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ORIGINAL PAPER

Lactide synthesis via thermal catalytic depolymerization of poly lactic acid oligomer using ZnO nanoparticle dispersion

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Abstract
Owing to its capacity to synthesize high molecular weight of Poly Lactic Acid (PLA), polymerization via Ring Opening Polymerization (ROP) has gotten the attention of researchers. Accordingly, since the ROP technique utilizes lactide as a potential monomer for PLA synthesis, the production of lactide is indispensable. Currently, in order to solve the problem associated with commonly used homogeneous tin-based catalyst, looking for alternative catalysts for lactide synthesis are becoming more attractive. In the present study, the optimum reaction conditions for lactide synthesis via thermal catalytic depolymerization by using ZnO nanoparticle dispersion were investigated. The effects of three major factors including reaction temperature (190 °C, 210 °C, and 230 °C), reaction time (1 h, 2 h, and 10 h), and catalyst concentration (0.3%w/w, 0.65%w/w, 1.0%w/w) on the yield of lactide were studied. The oligomer PLA was produced from an aqueous solution of Lactic acid (50 mL, 88%) via polycondensation reaction at 150 °C for 4 h. The suspension of Zno Nps was prepared by dissolving Zno Nps powder in distilled water with a ratio of 1:4. The produced oligomer of PLA was depolymerized via thermal catalytic depolymerization using 20% w/w of the prepared Zno NPs dispersion. The optimization of lactide yield and depolymerization reaction parameters was done via response surface methodology with a Box-Behnken design. Based on the analysis, the optimum conditions were found to be a reaction temperature of 215.73 °C, a reaction time of 7.32 h, and a catalyst concentration of 0.72%w/w along with the maximum lactide yield of 80.4%. Generally, the outcome of the study reveals that the utilization of ZnO nanoparticle dispersions as a catalyst for lactide synthesis from oligomer PLA via thermal catalytic depolymerization is worthful.

Keywords Oligomer PLA · Ring opening polymerization · Thermal catalytic depolymerization · ZnO nanoparticles · Lactide

Introduction

Recently, in order to alleviate the problem associated with fossil-based plastics, significant attention was directed to bio-based plastics. In this regard, Poly Lactic Acid (PLA), which is one of bio-based plastic, is the most promising product that has gotten the attention of researchers. It is a biocompatible, biodegradable, and environmentally friendly product, which is produced from renewable biomass [1–3]. Owing to its interesting characteristics, it is widely used in different sectors such as medicine, packaging, and textiles [4, 5].

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It can be synthesized from lactic acid by using four different methods including Ring Opening Polymerization (ROP), direct polycondensation, solid state polymerization, and azeotropic polycondensation [6–9]. Due to its capacity to synthesis the high molecular weight of PLA, ROP is becoming an attractive technique. Accordingly, since polymerization via ROP utilizes lactide as the potential feedstock for PLA synthesis, the demand for lactide has increased. Lactide can be synthesized by passing through three successive steps. These include dehydration, oligomerization (formation of oligomer PLA), and depolymerization [10–12]. Among these, depolymerization is the most determinant step on the yield and purity of synthesized lactide.

Depolymerization of oligomer PLA can be done by using various metal oxide catalysts including, tin-based catalysts (e.g. tin (II) 2-ethylhexanoate), Zinc acetate, zinc oxide dust, titanium (IV) oxide nanopowder, etc. As compared with the others tin-based-catalyst yields a high molecular weight of

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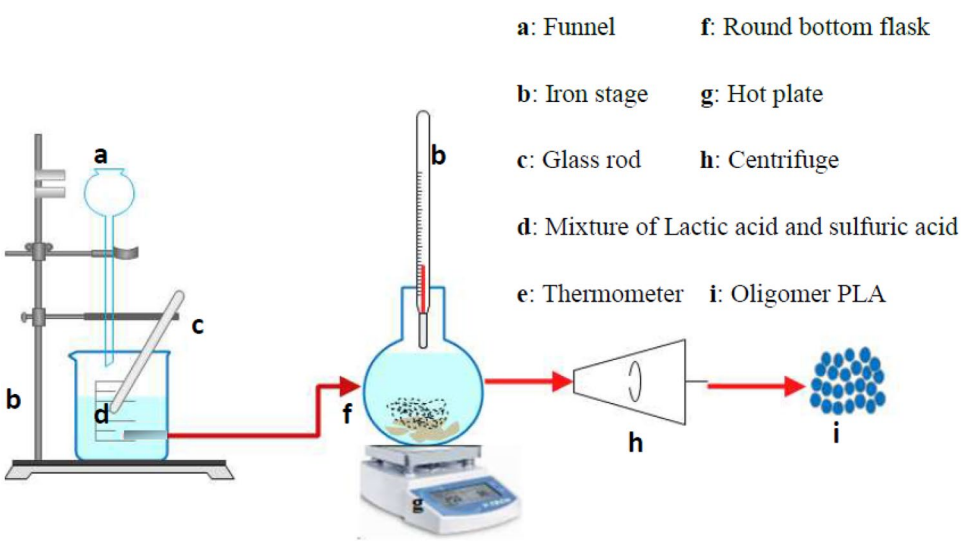

Fig. 1 Experimental setup for the synthesis of oligomer PLA synthesis

oligomer PLA, which is the main challenge for depolymerization reaction. During the depolymerization reaction, since oligomer with high molecular weight is too difficult to cleavage, the oligomerization step is recommended to synthesize the oligomer of PLAwith a range of (400–2,500) g/mol [11]. Besides, the utilization of a tin-based catalyst for depolymerization reaction leads the problem such as expensiveness of energy, consumption of time, and inadequacy of lactide yield. Consequently, researchers have attempted to look for a novel catalyst for lactide synthesis.

Nowadays, the synthesis of lactide from oligomer PLA by using Zinc oxide Nanoparticles (ZnO NPS) dispersion catalyst is a promising candidate. ZnO NPs dispersion is a nanofluid (mixture of ZnO nanoparticles and deionized water as a base fluid). As compared with the other metal oxide catalysts, it has the following advantages including minimizing energy consumption by minimizing the heat capacity of the reactants, enhancing the rate of depolymerization reaction, recoverable, highly stable, and environmentally friend [11, 13]. However, the yield of lactide obtained from the depolymerization reaction is highly affected by factors such as reaction temperature, reaction time, catalyst concentration, pressure, molecular weight of oligomer PLA, etc. [14, 15]. Therefore, in order to maximize the yield of lactide synthesized from the depolymerization reaction, optimization of the above parameters to maximize lactide yield is worthful.

Keeping in view the above ideas, this study focuses on the optimization of depolymerization reaction parameters for maximizing the yield of lactide via Response Surface Methodology with Box-Behnken Design (RSM-BBD). As compared with the other, RSM-BBD has a lot of advantage such as good efficiency for studying parameters with three levels and minimizing the number of the experimental run, which consequently reduces the experimental cost and time [16].

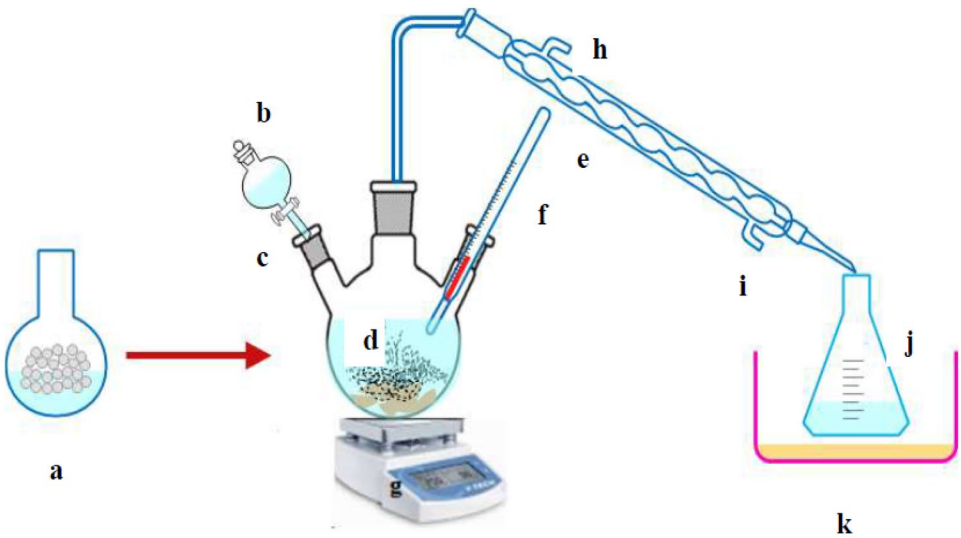

Fig. 2 Experimental setup for lactide synthesis **a** Oligomer PLA, **b** Nitrogen inlet, **c** Flow controller, **d** Mixture of oligomer PLA and ZnO Nps dispersion, **e** Condenser, **f** Thermometer, **g** Hot plate, **h** coolant inlet, **i** coolant outlet, **j** Crude lactide, **k**: Cooler

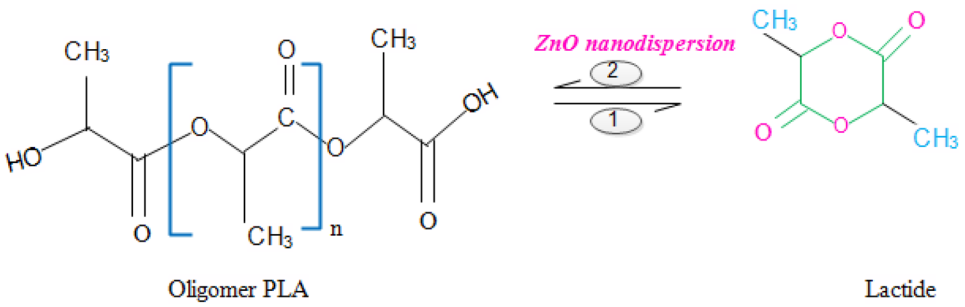

Fig. 3 Schematic representation of **1** Depolymerization and **2** polymerization reaction

Lactide was synthesized from oligomer PLA via thermal catalytic depolymerization by using aqueous ZnO Nps. The effects of reaction temperature, reaction time, and catalyst concentration were systematically determined. Besides, the optimum values of the above parameters and lactide yield were investigated.

Methodology

Lactic acid (89%wt), ethyl acetate, and zinc oxide nanoparticle (40 nm) were procured from *Fine chemicals supply plc in Addis Ababa, Ethiopia.*

Synthesis of Poly lactic acid oligomer

The oligomer of PLA was synthesized according to the method adopted [11, 12]. The aqueous solution of Lactic acid (50 mL, 88%) and 2.5% w/w H_2SO_4 catalyst were mixed under magnetic stirring in a round-bottom flask (1000 mL) at 60—80 °C and 60 kPa for 2 h in order to remove water content. After that, the temperature was slowly adjusted to 150 °C and maintained constantly for 4 h to produce PLA oligomer. Figure 1 depicts the diagrammatic representation of oligomer PLA synthesis.

Lactide synthesis

The thermal catalytic depolymerization of PLA oligomer was achieved according to the method adopted [17, 18]. In the beginning, the suspension of ZnoNps was prepared by dissolving Zno Nps powder in distilled water with a ratio of 1:4. The three-necked flask (1,000 mL) was prepared with a stirrer and a thermometer. The produced oligomer of PLA was fed to the flask and mixed with a catalyst (20% w/w of Zno NPs dispersion). The depolymerization reaction was carried out at different temperatures, times, and catalyst concentrations as designed by RSM-BBD. The crude lactide was collected in the receptacle and kept for purification. Schematically it is depicted in Figs. 2 and 3.

Design of experiment

Rather than using single parameter optimization, the optimization by response surface methodology offers more advantages like saving time, space, and raw material [19]. The design expert (v11) software was used to design the experiment and carry out optimization. From Response Surface Methodology (RSM), Box-Behnken Design (BBD) was used in this study to design the experiment with three independent process variables (temperature, time, and catalyst concentration) at two levels with five replication at the center points. The other factors like pressure (10 kpa) and molecular weight (800 g/mol) of oligomers remain constant. It can be seen from Table 1, the factors are mentioned with their levels.

The empirical relationship between the response function and independent parameters was developed by RSM-BBD. The suitable quadratic response surface model can be written mathematically:

$$Y = \beta_o + \sum_{i=1}^{3} \beta_i X_i + \sum_{i=1}^{3} \beta_{ii} X_i^2 + \sum_{i=1}^{3} \sum_{j=i+1}^{3} \beta_{ij} X_i X_j \quad (1)$$

where: Y = predicted response (i.e. Lactide), β_0, β_i, β_{ii},and β_{ij} are constant, linear, quadratic, and interaction coefficients, respectively and X_i and X_j were studied independent reaction parameters.

Table 1 Design factors of Temperature, Time, and Catalyst concentration

Factor	Parameter	Unit	Code	Level		
				low	Center	High
1	Temperature	°c	A	190	210	230
2	Time	hr	B	1	2	10
3	Catalyst concn (ZnO Nps dispersion, 40 nm)	%w/w	C	0.3	0.65	1

Table 2 The actual and predicted data reports from RSM-BBD

	F 1	F 2	F 3	Response	
R. No	A:Temperature	B:Time	C:Catalyst Concentration	Lactide yield	
	°C	hr	%w/w	%	
				Actual	Predicted
1	210	6	0.65	79.40	79.52
2	210	6	0.65	79.30	79.52
3	210	2	1	77.20	77.08
4	230	2	0.65	75.30	75.20
5	210	10	0.3	75.10	75.22
6	190	6	0.3	68.90	68.67
7	190	2	0.65	69.50	69.70
8	210	6	0.65	80.10	79.52
9	210	6	0.65	79.70	79.52
10	230	6	0.3	74.90	74.98
11	210	6	0.65	79.10	79.52
12	190	10	0.65	73.50	73.60
13	230	10	0.65	77.60	77.40
14	210	10	1	77.50	77.47
15	190	6	1	75.30	75.23
16	230	6	1	78.00	78.23
17	210	2	0.3	69.50	69.53

Lactide purification

In order to eliminate the impurities such as water, catalyst, lactic acid, and residual oligomers purification of the obtained product is mandatory. The crude lactide obtained from the depolymerization reactor is fed to the flask (1000 ml) and then mixed with ethyl acetate with the ratio of crude lactide to ethyl acetate (1:1.5 w/v). The mixture was stirred for 10 min and then undissolved impurities were separated by vacuum filtration. The filtrate was cooled down at 25 °C and then recrystallized at 4 °C for 24 h. The recrystallized lactide was then isolated from ethyl acetate by vacuum filtration and the filtrate was further dried in a vacuum oven at 40 °C, pressure 100 Pa for 24 h. Finally, the purified lactide was collected in the receptacle.

Analytical method

Determination of the yield of lactide produced was evaluated by dry weight according to the method adopted [11, 18]. The conversion yield of obtained Lactide from the lactic acid was calculated below.

$$LactideYield = \frac{Lactide(g)}{LA(g)} \times 100\% \quad (2)$$

LA (g) = % of purity of LA ∗ LA density ∗ volume of LA taken

Results and discussion

Statistical analysis of the experimental (depolymerization) results

The obtained experimental results were calculated after the experimental works and analyzed by Design expert (v11) software. The well-fitted regression model of the depolymerization process was determined from statistical analysis of RSM. The optimization of Process parameters and lactide yield was done using RSM-BBD. Table 2 illustrates the experimental data and reports attained from the software.

Analysis of variance (ANOVA)

As revealed in Table 3, the statistical significance of each factor and their interactions in the quadratic response surface model was

Table 3 ANOVA for the suggested quadratic response surface model

Source	Sum of Squares	Df	Mean Square	F-value	p-value	
Model	215.86	9	23.98	196.82	< 0.0001	Significant
A-Temperature	43.24	1	43.24	354.88	< 0.0001	
B-Time	18.60	1	18.60	152.68	< 0.0001	
C-Catalyst Concentration	48.02	1	48.02	394.07	< 0.0001	
AB	0.7225	1	0.7225	5.93	0.0451	
AC	2.72	1	2.72	22.34	0.0021	
BC	7.02	1	7.02	57.63	0.0001	
$\mathbf{A^2}$	39.10	1	39.10	320.90	< 0.0001	
$\mathbf{B^2}$	26.26	1	26.26	215.52	< 0.0001	
$\mathbf{C^2}$	20.33	1	20.33	166.86	< 0.0001	
Residual	0.8530	7	0.1219			
Lack of Fit	0.2450	3	0.0817	0.5373	0.6815	not significant

Table 4 Fit statistics for the suggested quadratic response surface model

Std. Dev	**0.3491**	R^2	**0.9961**
Mean	75.88	**Adjusted R^2**	0.9910
C.V. %	0.4601	**Predicted R^2**	0.9775
		Adeq Precision	40.5069

confirmed by Analysis of variance (ANOVA). The **P-values** less than 0.050 indicate that the model terms are statistically significant. In this case, A, B, C, AB, AC, BC, A^2, B^2, and C^2 are significant model terms. Moreover, the **Lack of Fit F-value** of 0.54 implies the Lack of Fit is not significant relative to the pure error.

Model adequacy analysis

The adequacy of the developed model can be deduced by using the R^2 value. Hence, the correlation between the actual and the predicted responses was determined by the R^2 value. It can be seen from Table 4, the response of R^2 was 0.9961, which mentions that 99.61% of the response variability in Lactide yield can be described by the analyzed process variables. The obtained value of R^2 is very close to 1, showing the closeness between the experimental and predicted value. Thus, the model is suitable. The difference between the **predicted R^2** (0.9775) and **Adjusted R^2** (0.9910) is less than 0.2, which indicates the appropriateness of the model.

Development of a model equation by using RSM-BBD

As shown in Eq. (3), the quadratic response surface model that relates the yield of Lactide with process variables was developed. Owing to its capacity to predict the response for given levels of each factor the equation in terms of coded factors was selected for regression analysis.

$$Lactideyield(\%) = 79.52 + 2.32A + 1.52B + 2.45C - 0.425AB - 0.825AC - 1.32BC - 3.05A^2 - 2.50B^2 - 2.20C^2 \quad (3)$$

where, A: reaction temperature (^oC), B: reaction time (hr), and C: Catalyst concn(%w/w)

Generally, the negative coefficients describe that the factors negatively affect the yield of lactide, which means an increment of the factors level results in a decrement of Lactide yield and vice versa.

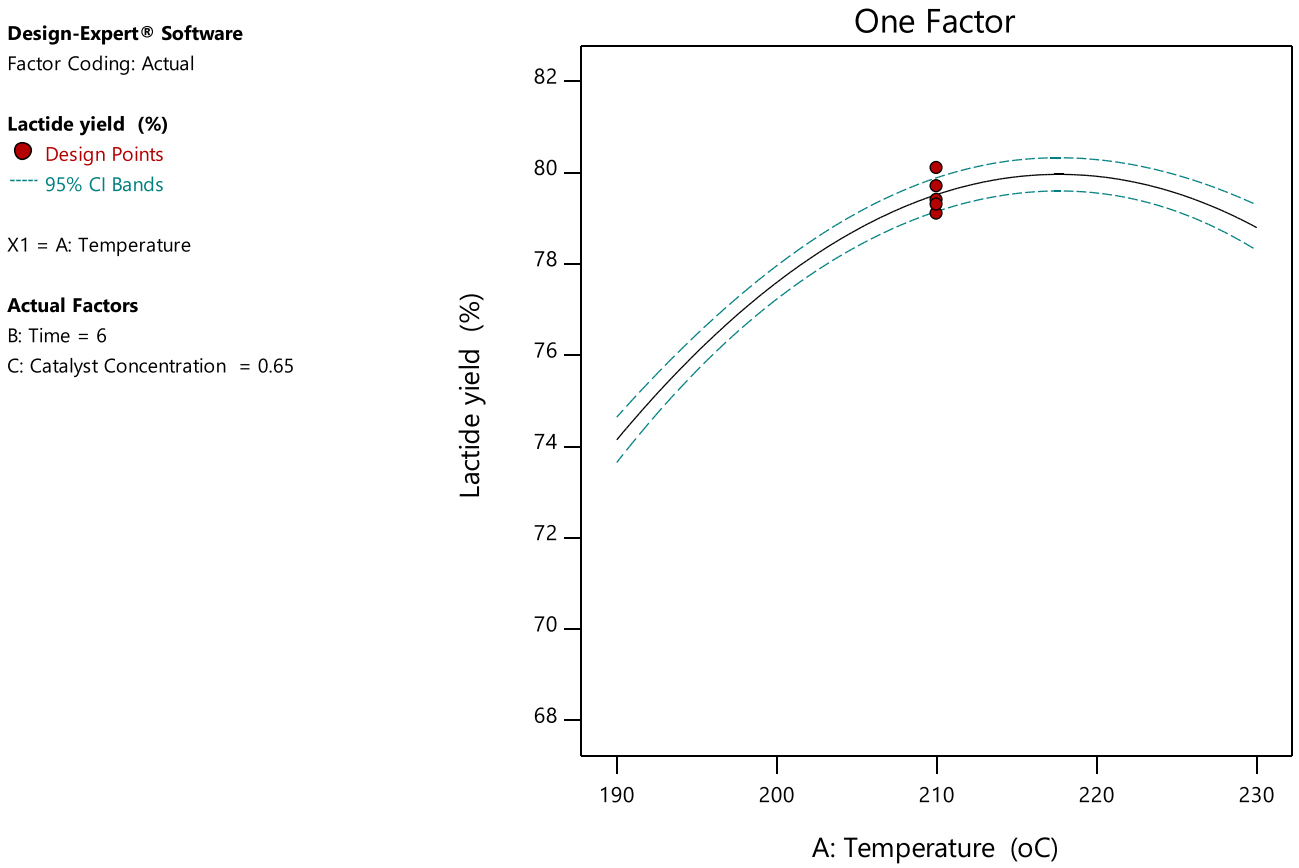

Fig. 4 Effect of reaction temperature on the yield of lactide

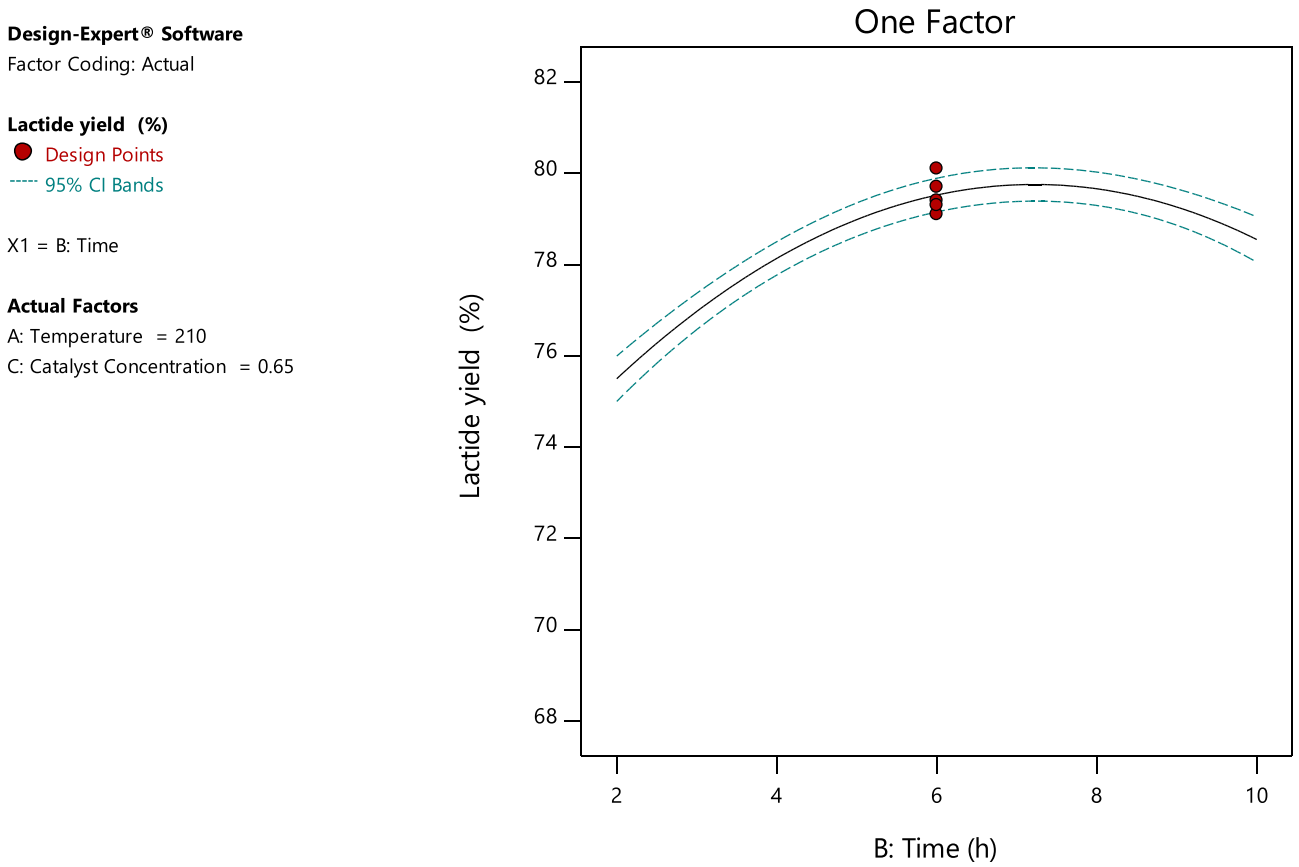

Fig. 5 Effect of reaction time on the yield of lactide

Main effects of model parameters on the lactide yield

Effect of reaction temperature

The yield of lactide obtained from oligomer PLA via thermal catalytic depolymerization reaction was found to be dependent on the reaction temperature. As revealed in Fig. 4, an increment in temperature results in an increment of lactide yield. During the first 190 °C to 195 °C of temperature, the obtained yield of lactide was low (74.5%). However, as the temperature gets increased to 215 °C, the yield was substantially increased to 80.4%. This is mainly because increasing the reaction temperatures will increase the rate of reaction. Moreover, as the reaction temperature gets increased viscosity of the reactant becomes decreased, which enhances the rate of heat and mass transfer in backbiting reaction. Furthermore, an increment in temperature increases the rate of the deprotonation process of PLA oligomer, which favors the formation of a dimer [1, 10]. The rate of depolymerizing oligomer PLA was facilitated with a progressive increment of reaction temperature. Thus, this condition favors the formation of a cyclic dimer of lactide by breaking down the long chain of PLA. However, as temperature goes beyond this level, especially > 220 °C, the deprotonation process leads to the racemization of lactide, which yields optically inactivity lactide. Correspondingly, Gozan et al. [10] observed the same effects of temperature on oligomer PLA depolymerization, which is an increment of temperature increased the concentration of lactide. However, they reported 77.8% of lactide was produced at the optimum temperature of 220 °C using 0.45% of Zin acetate catalyst, which is below the outcome of this work (i.e. 80% at 215^{O}C). The improvement of the lactide yield at low temperatures via the ZnO nanoparticle dispersion catalyst is because of an enhancement of depolymeration reaction. This shows that the currently utilized catalyst has a good capacity to achieve the good depolymerization reaction at a lower temperature compared with the classical one.

Effect of reaction time

Reaction time is another major factor, which affects the yield of lactide obtained from oligomer PLA via the thermal catalytic depolymerization reaction. As evident from Fig. 5, there is a synergetic effect of time with the yield of lactide. It is

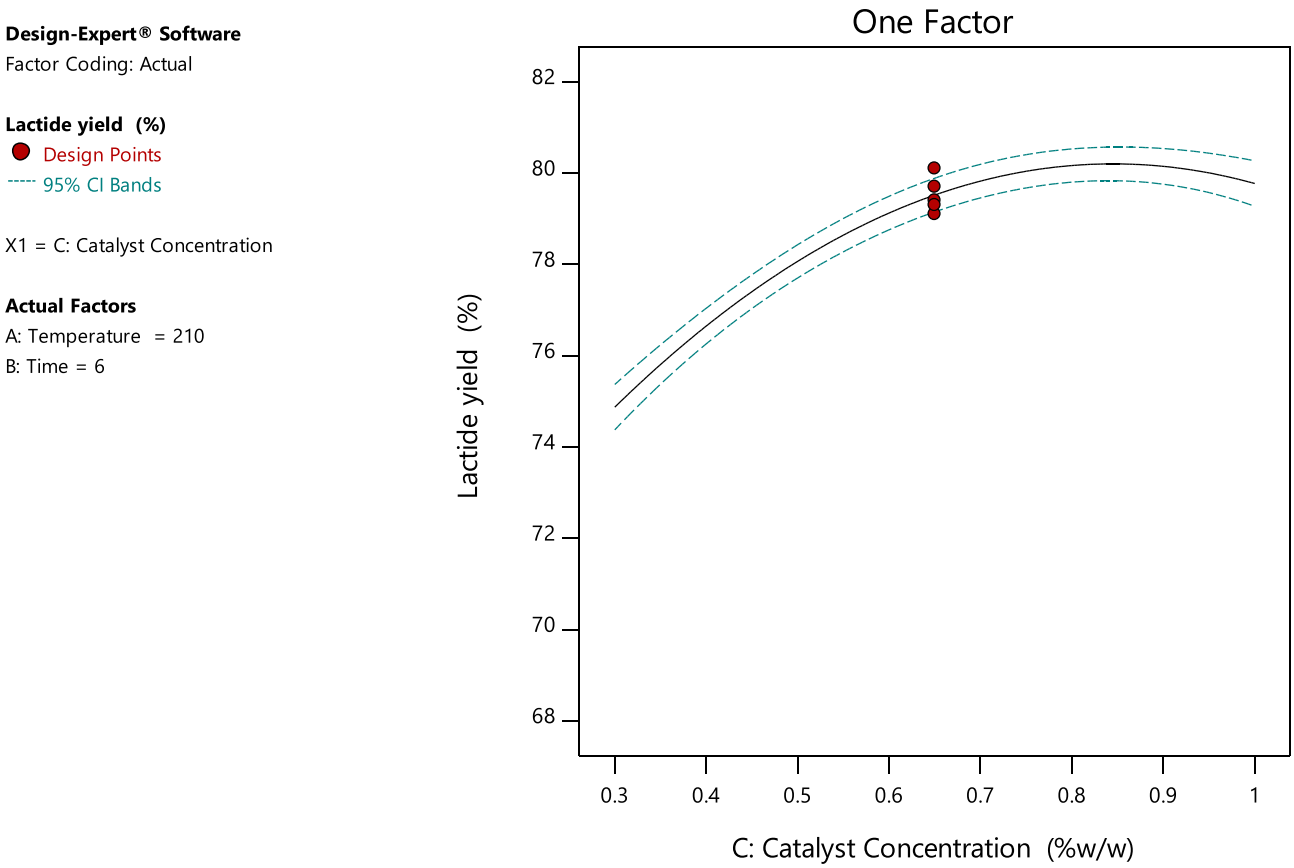

Fig. 6 Effect of catalyst concentration on the yield of lactide

observed that, as reaction time gets increased from 2 h to 7.3 h, there is a substantial increment of lactide yield from 75 5 to 80.4%. The reason behind this outcome is, it is clear that oligomer PLA depolymerization using the metal-ion-catalyzed system is a reversible reaction. Hence, there are two main opposing equilibrium reactions such as depolymerization (backbiting reaction) and polymerization [11, 20]. Accordingly, for the first 7.3 h, the condition favors the backbiting reaction and yields lactide. Besides, as reaction time gets increased the catalyst (ZnONps dispersion) is properly distributed throughout the reaction medium and enhances the conversion efficiency of oligomer PLA into lactide dimer. However, Hu et al. [11] observed that utilization of 0.6%w tin-based catalyst $Sn(Oct)_2$ yields 80% of lactide after a reaction time of 10.5 h. Additionally, they reported that utilization of 0.6%w TiO_2 nano powder produces 84% of lactide after 11 h. This indicates that utilizing ZnO nanoparticle dispersion significantly improves the rate of Depolymerization reaction. However, as the reaction progressed beyond that, the condition favors the polymerization and yielded linear/cyclic oligomers of PLA. Concordantly, Hu et al. [11] observed that 8 h is sufficient time for the depolymerization of oligomer PLA for lactide synthesis by using ZnO Nps catalyst.

Effect of catalyst concentration

In addition to the above factors, catalytic weight was another major factor by which the yield of lactide obtained from the depolymerization reaction was affected. It can be seen in Fig. 6, an increment of catalyst concentration to 0.7%w/w results in an increment of lactide yield to 80.4%. This is mainly because of increasing the catalyst loading results in a remarkable increment of the surface area of contact between the oligomer PLA and catalyst [1, 10].

The interaction effect of model parameters on lactic acid yield

Effect of reaction temperature and time

The interactive effect of reaction temperature and time on the yield of lactide was shown on the 3D surface plot in Fig. 7. As it was discussed in the above sections, irrespective of reaction time, reaction temperature has synergetic effects on the yield of lactide. An analogous result was mentioned for reaction time. Nevertheless, as it is observed in Fig. 4, upon their interaction, they have a

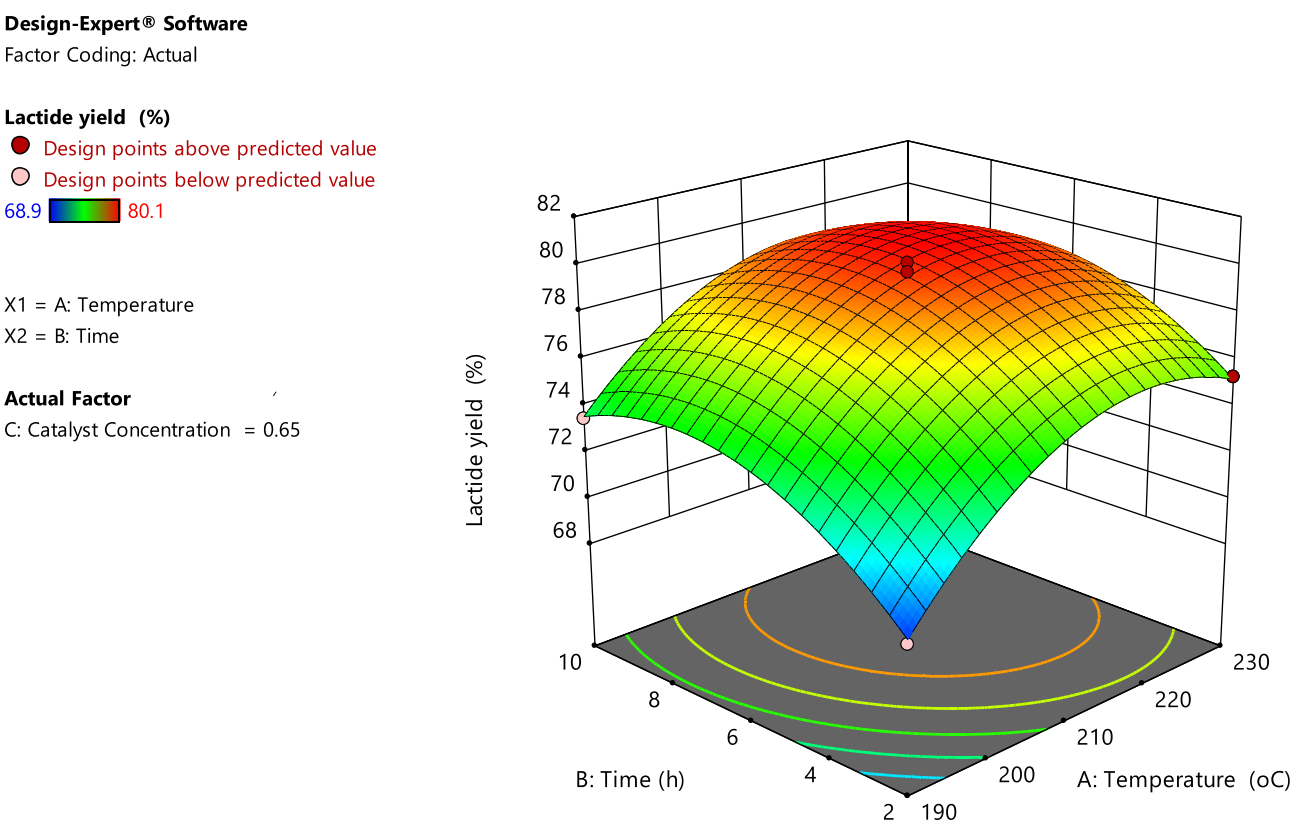

Fig. 7 the interaction effects of reaction temperature and time on the yield of lactide.

negative effect on lactide yield. The concurrent increment of reaction temperature and time results in a slight increment of lactide yield and then decreased substantially. This result might be because of reactions at these conditions favors the polymerization rate than the depolymerization. This enhances the rate of inter-molecular reactions (i.e. a hydroxyl group of oligomer PLA attacked with the positively charged carbonyl carbon in the different molecules of oligomer PLA), which results the formation of linear/cyclic oligomer along with different impurities. Accordingly, the yield of lactide was decreased.

Effect of temperature and catalyst concentration

As depicted in the 3D surface plot of Fig. 8, it can be seen that the interaction effect of reaction temperature and catalyst concentration was found to be significant. As it is shown in Fig. 5, upon their interaction, they have a negative effect on the yield of lactide. The simultaneous increment of reaction temperature and catalyst concentration results in a slight increment of lactide yield and then decreased significantly. The reason behind this result is a reaction at high temperature along with high catalyst concentration favors the polymerization rate than the Depolymerization. Hence, the reaction reverses in a backward direction to form linear/cyclic oligomer along with different impurities. Hence, the yield of lactide was decreased.

Effect of time and catalyst concentration

The interaction effect of reaction time and catalyst concentration was investigated. As revealed in Fig. 9, upon their interaction, reaction time and catalyst concentration have a negative effect on lactide yield. At a low level of reaction time, an increment of lactide yield was observed with increasing catalyst weight and vice versa. However, the instantaneous increment of reaction time and catalyst concentration results in a considerable decrement in lactide yield. The reason behind this outcome is, as the reaction takes place with a high concentration of catalyst for a long period, the rate of racemization was enhanced and the compositions of impurities were gets increased. Moreover, owing to reactions at these conditions retards the intra-molecular reaction of depolymerization, the rate of inter-molecular reactions, which results in the formation of oligomer PLA was enhanced. Consequently, the molecular weight of the residual oligomer PLA was increased. Therefore, since it is difficult to break the chain of such oligomers for lactide synthesis via a backbiting reaction, the yield of lactide was significantly decreased. In support with this, Hu et al. [11] stated that depolymerization

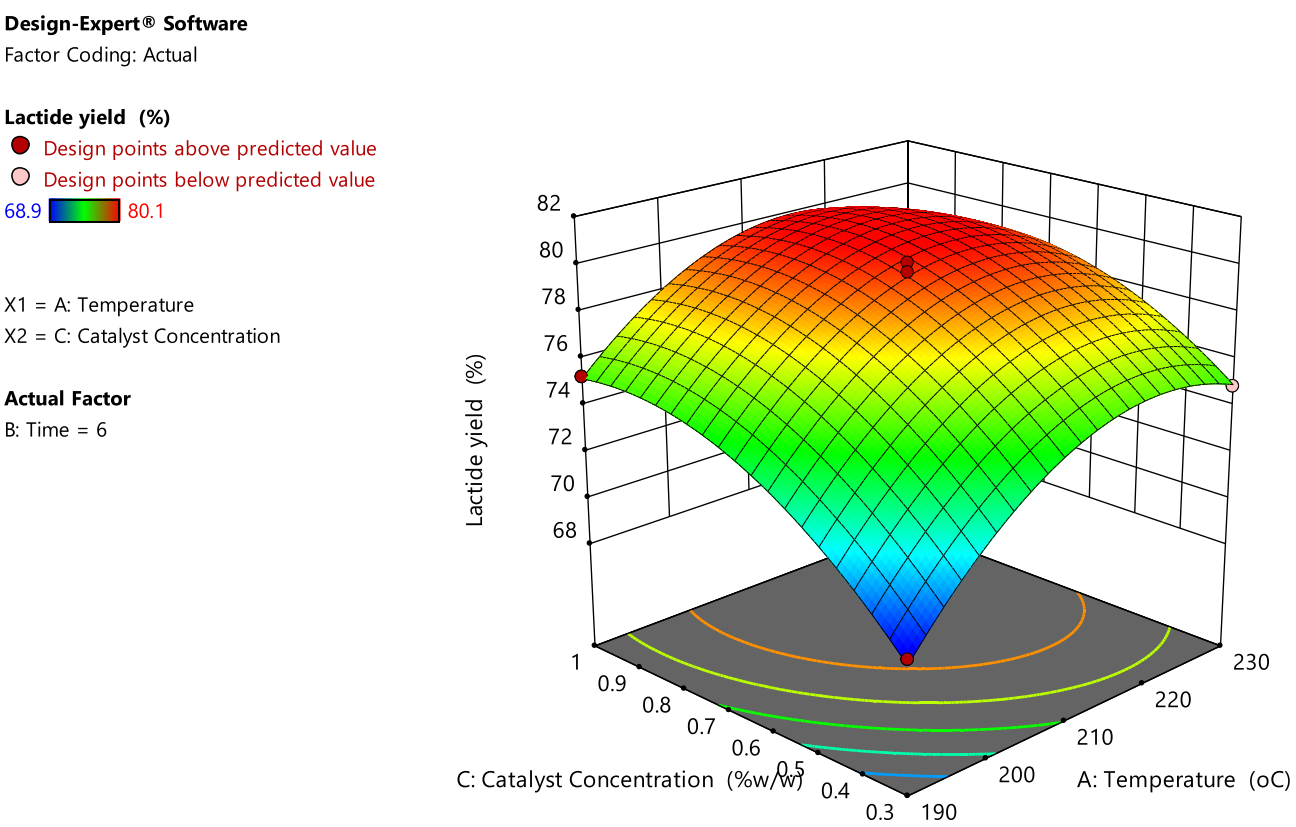

Fig. 8 the interaction effects of reaction temperature and catalyst concn on the yield of lactide.

of PLA oligomer with molecular weight beyond the range of (600–2500) g mol^{-1} is difficult to form a dimer.

Numerical optimization of lactide yield

The target of the current study is to optimize the depolymerization reaction conditions to get the maximum yields of lactide. Accordingly, the optimum condition for the specified independent process variables (depolymerization reaction parameters) was determined by using design-expert software (i.e., numerical optimization feature). Generally, about 100 possible optimal solutions had been generated. Nevertheless, as revealed in Table 5, the best solution was selected. These include reaction temperature (215.7 °C), reaction time (7.3 h), catalyst concentration (0.7%w/w), and lactide yield (80.4%). The highest composite desirability of 1.0 at optimum conditions was obtained, which indicates the degree of satisfaction of the optimum conditions for the ultimate goal of response was successfully attained.

Validation of the model

To increase our confidence, validating the developed model is indispensable. Accordingly, additional experimental works under optimum conditions were done with three replications. The result obtained from the experiment ($79.65 \pm 0.27\%$) is very close to the result obtained from the model (80.40%) used by design-expert software. Hence, we assured that the model has a good capacity to predict the response.

FTIR data analysis

Fourier Transform Infrared (FTIR) Spectroscopy (Perkins Elmer L1600300) was used to determine the functional group of synthesized lactide. As depicted in Fig. 10, the result from the FTIR spectrum showed that there were different functional groups present in the lactide product. The spectra of the sample showed transmittance peaks at 935 cm^{-1}, 1055 cm^{-1}, 1098 cm^{-1}, 1287 cm^{-1}, and 1755 cm^{-1}. The peak observed at 935 cm^{-1} is attributed to the ester group C-COO stretching, whereas the 1055 cm^{-1} is attributed to COO ring deformation. The peak observed at 1098 cm^{-1} is related to the C–C stretching and C = O stretching. Moreover, the peak observed at 1287 cm^{-1} is contributed to the CH_2 and CH wagging. Furthermore, the peak observed at 1755 cm^{-1} generally represents asymmetric CH_3 deformation. These results were in smooth agreement with previous findings reported by [14, 21].

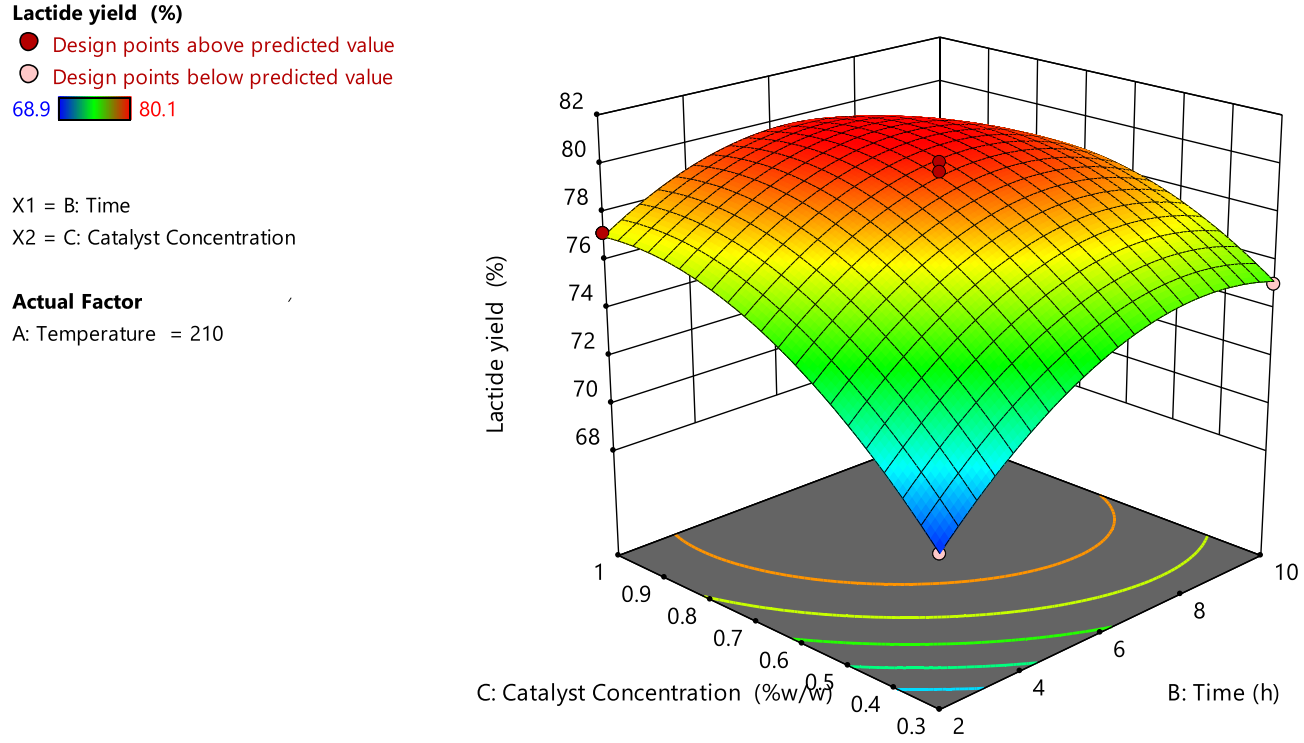

Figure 9 the interaction effects of reaction time and catalyst concn on the yield of lactide.

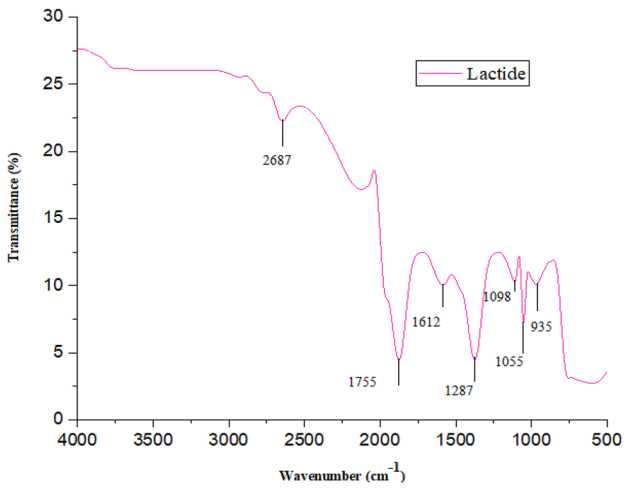

Fig. 10 FTIR Spectra of the synthesized lactide

Conclusions

In the present study, lactide was synthesized from oligomer PLA via thermal catalytic depolymerization by using ZnO nanoparticle dispersion. The proposed catalyst (i.e. ZnO Nps dispersion) efficiently produced the lactide. The optimum conditions for Depolymerization reactions were successfully attained. The effects of three major factors including reaction temperature, reaction time, and catalyst concentration on the yield of lactide were investigated. The optimization of lactide yield and depolymerization reaction parameters was done via response surface methodology with a Box-Behnken design. Based on the analysis, the optimum conditions were found to be a reaction temperature of 215.73 °C, a reaction time of 7.32 h, and a catalyst concentration of 0.72%w/w along with the maximum lactide yield of 80.4%. The experimental

Table 5 the optimum conditions selected by RSM-BBD.

Number	Temperature	Time	Catalyst Concentration	Lactide yield	Desirability	
1	**215.752**	**7.319**	**0.723**	**80.403**	**1.000**	**Selected**

yield of lactide (79.65 ± 0.27%) is very close to the result obtained from the model (80.40%), indicating the suitability of the quadratic model used. The ANOVA of the developed model confirmed that all parameters significantly affected the lactide yield. Generally, the outcome of the study reveals that the utilization of ZnO nanoparticle dispersions as a catalyst for lactide synthesis from oligomer PLAvia thermal catalytic Depolymerization is worthful.

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Declarations

Conflict of interest I confirm that I have read, understand, and agreed to the submission guidelines, policies, and submission declaration of the journal. I confirm that all authors of the manuscript have no conflict of interests to declare. I confirm that the manuscript is the authors' original work and the manuscript has not received prior publication and is not under consideration for publication elsewhere. On behalf of all Co-Authors, I shall bear full responsibility for the submission. I confirm that all authors listed on the title page have contributed significantly to the work, have read the manuscript, attest to the validity and legitimacy of the data and its interpretation, and agree to its submission. I confirm that the paper now submitted is not copied or plagiarized version of some other published work. I declare that I shall not submit the paper for publication in any other Journal or Magazine till the decision is made by journal editors. If the paper is finally accepted by the journal for publication, I confirm that I will either publish the paper immediately or withdraw it according to withdrawal policies. I understand that submission of false or incorrect information/undertaking would invite appropriate penal actions as per norms/rules of the journal and UGC guidelines.

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