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Heat Flux Predictions for a 3-D Compost Model

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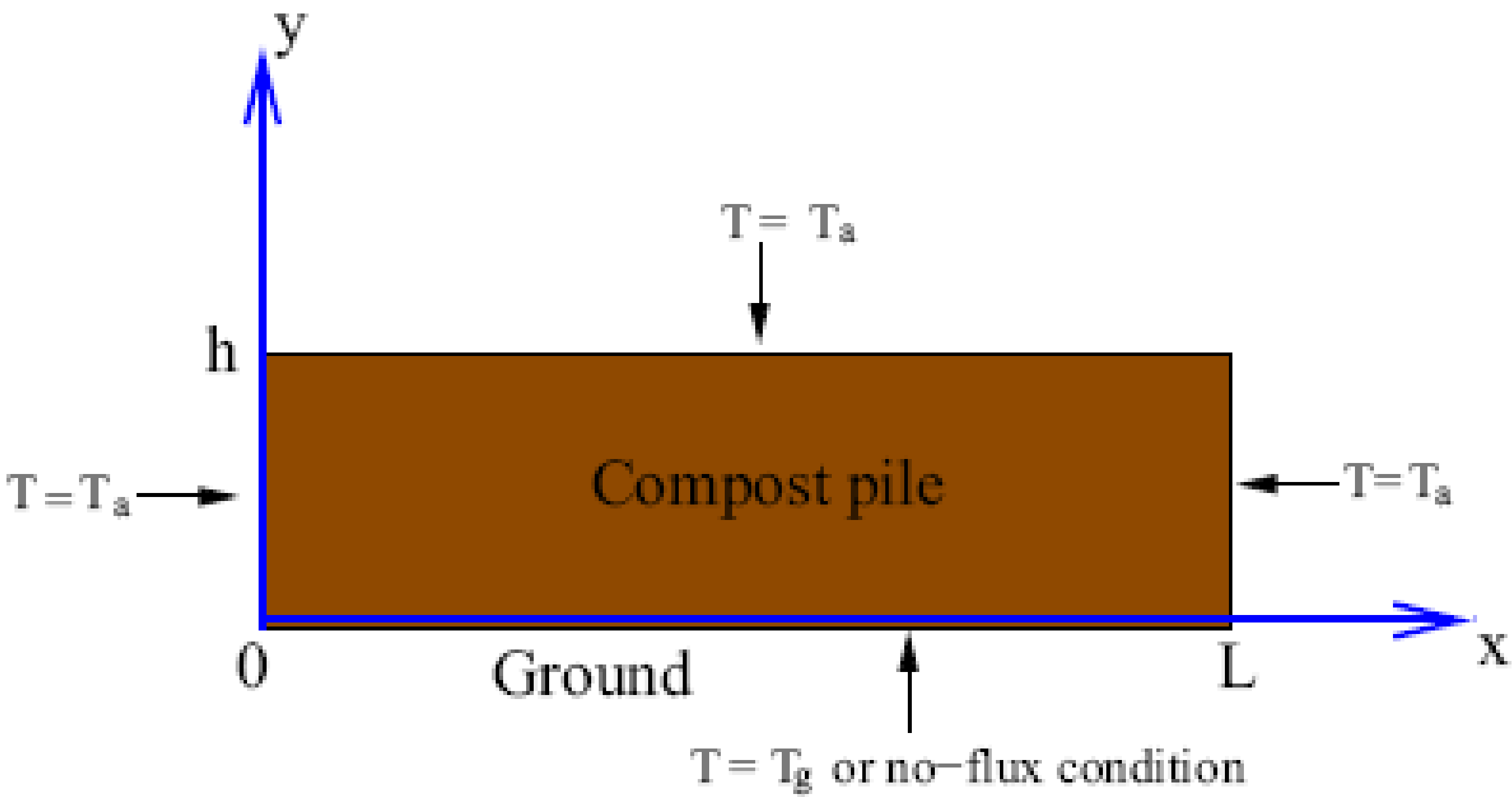
Introduction

- Biodegradation compost systems are an alternative for treatment of organic solid wastes
- Compost process allows organic matter volume reduction of materials to be disposed
- Composting produces an useful product for soil improvement
- Industrial compost piles have been matter of study and mathematical modeling,
- Some models have focused on the auto ignition phenomena, in which heating is attributed to organic matter oxidation and biological activity
- Steady state temperature predictions from these models are in the range of 350–530 K,
- Required time for reaching the steady state time goes from 26 to 31 weeks (>6 months)

Sidhu model


y
T = T_a
h
T = T_a
Compost pile
T = T_a
0
Ground
L
x
T = T_g or no−flux condition

Governing equations

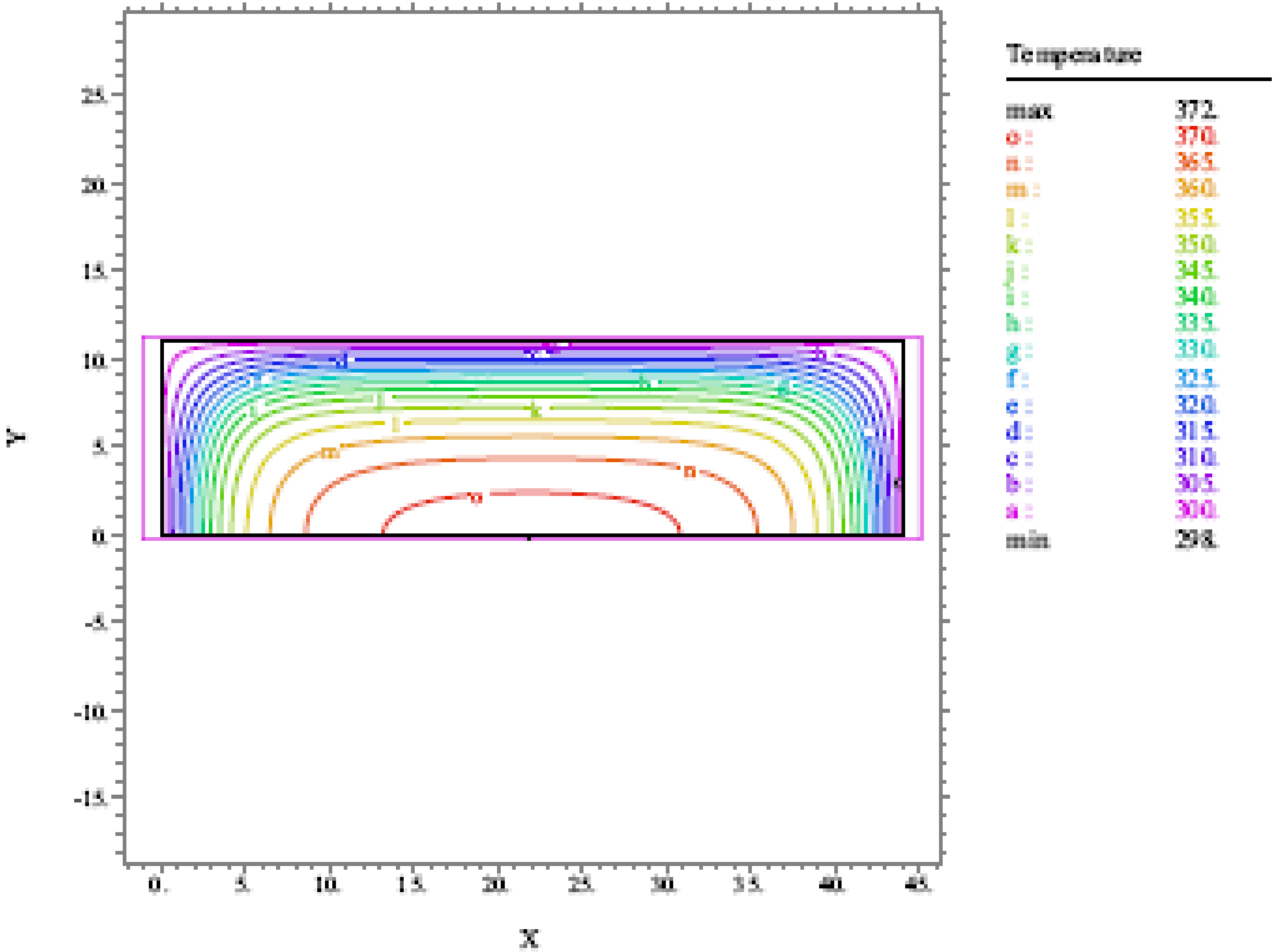
$$(\rho C)_{ef}\frac{\partial T}{\partial t} = k_{ef}\nabla^2 T + (1-\varepsilon)Q_c\rho_c A_c \exp\left[\frac{-E_c}{RT}\right] + (1-\varepsilon)Q_b\rho_b \frac{A_1\exp\left[\frac{-E_1}{RT}\right]}{1+A_2\exp\left[\frac{-E_2}{RT}\right]} \quad (1)$$

With:

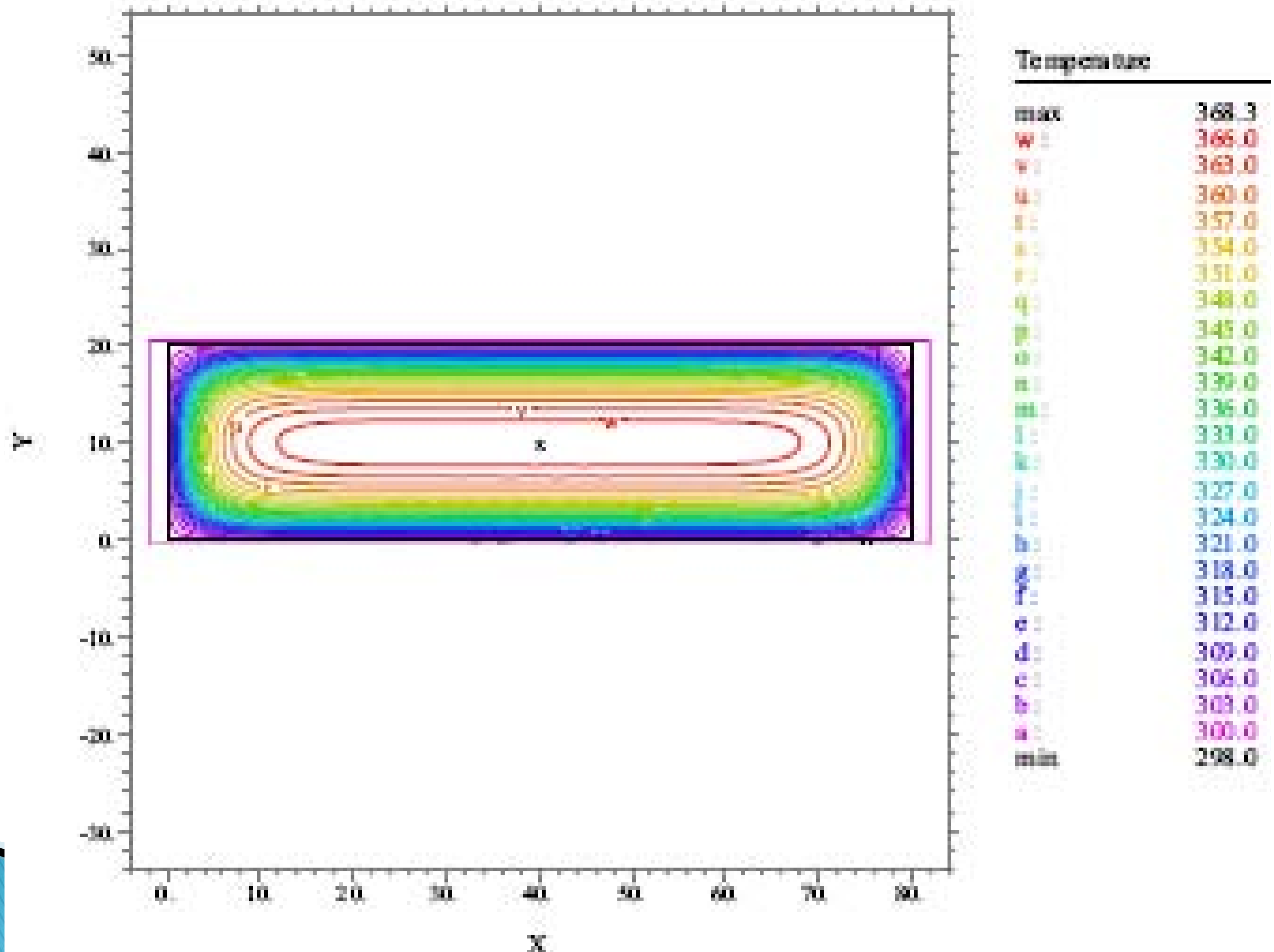
$$k_{ef} = \varepsilon k_a + (1-\varepsilon)k_c \quad (2)$$

$$(\rho C)_{ef} = \varepsilon\rho_a C_a + (1-\varepsilon)\rho_c C_c \quad (3)$$

Sidhu predictions



Sidhu predictions



Industrial scale

Observations

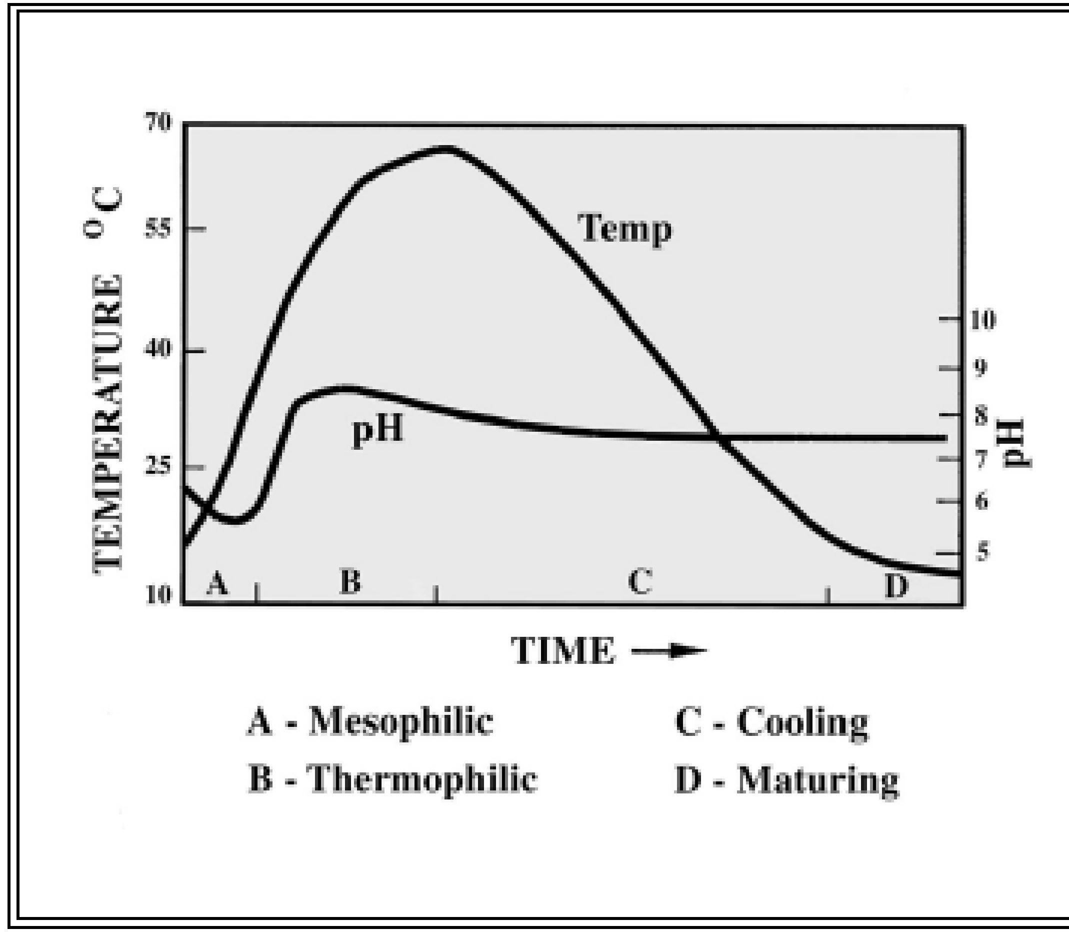
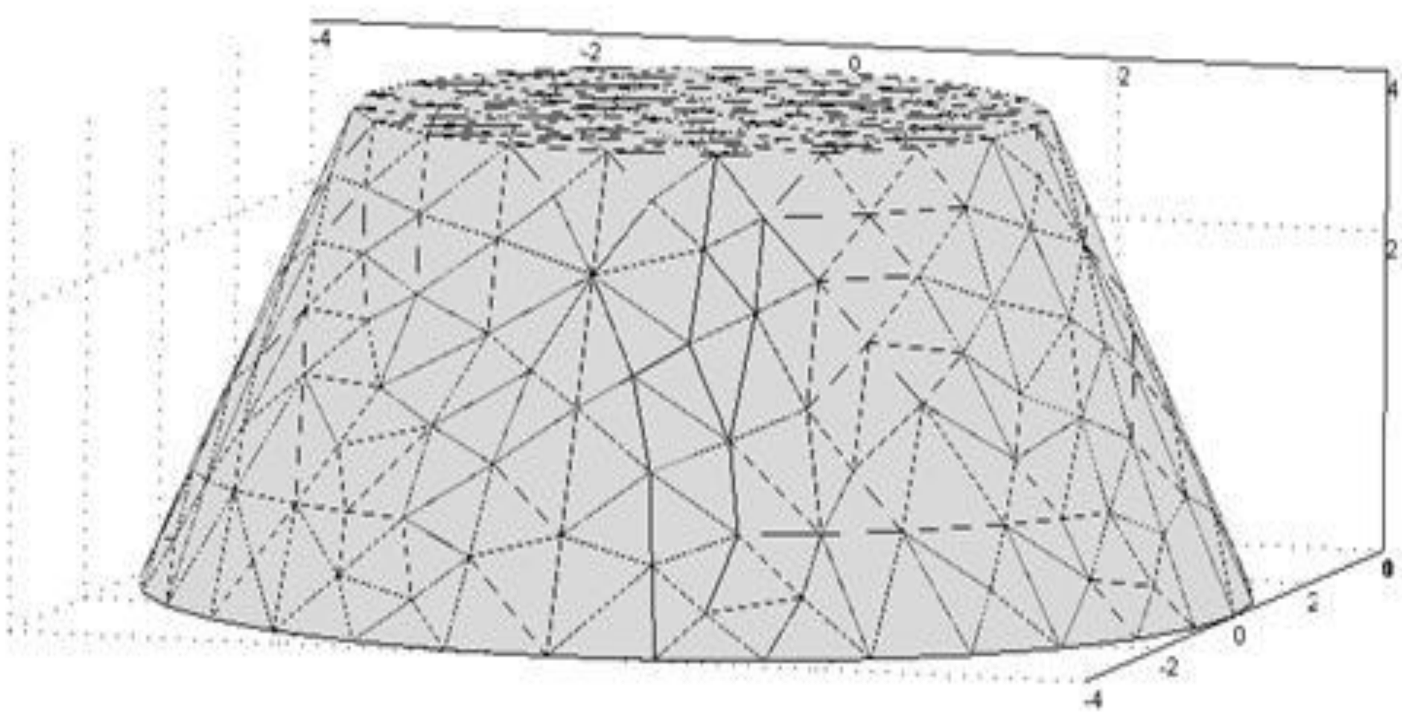


Figure 3 Compost Temperature and pH Variation with Time

Smaller scale

Geometry proposal



H= 3 m
R=4 m

Governing equations

$$(\rho C)_{ef}\frac{\partial T}{\partial t} = k_{ef}\nabla^2 T + (1-\varepsilon)Q_c\rho_c A_c \exp\left[\frac{-E_c}{RT}\right] + (1-\varepsilon)Q_b\rho_b \frac{A_1\exp\left[\frac{-E_1}{RT}\right]}{1+A_2\exp\left[\frac{-E_2}{RT}\right]} \quad (1)$$

With:

$$k_{ef} = \varepsilon k_a + (1-\varepsilon)k_c \quad (2)$$

$$(\rho C)_{ef} = \varepsilon\rho_a C_a + (1-\varepsilon)\rho_c C_c \quad (3)$$

Modified parameters

	Old value	Ref	New value	Ref	Modif
A_1	$2x10^6$ s^{-1}	3,4, 6	$1x10^6$ s^{-1}	---	-50%
ε	0.3	3,4, 6	0.34	12	+13%
E_1	$1x10^5$ J(biomass mol)$^{-1}$	3,4, 6	$8.4x10^4$ J(biomass mol)$^{-1}$	7	-16%
E_2	$2x10^5$ J(biomass mol)$^{-1}$	3,4, 6	$2.5x10^5$ J(biomass mol)$^{-1}$	7	+25%
ρ_b	575 kgm^{-3}	3,4, 6	546 kgm^{-3}		-5%
Q_b	$6.66x10^6$ Jkg^{-1}	3,4, 6	$6.327x10^6$ Jkg^{-1}		-5%

Predictions

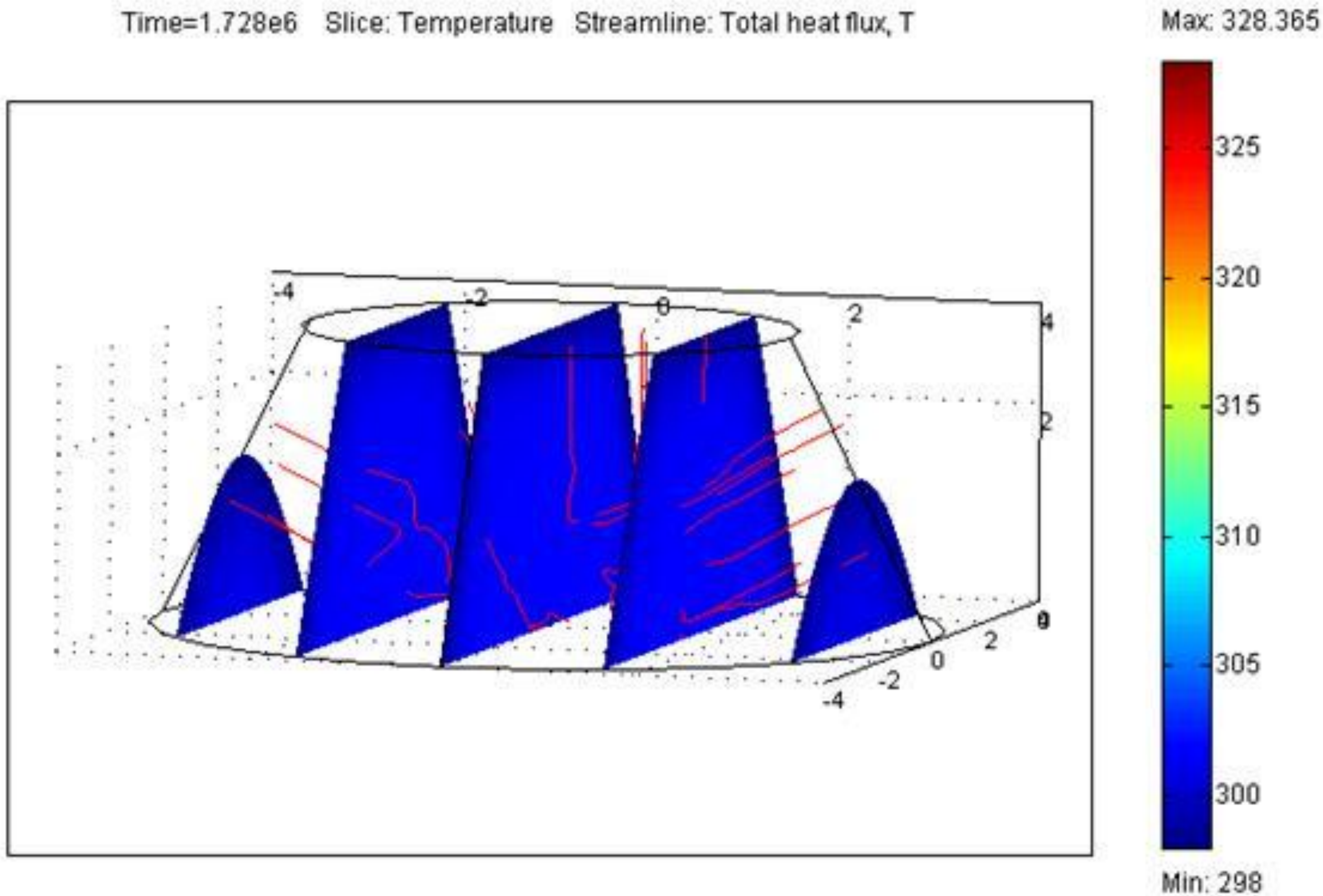


Figure 1. Temperature and heat flux predictions for a 20 days period of composting process

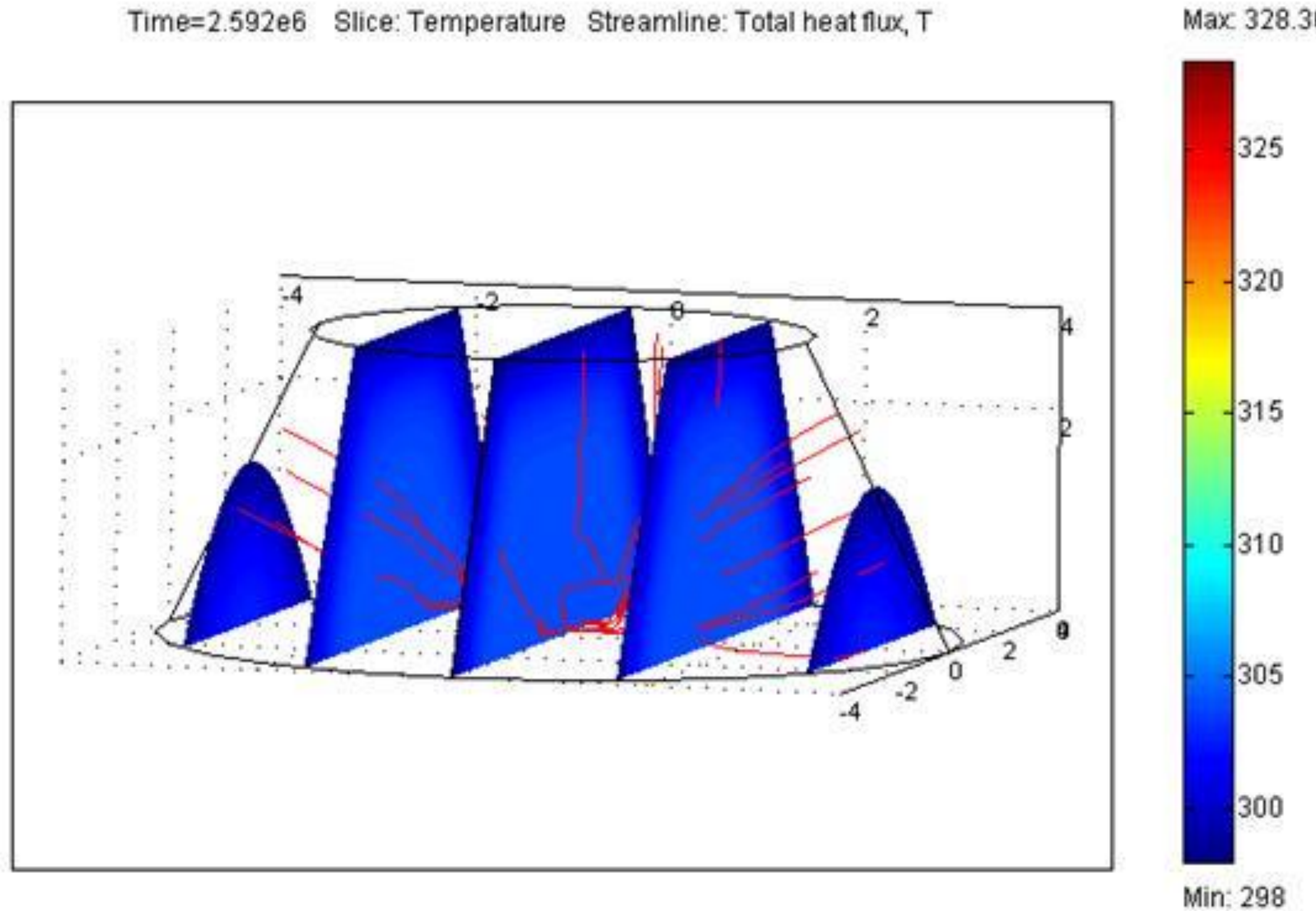


Figure 2. Temperature and heat flux predictions for a 30 days period of composting process

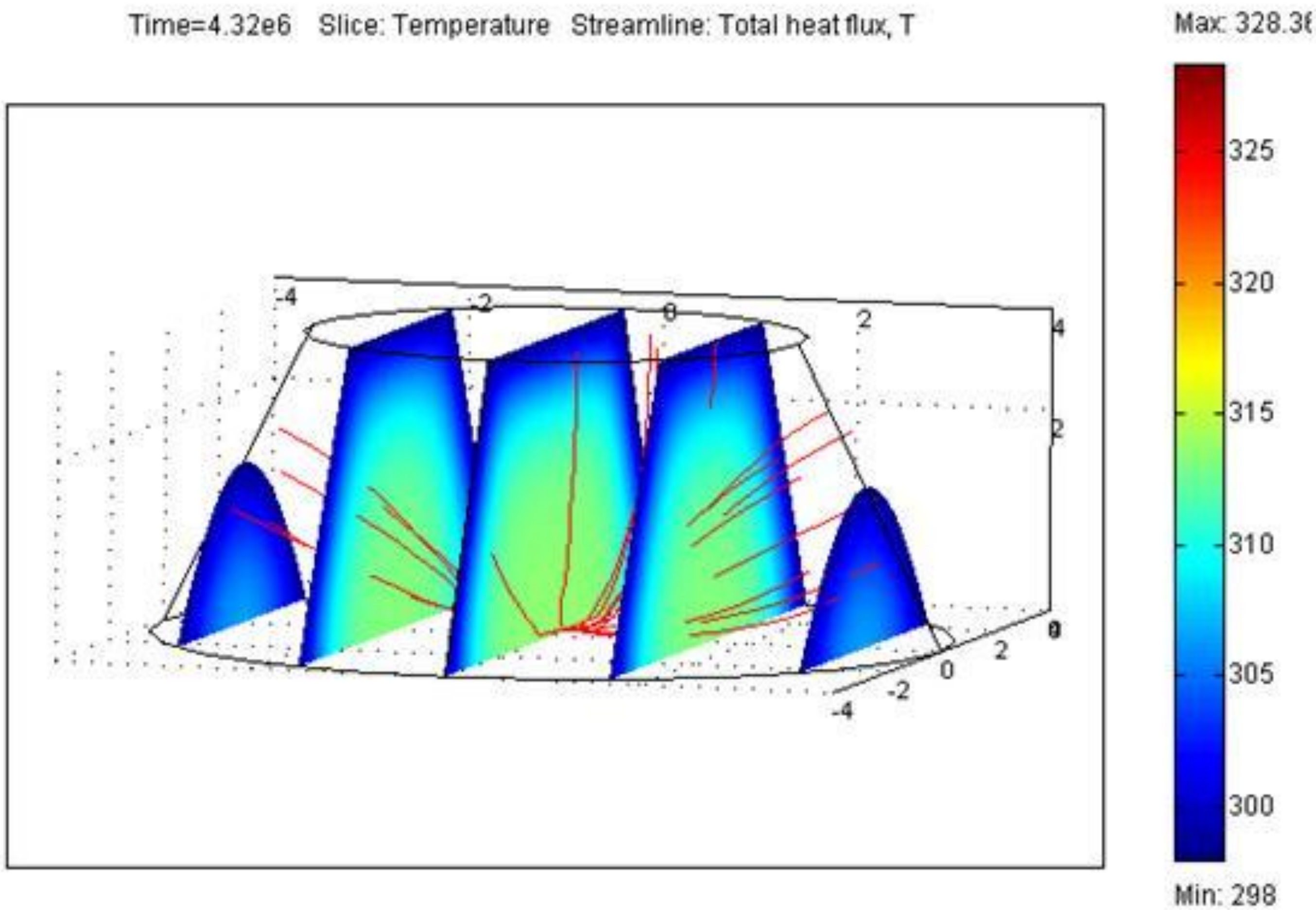


Figure 3. Temperature and heat flux predictions for a 50 days period of composting process

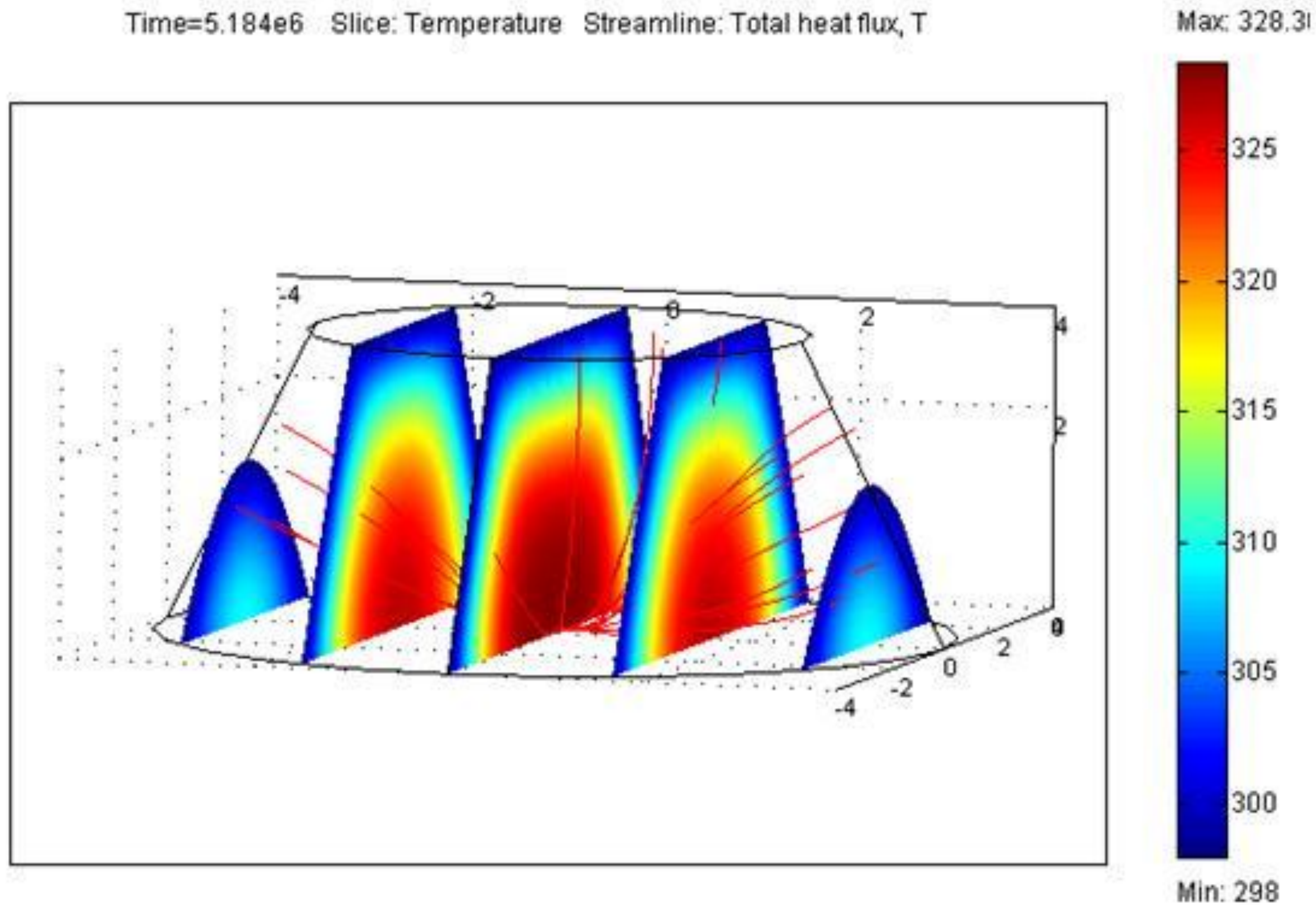


Figure 4. Temperature and heat flux predictions for a 60 days period of composting process

Conclusions

- Modeling approach has produced satisfactory predictions similar to those observed in conventional compost systems.
- In order to best reflect the real conditions in a composting system, models must should include variables like:
  - Oxygen
  - Water content
  - pH
  - Volume change

References

- Sidhu, H. S., Nelson, M. I. & Chen, X. D. A simple spatial model for self-heating compost piles. *ANZIAM J*. **48** (CTA2006) pp. C135–C150, (2007).
- Sidhu, H. S., Nelson, M. I., Luangwilai, T. & Chen, X. D. Mathematical modelling of the self-heating process in compost piles. *Chemical Product and Process Modeling,* **2**, 2, Art. 8, 1–12, (2007).
- Luangwilai, T., Sidhu, H. S., Nelson, M. I. & Chen, X. D. The Semenov formulation of the biological self-heating process in compost piles. *ANZIAM J*. **51** (EMAC2009), C425–C445, (2010).
- Moraga B., N. y Zambra S., C. 3-D self-ignition in sewage sludge wastewater treatment plants. *Ingeniare*. *Revista chilena de ingeniería*, **16**, 2, 352–357, (2008).
- Johnson, A. T. *Biological Process Engineering: an analogical approach to fluid flow, heat transfer and mass transfer applied to biological systems*. Chap. 3, 360–381. John Wiley & Sons Inc. (1999).
- Mason, I. G. Mathematical modeling of the composting process: A review. *Waste Management*, **26**, 3–21, 2006.
- Ahn, H. K., Sauer, T. J., Richard, T. L. & Glanville, T. D. Determination of thermal properties of composting bulking materials. *Bioresource Technology* **100,** 3974–3981, (2009).
- Stoffella, P. J., Kahn, B. A. Compost utilization in horticultural cropping systems. 36–37, Marcel Dekker Inc, USA. (2001).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