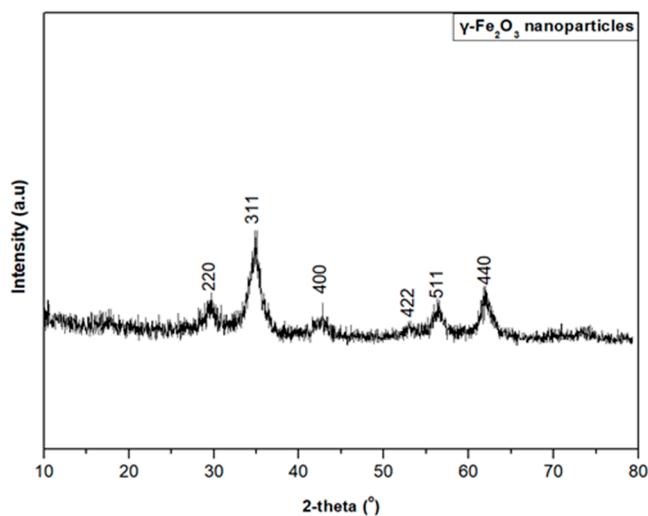


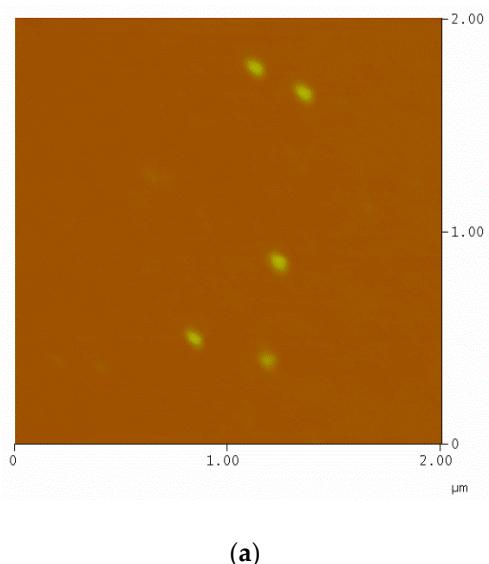
## Supplementary

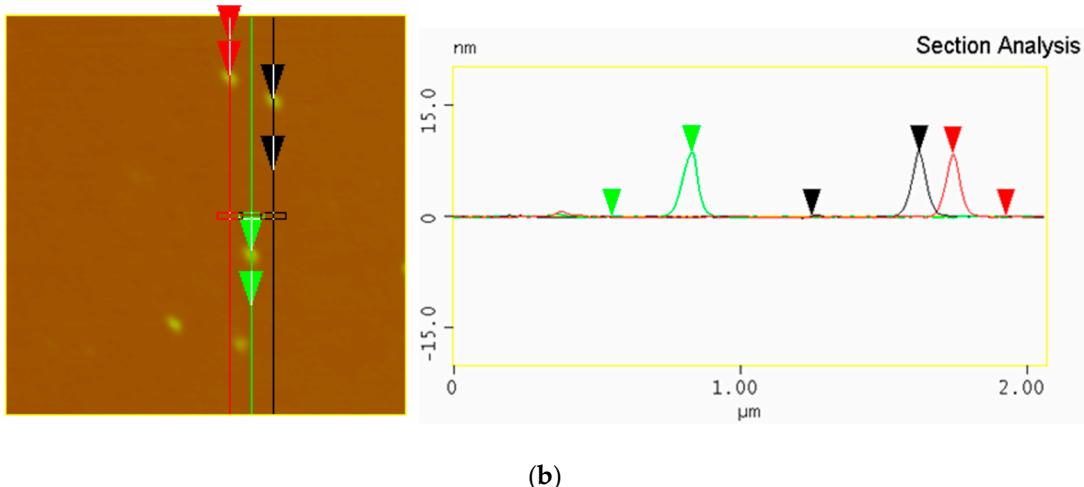
**Table S1.** Immobilization yield of CelDZ1, bgl, GOx and HRP individually immobilized on amino-functionalized magnetic nanoparticles (the standard deviation was less than 5% in all cases).

Enzyme	Immobilization yield (%)
CelDZ1	50.33
bgl	99.40
GOx	59.42
HRP	10.00



**Figure S1.** XRD patterns of maghemite  $\gamma\text{-Fe}_2\text{O}_3$  nanoparticles obtained by thermolysis method.





**Figure S2.** AFM height image (a) and cross section analysis (b) of  $\gamma\text{-Fe}_2\text{O}_3$  magnetic nanoparticles.

**Table S2.** Thermal inactivation kinetics parameters of free and co-immobilized bgl at 70, 80 and 90 °C.

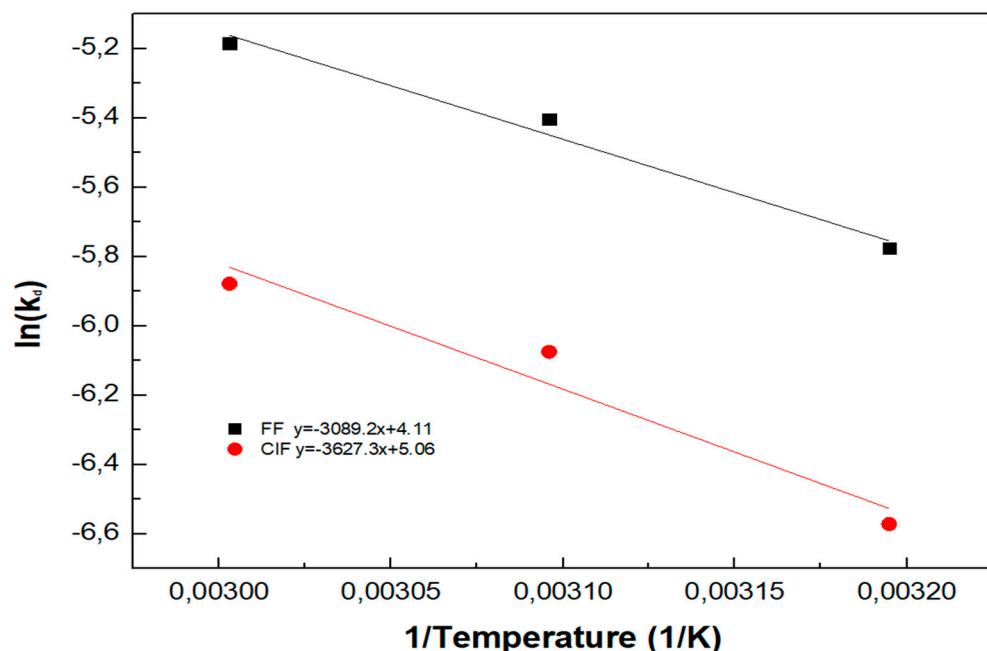
Enzyme	Thermal inactivation kinetics parameters	70°C	80 °C	90 °C	$E_a$ (kJ/mol)
Free form of bgl	$k_d$ (min <sup>-1</sup> ) $t_{1/2}$ (h)	0.0009 12.8	0.0011 10.5	0.0027 4.2	57.5
Co-immobilized form of bgl	$k_d$ (min <sup>-1</sup> ) $t_{1/2}$ (h)	0.0005 23.1	0.0009 12.8	0.10016 7.2	60.2

**Table S3.** Thermal inactivation kinetics parameters of free and co-immobilized HRP at 30, 40 and 50 °C.

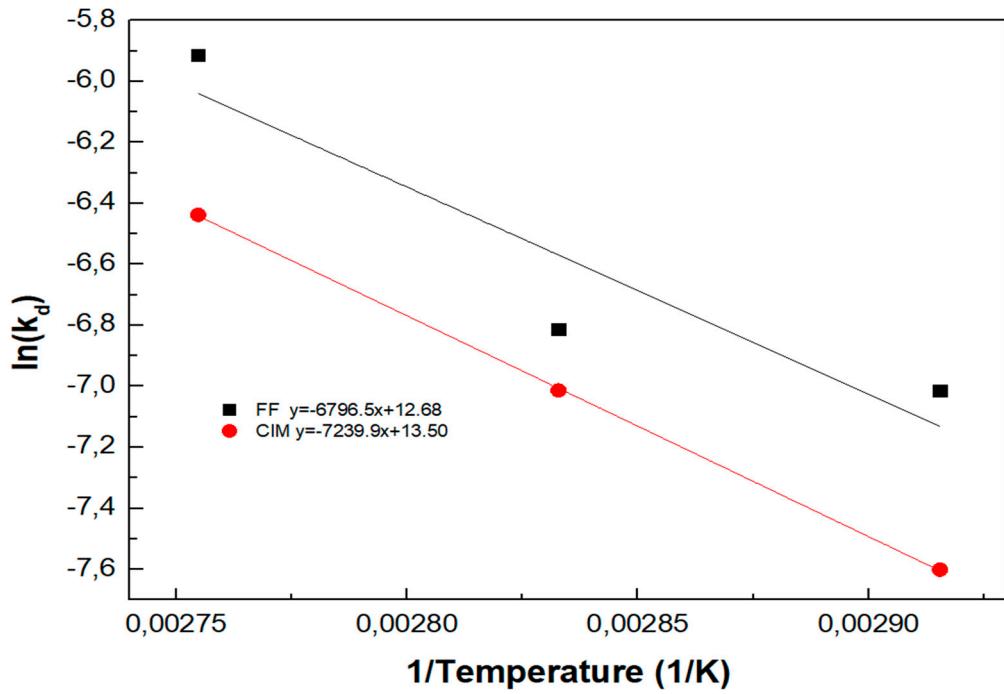
Enzyme	Thermal inactivation kinetics parameters	30°C	40 °C	50 °C	$E_a$ (kJ/mol)
Free form of HRP	$k_d$ (min <sup>-1</sup> ) $t_{1/2}$ (h)	0.0010 11.5	0.0031 3.7	0.0048 2.4	64.1
Co-immobilized form of HRP	$k_d$ (min <sup>-1</sup> ) $t_{1/2}$ (h)	0.0007 16.5	0.0024 4.8	0.0039 2.9	70.1

**Table S4.** Thermal inactivation kinetics parameters of free and co-immobilized cellulase and GOx at 40, 50 and 60 °C.

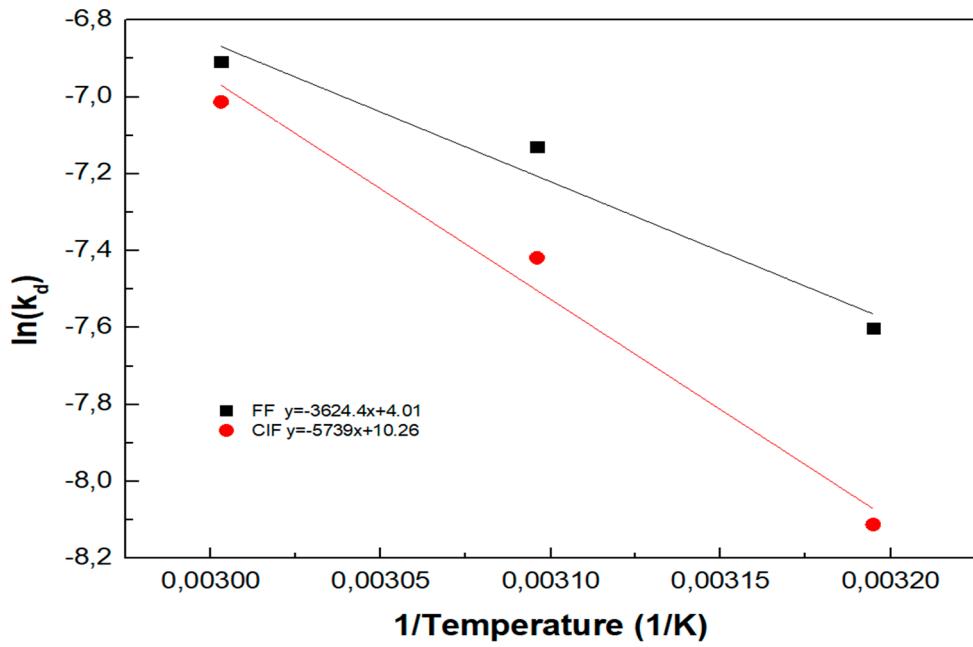
Enzyme	Thermal inactivation kinetics parameters	40°C	50 °C	60 °C	E <sub>d</sub> (kJ/mol)
Free form of cellulase	k <sub>d</sub> (min <sup>-1</sup> ) t <sub>1/2</sub> (h)	0.0031 3.7	0.0045 2.5	0.0056 2.0	25.6
Co-immobilized form of cellulase	k <sub>d</sub> (min <sup>-1</sup> ) t <sub>1/2</sub> (h)	0.0014 8.2	0.0023 5.0	0.0028 4.1	30.1
Free form of GOx	k <sub>d</sub> (min <sup>-1</sup> ) t <sub>1/2</sub> (h)	0.0005 23.1	0.0008 14.4	0.0010 11.5	30.1
Co-immobilized form of GOx	k <sub>d</sub> (min <sup>-1</sup> ) t <sub>1/2</sub> (h)	0.0003 38.5	0.0006 19.2	0.0009 12.8	47.7



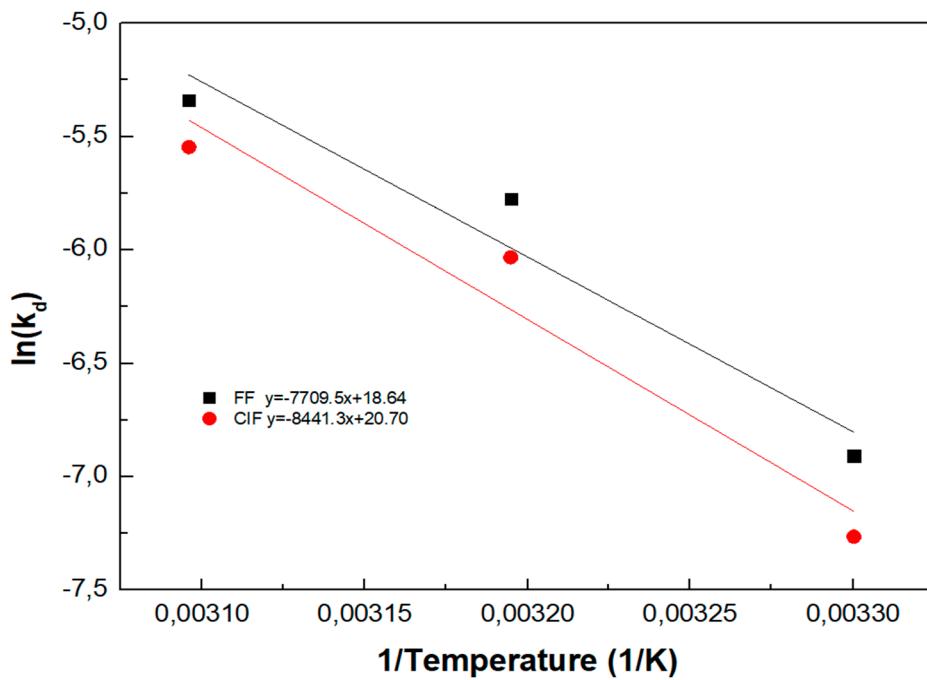
**Figure S3.** Arrhenius plot for the inactivation of free form (FF) and co-immobilized form (CIF) of celDZ1.



**Figure S4.** Arrhenius plot for the inactivation of free form (FF) and co-immobilized form (CIF) of bgl.



**Figure S5.** Arrhenius plot for the inactivation of free form (FF) and co-immobilized form (CIF) of GOx.



**Figure S6.** Arrhenius plot for the inactivation of free and co-immobilized HRP.

**Table S5.** Thermodynamic parameters of free and co-immobilized bgl at 70, 80 and 90 °C.

Thermodynamic parameters	Form of enzyme	70 °C	80 °C	90 °C
ΔH° (kJ/mol)	Free bgl	54.65	54.57	54.49
ΔH° (kJ/mol)	Co-immobilized form of bgl	57.35	57.27	57.19
ΔG° (kJ/mol)	Free bgl	102.91	111.52	105.78
ΔG° (kJ/mol)	Co-immobilized form of bgl	104.60	112.11	107.37
ΔS° (J/mol/K)	Free bgl	-140.69	-161.33	-141.29
ΔS° (J/mol/K)	Co-immobilized form of bgl	-137.75	-155.35	-138.23

**Table S6.** Thermodynamic parameters of free and co-immobilized HRP at 30, 40 and 50 °C.

Thermodynamic parameters	Form of enzyme	30 °C	40 °C	50 °C
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$\Delta H^\circ$ (kJ/mol)	Free HRP	61.59	61.50	61.42
$\Delta H^\circ$ (kJ/mol)	Co-immobilized form of HRP	67.59	67.50	67.42
$\Delta G^\circ$ (kJ/mol)	Free HRP	90.36	90.48	92.27
$\Delta G^\circ$ (kJ/mol)	Co-immobilized form of HRP	91.24	91.13	92.83
$\Delta S^\circ$ (J/mol/K)	Free HRP	-94.95	-92.58	-95.51
$\Delta S^\circ$ (J/mol/K)	Co-immobilized form of HRP	-78.05	-75.49	-78.66

**Table S7.** Thermodynamic parameters of free and co-immobilized cellulase and GOx at 40, 50 and 60 °C.

<b>Thermodynamic parameters</b>	<b>Form of enzyme</b>	<b>40°C</b>	<b>50 °C</b>	<b>60 °C</b>
$\Delta H^\circ$ (kJ/mol)	Free cellulase	23.08	23.00	22.92
$\Delta H^\circ$ (kJ/mol)	Co-immobilized form of cellulase	27.55	27.47	27.39
$\Delta G^\circ$ (kJ/mol)	Free cellulase	90.48	92.45	94.79
$\Delta G^\circ$ (kJ/mol)	Co-immobilized form of cellulase	92.53	94.25	96.70
$\Delta S^\circ$ (J/mol/K)	Free cellulase	-215.33	-215.01	-215.82
$\Delta S^\circ$ (J/mol/K)	Co-immobilized form of cellulase	-207.60	-206.74	-208.13
$\Delta H^\circ$ (kJ/mol)		27.50	27.42	

	Free GOx		27.34	
$\Delta H^\circ$ (kJ/mol)	Co-immobilized form of GOx	45.10	45.02	44.94
$\Delta G^\circ$ (kJ/mol)	Free GOx	95.21	97.07	99.55
$\Delta G^\circ$ (kJ/mol)	Co-immobilized form of GOx	96.54	97.85	99.86
$\Delta S^\circ$ (J/mol/K)	Free GOx	-216.32	-215.63	-216.84
$\Delta S^\circ$ (J/mol/K)	Co-immobilized form of GOx	-164.34	-163.56	-164.92



**Figure S7.** Nanobiocatalyst's magnetic separation by the use of an external magnetic field.