Modelado matemático de un proceso de compostaje mediante la utilización de una plataforma libre con incertidumbre

CONICET CIT RÍO NEGRO

UNRN Universidad Nacional de Río Negro

VIII CONGRESO INTERNACIONAL DE CIENCIA Y TECNOLOGÍA DE LOS ALIMENTOS CÓRDOBA (CICyTAC 2022)

Planta Piloto de Alimentos Sociales

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ABSTRACT

In Alto Valle of Rio Negro, fruitculture is the main economic activity in the region, mainly characterized by the apples and pears production. These agro-industries generates organic waste (pomace and bagasse which is around 20 and 40%) during the processing fruits depending of the industry (cider or juice). Fruitculture in Rio Negro province has been going though a crisis for years with a clear trendding of losing competitiveness, mainly asociated with the incessant dollar increasing in cost production. In this complex economic framework, the waste agroindustrial treatment becomes very complicated, since it is very difficult for industries to face the high maintenance and investment cost generated by this treatments, which makes them economically impossible. For this reason, it is extremely necessary to implement simulation and optimization models in order to make a reasonable use of the necessary reasources for the solid waste treatment generated during natural juice production. In this work, contributions have been made for the treatment of solid waste generated during apple and pears processing from a juice industry in the Alto Valle of Rio Negro. A highly nonlinear dynamic mathematical model based on first principles of a waste treatment system was formulated and calibrated. These simulation algorithm provide a very good estimation of real data and offer a great advantage for the knowledge and understanding of the complex process system where microoganinms participate. However, there are very few mathematical models in the literature for solid waste treatment problems by composting. A huge quantity of models developed in the literature are related to laboratory scale reactor. The computational development carried out for this agroindustry provides and efficient and reliable tool to support decision-making during production process and also determine optimal control strategies in a dynamic optimization framework. The pomace treatment is carried out with a system of piles wich are turned to allow a significant reduction of the residues generated during the natural juice processing. Through the implementation of an appropiate model thigted to this case, it is possible to apply strategies to determine optimal processing time during composting. In this mathematical model, dynamic mass balances have been formulated for the main components of the compost pile and originating a complex system of ordinary and algebraic equations that were solved in the OCTAVE platform.

SISTEMA DE ECUACIONES

El modelo matemático desarrollado, se fundamenta en el desarrollo de un balance de masa general y un balance de masa por componentes de cada corriente involucrada en cada etapa del proceso de la elaboración de compostaje.

$$\frac{dT}{dt} = \frac{-UA * (T - T_a) - \Delta H_S \frac{dS}{dt}}{mc}$$

$$\frac{dS}{dt} = -\frac{1}{Y_{\frac{X}{S}}}\mu.X + \frac{1}{Y_{\frac{X}{S}}} k_D X$$

$$\frac{dX}{dt} = \mu.X - k_D.X$$

$$\frac{dO_2}{dt} = \frac{-Y_{O_2/S}}{Y_{X/S}}.\mu.X$$

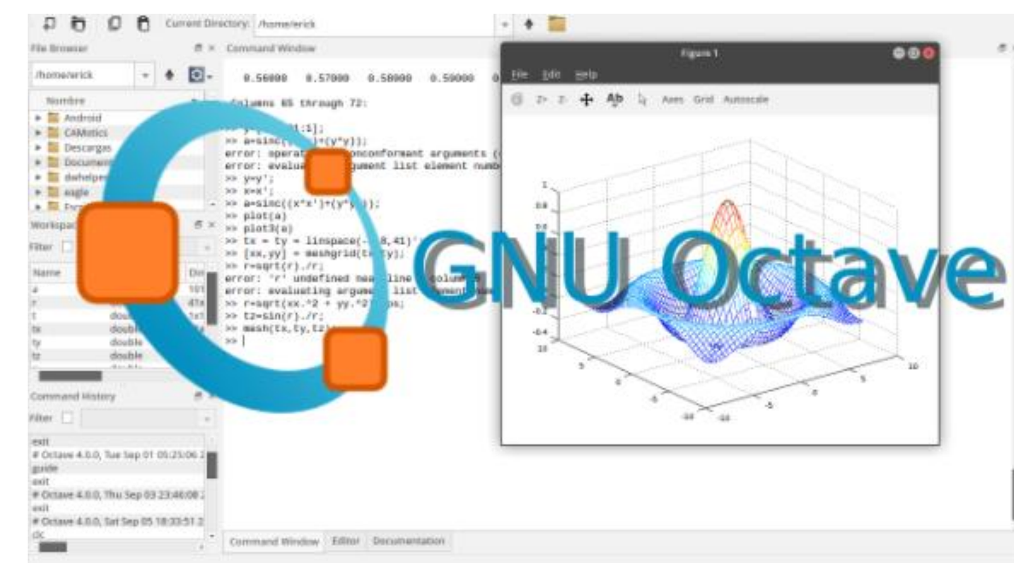
$$\frac{dH_2O}{dt} = \frac{Y_{H_2O/S}}{Y_{X/S}}.\mu.X - \frac{1}{Y_{\frac{H_2O}{X}}}.\mu.X + Y_{\frac{H_2O}{X_{muerta}}}.k_D.X + H_2O_{agregada}.A.\rho$$

$$\mu = \mu_{máx}\frac{S}{S + K_L\varepsilon_w V_c}.\frac{O_2}{O_2 + K_o\varepsilon_w V_c}.F_T.F_{hum}$$

$$F_T = \frac{(T - T_{máx}).(T - T_{min})^2}{(T_{opt} - T_{min}).[(T_{opt} - T_{min}).(T - T_{opt}) - (T_{opt} - T_{máx}).(T_{opt} + T_{min} + 2T)]}$$

$$F_{hum} = 1 - 17{,}3.\left(1 - \frac{HR}{100}\right)^{6{,}94}$$

PLATAFORMA LIBRE



INTRODUCCION Y OBJETIVOS

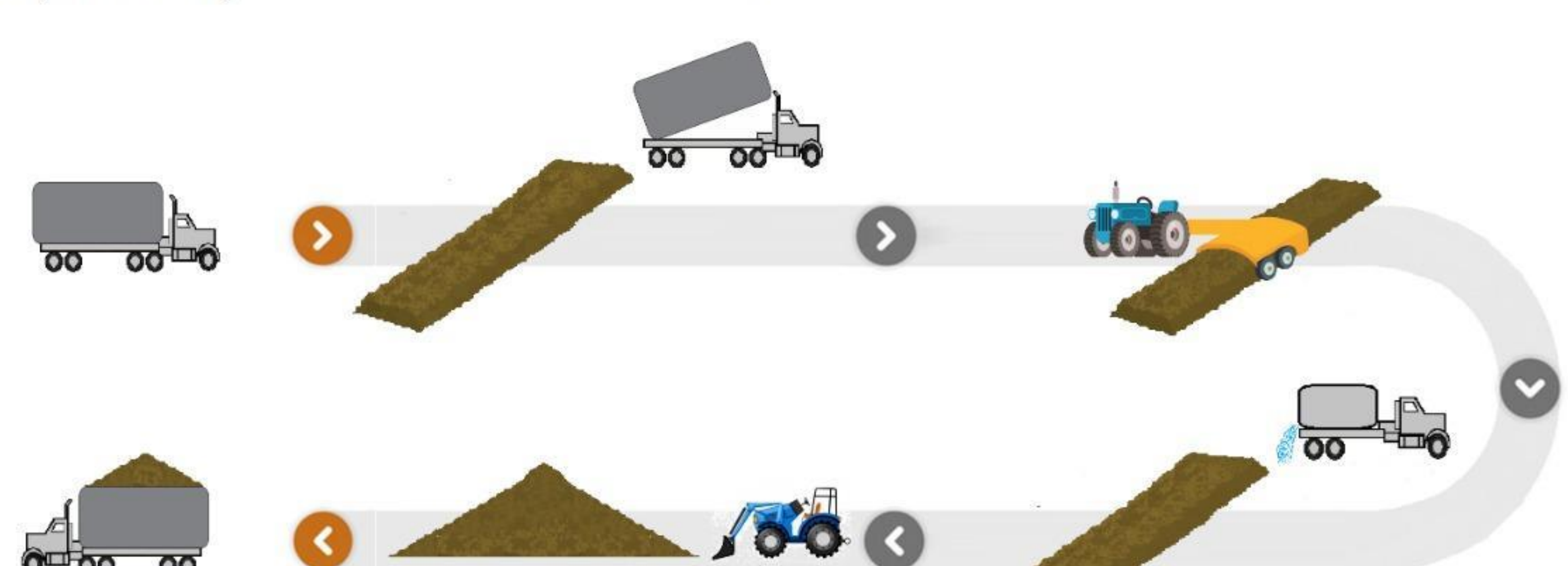
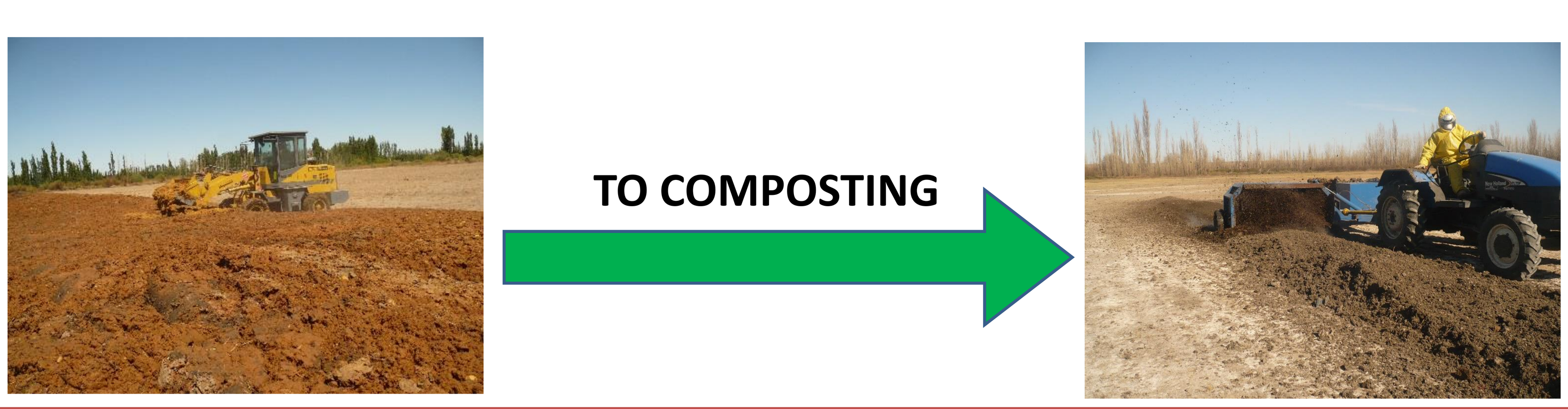


Figura 1. Diagrama de flujo del proceso de obtención de compost.



INCERTEZAS Y ESCENARIOS

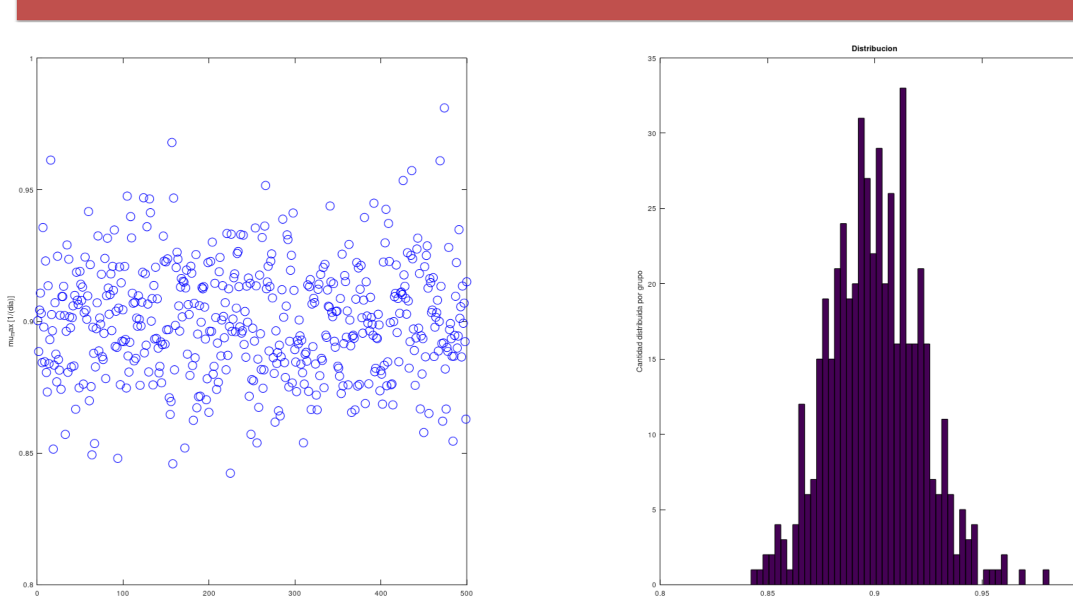
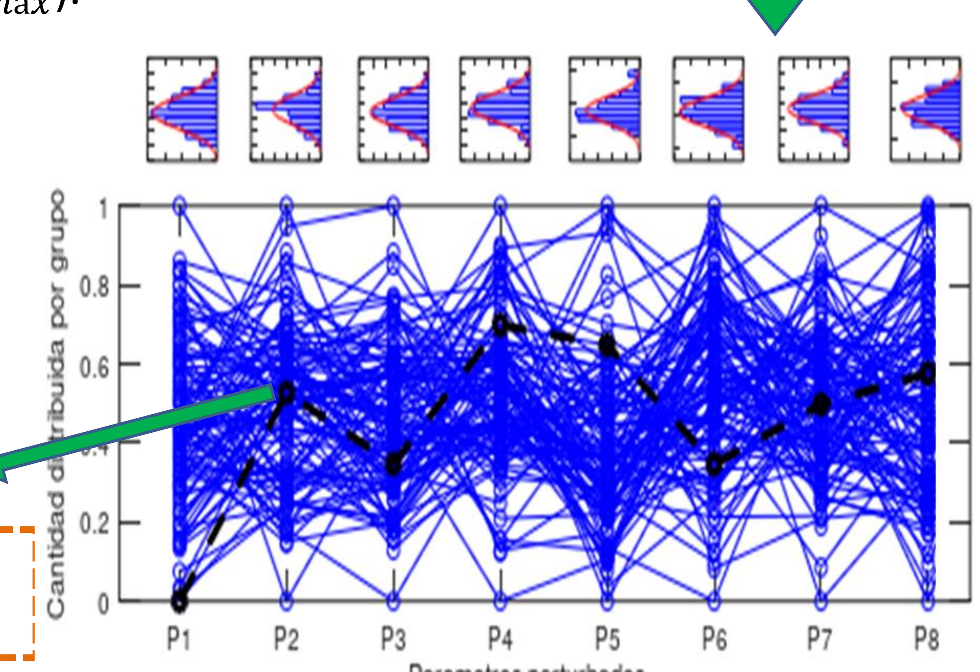


Figura 2. Valores aleatorios y distribución de uno de los parámetro perturbado ($\mu_{máx}$).

TOTAL DE PARAMETROS PERTURBADOS Y COMBINACIONES



Combinación óptima de parámetros

Mínima $\sum_{i=1}^{N}(y_{predicho,t} - y_{real,t})^2$

CONDICIÓN (1)

Figura 3. Diagrama de CobWeb.

RESULTADOS Y CONCLUSIONES

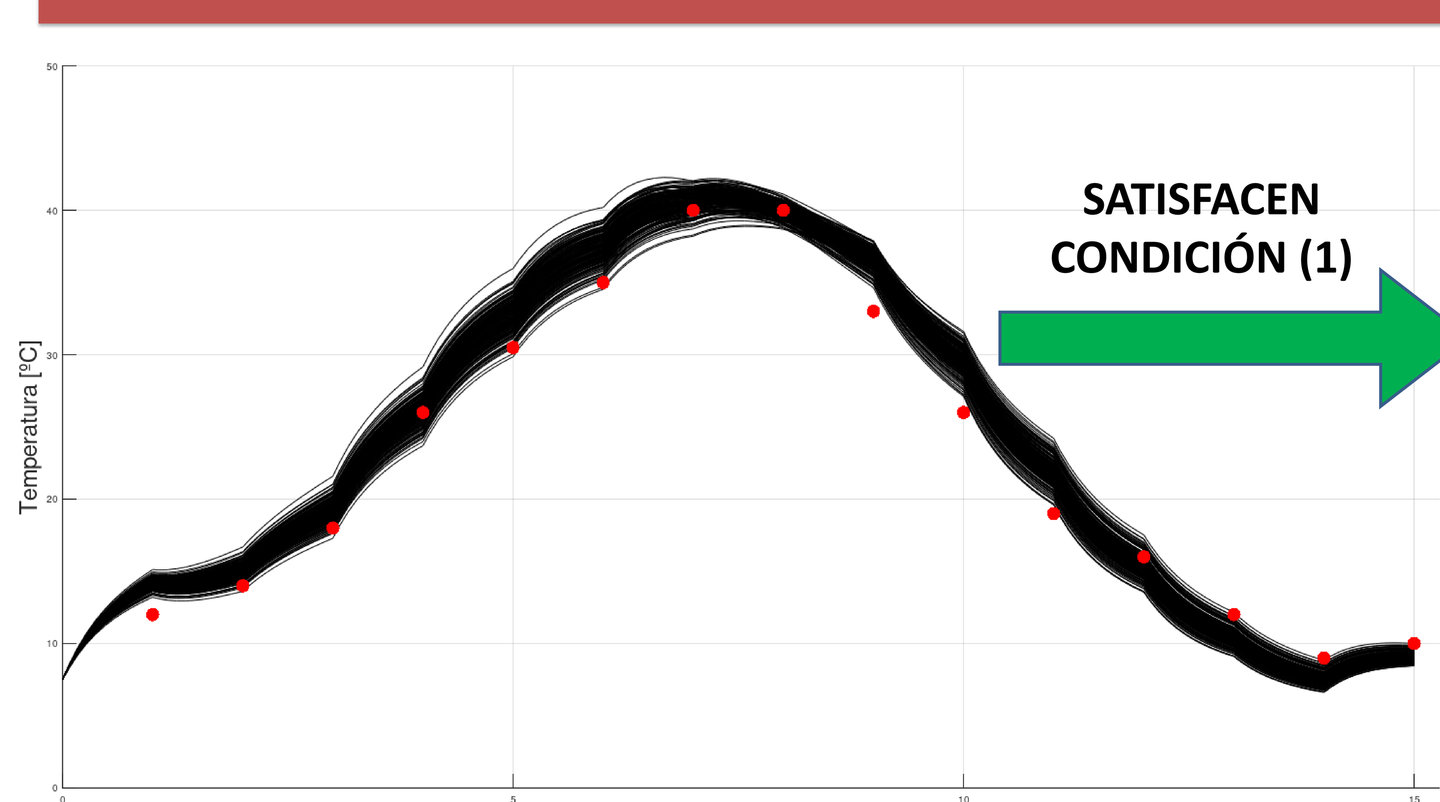


Figura 4. Perfiles de temperatura y datos experimentales.

Tabla 1. Valores óptimos de los parámetros del modelo matemático.

Parámetros	Valor óptimo	Unidades
ΔH_S (Calor generado por la biomasa)	4632.4	[kJ/kg]
$Y_{\frac{X}{S}}$ (Rendimiento de biomasa-sustrato)	0.578	[kgX/kgS]
$\mu_{máx}$ (Tasa máxima de crecimiento)	0.905	[1/mes]
k_D (Tasa de muerte)	0.061	[1/mes]
$Y_{H_2O/S}$ (Rendimiento agua-sustrato)	0.058	[kgH2O/kgS]
$Y_{\frac{H_2O}{X}}$ (Rendimiento agua-biomasa)	0.584	[kgH2O/kgX]
$Y_{O_2/S}$ (Rendimiento oxigeno-sustrato)	0.734	[kgO2/kgS]
K_L (Constante de saturación de sustrato)	9.987	[kg/m3]

Los rangos de variación de los mismos se definieron en función de las restricciones físicas y biológicas del proceso, permitiendo realizar un estudio de sensibilidad del modelo. **Por lo tanto, se encontraron los parámetros del modelo matemático desarrollado que mejor se ajustaban a los datos experimentales.**

La combinación de parámetros que mejor se ajusta en el modelo se muestra en la figura de CobWeb presentada (Figura 3).