

## *Supplementary Material*

### **CATALOGUE**

Supplementary tables.....	2
Table S1. DNA sequence result of yeasts in Kazakh cheese.....	2
Table S2. Enzymatic activity of yeasts (U/mL). .....	3
Table S3. Free amino acid content of four Kazakh cheeses (g/100 g).....	4
Table S4. Organic acid content of four Kazakh cheeses (g/kg) .....	5
Table S5. Texture analysis of cheeses .....	5
Table S6. Odor description and odor activity value (OAV) of aroma compounds in Kazakh cheese.....	6
Supplementary figures.....	7
Figure S1A. Protease hydrolysis diagram of yeasts.....	7
Figure S1B. Lipase hydrolysis diagram of yeasts.....	8
Figure S1C. $\beta$ -galactosidase hydrolysis diagram of yeasts .....	8
Figure S2. PCA analysis of volatile compounds in four Kazakh cheese. ....	9
Figure S3. Volatile flavor map of four cheeses .....	9

## Supplementary tables

**Table S1.** DNA sequence result of yeasts in Kazakh cheese

Strain	Size (bp)	Identification	Similarity (%)	Accession number
A1	568	<i>Kluyveromyces lactis</i> strain GG799	99.30	CP021245.1
A2	697	<i>Kluyveromyces marxianus</i> strain P2	99.85	KF851351.1
A3	569	<i>Kluyveromyces lactis</i> strain CBS 2105	100	CP042459.1
A4	627	<i>Kluyveromyces marxianus</i> strain TY17	99.66	FJ972218.1
A5	773	<i>Torulaspora debrueckii</i> strain BZL-163	99.48	MN371902.1
A6	646	<i>Kluyveromyces lactis</i> strain GG799	99.69	CP021245.1
A7	528	<i>Lodderomyces elongisporus</i> strain NX-15	99.24	MN371867.1
A8	544	<i>Pichia kudriavzevii</i> strain PK1	99.09	MN648834.1
A9	582	<i>Pichia kudriavzevii</i> strain Z2	100	MK310151.1
A10	504	<i>Candida parapsilosis</i> strain SLDY-016	99.60	MH748620.1
A11	480	<i>Pichia kudriavzevii</i> strain SLDY-035	99.38	MH752055.1
A12	579	<i>Kluyveromyces marxianus</i> strain T1	99.31	JX141370.1
A13	561	<i>Clavispora lusitaniae</i> strain PC5	99.64	EF063132.1
A14	590	<i>Lodderomyces elongisporus</i> strain WY6	99.49	EF643601.1
A15	516	<i>Candida parapsilosis</i> strain SLDY-277	99.61	MH782053.1
A16	409	<i>Pichia fermentans</i> strain Y1-4	99.03	KF646172.1
A17	549	<i>Clavispora lusitaniae</i> strain TY11	99.45	FJ972214.1
A18	504	<i>Pichia fermentans</i> strain NRRL Y-1619	99.21	EF552458.1
A19	461	<i>Pichia fermentans</i> strain DF-2	100	KJ638687.1

**Table S2.** Enzymatic activity of yeasts (U/mL).

Identification	Number	Protease activity	Lipase activity	$\beta$ -galactosidase activity
<i>Kluyveromyces marxianus</i>	A2	135 $\pm$ 17	203 $\pm$ 19	217 $\pm$ 23
<i>Pichia kudriavzevii</i>	A11	103 $\pm$ 10	nd	375 $\pm$ 26
<i>Pichia fermentans</i>	A19	111 $\pm$ 12	227 $\pm$ 23	334 $\pm$ 32
<i>Clavispora lusitaniae</i>	A13	86 $\pm$ 9	187 $\pm$ 18	nd
<i>Lodderomyces elongisporus</i>	A14	94 $\pm$ 7	nd	254 $\pm$ 20
<i>Candida parapsilosis</i>	A10	121 $\pm$ 11	nd	nd
<i>Kluyveromyces marxianus</i>	A4	105 $\pm$ 15	147 $\pm$ 15	nd
<i>Pichia fermentans</i>	A16	91 $\pm$ 17	104 $\pm$ 10	nd
<i>Kluyveromyces lactis</i>	A1	82 $\pm$ 14	nd	nd
<i>Kluyveromyces marxianus</i>	A12	113 $\pm$ 19	nd	243 $\pm$ 18
<i>Lodderomyces elongisporus</i>	A7	117 $\pm$ 12	200 $\pm$ 13	nd
<i>Pichia fermentans</i>	A18	108 $\pm$ 15	203 $\pm$ 21	nd
<i>Kluyveromyces lactis</i>	A3	114 $\pm$ 17	nd	nd
<i>Pichia kudriavzevii</i>	A9	73 $\pm$ 8	173 $\pm$ 18	nd
<i>Torulasporea debrueckii</i>	A5	85 $\pm$ 10	113 $\pm$ 13	nd
<i>Pichia kudriavzevii</i>	A8	107 $\pm$ 11	127 $\pm$ 13	nd

<sup>nd</sup> Means not detected.

<sup>1</sup> Data are mean  $\pm$  standard deviation of three replicate analyses (n = 3).

**Table S3.** Free amino acid content of four Kazakh cheeses (g/100 g)

<b>FAA</b>	<b>Control</b>	<b>KmC</b>	<b>PkC</b>	<b>PfC</b>
Asp	0.225 ± 0.003 <sup>b</sup>	0.268 ± 0.002 <sup>a</sup>	0.225 ± 0.001 <sup>b</sup>	0.229 ± 0.002 <sup>b</sup>
Thr	0.132 ± 0.001 <sup>b</sup>	0.148 ± 0.002 <sup>a</sup>	0.129 ± 0.001 <sup>c</sup>	0.126 ± 0.002 <sup>d</sup>
Ser	0.157 ± 0.002 <sup>b</sup>	0.172 ± 0.002 <sup>a</sup>	0.147 ± 0.002 <sup>c</sup>	0.146 ± 0.003 <sup>c</sup>
Glu	0.514 ± 0.003 <sup>c</sup>	0.627 ± 0.004 <sup>a</sup>	0.503 ± 0.003 <sup>d</sup>	0.560 ± 0.004 <sup>b</sup>
Gly	0.066 ± 0.001 <sup>c</sup>	0.077 ± 0.001 <sup>a</sup>	0.068 ± 0.003 <sup>b</sup>	0.064 ± 0.002 <sup>c</sup>
Ala	0.115 ± 0.001 <sup>bc</sup>	0.132 ± 0.001 <sup>a</sup>	0.117 ± 0.002 <sup>b</sup>	0.113 ± 0.001 <sup>c</sup>
Cys	0.002 ± 0.001 <sup>a</sup>	0.003 ± 0.001 <sup>a</sup>	0.003 ± 0.001 <sup>a</sup>	0.002 ± 0.001 <sup>a</sup>
Val	0.217 ± 0.003 <sup>b</sup>	0.204 ± 0.002 <sup>c</sup>	0.228 ± 0.002 <sup>a</sup>	0.207 ± 0.001 <sup>c</sup>
Met	0.086 ± 0.001 <sup>b</sup>	0.096 ± 0.002 <sup>a</sup>	0.085 ± 0.001 <sup>b</sup>	0.082 ± 0.002 <sup>c</sup>
Ile	0.187 ± 0.002 <sup>c</sup>	0.211 ± 0.003 <sup>a</sup>	0.197 ± 0.001 <sup>b</sup>	0.181 ± 0.002 <sup>d</sup>
Leu	0.017 ± 0.002 <sup>a</sup>	0.016 ± 0.001 <sup>a</sup>	0.018 ± 0.003 <sup>a</sup>	0.012 ± 0.002 <sup>b</sup>
Tyr	0.180 ± 0.002 <sup>b</sup>	0.190 ± 0.002 <sup>a</sup>	0.161 ± 0.001 <sup>c</sup>	0.153 ± 0.003 <sup>d</sup>
Phe	0.164 ± 0.002 <sup>c</sup>	0.187 ± 0.003 <sup>a</sup>	0.175 ± 0.002 <sup>b</sup>	0.159 ± 0.002 <sup>d</sup>
Lys	0.261 ± 0.001 <sup>c</sup>	0.291 ± 0.002 <sup>a</sup>	0.269 ± 0.002 <sup>b</sup>	0.225 ± 0.003 <sup>d</sup>
His	0.091 ± 0.001 <sup>c</sup>	0.103 ± 0.001 <sup>a</sup>	0.095 ± 0.002 <sup>b</sup>	0.088 ± 0.002 <sup>d</sup>
Arg	0.120 ± 0.002 <sup>b</sup>	0.131 ± 0.002 <sup>a</sup>	0.118 ± 0.001 <sup>b</sup>	0.111 ± 0.002 <sup>c</sup>
Pro	0.250 ± 0.001 <sup>c</sup>	0.278 ± 0.003 <sup>a</sup>	0.259 ± 0.002 <sup>b</sup>	0.238 ± 0.003 <sup>d</sup>
Total	2.784 ± 0.032 <sup>b</sup>	3.134 ± 0.025 <sup>a</sup>	2.797 ± 0.027 <sup>b</sup>	2.696 ± 0.034 <sup>c</sup>

<sup>1</sup> Data are mean ± standard deviation of three replicate analyses (n = 3).

<sup>a-d</sup> Means with different superscripts within the same row are significantly (P < 0.05) different.

**Table S4.** Organic acid content of four Kazakh cheeses (g/kg)

Organic acids	Control	KmC	PkC	PfC
Lactic acid	17.910 ± 1.210 <sup>b</sup>	38.770 ± 3.420 <sup>a</sup>	17.150 ± 1.270 <sup>b</sup>	15.380 ± 1.360 <sup>b</sup>
Malic acid	1.710 ± 0.709 <sup>b</sup>	3.310 ± 0.615 <sup>a</sup>	3.110 ± 0.526 <sup>a</sup>	2.980 ± 0.721 <sup>a</sup>
Citric acid	3.631 ± 0.385 <sup>a</sup>	3.803 ± 0.853 <sup>a</sup>	3.527 ± 0.174 <sup>a</sup>	3.762 ± 0.203 <sup>a</sup>
Tartaric acid	4.864 ± 0.813 <sup>b</sup>	5.318 ± 0.974 <sup>b</sup>	9.492 ± 1.023 <sup>a</sup>	9.241 ± 1.022 <sup>a</sup>
Succinic acid	3.700 ± 0.624 <sup>b</sup>	8.340 ± 1.533 <sup>a</sup>	3.070 ± 0.617 <sup>b</sup>	3.350 ± 1.014 <sup>b</sup>
Total	31.815 ± 3.741 <sup>b</sup>	59.541 ± 7.395 <sup>a</sup>	36.349 ± 3.610 <sup>b</sup>	34.713 ± 4.320 <sup>b</sup>

a Data are mean ± standard deviation of three replicate analyses (n = 3).

<sup>a-d</sup> Means with different superscripts within the same row are significantly (P < 0.05) different.

**Table S5.** Texture analysis of cheeses

Texture	Control	KmC	PkC	PfC
Hardness (N)	2.820 ± 0.150 <sup>a</sup>	2.446 ± 0.120 <sup>b</sup>	1.657 ± 0.110 <sup>c</sup>	1.851 ± 0.130 <sup>c</sup>
Springiness	0.755 ± 0.026 <sup>a</sup>	0.616 ± 0.024 <sup>b</sup>	0.605 ± 0.022 <sup>b</sup>	0.573 ± 0.021 <sup>b</sup>
Cohesiveness	0.514 ± 0.014 <sup>a</sup>	0.452 ± 0.012 <sup>b</sup>	0.510 ± 0.011 <sup>a</sup>	0.501 ± 0.010 <sup>a</sup>
Chewiness (N)	1.450 ± 0.094 <sup>a</sup>	1.115 ± 0.087 <sup>b</sup>	0.846 ± 0.072 <sup>c</sup>	0.927 ± 0.081 <sup>c</sup>
Gumminess (N)	1.094 ± 0.084 <sup>a</sup>	0.687 ± 0.034 <sup>b</sup>	0.512 ± 0.023 <sup>c</sup>	0.531 ± 0.027 <sup>c</sup>
Chewing resilience	0.253 ± 0.014 <sup>a</sup>	0.197 ± 0.012 <sup>b</sup>	0.207 ± 0.015 <sup>b</sup>	0.204 ± 0.017 <sup>b</sup>

<sup>1</sup> Data are mean ± standard deviation of three replicate analyses (n = 3).

<sup>a-d</sup> Means with different superscripts within the same row are significantly (P < 0.05) different.

**Table S6.** Odor description and odor activity value (OAV) of aroma compounds in Kazak cheese.

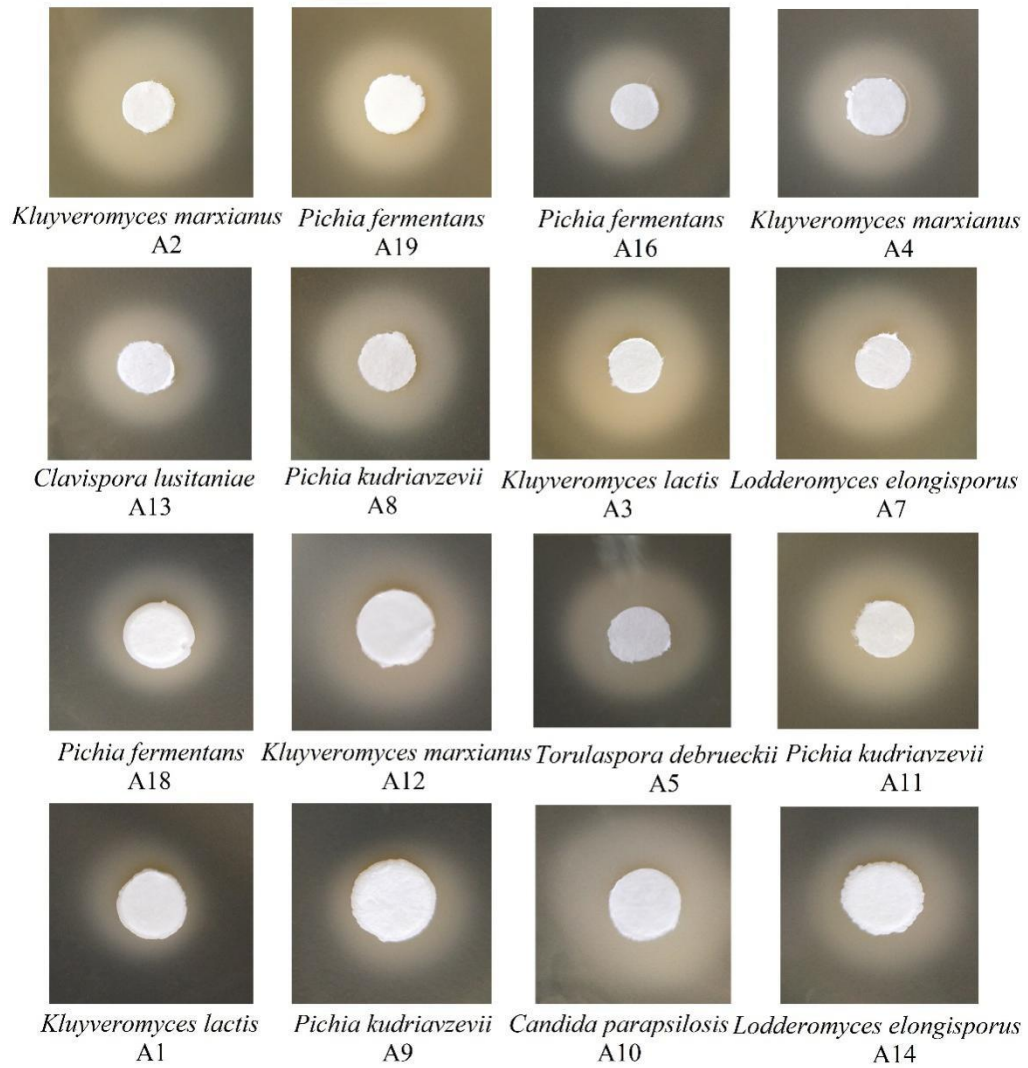
<b>Compound</b>	<b>Odor description</b>	<b>Odor threshold<sup>a</sup> (<math>\mu\text{g/L}</math>)</b>	<b>OAV in Control</b>	<b>OAV in KmC</b>	<b>OAV in PkC</b>	<b>OAV in Pfc</b>
1-Hexanol	Herbaceous, fruity	5.6	nd	2.57	3.74	1.07
2,3-Butanediol	Fruity, onion	95.1	3.4	42.81	4.38	1.23
Hexanal	Herbaceous	10	nd	3.67	3.03	nd
Nonanal	Citrus-like, oily, rose	8	nd	7.34	1.91	1.74
Ethyl acetate	Fruity, orange	5	124.02	98.79	138.18	53.45
Ethyl butanoate	Fruity, apple	18	nd	9.92	1.70	nd
Isoamyl acetate	Fruity, banana	30	19.04	1.22	19.11	64.37
Ethyl hexanoate	Brandy, orange, sour, fatty	5	7.17	4.71	14.79	3.00
2-Nonanone	Fruity, flower, herbaceous	41	nd	1.34	nd	nd

<sup>1</sup> OAV: odor activity values.

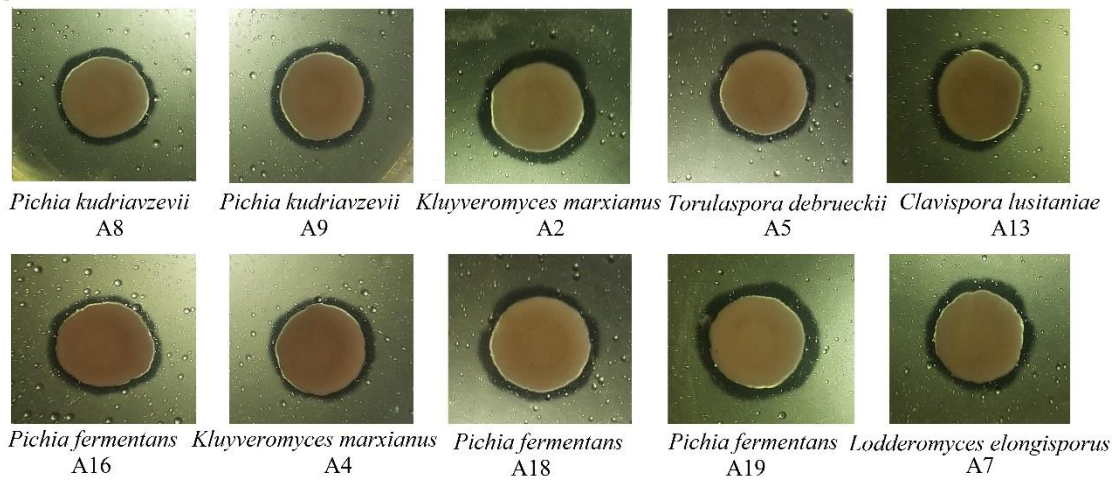
<sup>nd</sup> Means not detected.

<sup>3</sup> The letter indicates odor threshold in water from reference (Gemert, 2011) <sup>a</sup>.

Supplementary figures



**Figure S1A.** Protease hydrolysis diagram of yeasts

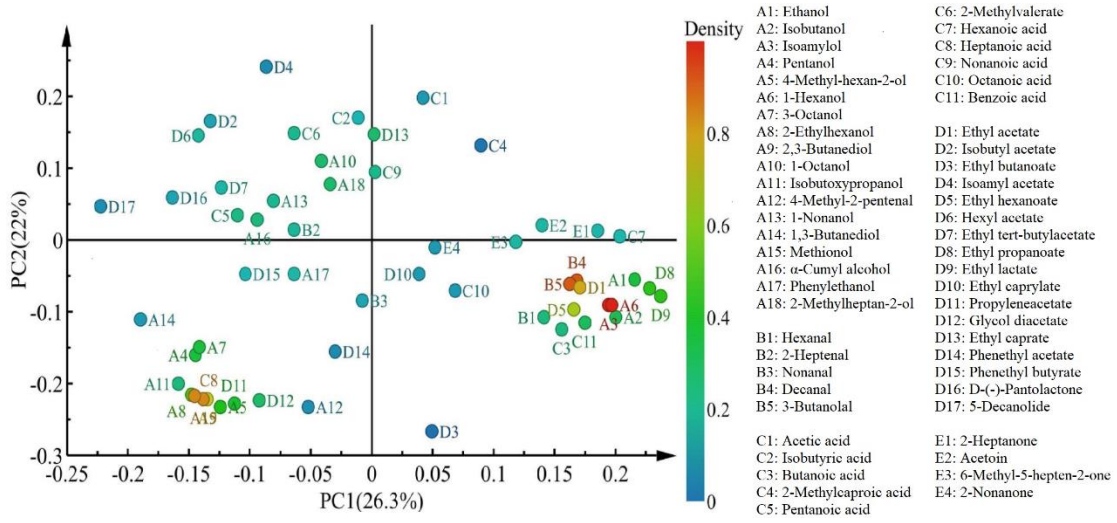


**Figure S1B.** Lipase hydrolysis diagram of yeasts

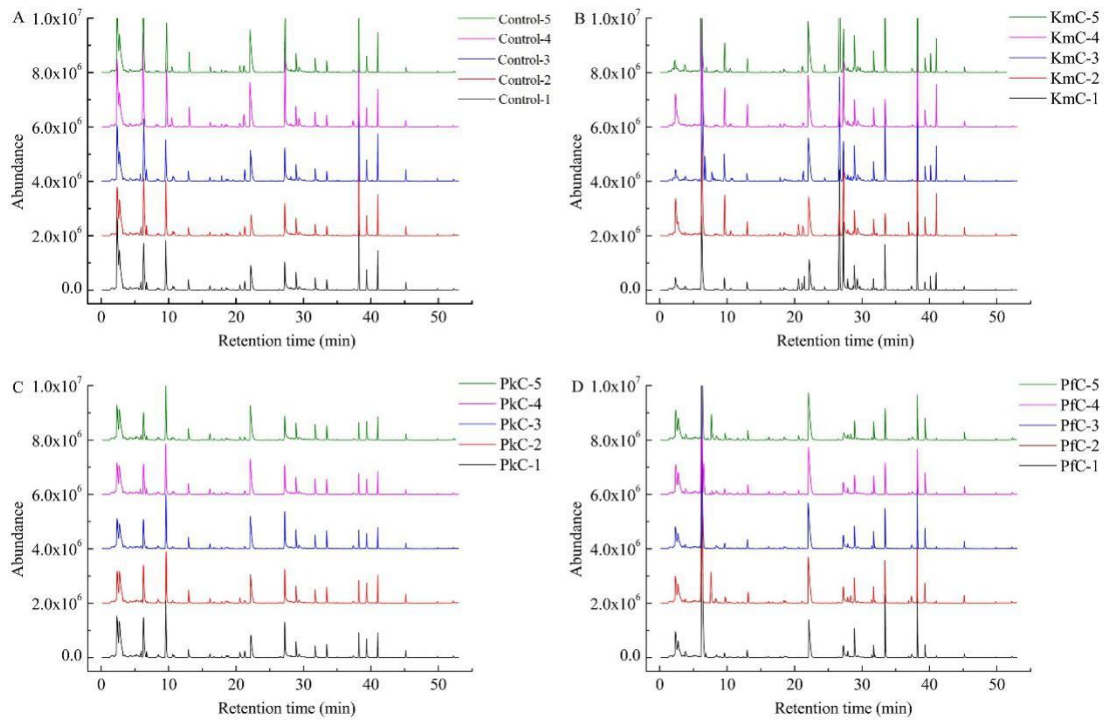


**Figure S1C.**  $\beta$ -galactosidase hydrolysis diagram of yeasts





**Figure S2.** PCA analysis of volatile compounds in four Kazakh cheese.



**Figure S3.** Volatile flavor map of four cheeses