelerated aging	Control	23 a	16 b	89 a	44 a	94 a	11 a	1.7 a
		MLFB	23 a	26 a	88 a	42 a	81 b	10 ab	1.5 b
		Lachancea	15 c	12 c	55 c	25 c	28 c	10 a	1.3 c
		IE	20 b	27 a	58 b	38 b	87 ab	8 b	1.3 c
		p-value	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**0.034**	**0.000**

** Bold values indicate significant differences between treatments for the Fisher (LSD) test and p < 0.05.*

Table S10. Time-intensity data analysis of Nebbiolo wines.

Treatment	Area under the curve	Peak value
Control	124 b	6.2 b
MLFB	122 b	6.3 b
Lachancea	161 a	7.4 a
IE	140 ab	6.7 ab
p-value	**0.026**	**0.043**

** Bold values indicate significant differences between treatments for the Fisher (LSD) test and $p < 0.05$.*

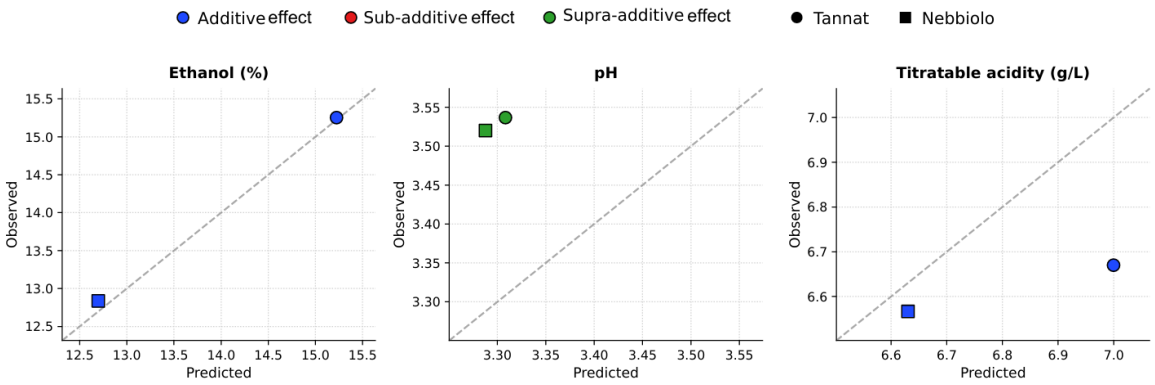

Figure S1. Relationship between observed and predicted values of ethanol (% *v/v*), pH, and titratable acidity (g/L) for Nebbiolo and Tannat IE wines.

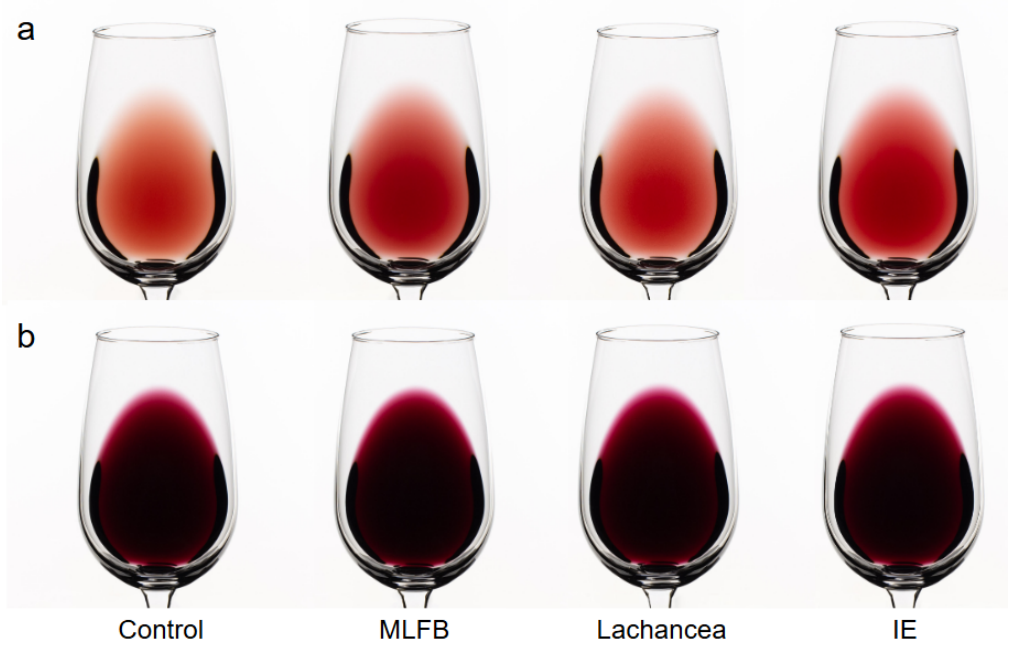

Figure S2. Visual aspect of a) Nebbiolo and b) Tannat wines after one year of bottle aging for control, MLFB, Lachancea, and 30 % ion exchange wine blend.