

Supplementary tables and figures.

Table S1. Pearson's correlation coefficients matrix of phenolic acids, antioxidant properties, and overall color difference of bicultured jujube purees, JP

	Morin	Chlo	Sinp	Fer	Gal	Neo	Caf	Quer	Prot	Cat	Rutin	Syri	THB	Coum	C3R	P3G	P3DG	DPPH	ABTS	ΔE
Morin	1																			
Chlo	0.008	1																		
Sinp	-0.159	-	1																	
		0.801*																		
Fer	-0.230	-	0.997*	1																
		0.788*																		
Gal	-0.359	-	0.977*	0.989*	1															
		0.789*																		
Neo	-0.834*	0.231	0.231	0.291	0.364	1														
Caf	-0.027	0.256	0.359	0.359	0.295	0.564	1													
Quer	0.989*	0.131	-0.302	-0.371	-0.493	-	-0.072	1												
						0.836*														
Prot	-0.808*	0.095	0.383	0.439	0.502	0.987*	0.608*	-	1											
								0.833*												
Cat	-0.597*	0.580*	-0.055	-0.008	0.031	0.910*	0.697*	-0.562	0.860*	1										
Rutin	-0.269	-	0.993*	0.998*	0.995*	0.296	0.311	-0.408	0.442	-0.020	1									
		0.808*																		
Syri	-0.501	0.271	0.335	0.370	0.377	0.892*	0.877*	-0.528	0.909*	0.911*	0.347	1								
THB	-0.361	0.587*	0.004	0.033	0.030	0.801*	0.859*	-0.342	0.771*	0.957*	0.003	0.936*	1							

Coum	0.330	0.793*	-	-	-	-0.344	-0.305	0.465	-0.485	-0.018	-	-0.371	-0.025	1						
			0.983*	0.993*	0.999*						0.998*									
C3R	0.806*	-0.130	-0.352	-0.408	-0.472	-	-	0.827*	-	-	-0.411	-	-	0.455	1					
						0.992*	0.613*		0.999*	0.877*		0.914*	0.787*							
P3G	-0.058	-	0.014	0.015	0.078	-0.493	-	-0.065	-0.481	-	0.065	-	-	-0.069	0.498	1				
		0.589*					0.928*			0.753*		0.795*	0.909*							
P3DG	0.732*	-0.069	0.335	0.278	0.136	-0.291	0.616*	0.661*	-0.207	-0.108	0.220	0.168	0.181	-0.166	0.211	-0.544	1			
DPPH	-0.035	0.790*	-	-	-	-0.088	-0.388	0.112	-0.247	0.147	-	-0.267	0.037	0.929*	0.216	0.029	-0.498	1		
			0.980*	0.964*	0.916*						0.950*									
ABTS	-0.073	0.819*	-	-	-	-0.027	-0.335	0.074	-0.186	0.212	-	-0.203	0.101	0.916*	0.155	-0.023	-0.497	0.996*	1	
			0.971*	0.952*	0.903*						0.939*									
ΔE	-0.370	-0.164	0.681*	0.700*	0.689*	0.695*	0.793*	-0.454	0.778*	0.596*	0.679*	0.841*	0.654*	-0.689*	-	-0.572	0.319	-0.637*	-	1
															0.768*				0.577*	

Correlation matrix coefficients with asterisk * denote significant correlation (p<0.05).

Note

Chlo- chlorogenic acid; Sinp- sinapic acid; Fer- ferulic acid; Gal- gallic acid; Neo- neochlorogenic acid; Caf- caffeic acid; Quer- quercetin; Prot- protocatechuic acid; Cat- catechin; Syri- syringic acid; THB- 2,3,4-trihydroxybenzoic acid; Coum- *p*-coumaric acid; C3R- cyanidin-3-O-rutinoside; P3G- peonidin-3-O-glucoside; P3DG- peonidin-3,5-diglucoside; DPPH- 2,2-diphenyl-1-picrylhydrazyl radical scavenging activities; ABTS- 2,2-azino-bis-3- ethylbenzothiazoline-6-sulfonic acid radical scavenging activities; ΔE- overall color difference.

Table S2. Semi-quantitative amounts of volatile compounds identified in bi-cultured Junzao jujube purees by HS-SPME-GC/MS method.

Volatile groups	SN	Compound name	CAS number	Odor description	Concentration of JP, % (mean \pm SD)			
					JCON	JLcAp	JLhAp	JLpAp
Alcohols	AL1	1-Decanol	112-30-1	Floral, fatty	3.73 \pm 0.02 ^a	n.d	n.d	n.d
	AL2	1-Dodecanol	112-53-8	Sweet, fats, coconut	n.d	n.d	0.37 \pm 0.01 ^a	0.29 \pm 0.01 ^b
	AL3	1-Heptanol	111-70-6	Green	n.d	0.62 \pm 0.01 ^a	n.d	0.60 \pm 0.01 ^a
	AL4	1-Hexanol	111-27-3	Resin, flower, green	0.49 \pm 0.01 ^a	0.45 \pm 0.01 ^b	0.37 \pm 0.02 ^c	0.38 \pm 0.01 ^c
	AL5	1-Hexanol, 2-ethyl-	104-76-7	Green, rose	2.37 \pm 0.01 ^a	0.23 \pm 0.01 ^b	0.21 \pm 0.01 ^b	0.19 \pm 0.01 ^c
	AL6	1-Hexanol, 5-methyl-	627-98-5		n.d	n.d	0.57 \pm 0.01 ^a	n.d
	AL7	1-Nonanol	143-8-8	Fatty	0.20 \pm 0.00 ^a	n.d	n.d	n.d
	AL8		111-87-5	Chemical, metal, burnt	0.67 \pm 0.01 ^b	n.d	n.d	1.09 \pm 0.01 ^a
		1-Octanol						
	AL9	2,3-Butanediol	24347-58-8	Buttery, creamy	43.21 \pm 0.16 ^a	10.79 \pm 0.03 ^b	10.96 \pm 0.01 ^b	10.87 \pm 0.01 ^b
	AL10	2,4-Di-tert-butylphenol	96-76-4	Phenolic	0.57 \pm 0.01 ^a	0.22 \pm 0.01 ^d	0.30 \pm 0.01 ^b	0.25 \pm 0.01 ^c
	AL11	2-Butanol, 1-methoxy-	53778-73-7		n.d	n.d	0.23 \pm 0.01 ^a	n.d
	AL12		628-99-9	Orange, rose, mushroom	0.20 \pm 0.00 ^b	n.d	0.45 \pm 0.01 ^a	n.d
		2-Nonanol						
	AL13	Benzyl alcohol	100-51-6	Walnut, nutty	2.45 \pm 0.01 ^a	0.95 \pm 0.02 ^b	0.86 \pm 0.01 ^c	0.95 \pm 0.01 ^b
	AL14	Phenol	108-95-2	Plastic, rubber	n.d	1.23 \pm 0.03 ^b	n.d	1.28 \pm 0.01 ^a
	AL15	Phenol, 4-ethyl-	123-7-9	Phenol	n.d	0.93 \pm 0.02 ^a	n.d	0.52 \pm 0.01 ^b

Acids	AL16		60-12-8	Floral, rosy, honey, spice	0.83 ± 0.01^d	15.93 ± 0.03^a	15.12 ± 0.02^b	14.95 ± 0.02^c
		Phenylethyl alcohol						
	AL17	Thymol	89-83-8	Herb, pleasant	n.d	2.63 ± 0.01^a	n.d	n.d
		Subtotal			54.53 ± 0.12^a	33.75 ± 0.01^b	29.44 ± 0.01^d	31.37 ± 0.03^c
	ACD1	2-Heptenoic acid	18999-28-5	Green, fruity	1.29 ± 0.01^a	n.d	n.d	n.d
	ACD2	2-Octenoic acid	1470-50-4		n.d	0.21 ± 0.01^a	0.15 ± 0.02^b	n.d
	ACD3	3-Decenoic acid, (E)-	53678-20-9		n.d	0.19 ± 0.01^b	0.23 ± 0.02^a	n.d
	ACD4	3-Hexenoic acid, (E)-	1577-18-0	Must, fat	0.34 ± 0.00^a	n.d	n.d	n.d
	ACD5	3-Octenoic acid, (E)-	5163-67-7		0.53 ± 0.01^a	n.d	0.36 ± 0.01^b	n.d
	ACD6	Benzoic acid	65-85-0	Leather	1.04 ± 0.01^c	n.d	3.31 ± 0.01^a	1.13 ± 0.01^c
	ACD7	Benzoic acid, p-tert-butyl-	98-73-7		0.24 ± 0.00^a	n.d	n.d	n.d
	ACD8	Butanoic acid, 2-methyl-	116-53-0	Cheesy, sweaty	0.33 ± 0.00^a	n.d	n.d	n.d
	ACD9		503-74-2	Rancid, cheesy,	0.28 ± 0.00^a	n.d	n.d	n.d
		Butanoic acid, 3-methyl-		sweaty				
	ACD10	Dodecanoic acid	143-7-7	Rancid, moldy	2.46 ± 0.01^a	2.21 ± 0.01^b	1.94 ± 0.01^d	2.08 ± 0.00^c
	ACD11	Heptanoic acid	111-14-8	Rancid, fatty	0.66 ± 0.00^c	0.87 ± 0.02^b	1.92 ± 0.01^a	0.65 ± 0.00^c
	ACD12	Hexanoic acid	142-62-1	Cheesy, fatty	7.98 ± 0.05^a	1.27 ± 0.02^b	n.d	n.d
	ACD13	Hydrocinnamic acid	501-52-0	Cheesy	0.65 ± 0.01^b	0.65 ± 0.01^b	0.51 ± 0.01^c	0.75 ± 0.01^a
	ACD14	n-Decanoic acid	334-48-5	Fatty, citrus	7.17 ± 0.04^a	1.38 ± 0.02^c	1.53 ± 0.01^b	0.98 ± 0.01^d
	ACD15	Nonanoic acid	112-5-0	Waxy, cheese-like	2.36 ± 0.01^a	2.00 ± 0.02^b	n.d	0.59 ± 0.01^c
	ACD16	Octanoic acid	124-7-2	Fatty, rancid	4.00 ± 0.01^a	2.10 ± 0.03^c	3.71 ± 0.01^b	1.71 ± 0.00^d
	ACD17	Pentanoic acid	109-52-4	Sweet	0.78 ± 0.00^a	0.42 ± 0.00^b	n.d	n.d
	ACD18	Pentanoic acid, 3-methyl-	105-43-1	Cheesy, fruity	0.74 ± 0.01^a	n.d	n.d	n.d

	ACD19	Tetradecanoic acid	544-63-8	Waxy, fatty, coconut	0.33 ± 0.01 ^a	n.d	n.d	n.d
		Subtotal			31.17 ± 0.10^a	11.30 ± 0.08^c	13.65 ± 0.03^b	7.89 ± 0.02^d
Ketones	KTN1	2-Pentanone, 5-methoxy-	17429-4-8		1.42 ± 0.01 ^a	n.d	n.d	n.d
	KTN2	2-Hydroxy-3-hexanone	54073-43-7		1.20 ± 0.00 ^a	n.d	n.d	n.d
	KTN3	2-Nonanone	821-55-6	Vegetable, moldy	2.07 ± 0.01 ^a	n.d	n.d	n.d
		Subtotal			4.69 ± 0.01^a			
Aldehydes	ALD1	2-Decenal, (E)-	3913-81-3	Soap, tallow	n.d	n.d	0.31 ± 0.01 ^a	0.29 ± 0.02 ^a
	ALD2		100-52-7	Sweet, almond, cherry	n.d	3.41 ± 0.01 ^b	3.92 ± 0.01 ^a	3.21 ± 0.01 ^c
	ALD3	Benzaldehyde, 2,4-dimethyl-	15764-16-6	Cherry, almond, vanilla	4.25 ± 0.02 ^a	0.52 ± 0.01 ^c	2.11 ± 0.01 ^b	0.52 ± 0.02 ^c
	ALD5		122-78-1	Rose-like, honey, floral	0.22 ± 0.02 ^d	8.54 ± 0.01 ^b	15.43 ± 0.00 ^a	7.06 ± 0.02 ^c
	ALD6	Decanal	112-31-2	Soap, tallow	n.d	n.d	n.d	0.23 ± 0.01 ^a
	ALD7	Heptanal	111-71-7	Fat, citrus, rancid	0.18 ± 0.00 ^a	n.d	n.d	n.d
	ALD8	Hexanal	66-25-1	Green, sweet	n.d	n.d	n.d	0.48 ± 0.01 ^a
	ALD9	Paraldehyde	123-63-7	Sweet, pleasant	n.d	n.d	n.d	1.28 ± 0.01 ^a
		Subtotal			4.65 ± 0.01^d	12.46 ± 0.01^c	21.78 ± 0.01^a	13.08 ± 0.03^b
Esters	EST1	1-Butanol, 2-methyl-, acetate	624-41-9	Fruity, floral	n.d	3.23 ± 0.02 ^b	2.72 ± 0.01 ^c	4.75 ± 0.02 ^a
	EST2	1-Butanol, 3-methyl-, acetate	123-92-2	Fruity, floral, sweet	0.12 ± 0.01 ^d	11.33 ± 0.03 ^b	9.17 ± 0.01 ^c	16.11 ± 0.04 ^a

EST3	1-Methoxy-2-propyl acetate	108-65-6	Fruity	n.d	0.36 ± 0.02^a	0.32 ± 0.01^b	n.d
EST4	2-Butanol, 3-methyl-, acetate	5343-96-4	Fruity	n.d	n.d	0.31 ± 0.01^a	n.d
EST5	3-Hexenoic acid, ethyl ester	2396-83-0	Fruity, brandy, wine-like	n.d	0.27 ± 0.02^b	0.31 ± 0.01^a	0.22 ± 0.02^c
EST6	3-Methyl-3-buten-1-ol, acetate	5205-07-2	Fruity	n.d	0.46 ± 0.02^b	n.d	0.50 ± 0.01^a
EST7	7-Octenoic acid, ethyl ester	35194-38-8	Fruity	n.d	0.51 ± 0.01^a	n.d	0.50 ± 0.01^a
EST8	Acetic acid, 2-phenylethyl ester	103-45-7	Fruity, rose	n.d	12.63 ± 0.01^c	12.68 ± 0.02^b	14.47 ± 0.01^a
EST9	Acetic acid, butyl ester	123-86-4	Fruity, sweet, solvent	n.d	n.d	n.d	0.38 ± 0.01^a
EST10	Acetic acid, pentyl ester	628-63-7	Fruity, apple	n.d	n.d	n.d	0.13 ± 0.02^a
EST11	Acetic acid, phenylmethyl ester	140-11-4	Fruity	n.d	0.95 ± 0.01^b	0.83 ± 0.01^c	1.24 ± 0.01^a
EST12	Acetoin acetate	4906-24-5	Fruity	n.d	1.50 ± 0.01^a	n.d	n.d
EST13	Benzeneacetic acid, ethyl ester	101-97-3	Fruity	n.d	n.d	n.d	0.25 ± 0.00^a
EST14	Benzenepropanoic acid, ethyl ester	2021-28-5	Fruity	n.d	3.22 ± 0.01^a	n.d	2.85 ± 0.01^b
EST15	Benzoic acid, ethyl ester	93-89-0	Fruity, floral	0.43 ± 0.00^d	1.27 ± 0.01^c	1.83 ± 0.02^a	1.41 ± 0.01^b
EST16	cis-9-Tetradecenoic acid, propyl ester		Fruity	n.d	0.24 ± 0.02^a	0.16 ± 0.01^b	0.15 ± 0.01^b

EST17	Dodecanoic acid, ethyl ester	106-33-2	Fruity	n.d	1.06 ± 0.01 ^a	1.06 ± 0.01 ^a	0.71 ± 0.01 ^b
EST18	Dodecyl tiglate	1231959-17-3	Fruity	n.d	n.d	n.d	0.18 ± 0.01 ^a
EST19	Ethyl 4-acetoxybutanoate	25560-91-2	Fruity	n.d	0.18 ± 0.01 ^a	n.d	0.19 ± 0.01 ^a
EST20	Ethyl 9-hexadecenoate	54546-22-4	Fruity	n.d	0.17 ± 0.02 ^a	n.d	n.d
EST21	Ethyl Acetate	141-78-6	Pineapple, fruity	n.d	n.d	0.17 ± 0.01 ^a	0.14 ± 0.01 ^b
EST22	Heptanoic acid, ethyl ester	106-30-9	Wine-like, fruity, brandy	n.d	n.d	0.26 ± 0.01 ^a	n.d
EST23	Hexadecanoic acid, ethyl ester	628-97-7	Fruity	n.d	0.55 ± 0.01 ^a	0.32 ± 0.01 ^b	0.24 ± 0.01 ^c
EST24	Hexanoic acid, ethyl ester	123-66-0	Fruity, apple, banana	2.73 ± 0.01 ^b	1.58 ± 0.01 ^d	3.40 ± 0.01 ^a	1.72 ± 0.01 ^c
EST25	Isoamyl lactate	19329-89-6	Fruity, banana, pear	n.d	0.25 ± 0.02 ^a	n.d	0.14 ± 0.02 ^b
EST26	Methyl salicylate	119-36-8	Fruity, peppermint	0.44 ± 0.00 ^a	n.d	n.d	n.d
EST27	Octanoic acid, ethyl ester	106-32-1	Brandy, pear, musty	n.d	0.58 ± 0.02 ^b	0.88 ± 0.01 ^a	0.51 ± 0.00 ^c
EST28	Pentanoic acid, ethyl ester	539-82-2	Fruity, berry	n.d	0.41 ± 0.01 ^a	0.38 ± 0.01 ^b	0.43 ± 0.01 ^a
EST29	Propanoic acid, 2-hydroxy-, ethyl ester	97-64-3	Fruity	n.d	0.57 ± 0.02 ^a	n.d	0.17 ± 0.01 ^b
EST30	Propanoic acid, 2-methyl-, 3-hydroxy-2,2,4-trimethylpentyl ester	77-68-9	Fruity	n.d	0.32 ± 0.02 ^{a,b}	0.31 ± 0.01 ^b	0.35 ± 0.01 ^a
EST31	Tetradecanoic acid, ethyl ester	124-6-1	Soap, mild, polish	n.d	0.26 ± 0.01 ^a	n.d	n.d
Subtotal				3.72 ± 0.02^d	42.28 ± 0.08^b	35.13 ± 0.03^c	47.75 ± 0.17^a

Other(s)	NAT1	Naphthalene, 1,2,3,4-tetrahydro-1,1,6-trimethyl-	475-3-6	tar	1.24 ± 0.00 ^a	n.d	n.d	n.d
		Total of volatile compounds			100	100	100	100

Data expressed as mean ± standard deviation. Means in the same row with different superscript letters are significantly different (p < 0.05).

Note

CAS- Chemical Abstracts Service; n.d- not detected; JLaAp- *Lactocaseibacillus casei* Lc 122- *Acetobacter pasteurianus* Ap-As.1.41 HuNiang 1.01 puree; JLaAp- *Lactobacillus helveticus* Lh 43- *A. pasteurianus* Ap-As.1.41 HuNiang 1.01 puree; JLaAp- *Lactiplantibacillus plantarum*- *A. pasteurianus* Ap-As.1.41 HuNiang 1.01 puree; (JCON)- puree with no bacteria inoculants (unfermented).

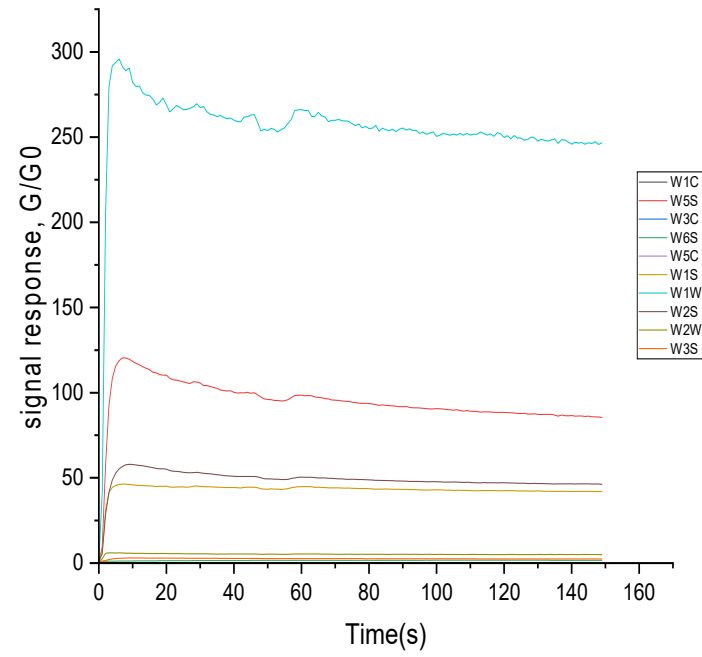
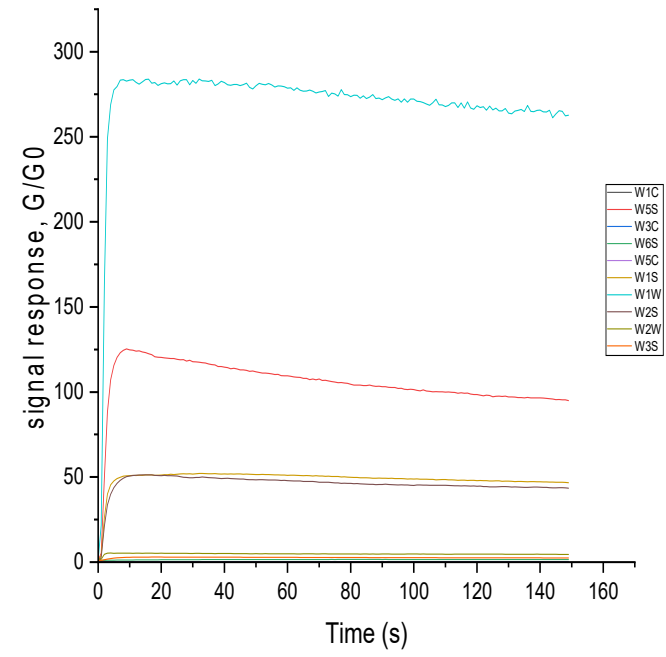
Table S3. Electronic nose analysis of bi-cultured jujube purees, JP

Properties	Description	Sensor bioactives of JP			
		JLcAp	JLhAp	JLpAp	JCON
W1C	Aromatic organic compounds	0.04 ± 0.00 ^b	0.04 ± 0.01 ^b	0.04 ± 0.00 ^b	0.22 ± 0.05 ^a
W5S	Broad range sensitivity	94.73 ± 0.50 ^a	105.29 ± 7.01 ^a	107.64 ± 0.33 ^a	67.31 ± 23.23 ^a
W3C	Aromatic compounds	0.08 ± 0.00 ^b	0.08 ± 0.01 ^b	0.08 ± 0.00 ^b	0.34 ± 0.03 ^a
W6S	Hydrogen gas	1.52 ± 0.01 ^{a,b}	1.45 ± 0.05 ^b	1.58 ± 0.02 ^a	1.08 ± 0.01 ^c
W5C	Aromatic-aliphatic compounds	0.05 ± 0.00 ^b	0.05 ± 0.00 ^b	0.05 ± 0.00 ^b	0.31 ± 0.01 ^a
W1S	Broad-methane	43.00 ± 0.16 ^a	48.88 ± 4.26 ^a	46.27 ± 2.48 ^a	10.22 ± 2.34 ^b
W1W	Organic Sulphur compounds and terpenes	253.90 ± 1.78 ^a	270.05 ± 17.53 ^a	266.66 ± 7.55 ^a	86.01 ± 2.62 ^b
W2S	Broad range-alcohols	48.43 ± 0.62 ^a	45.98 ± 3.98 ^a	50.55 ± 9.84 ^a	7.37 ± 1.84 ^b
W2W	Aromatic, inorganic Sulphur and organic compounds	5.18 ± 0.01 ^{a,b}	4.80 ± 0.16 ^b	5.45 ± 0.00 ^a	2.50 ± 0.13 ^c
W3S	Methane and aliphatic organic compounds	2.52 ± 0.04 ^a	2.70 ± 0.17 ^a	2.54 ± 0.00 ^a	1.27 ± 0.05 ^b

Data expressed as mean ± standard deviation. Means in the same row with different superscript letters are significantly different ($p < 0.05$).

Note

JLcAp- *Lactocaseibacillus casei* Lc 122- *Acetobacter pasteurianus* Ap-As.1.41 HuNiang 1.01 puree; JLhAp- *Lactobacillus helveticus* Lh 43- *A. pasteurianus* Ap-As.1.41 HuNiang 1.01 puree; JLpAp- *Lactiplantibacillus plantarum*- *A. pasteurianus* Ap-As.1.41 HuNiang 1.01 puree; (JCON)- puree with no bacteria inoculants (unfermented).

a**b**

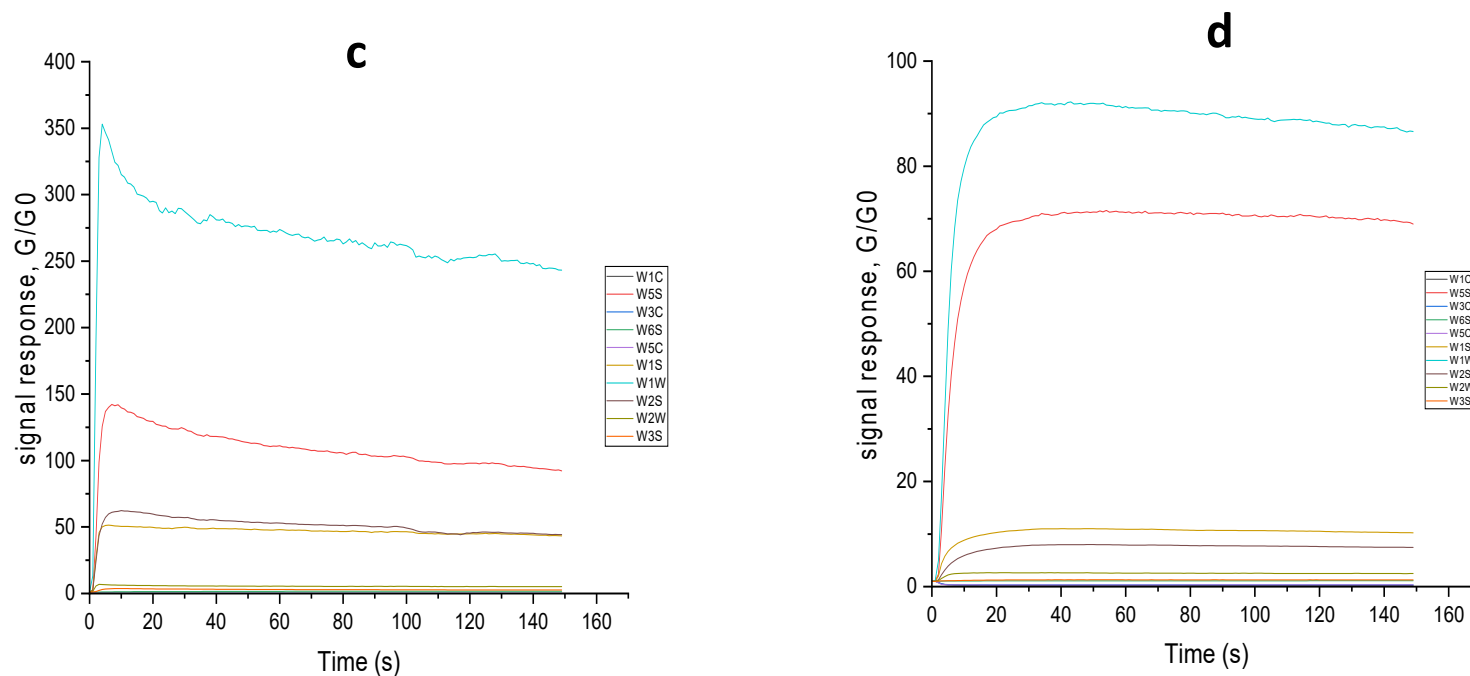
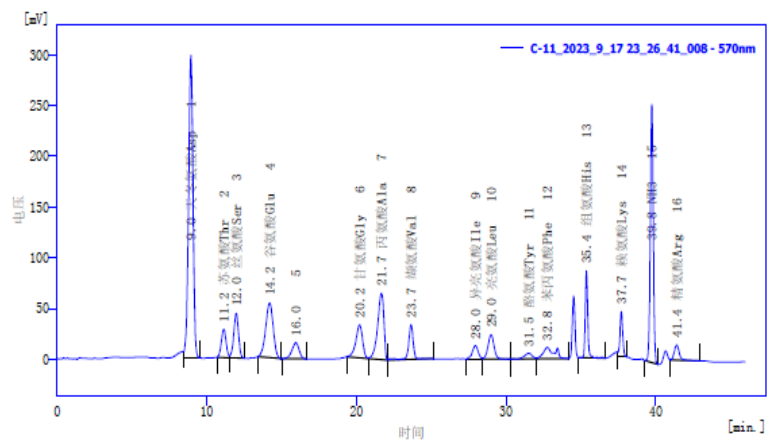


Fig. S1. Sensorgrams (a,b,c,d) of electronic nose sensor sensitivities of bi-cultured jujube purees. Sensorgrams: **a-** JLCp; **b-** JLCp; **c-** JLPp; **d-** control.

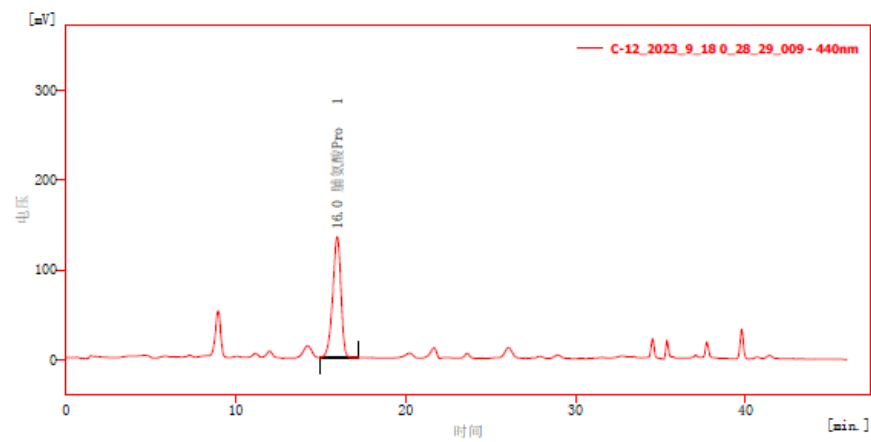
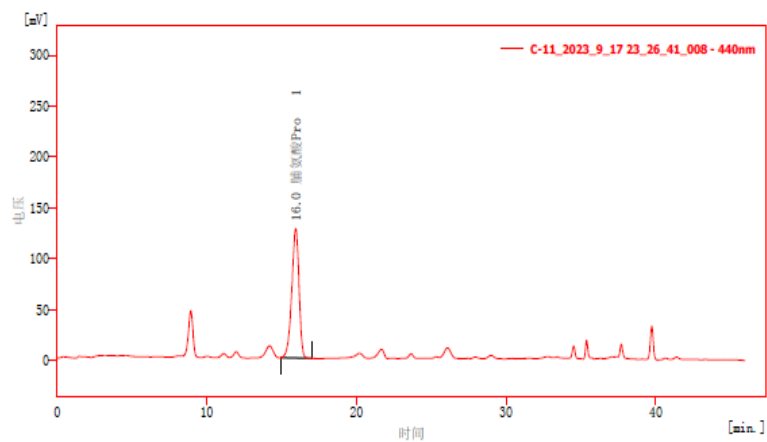
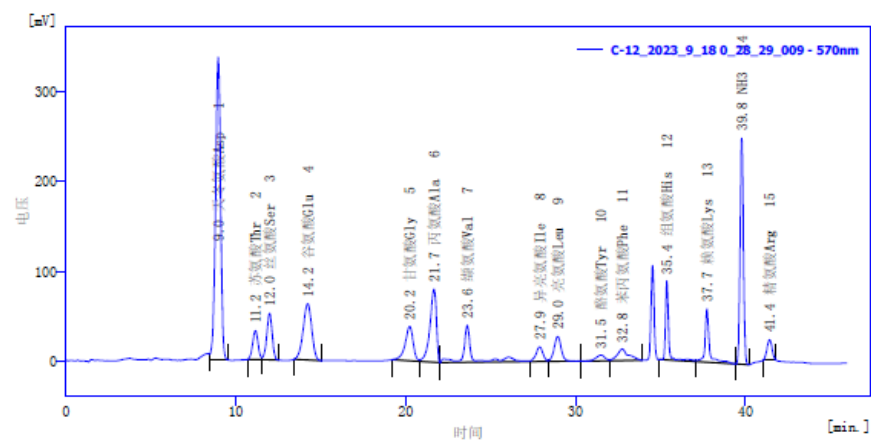
Note

W1C- Aromatic organic compounds; W5S- Broad range sensitivity; W3C- Aromatic compounds; W6S- Hydrogen gas; W5C- Aromatic-aliphatic compounds; W1S- Broad-methane; W1W- Organic Sulphur compounds and terpenes; W2S- Broad range-alcohols; W2W- Aromatic, inorganic Sulphur and organic compounds; W3S- Methane and aliphatic organic compounds. JLCp- *Lactocaseibacillus casei* Lc 122- *Acetobacter pasteurianus* Ap-As.1.41 HuNiang 1.01 puree; JLCp- *Lactobacillus helveticus* Lh 43- *A. pasteurianus* Ap-As.1.41 HuNiang 1.01 puree; JLPp- *Lactiplantibacillus plantarum*- *A. pasteurianus* Ap-As.1.41 HuNiang 1.01 puree; (JCON)- puree with no bacteria inoculants (unfermented).

a



b



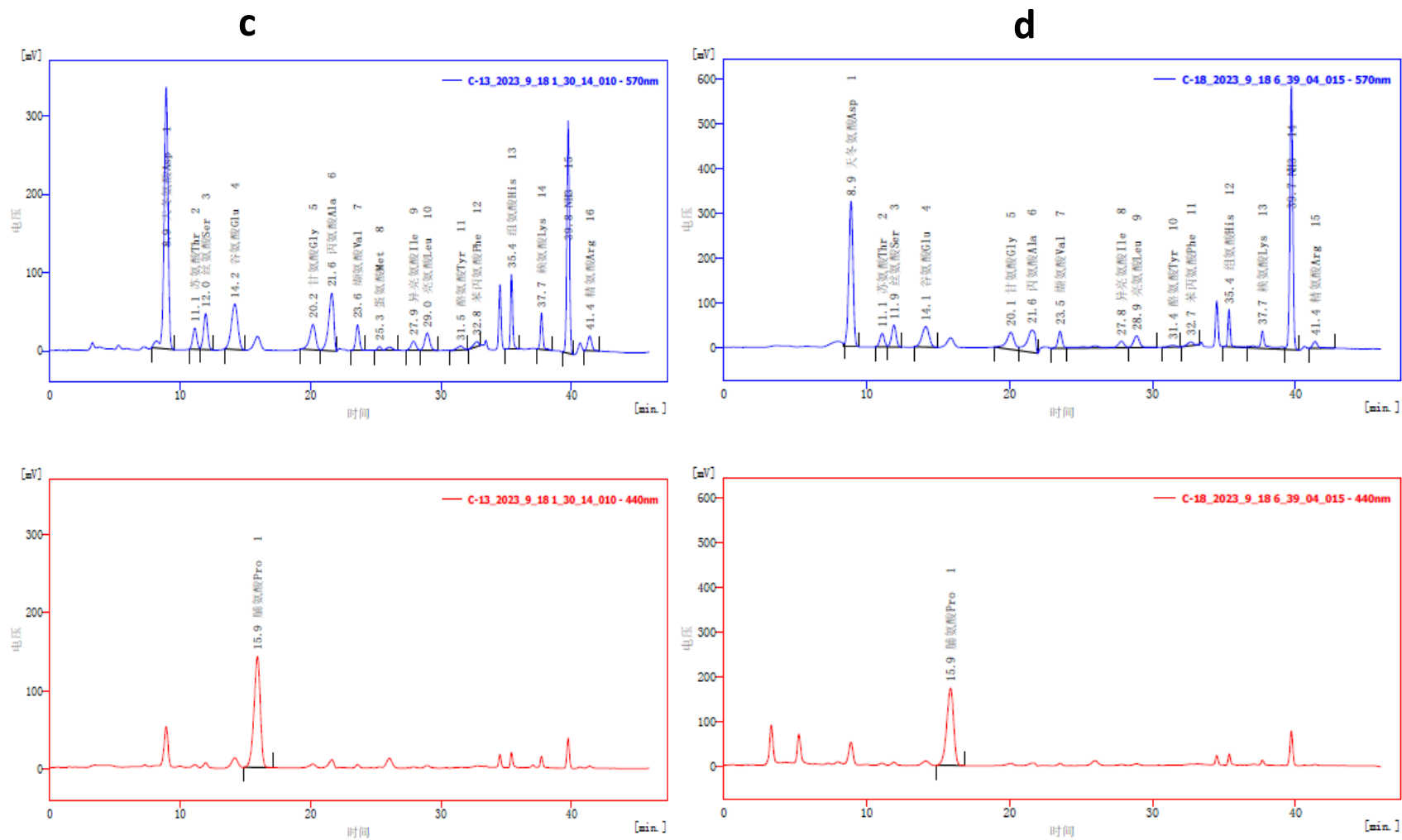


Fig.S2. The chromatographic output of free amino acids in the bicultured jujube purees. Chromatograms: a- JLCaP; b-JLhAp; c- JLPaP; d- control.

Note.

JLcAp- *Lactocaseibacillus* casei Lc 122- *Acetobacter pasteurianus* Ap-As.1.41 HuNiang 1.01 puree; JLhAp- *Lactobacillus helveticus* Lh 43- *A. pasteurianus* Ap-As.1.41 HuNiang 1.01 puree; JlpAp- *Lactiplantibacillus* plantarum- *A. pasteurianus* Ap-As.1.41 HuNiang 1.01 puree; (JCON)- puree with no bacteria inoculants (unfermented).

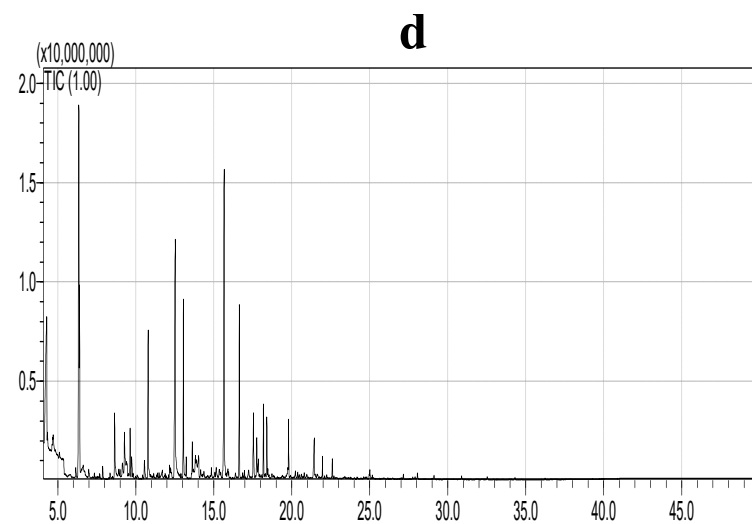
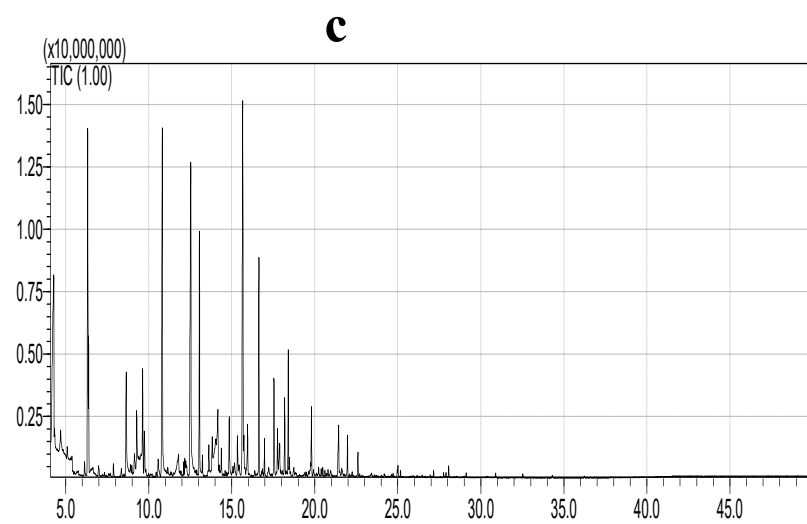
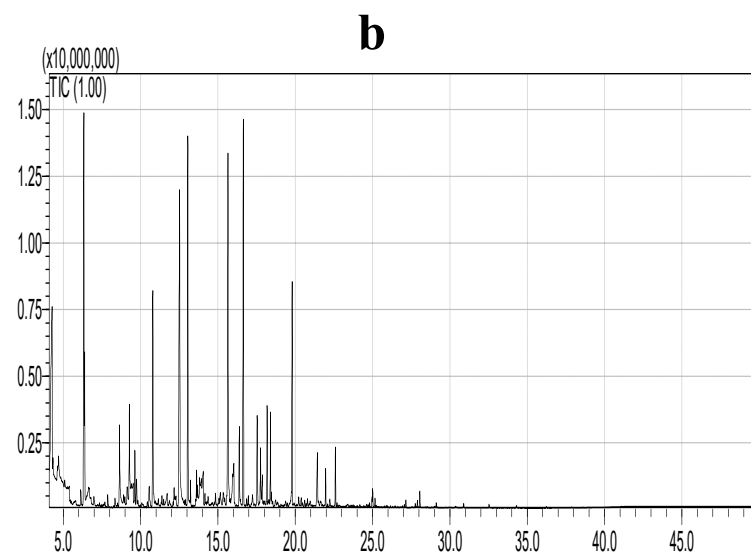
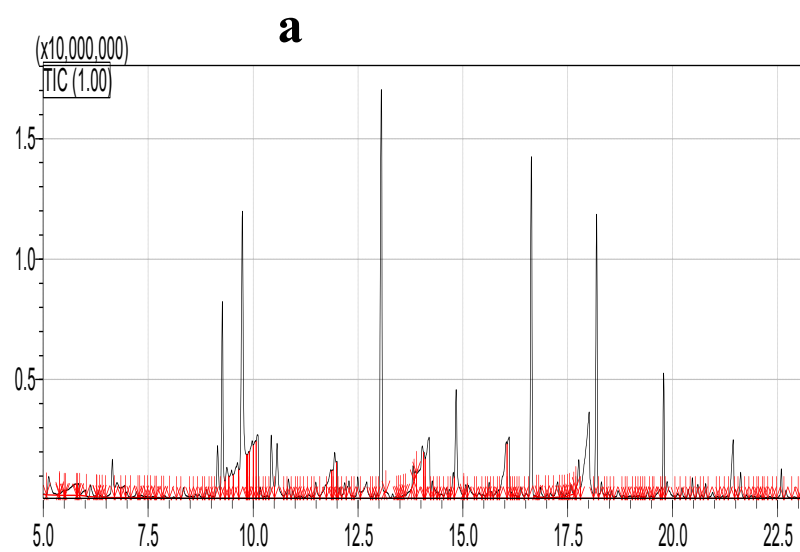


Fig.S3. Chromatograms showing relative volatile compounds in bicultured Junzao jujube purees after HS-SPME GC-MS analysis.

Note

a- puree with no bacteria inoculants (unfermented) (JCON); **b-** *Lactocaseibacillus casei*- *Acetobacter pasteurianus* Ap-As.1.41 HuNiang 1.01 puree (JLcAp); **c-** *Lactobacillus helveticus*- *A. pasteurianus* Ap-As.1.41 HuNiang 1.01 puree (JLhAp); **d-** *Lactiplantibacillus plantarum*- *A. pasteurianus* Ap-As.1.41 HuNiang 1.01 puree (JLpAp)