New Kinetic Modeling Parameters for Composting Process Applied to Composting of Chicken Manure

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Composting

- Composting has been defined as a controlled microbial aerobic decomposition process with the formation of stabilized organic materials that may be used as soil conditioners and/or organic fertilizer and growing media.

Kinetic Models

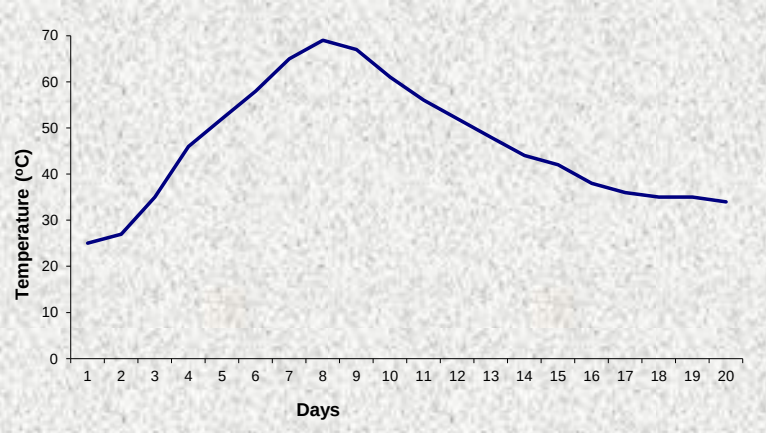
- Kinetic model can be used as a tool to study composting process on an industrial scale for the optimization of the process. The degradation rate of waste can be predicted using kinetic models of the process indicators (temperature, organic matter content, moisture content, O_2/CO_2 concentration, pH, C/N ratio, particle size, etc.)

Aim of the Study

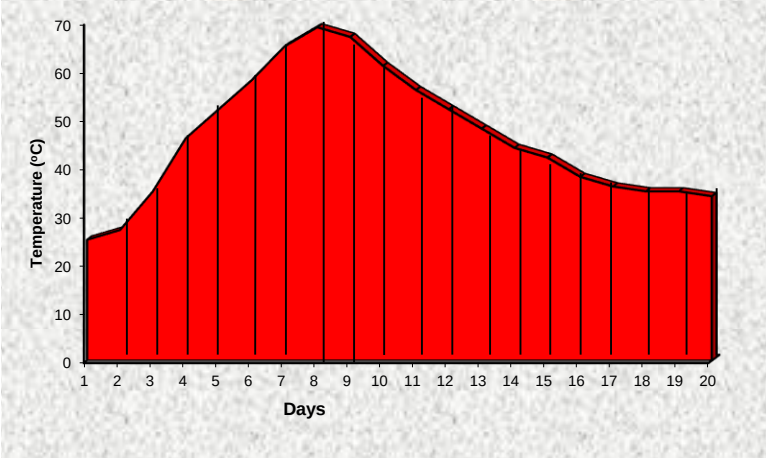
- This study aimed to evaluate the applicability of the area lying below the process temperature as a function of time a **(ALT)** and an area lying between ambient and process temperature as a function of time β **(ALAT)** as kinetic parameters to increase the predictivity of kinetic models for modeling of decomposition rate.
- Determine the optimum mixture ratio of chicken manure, sawdust and wheat straw.

α (ALT)

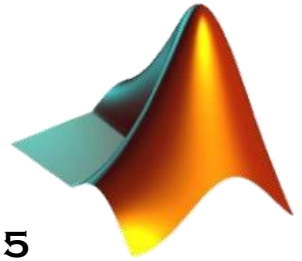
(the area lying below the process temperature)



→ Average temperature



→ a (ALT)

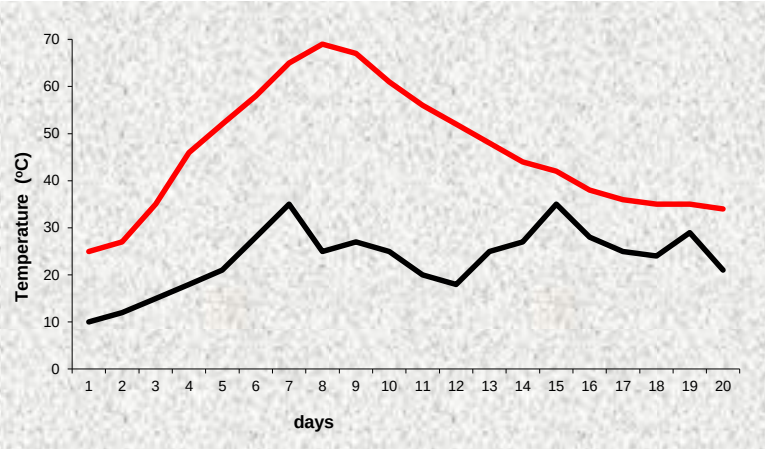


MATHLAB 6.5

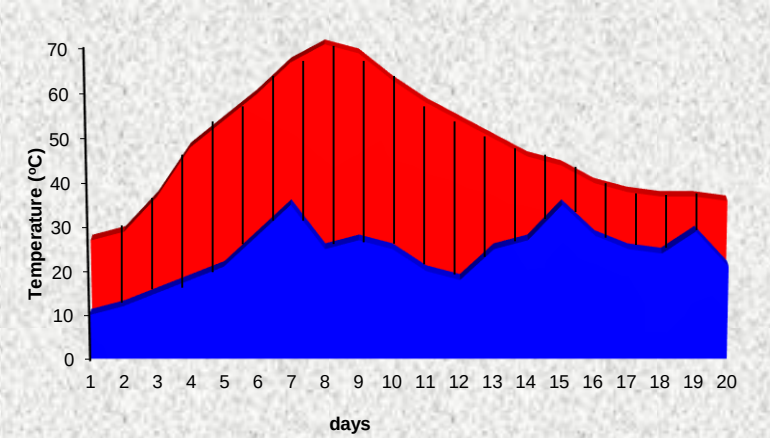
TRAPEZODIAL NUMERICAL INTEGRATION

β (ALAT)

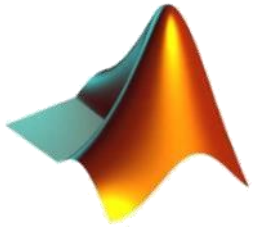
(an area lying between ambient and process temperature)



→ Compost and ambient temperatures



→ β (ALAT)



MATHLAB 6.5

TRAPEZODIAL NUMERICAL INTEGRATION

Materials and Methods

- Chicken manure, wheat straw and sawdust were used as experimental materials.

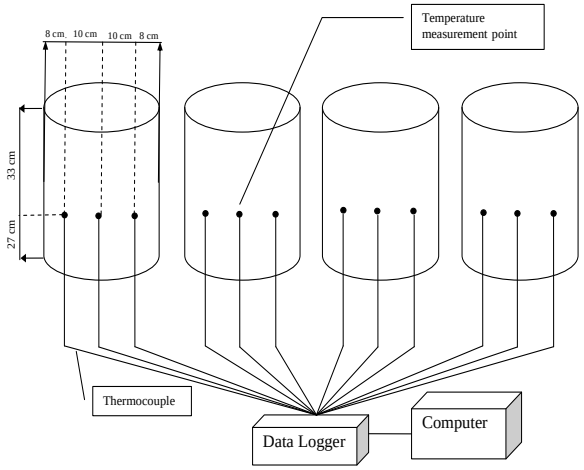
	Moisture Content (%w.b.)	Organic Material (OM)(%)	N (%)	C (%)	C/N
Sawdust	3.81	76.06	0.24	42.25	176.04
Wheat Straw	16.11	84.11	0.51	46.72	91.60
Chicken Manure	60.24	51.13	2.01	28.40	14.13

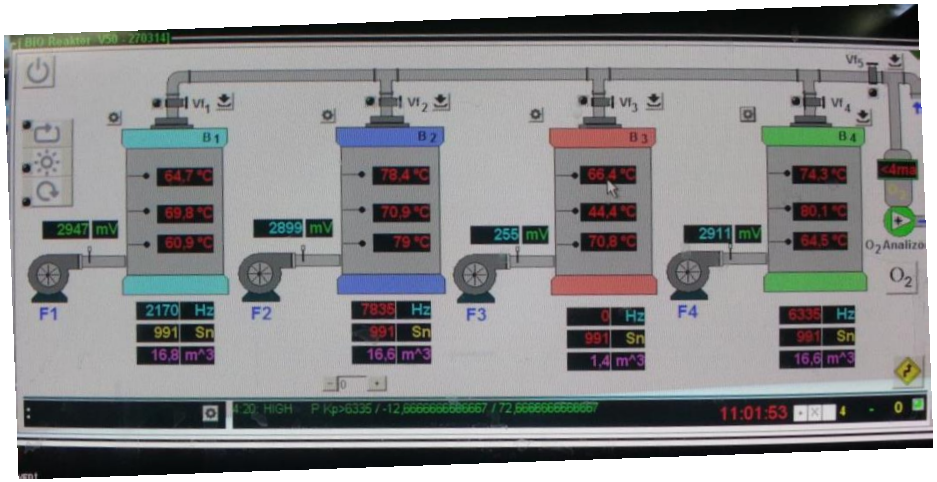
Mixing equipment

Analysis Equipments

Gas Analyzer

Experimental composting reactors





Mixtures

- Chicken manure, wheat straw, and sawdust were mixed at four different ratios to determine optimum mixture ratio. C/N ratios and Free Air Spaces (FAS) of each mixtures were different due to their physical and chemical properties.

Reactor No	Chicken Manure (%)	Wheat Straw (%)	Sawdust (%)	C/N	Free Air Space (FAS) (%)
Reactor 1	50	10	40	33.72	32.12
Reactor 2	70	10	20	25.14	28.21
Reactor 3	55	20	25	32.24	39.06
Reactor 4	60	10	30	27.11	30.13

Kinetics of Composting

To determine biodegradability of waste and generate a useful measure for the loss of organic matter during composting, it is necessary to determine process kinetics using data obtained by experimental study under controlled conditions. The degradation of organic matter as a function of time follows first-order kinetics were calculated according to the following equation

$$\frac{d(OM)}{dt} = -k(OM)$$

where OM is the quantity of biodegradable volatile solids at any time of the composting process in kg, t is time in days, k is the reaction rate constant.

Kinetic Models used in the study

- The three different kinetic models were applied for modeling decomposition rate to the experimental values. Three different kinetic parameters, which were average of daily process temperature (T), a (ALT) and β (ALAT), were used in these models as temperature function.

$$k = k_{\min} . a^{(T - \min)}$$

Haug (1993)

$$k = a . e^{b.\left[\left(\frac{M_i - c}{d}\right) + \left(\frac{T - f}{g}\right)\right]}$$

Ekinci (2001)

$$k = \frac{\frac{a}{M_C}}{T - (C.b)} . e^{\left[(T.c) - \left(d x . \frac{M_c}{T}\right)\right]}$$

Külcü and Yaldiz (2004)

Statistical Parameters

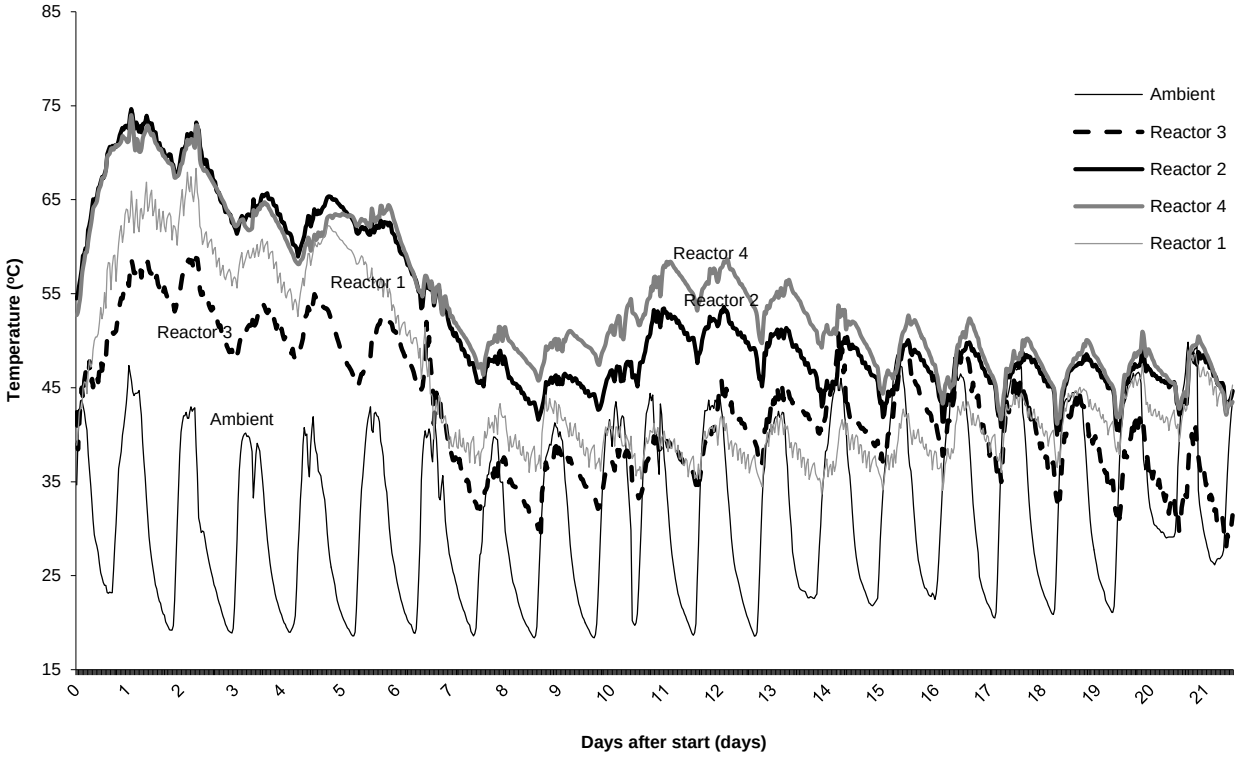
- The suitability of the models was compared and evaluated using Chi-square (χ^2), root mean square error (RMSE) and modeling efficiency (EF);

$$\chi^2 = \frac{\sum_{i=1}^{N}\left(k_{\exp,i} - k_{pre,i}\right)^2}{N-n}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}\left(k_{pre,i} - k_{\exp,i}\right)^2}{N}}$$

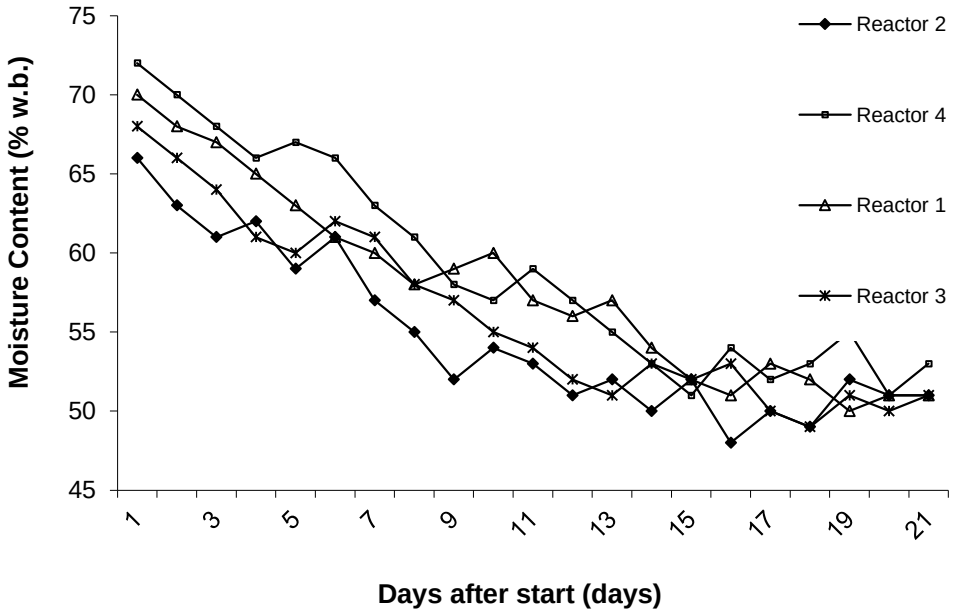
$$EF = \frac{\sum_{i=1}^{n}\left(k_{\exp,i} - k_{\exp,mean}\right)^2 - \sum_{i=1}^{n}\left(k_{pre,i} - k_{\exp,i}\right)^2}{\sum_{i=1}^{n}\left(k_{\exp,i} - k_{\exp,mean,i}\right)^2}$$

Results Temperatures



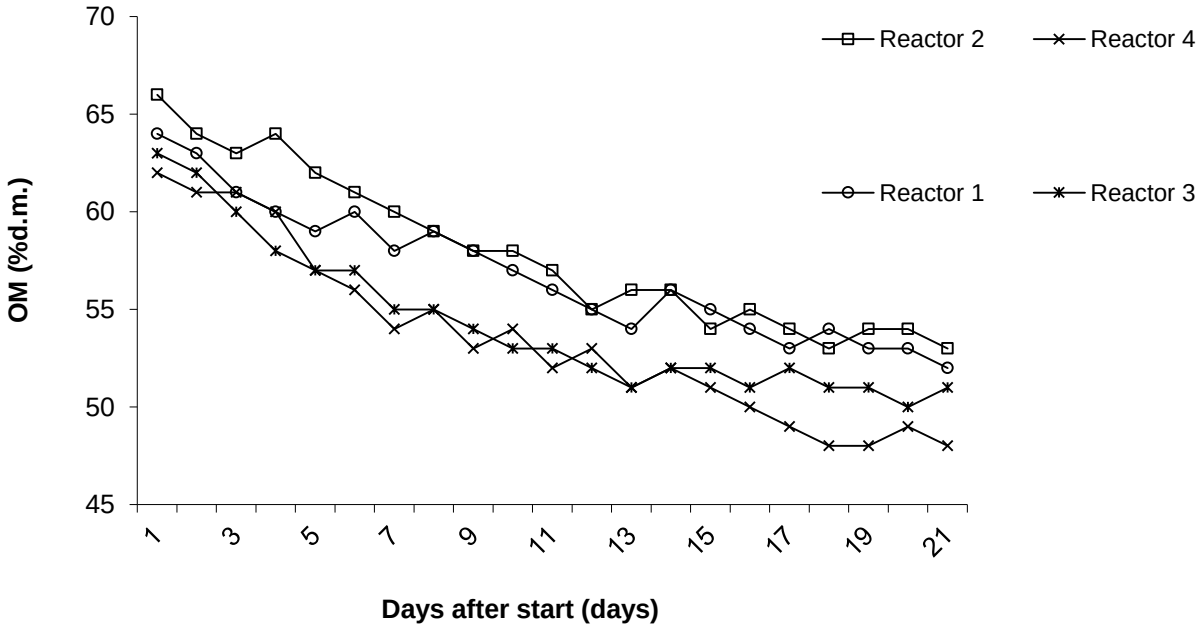
The highest temperature values were in R4 reactor during the process

Moisture Contens



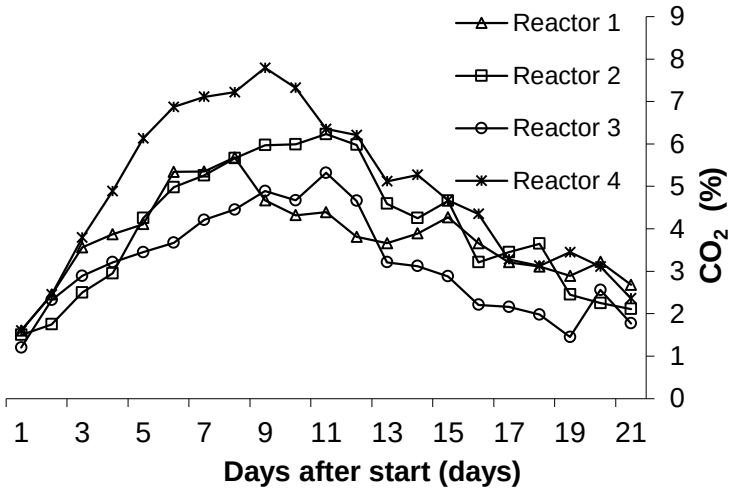
Water loss was the similar for all the composting reactors during the process

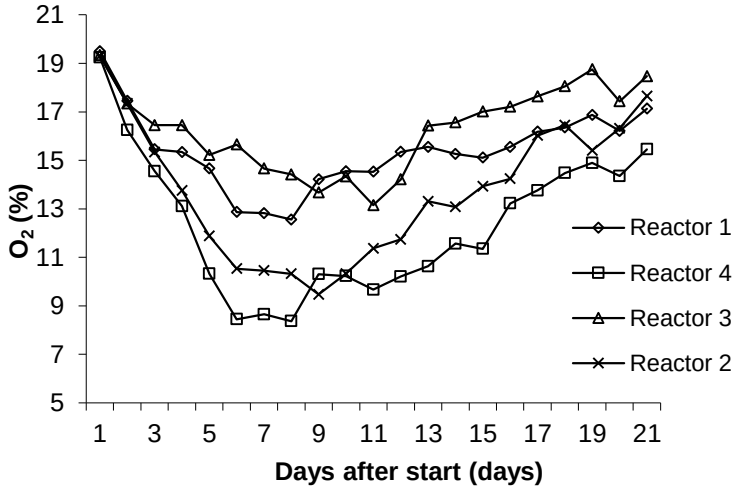
Organic Matter Contents



Organic material content of mixtures decreased gradually during the process, this decrement was faster in R4 than the others.

O_2 and CO_2


Reactor 1
Reactor 2
Reactor 3
Reactor 4
CO2 (%)
0
1
2
3
4
5
6
7
8
9
1 3 5 7 9 11 13 15 17 19 21
Days after start (days)


O2 (%)
5
7
9
11
13
15
17
19
21
1 3 5 7 9 11 13 15 17 19 21
Days after start (days)
Reactor 1
Reactor 4
Reactor 3
Reactor 2

Organic Material Loss

	Reactor 1	Reactor 2	Reactor 3	Reactor 4
OML	39.18	41.21	38.23	43.67

Optimum Mixture

- Results showed that the highest organic matter degradation and temperature value were obtained in the R4. Thus, chicken manure of 60%, sawdust of 30% and wheat straw of 10% on dry basis mixture ratio could be applied for composting process.

Results of statistical analysis (RMSE, χ^2,and EF) of models were given in Table 5. Statistical analyses showed that; when ALAP used as temperature parameters, RMSE and χ^2 of all the model values decreased and EF values increased.

Parameter		RMSE	χ^2	EF	a	b	c	d	f	g
	Model 1	0.0112629	0.0001335	0.5667	0.9998	-	-	-	-	-
β(ALAT)	Model 2	0.0090109	0.0000855	0.6900	-53687091.19	-14694024.83	5.3430	3846.28	5.3519	142687.39
	Model 3	0.0084559	0.0000753	0.8690	68.7383	0.0274	0.0015	-0.1093		
	Model 1	0.0115309	0.0001509	0.5376	0.9999	-	-	-	-	-
α(ALT)	Model 2	0.0151102	0.0001399	0.6587	0.0057	0.0009	1.0000	1.0005	1.00000	1.0079
	Model 3	0.0096908	0.0000988	0.7838	127.6732	6.9020	0.0020	3.5846	-	-
	Model 1	0.0119730	0.0002403	0.5236	0.9920	-	-	-	-	-
T	Model 2	0.0163148	0.0002802	0.5771	0.0298	-12.7932	46.595	21.7649	61.7676	21.4462
	Model 3	0.0096977	0.0000989	0.6295	1.3272	0.1353	0.0632	-0.1193	-	-

Kinetic Parameters

- Based on results of the statistical analysis, it can be said that all kinetic models were found to be applicable to this study but when β and a used as temperature functions, all kinetic models yielded more accurate results when comparing with the experimental values.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