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SORPTION OF IRON AND ZINC IONS FROM LAKE GERIO USING IMMOBILIZED BAKER'S YEAST

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Abstract: Iron and Zinc ions are considered to pose great risks to living things and there is the need in providing an alternative environmentally friendly and cost-effective technique such as sorption for the remediation of Iron and Zinc ions in natural water bodies using microorganisms. This research work contains an analysis on sorption of Iron and Zinc ions from Lake Gerio water in a batch process system using an immobilized baker's yeast. The optimal parametric factors affecting sorption for Iron and Zinc ions onto immobilized baker's yeast of contact time, sorbent dosage and temperature in a batch process system were investigated. The sorbent developed was characterized using Scanning electron microscope and Fourier transform infrared spectroscopy. The optimum uptake of Iron and Zinc ions by the sorbent were recorded to be 249.55 mg/g and 120.05 mg/g, respectively for contact time (180 min), temperature (25 ℃), and sorbent dosage (5 g) in the batch process system. Models obtained for Iron and Zinc ions uptake by sorbent were both significant with same P-values of < 0.0001. Higher F-value of 724.9024522 and lower coefficient of variance of 2.363626919 %, for Iron ions compare to Zinc ions with lower F-value of 169.5968982 and coefficient of variance value of higher 4.864852 %, implies better fitness of the Iron ions model. The coefficient of regression R^2, and adjusted R^2 were depicted as 0.998469573 and 0.997092188, respectively for Iron ions; whereas coefficient of regression R^2, and adjusted R^2 of Zinc ions were recorded as 0.99349116 and 0.987633204, respectively, further confirm that uptake of Iron ions give better fitness to that of Zinc ions by the Baker's yeast sorbent from Lake Gerio water. The results show that immobilized living baker's yeast is efficient in the removal of Iron and Zinc ions from Lake Gerio water as sorbent.

Keywords: Sorption, Baker's yeast, Response surface methodology, Lake Gerio water

Introduction

Improper management of municipal, agricultural, industrial, and solid waste in Nigeria has deteriorated the quality of many surfaces water that are frequently used as medium for dumping waste by the inhabitant (Luka *et al.,* 2013). Nutrients and organic pollutants from agriculture are the major sources of surface water quality impairment via unrestricted use of fertilizer, herbicides, pesticides and indiscriminate dumping of animal waste, plant residue and Agro-industry by-products in the open environment (Luka *et al.,* 2013; Adejumobi *et al.,* 2022). Excess irrigation water is the largest subset of agricultural wastewater; reuse of this water could be a valuable source in the face of the growing demand for freshwater for agriculture which is the major practice at Lake Gerio. Quality minimization of and reuse of agricultural drainage water are not limited to providing irrigation water, but it is also essential to prevent freshwater salinization, eutrophication, and other environmental pollution (Adejumobi *et al.,* 2022).

Lake Gerio is surface water located in Jambutu very close to River Benue in Jimeta-Yola. Most of the inhabitant of Jambutu rely on this lake as a source of drinking water for animal, fishing, farming, and commercial activities. Due to its closeness to the residents of Jimeta-Yola, the capital city of Adamawa State in North-Eastern part of Nigeria, human and animal activities end up contaminating the water in the lake with substances such as fertilizer, animal dung, woods, pesticides, herbicides, metals, which eventually affect the inhabitant of the area and the aquatic life. The activities also affect the river because when the lake is flooded during rainy season, it is channeled into the river (Luka *et al.,* 2014; Luka *et al.,* 2017).

Sorption involves sorbent (solid phase or biological materials) and solvent (liquid phase or Lake Gerio water) containing a dissolve species to be sorbed known as sorbate (metal) (Asfaram *et al.,* 2016). Sorption (Biosorption) is now a vital method for metal removal from wastewater since it does not involve chemical usage, high efficiency in uptake of metal from effluents, and low maintenance and operational cost (Hasan *et al.,* 2016).

Response surface methodology (RSM) involves the collection of mathematical and statistical techniques useful for analyzing the effects of several independent variables. RSM can also aid in evaluating the interactive effect of process variables and in building a mathematical model that accurately describes the overall process (Bezerra *et al.,* 2008; Verma *et al.,* 2016., Kefas *et al.,* 2022). The conventional linear optimization involves changing a parameter and fixing other variant parameters constant which is more commonly referred as one-variable-at- a-time. RSM uses several variables by operating the regression statistical analysis on the independent variables to obtain the optimum overall factor surface. Through the representation of the surface model, responses based on the combined variables can be determined (Kefas *et al.* 2022). The aim of this research is to study the optimization of sorption of iron and Zinc ions from Lake Gerio water using immobilized fresh living baker's yeast as sorbent to remediate in a batch system. This was achieved using a full-factorial central composite design (CCD) method of RSM statistical analysis with a probability of significance 5% (α = 0.05) with the aid of Design Expert software.

Materials and Methods

Preparation of Biomass

The baker's yeast biomass used was the commercial pressed *baker's yeast* (*Saccharomyces cerevisiae),* obtained from a local supplier at Jimeta-Yola. The biomass required for the investigation were cultured in the Department of Microbiology, Modibbo Adama University, Yola; routinely maintained on a solid medium SDA (standard yeast complete medium) agar, and preserved at 4 °C. About, 10 g of Bacro Yeast Extract, 20 g of Bacto Peptone and 20 g of Bacto Agar were added to 2 approximately 700 ml of distilled water with constant stirring. Separately, 20 g of Glucose/Dextrose was dissolved in 100 ml of distilled water. Both were autoclaved separately. After allowing it to cool to about 50 ^{O}C, both (media and glucose solution) were combined, and the volume adjusted to 1 L with distilled water. The media was poured into sterile Petri dish. For experimental purposes, cultures were grown by inoculating the liquid medium comprising the same substances except the agar with the bacterial cells obtained from the SDA agar medium. Cultures were grown at 37 ^{O}C on an orbital shaker (200 rpm). The biomass needed for Experimental in the flask were harvested by centrifugation (2500 rpm, 10 min) at room temperature from the late exponential growth phase (72 h) and the supernatant was decanted. The cell pellet was washed thoroughly with sterile 20.0 g/L potassium chloride solution, followed by sterile distilled water.

Immobilization of Biosorbent

Entrapment method that involved drop wise addition of biomass suspended in polymer matrix of $2\ \%\ (w/v)$ sodium alginate solution and $5\ \%\ (w/v)$ biomass was adapted to produce the bead (Luka *et al.* 2021). The fresh living strain of immobilized biomass bead was kept inside tight bottle for future use as biosorbent in fridge at temperature of 4 °C.

Characterization of the Immobilized Baker's Yeast

The Characterization of Immobilized *Baker's Yeast* was done before and after sorption of metal ions to test for the suitability of the sorbent. PHENOM Prox Netherland Scanning electron microscope (SEM) gives information on surface morphology of sorbent; while PERKIN ELMER SPECTRUM VERSION 10.4.3 Fourier transform infrared spectroscopy (FTIR) gives information on functional groups presence and chemical composition of the sorbent.

Batch Process System Optimization

Batch process system that was used in this study are Erlenmeyer conical flasks of $100\ ml$ (Luka *et al.*, 2021). Twenty (20) flasks were incubated in a rotary shaker type at $150\ rpm$ to obtain final concentration for each sorbate at a given process parameters. The concentration of each metal ions was evaluated using Standard Method for Examination of Water and Wastewater as adapted by Luka *et al.*, 2021(APHA,1998). The mixtures of Lake Gerio water and immobilized Baker's Yeast were decanted and the residual concentration of each solution after sorption was determined using VGP210 – AAS for each metal ions, respectively. Lake Gerio water initial mean metal concentration for Iron and Zinc ions were recorded as 28.115 mg/l and 14.225 mg/l, respectively. The uptake value for each metal ions was calculated using equation (1) (Dobaradaran *et al.*, 2016; Ahmad *et al.*, 2018):

$$q = \frac{V(C_i - C_f)}{m} \qquad (1)$$

Where, q is the uptake of metal (mg/g), C_i and C_f are the initial and final metal concentrations in the water (mg/l) respectively; V is the volume of solution (l) and m is the mass of sorbent (g). Optimization of Batch Process Systems experiment design was carried out using Design Expert 7.0. The RSM ascertain the number of experiments for the optimization. A full-factorial central composite design (CCD) was adapted (Verma *et al.*, 2016., Kefas *et al.*, 2022) involving the three independent variables comprising of contact time, biosorbent dosage and temperature as presented in Table 1. The range of values chosen for each independent parameter was based on information from literature (Kefas *et al.* 2022).

Table 1: Sorption variables and Levels in RSM Design

Variables	Symbols	-1	0	+1
Contact Time (min)	A	20	100	180
Temperature (°C)	B	25	37.5	50
Sorbent Dosage (g)	C	5	10	15

Results and Discussion

Characterization of the Immobilized Baker's Yeast

SEM analysis

The results are presented in Plates 1 and 2, chronologically.

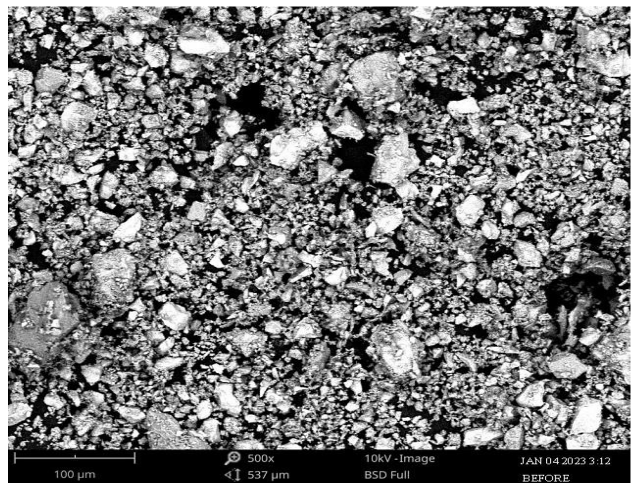

Plate 1: SEM Image of Immobilized Baker's Yeast before Sorption at 500 x magnification

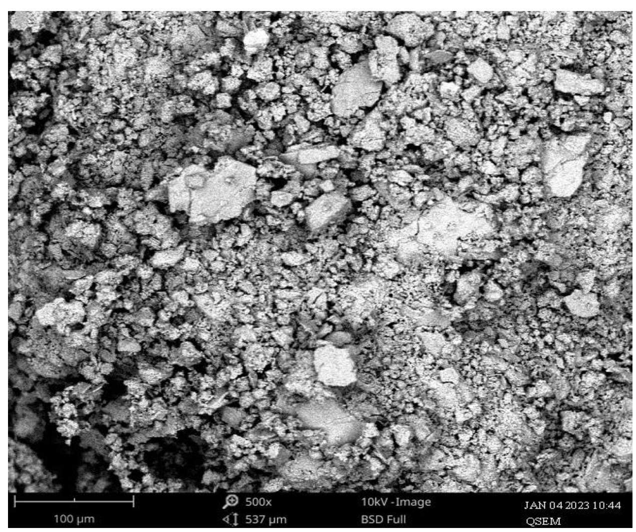

Plate 2: SEM Image of Immobilized Baker's Yeast after Sorption at 500 x magnification

The results shown by SEM images of immobilized Baker's Yeast sorbent for Iron and Zinc ions clearly displayed a change in the surface morphology of the sorbent after exposure to sorbates. The surface of sorbent was observed to be made up of heterogeneous structure and micropores which were known for more sorption and internally bioaccumulation of sorbates. The results of this study show similarity to that of Luka et al. (2021), which was reported that SEM of immobilized *Bacillus Circulans* after sorption show changes. This morphological change occurs due to metals ions sorption at the cell wall.

FTIR analysis

The FTIR results are presented in Figures 1 and 2, respectively.

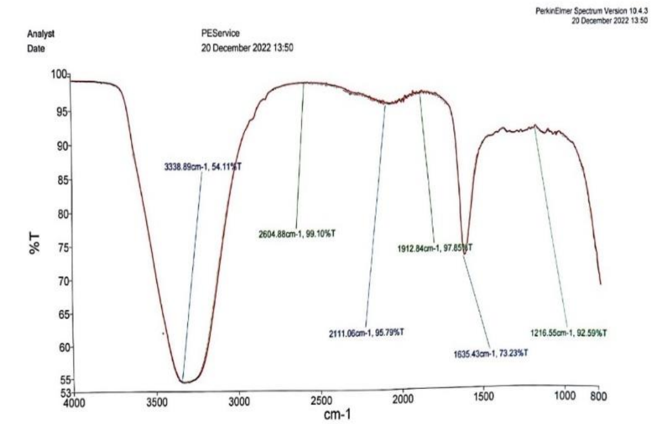

Figure1: FTIR Image of the Immobilized Baker's Yeast before Sorption

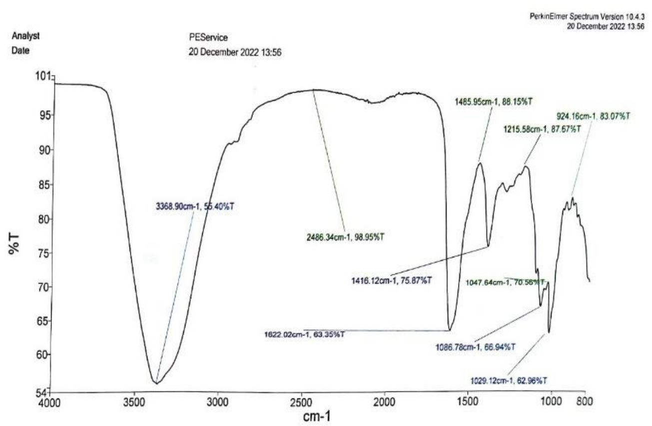

Figure 2: FTIR Image of the Immobilized Baker's Yeast after Sorption

The FTIR spectra for immobilized Baker's yeast (Figure 1) showed the functional groups that are present in the sorbent before sorption. The major peaks were depicted at 3338.89 cm^{-1}, 2604.88 cm^{-1}, 2111.06 cm^{-1}, 1912.84 cm^{-1}, 1635.43 cm^{-1}, and 1216.55 cm^{-1}; this implies the assigned functional group are -OH stretch for carboxylic acid, C-H stretch for aldehyde, C=C stretch for alkyne, N-H bend for amine, -OH bend for phenol/ tertiary alcohol, C-N stretch for primary amine and -OH for alcohol out of phase bend, respectively. This showed interaction exist between the metal ions and the immobilized baker's yeast because the peaks were shifted after sorption, the transmitted peaks shifted to a new record of 3368.90 cm^{-1}, 2486.34 cm^{-1}, 1622.02 cm^{-1}, 1485.95 cm^{-1}, 1416.12 cm^{-1}, 1215.58 cm^{-1}, 1086.78 cm^{-1}, 1047.64 cm^{-1}, 1029.12 cm^{-1}, and 924.16 cm^{-1}. This is best explained by Luka *et al.* (2021), where the peaks for immobilized *Bacillus Circulans* changes after sorption of metal ions, which reveals that chemical interaction between the sorbate and sorbent exist.

Process Optimization

The results for batch process system optimization of Iron and Zinc ions onto immobilized baker's yeast for the three variables (contact time (A), temperature (B), and sorbent dosage (C)) that can affect sorption considered in this research with their responses, uptake of metal ions by the sorbent (q) were evaluated for each run and are presented in Table 2- 11 and Figure 3- 10. The total number of experimental runs performed were 20, with 8 factorial point runs, 6 axial point runs, and 6 center point runs as replicate which helps to reduce experimental error (Bezerra *et al.*, 2008; Rashid *et al.*, 2011; Kefas *et al.* 2022).

For uptake of Iron ions by the sorbent (q), results are presented in Table 2- 6 and Figure 3- 6. The results for experimental design for optimization of sorption of Iron ions is depicted in Table 2.

Table 2: Experimental Design for Optimization of sorption (Iron Ions).

Run	Type	A: Time (min)	B: Temperature (℃)	C: Dosage (g)	q (mg/g)
1	Fact	20	25	5	239
2	Axial	180	37.5	10	120.83
3	Axial	20	37.5	10	121.7
4	Fact	180	25	5	249.55
5	Fact	20	50	15	81.53
6	Fact	180	50	5	217.8
7	Center	100	37.5	10	117.58
8	Center	100	37.5	10	116.38
9	Axial	100	37.5	15	71.65
10	Axial	100	25	10	124.93
11	Axial	100	50	10	124.33
12	Center	100	37.5	10	116.35
13	Center	100	37.5	10	116.4
14	Center	100	37.5	10	116.45
15	Fact	20	25	15	70.35
16	Fact	20	50	5	237.9
17	Center	100	37.5	10	116.8
18	Fact	180	50	15	83.3
19	Fact	180	25	15	77.57
20	Axial	100	37.5	5	223.15

It is clearly demonstrated in Table 2 that the optimal value is obtain at contact time (180 min), temperature (25 ℃), and sorbent dosage (5 g) as 245.55 mg/g for iron ions.

The results of the sequential model sum of squares for the experimental design and the model summary statistics are Presented in Tables 3 and 4, respectively.

Table 3: Sequential Model Sum of Squares (Iron ions).

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
Mean vs Total	376353.33	1	376353.3			
Linear vs Mean	61336.462	3	20445.49	44.46917	< 0.0001	
2FI vs Linear	515.3749	3	171.7916	0.326461	0.8063	
Quadratic vs 2FI	6735.7784	3	2245.259	213.5713	< 0.0001	Suggested
Cubic vs Quadratic	100.4327	4	25.10818	32.07644	0.0003	Aliased
Residual	4.6965636	6	0.782761			
Total	445046.07	20	22252.3			

Table 4: Model Summary Statistics (Iron ions).

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	21.442193	0.892910341	0.87283103	0.807822485	13201.20085	
2FI	22.939565	0.900412952	0.854449699	0.3092895	47446.79964	
Quadratic	3.2423643	0.998469573	0.997092188	0.970367889	2035.511045	Suggested
Cubic	0.8847376	0.999931629	0.999783493	0.93658038	4356.467714	Aliased

From the Tables 3 and 4, the software suggested the quadratic model as the best model for this design from the response of the experimental data.
The results for statistical analysis of variance are presented in Table 5.

Table 5: Analysis of variance (ANOVA) for response surface quadratic model (Iron ions).

Source	Sum of Squares	Df	Mean Square	F- value	p-value Prob > F	
Model	68587.61491	9	7620.846101	724.9024522	< 0.0001	significant
A-Time	0.20449	1	0.20449	0.019451292	0.8918	
B-Temperature	27.35716	1	27.35716	2.602240238	0.1378	
C-Dosage	61308.9	1	61308.9	5831.763477	< 0.0001	
AB	162.90125	1	162.90125	15.49532874	0.0028	
AC	42.96645	1	42.96645	4.08701141	0.0708	
BC	309.5072	1	309.5072	29.44063235	0.0003	
A^2	35.02170511	1	35.02170511	3.331299383	0.0979	
B^2	132.2071114	1	132.2071114	12.57567178	0.0053	
C^2	2426.341536	1	2426.341536	230.7960174	< 0.0001	
Residual	105.1292636	10	10.51292636			
Lack of Fit	103.9770636	5	20.79541273	90.24220069	< 0.0001	
Pure Error	1.1522	5	0.23044			
Cor Total	68692.74418	19				
Std. Dev.	3.242364317		R-Squared	0.998469573		
Mean	137.1775		Adj R-Squared	0.997092188		
C.V. %	2.363626919		Pred R-Squared	0.970367889		
PRESS	2035.511045		Adeq Precision	77.54140138		

Table 5 illustrates the Analysis of variance (ANOVA) used to evaluate fitness, statistical importance, and adequacy of quadratic model and to investigate the effect of input variables on the output response (uptake of Iron ions by the sorbent) and further establishing the significance of each input variable. The results obtained from the ANOVA was used in the model fitting with the aid of several statistical criteria. The p-value (probability of error value) represents the significance of the model and F-value represents the most influencing factor in research.

Furthermore, Table 5 demonstrates that P-values higher than 0.05 indicates insignificance and P-values less than 0.05 indicates significance of these parameters on the uptake of Iron ions by the sorbent (Verma *et al.,* 2016; Kefas *et al.,* 2022). Therefore, the results from the table indicated that the linear parameters C (dosage), interactive parameters AB and BC as well as the quadratic parameters B^2 and C^2 have significant effect on the uptake of iron ions by sorbent from Lake Gerio water. The parameter, C (dosage) was established to be the most significant variables for the uptake of iron ions by sorbent from Lake Gerio to give a higher uptake with a P-value of < 0.0001 and F-value of 5831.763477. F-value normally shows the strength of the effect of each parameter to response (Lee et al., 2011; Kefas *et al.,* 2022). Therefore, the high F-value expresses stronger influence of variables on response (Boey et al., 2013). The quadratic variable C^2 appeared to be the second most influential variable with F-value of 230.7960174 and low significant effect P-value of < 0.0001. Also, the model was significant and is confirmed by the P-value of < 0.0001 and the higher F value of 724.9024522 (Verma *et al.,* 2016; Kefas *et al.,* 2022).

The coefficient of regression R^2 which depicts relationships between the predicted and actual uptake of metal ions by the sorbent is obtained as 0.998469573. Also, the adjusted R^2 value of 0.997092188 was in close agreement with R^2 value which shows the model has related variable. The other important parameter for evaluating the model is coefficient of variance (C.V.) which must be less than 10%. The C.V. value of the fitting model is 2.363626919 %, so this model and the experimental results are reliable and as well suitable for the predicted uptake of iron ions by the sorbent from Lake Gerio water produced from Baker's yeast (Verma *et al.,* 2016; Kefas et al., 2018; Kefas et al., 2022).

Regression coefficients and significance of response quadratic model are presented in Table 6.

Table 6: Regression coefficients and significance of response quadratic model (Iron ions).

Factor	Coefficient Estimate	Df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	117.0745	1	1.11464647	114.591	119.5581	
A-Time	-0.143	1	1.025325625	-2.42757	2.141568	1
B-Temperature	-1.654	1	1.025325625	-3.93857	0.630568	1
C-Dosage	-78.3	1	1.025325625	-80.5846	-76.0154	1
AB	-4.5125	1	1.146348898	-7.06672	-1.95828	1
AC	2.3175	1	1.146348898	-0.23672	4.871725	1
BC	6.22	1	1.146348898	3.665775	8.774225	1
A^2	3.568636	1	1.95521925	-0.78786	7.925136	1.818182
B^2	6.933636	1	1.95521925	2.577136	11.29014	1.818182
C^2	29.70364	1	1.95521925	25.34714	34.06014	1.818182

The uptake of Iron ions by the sorbent (q) was optimized based on the response factor and the three independent variables. The uptake of Iron ions by the sorbent (q) regression equation in terms of the coded factor is given by Equation 2.

$$q_{(Fe)}=117.0745 - 0143A - 1.654B - 78.3C - 4.5125AB + 2.3175AC + 6.22BC + 3.568636A^2 + 6.933636B^2 + 29.70364C^2. \quad (2)$$

Figure 3 shows a plot of predicted versus actual uptake of Iron ions by the sorbent.

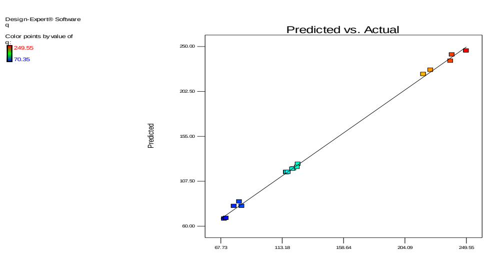

Figure 3: A plot of predicted versus actual uptake of Iron ions by the sorbent.

Actual uptake of Iron ions by the sorbent compared to predicted uptake of Iron ions by the sorbent graph is presented in Figure 3.

It can be clearly observed that an acceptable correlation was obtained between predicted and actual data of the uptake of Iron ions by the sorbent; hence, the errors of the distributed points can be said to be small (Lokman et al., 2015; Hasan *et al.,* 2016; Verma *et al.,* 2016; Kefas, et al., 2022). In addition, the line of (y = x) shown a better fitting of the model with experimental results. Figure 4-6 represent interaction of variables and their effects on response which is normally studied with the help of three-dimension graphs.

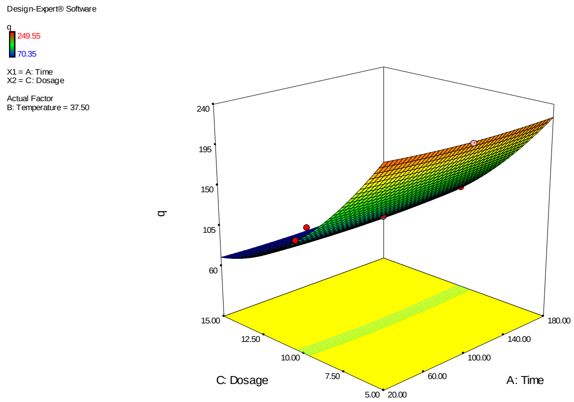

Figure 4: Response Surface Combined Effect Plot of Dosage (g) and Time (min) Variables for Uptake of Iron Ions by Sorbent.

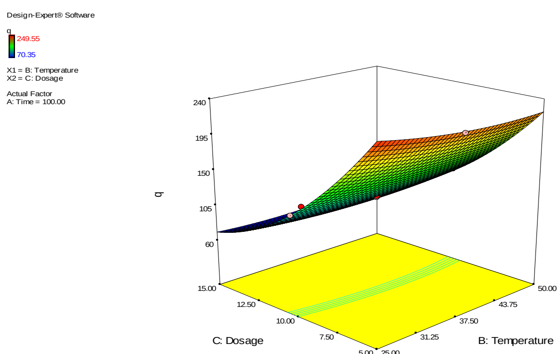

Figure 5: Response Surface Combined Effect Plot of Dosage (g) and Temperature (℃) Variables for Uptake of Iron Ions by Sorbent.

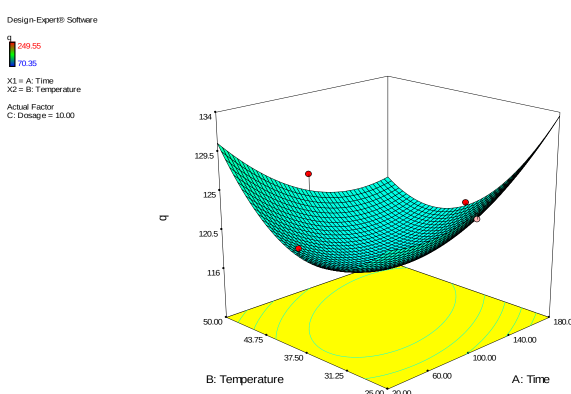

Figure 6: Response Surface Combined Effect Plot of Temperature (℃) and Time (min) Variables for Uptake of Iron Ions by Sorbent.

The interaction of variables and their effects on response were investigated with the aid of three-dimension graphs. Figure 3 - 6 show the 3D response surface plots for uptake of Iron Ions by Sorbent depending on: Dosage and Time (Figure 4), Dosage and Temperature (Figure 5), Temperature and Time (Figure 6), chronologically. Figure 4 demonstrates that uptake of Iron Ions by Sorbent decreased when the quantity of sorbent dosage increases with increase in Time. This best explains by Hasan *et al.*, (2016) which stated that increasing the biomass concentrations enhanced the interference between binding sites of surface biomass cells, thus lowered the uptake capacity. Figure 5 also, exhibits decrease in uptake of Iron Ions by Sorbent when the quantity of sorbent dosage increases with increase in Temperature. Figure 6 shows that Temperature and Time do not have significant effect on the uptake of Iron Ions by Sorbent.

Considering uptake of Zinc ions by the sorbent (q), results were calculated for each run and are presented in Table 7- 11 and Figure 7- 10.

The Experimental Design for Optimization of sorption of Zinc Ions for sorbent are presented in Table 7 which were set at same condition as that of Iron ions.

Table 7: Experimental Design for Optimization of Sorption of Zinc Ions.

Run	Type	A: Time (*min*)	B: Temperature (℃)	C: Dosage (*g*)	q (mg/g)
1	Axial	100	37.5	5	93.5
2	Fact	180	25	5	120.05
3	Axial	100	50	10	59.2
4	Axial	180	37.5	10	60
5	Axial	100	37.5	15	30.63
6	Fact	20	50	15	36.23
7	Fact	180	50	5	110.5
8	Fact	20	25	15	30.65
9	Center	100	37.5	10	54.75
10	Axial	20	37.5	10	59.43
11	Center	100	37.5	10	55
12	Fact	20	50	5	110
13	Center	100	37.5	10	56.05
14	Center	100	37.5	10	55.8
15	Axial	100	25	10	58.9
16	Fact	20	25	5	107.65
17	Center	100	37.5	10	56
18	Center	100	37.5	10	55
19	Fact	180	25	15	37.49
20	Fact	180	50	15	39.23

The optimal uptake value of 120.05 mg/g for Zinc ions was observed at same independent variable values of contact time (180 min), temperature (25 ℃), and sorbent dosage (5 g) as recorded for Iron ions.

For Zinc ions, results of the sequential model sum of squares for the experimental design and the model summary statistics are Presented in Tables 8 and 9, respectively.

Table 8: Sequential Model Sum of Squares for Optimization of Sorption of Zinc Ions.

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
Mean vs Total	82697.52	1	82697.51618			
Linear vs Mean	13557.77	3	4519.25778	48.95472783	< 0.0001	
2FI vs Linear	58.4927	3	19.49756667	0.17868156	0.9089	
Quadratic vs 2FI	1320.689	3	440.2295939	44.98602095	< 0.0001	Suggested
Cubic vs Quadratic	89.15826	4	22.289565	15.37045629	0.0026	Aliased
Residual	8.700938	6	1.450156364			
Total	97732.33	20	4886.61651			

Table 9: Model Summary Statistics (Zinc Ions).

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	9.608072	0.901759	0.883338377	0.818390184	2730.469807	
2FI	10.44601	0.905649	0.862102555	0.269644125	10980.76474	
Quadratic	3.128245	0.993491	0.987633204	0.943439346	850.3789199	Suggested
Cubic	1.204224	0.999421	0.998167389	0.42594001	8630.885189	Aliased

From the Tables 8 and 9, the software also suggested the quadratic model as the best model for this design from the response (q) of the experimental data.
Table 10 presents the analysis of variance (ANOVA) for response surface quadratic model (Zinc Ions).

Table 10: Analysis of variance (ANOVA) for response surface quadratic model (Zinc Ions).

Source	Sum of Squares	Df	Mean Square	F Value	p-value Prob > F	
Model	14936.95	9	1659.661647	169.5968982	< 0.0001	significant
A-Time	54.33561	1	54.33561	5.552427468	0.0402	
B-Temperature	0.01764	1	0.01764	0.00180259	0.9670	
C-Dosage	13503.42	1	13503.42009	1379.88256	< 0.0001	
AB	30.96845	1	30.96845	3.164592657	0.1056	
AC	1.17045	1	1.17045	0.119605517	0.7366	
BC	26.3538	1	26.3538	2.693032488	0.1318	
A^2	90.62025	1	90.62025057	9.260269065	0.0124	
B^2	70.84066	1	70.84065682	7.239039164	0.0227	
C^2	180.0025	1	180.0025006	18.39402978	0.0016	
Residual	97.8592	10	9.785919818			
Lack of Fit	96.18086	5	19.23617297	57.30736734	0.0002	
Pure Error	1.678333	5	0.335666667			
Cor Total	15034.81	19				
Std. Dev.	3.128245		R-Squared	0.99349116		
Mean	64.303		Adj R-Squared	0.987633204		
C.V. %	4.864852		Pred R-Squared	0.943439346		
PRESS	850.3789		Adeq Precision	41.03244192		

Table 10 shows that P-values higher than 0.05 indicates insignificance and P-values less than 0.05 indicates significance of these parameters on the uptake of zinc ions by the sorbent (Verma et al., 2016; Kefas *et al.,* 2022). Hence, the results from the table indicated that the linear parameters C (dosage) and A (Time) are significance with P-value of < 0.0001 and 0.0402, respectively and their corresponding F-value are 1379.88256 and 5.552427468, quadratic parameters A^2, B^2 and C^2 have significant effect on the uptake of zinc ions by sorbent from Lake Gerio water. C (dosage) was established to be the most significant variables also for the uptake of zinc ions by sorbent from Lake Gerio to give a higher uptake with a P-value of < 0.0001 and F-value of 1379.88256. this depicts the strength of the effect of C (dosage) to uptake of zinc by the sorbent (Lee et al., 2011; Kefas *et al.*, 2022). This is like what was observed for iron ions, the high F-value expresses stronger influence of variable on response (Boey et al., 2013). The quadratic variable C^2 appeared to be the second most influential variable with F-value of 18.39402978 and low significant effect P-value of < 0.0016. Furthermore, the model was significant and is confirmed by the P-value of < 0.0001 and the higher F-value of 169.5968982.

The coefficient of regression R^2 which depicts relationships between the predicted and actual uptake of metal ions by the sorbent is obtained as 0.99349116. Also, the adjusted R^2 value of 0.987633204 was in close agreement with R^2 value which shows the model has related variable. The other important parameter for evaluating the model is C.V. which must be less than 10%. The C.V. value of the fitting model is 4.864852 %, so this model and the experimental results are reliable and as well suitable for the predicted uptake of zinc ions by the sorbent from Lake Gerio water produced from Baker's yeast (Verma et al., 2016; Kefas et al., 2022).

Regression coefficients and significance of response (uptake of zinc ions by the sorbent from Lake Gerio water) quadratic model are presented in Table 11.

Table 11: Regression coefficients and significance of response quadratic model (Zinc ions).

Factor	Coefficient Estimate	Df	Standard Error	95% CI Low	95% CI High	VIF
Intercept	54.84981818	1	1.075415	52.45364386	57.24599251	
A-Time	2.331	1	0.989238	0.126840204	4.535159796	1
B-Temperature	0.042	1	0.989238	-2.162159796	2.246159796	1
C-Dosage	-36.747	1	0.989238	-38.9511598	-34.5428402	1
AB	-1.9675	1	1.106002	-4.431825569	0.496825569	1
AC	-0.3825	1	1.106002	-2.846825569	2.081825569	1
BC	1.815	1	1.106002	-0.649325569	4.279325569	1
A^2	5.740454545	1	1.886403	1.537286733	9.943622358	1.81818182
B^2	5.075454545	1	1.886403	0.872286733	9.278622358	1.81818182
C^2	8.090454545	1	1.886403	3.887286733	12.29362236	1.81818182

The uptake of Zinc ions by the sorbent (q) was optimized based on the response factor and the three independent variables. The uptake of Zinc ions by the sorbent (q) regression equation in terms of the coded factor is presented by Equation 3.

$$q_{(Zn)} = 54.84981818 + 2.331A + 0.042B - 36.747C - 1.9675AB - 0.3825AC + 1.815BC + 5.740454545 + 5.075454545B^2 + 8.090454545C^2$$
(3)

Figure 7 shows a plot of predicted versus actual uptake of Zinc ions by the sorbent.

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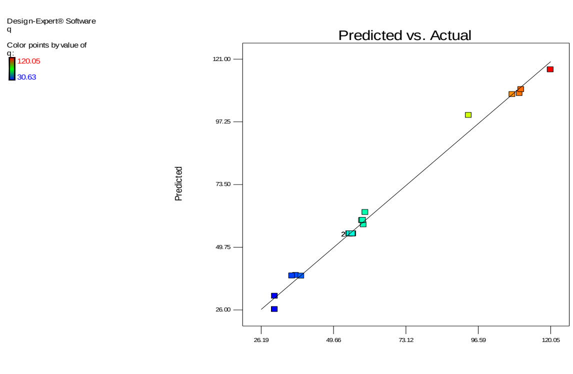

Figure 7: A plot of predicted versus actual uptake of Zinc ions by the sorbent.

Actual uptake of Iron ions by the sorbent compared to predicted uptake of Iron ions by the sorbent graph is presented in Figure 7. It can be clearly observed that an acceptable correlation was obtained between predicted and actual data of the uptake of Zinc ions by the sorbent; thus, the errors of the distributed points can be said to be small (Lokman et al., 2015; Verma *et al.*,2016; Kefas, et al., 2022). Finally, the line of (y = x) shown a better fitting of the model with experimental results which is similar to what was demonstrate by Iron ions.

Figure 8 - 10 represent interaction of variables and their effects on response which is normally investigated with the help of three-dimension graphs.

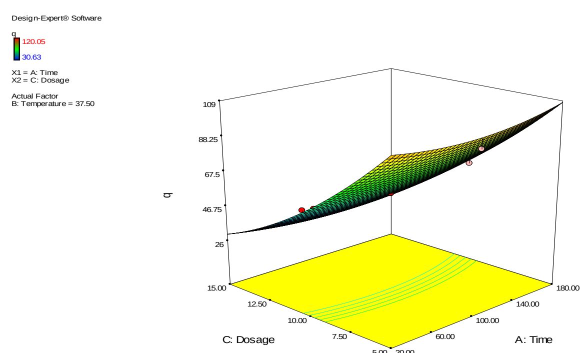

Figure 8: Response Surface Combined Effect Plot of Dosage (g) and Time (min) Variables for Uptake of Zinc Ions by Sorbent.

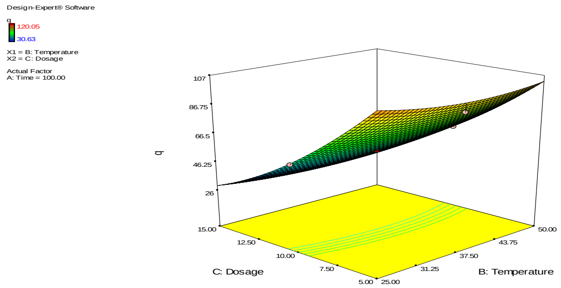

Figure 9: Response Surface Combined Effect Plot of Dosage (g) and Temperature (℃) Variables for Uptake of Zinc Ions by Sorbent.

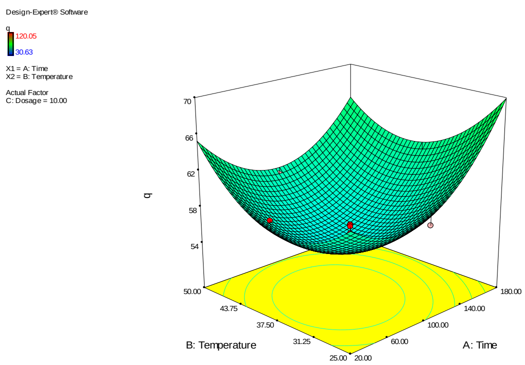

Figure 10: Response Surface Combined Effect Plot of Temperature (℃) and Time (min) Variables for Uptake of Zinc Ions by Sorbent.

Figure 8-10 illustrate the 3D response surface plots for optimization of uptake of Zinc Ions by *Baker's Yeast* from Lake Gerio water in a batch system depending on: Dosage and Time (Figure 8), Dosage and Temperature (Figure 9), Temperature and Time (Figure 10), respectively. Figure 8 shows similar trend to that of Figure 4 (uptake of Iron Ions) that uptake of Zinc Ions by Sorbent decreased when the quantity of sorbent dosage increases with increase in Time (Verma *et al.*,2016). Figure 9 also, demonstrates decrease in uptake of Zinc Ions by Sorbent when the quantity of sorbent dosage increases with increase in Temperature. In addition, Figure 10 demonstrates that Temperature and Time do not have significant effect on the uptake of Zinc Ions by Sorbent.

The models obtained for Iron and Zinc ions uptake by sorbent were both significant with same P-values of < 0.0001. The higher F-value of 724.9024522 and lower coefficient of variance (C.V.) of 2.363626919 %, for Iron ions to that of Zinc ions with F-value of 169.5968982 and C.V. value of 4.864852 %, implies better fitness of the Iron ions model (Verma *et al.*, 2016; Kefas *et al.*, 2022). The coefficient of regression R^2, and adjusted R^2 were depicted as 0.998469573 and 0.997092188, respectively for Iron ions; whereas coefficient of regression R^2, and adjusted R^2 of Zinc ions was recorded as 0.99349116 and 0.987633204, respectively, also confirm that uptake of Iron ions give better fitness to that of Zinc ions by the Baker's yeast sorbent from Lake Gerio water .

Conclusions

The following conclusions can be drawn from the results of this study:

1. The immobilized *baker's yeast* sorbent developed was suitable for sorption of Iron and Zinc ions from Lake Gerio water in a batch system.
2. The Scanning electron microscope with Fourier transform infrared spectroscopy depicted some change in surface morphology and peaks respectively, which were confirmation for binding of Iron and Zinc ions on the immobilized *baker's yeast* sorbent.
3. The optimum values could be used for further scale up purposes of batch contactor for sorption of Iron and Zinc ions onto immobilized *baker's yeast* sorbent.
4. The better fitness was observed for sorption of Iron ions onto immobilized *baker's yeast* sorbent in the batch system to Zinc contacting process for Lake Gerio water.
5. The Design Expert as well as Microsoft Excel-2016 software were successfully used as tools for optimization of Fe and Zn sorption on Lake Gerio water in a batch system, respectively.
6. Sorption has a good potential to replace conventional treatment techniques for metal ions from Lake Gerio water.

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