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Mathematical modeling of physical properties of banana (*Musa acuminata*) stored under different temperature conditions

A. KARTHIAYANI, M. SIDDHARTH AND N. VARADHARAJU

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See end of the Paper for authors' affiliation

Correspondence to :

A. KARTHIAYANI
College of Food and Dairy Technology, Tamil Nadu Veterinary and Animal Sciences University, CHENNAI (T.N.) INDIA
Email : mankarthi@yahoo.com

ABSTRACT : Respiration is a process of oxidative breakdown of organic matter present in the cells into simpler molecules along with concurrent production of energy and other molecules which can be used by the cell for synthetic reactions. Respiration rates have been used as an index for the metabolic activities of fruits during ripening and senescence. The respiration process depends on the physical properties like mass, volume and surface area of the produce. In the present study, the physical properties were determined and modeled using the graphical method. The respiration rate was determined at three different temperatures (ambient, 14°C and 24°C) by using formula method and the same was modeled based on enzyme kinetic reactions as per Michaelis- Menten type of equation using non-linear regression in Sigmaplot 8.0 software. Results indicated that the mathematical model was found to be good fit.

KEY WORDS : Banana, Physical properties, Respiration rate, Model, Sigmaplot 8.0

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Respiration is a process by which plants take in oxygen and give out carbon dioxide, water vapour and heat due to the breakdown of stored carbohydrates. Respiration results in the loss of moisture from the fresh produce which results in shrinkage and physiological loss in weight. The substances used for respiration are continually replaced through photosynthesis when they are attached to the plant. Once the fruits are harvested, photosynthesis ceases and there is no replacement for the lost ones. Thus, the biological process that keep the cell alive slows down and the cell structure breaks down followed by death of cells. The respiration occurring in the presence of oxygen is termed as aerobic respiration and in the absence of oxygen is termed as anaerobic respiration.

The stage of banana fruit ripening is marked by a large increase in respiratory rate and ethylene production, characterizing it as climacteric and making it highly perishable. Thus, it should be harvested before the rise of the respiratory rate (pre-climacteric) for best and extended conservation (Taiz and Zeiger, 2004; Chitarra and Chitarra, 2005 and Pinheiro *et al.*, 2005). Drying and storage processes need to be developed for these wastes in order to achieve important advantages such as easy transportation, reduced microbial load, nutrient concentration and availability for processing (Prachayawarakorn *et al.*, 2008).

Respiration is a biological process in which stored sugars are broken down and utilized for energy. The mass loss associated with respiration is water and carbon in the form of carbon dioxide. Respiration is considered as a catabolic process involving consumption of oxygen for oxidative breakdown of complex molecules *viz.*, starch, sugars, fats, proteins, organic acids to simpler ones such as carbon dioxide and water along with concurrent production of energy (Wills *et al.*, 1989).

Anaerobic respiration occurs when the availability of oxygen is limited and insufficient to maintain full aerobic metabolism, resulting in the conversion of glucose into lactic acid or acetaldehyde and ethanol. The oxygen concentration at which anaerobic respiration commences is known as 'extinct point'. Anaerobic conditions results in higher respiratory quotient and gives alcoholic odour and off flavour to fruits (Gareipy *et al.*, 1991).

A great number of mathematical models including two or more parameters have been used to represent the sorption isotherms. These models are classified as theoretical, semi-empirical or empirical (Barbosa-Cánovas *et al.*, 2007). Those based on the kinetics of the monolayer, multilayer and condensed layer are grouped into theoretical models, where the parameters are functions of the physical properties of the material (Basu *et al.*, 2006).

Non-climacteric commodities have higher respiration rates in the early stages of development that decline during maturation. The respiration rate of climacteric commodities are also high in early development and decline until a rise occurs that coincides with ripening or senescence (Lopez-Galvet *et al.*, 1997).

METHODOLOGY

Two varieties of banana (*Musa acuminata*), Poovan (AB group) and Robusta (AAA group) were selected for the study. The fresh banana bunches of Poovan and Robusta with 90 per cent maturity were procured from farm orchard, Coimbatore, India. The bunches were carefully dehanded and washed in tap water to remove latex, soil particles, floral remains etc. and shade dried.

Determination of physical properties :

The surface area of the fruits plays a major role in respiration. Hence, the determination of relationship between weight, volume and surface area will be useful criteria for respiration. Ten numbers of procured fruits from each variety under study were selected randomly, weighed individually in an electronic balance (Make: Avery; Model: OC-51; e=0.1g). Fruit volume was determined employing water displacement method (Mohsenin, 1980) using a graduated cylinder.

Determination of respiration rate :

Known quantities (mass) of fruits were kept under air tight condition in the plastic container fitted with a silicon septum (for sampling of gases). The samples were treated with fungicide before keeping them inside the container. The free volume of the container was determined by deducting the fruit volume from the total container volume. The gas sample were drawn from the chamber through silicon rubber septum using needle and oxygen concentration was found out using MAP analyzer (Make: PBI Dansensor Model: Checkmate). The needle of MAP analyser was inserted into gas sampling septum of the storage chamber and the pump was put on. The vacuum pump inside the MAP analyser sucks about 5ml of gas from the storage container and the gas concentration was displayed in the digital screen.

The respiration rates of the two varieties of banana were determined under three storage conditions *viz.*, ambient (27-33°C, 50 – 70 % RH), 24 ± 1°C (90- 95 per cent RH) and 14 ± 1°C (90- 95 % RH). The ambient condition was achieved by keeping the sample at room temperature and the latter two conditions were achieved by keeping the sample in a walk-in cold room and setting the required temperature and relative humidity (RH). The respiration rate was calculated by the change in oxygen concentration with time when the commodity was stored in a closed chamber as given below (Cameron *et al.*, 1989).

$$\mathbf{r = \frac{dCO_2}{dt}\frac{V_f}{m_s}} \qquad \text{......(1)}$$

where,

r - respiration rate, mg O_2 $kg^{-1}h^{-1}$

CO_2 - O_2 concentration inside the chamber, mg l^{-1}

$\frac{dCO_2}{dt}$ - change in oxygen concentration over time dt

t - time, h

V_f - free volume of the chamber, l

m_s - mass of the stored produce , kg.

Modeling the respiration rate :

The respiration rate of a commodity is assumed as a function of oxygen concentration at a determined temperature and the respiration rate was modeled based on enzyme kinetic reactions as per Michaelis- Menten type of equation (Ratti *et al.*, 1996) as follows :

$$\mathbf{r = \frac{aCO_2}{b + CO_2}} \qquad \text{......(2)}$$

where,

r - respiration rate, mg O_2 $kg^{-1}h^{-1}$

CO_2- concentration of oxygen inside the container, per cent

'a' and 'b' - constants.

The model (2) was fitted to the experimental data and the respiration rate was plotted as a function of oxygen concentration. The constants 'a' and 'b' were obtained using non-linear regression in Sigmaplot 8.0 software.

RESULTS AND DISCUSSION

The findings of the present study as well as relevant discussion have been presented under following heads :

Physical properties :

It was found that as the weight of the fruit increased, the volume and surface area also increased for both the varieties and the relationship was found to be linear. Similar type of relationship was obtained by Emond *et al.* (1991) for banana. Relationship between fruit weight, volume and surface area

Table 1 : Relationship between fruit weight (W), volume (V) and surface area (A_s)

Variety	Relationship between fruit weight (W) and volume (V)
Poovan	V = 1.22 W + 3.53 (R^2= 0.878)
Robusta	V = 2.06 W – 114 (R^2= 0.895)
	Relationship between weight (W) and surface area (A_s)
Poovan	A_s = 1.15 W – 6.68 (R^2= 0.874)
Robusta	A_s = 2.26 W – 152.45 (R^2= 0.82)

of banana is presented in Table 1. The prediction of surface area and fruit volume from the weight of the fruit is found to be more reliable from the above equations.

Respiration rates :

The oxygen concentration attained by the fruits inside the respiration chamber was measured at one day interval for thirteen days and the respiration rate was calculated using Equation (1). The experimental values were used in the model (2) and the values of constants 'a' and 'b' were obtained and presented in Table 2.

Table 2 : Values of constants 'a' and 'b' for banana at different storage temperatures

Variety	Parameters	Storage temperatures		
		Ambient	24°C	14°C
Poovan	a	18.3	12.23	10.95
	b	0.0675	0.0445	2.3
Robusta	a	19.82	10.96	8.833
	b	1.165	0.0365	0.82

The actual and predicted values of respiration rate for Poovan and Robusta was presented in Fig. 1 and 2, respectively. The respiration rate was found to decrease with decrease in oxygen concentration as the time proceeded. Decreasing respiration rate with time is in agreement with results of Lee *et al.* (1996). Also, respiration rate decreased

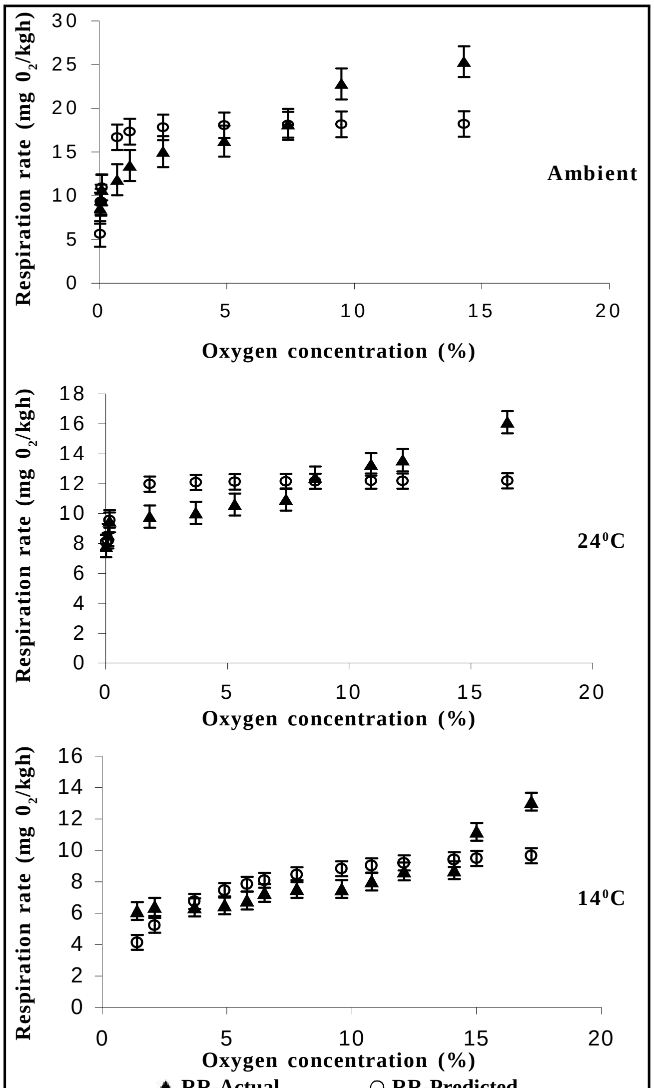

Fig. 1 : Actual and predicted respiration rates of Poovan at different temperatures

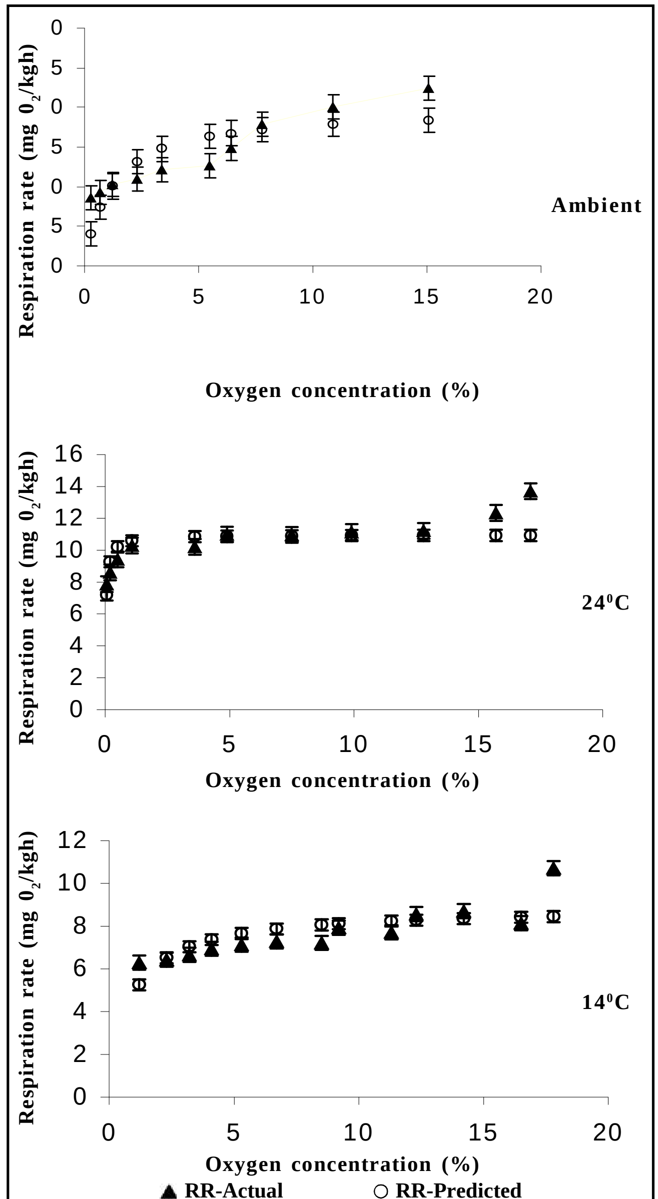

Fig. 2 : Actual and predicted respiration rates of Robusta at different temperatures

with temperature due to the less reaction rates at lower temperatures (Zhang *et al.*, 1993). Predicted values of respiration rate also decreased with the oxygen concentration but the rate of decrease is not more pronounced as the actual values. The R^2 value for the predicted and the experimental data ranged between 0.85 to 0.95.

Conclusion :

A relationship was established between fruit weight (W) and volume (V) and fruit weight (W) and surface area (A_s) for both the varieties of banana. The volume and surface area of the fruit increased with the fruit weight for both the varieties. The respiration rates of the fruits stored in three different temperatures were determined experimentally and also predicted using mathematical model by employing non-linear regression in Sigmaplot 8.0 software. The respiration rate decreased with oxygen concentration as well as with temperature. Among the varieties of banana chosen for study, Poovan showed higher respiration rate under all the storage temperatures.

Authors' affiliations:

M. SIDDHARTH, College of Food and Dairy Technology, Tamil Nadu Veterinary and Animal Sciences University, CHENNAI (T.N.) INDIA
Email : m.siddharth@tanuvas.org.in

N. VARADHARAJU, Post Harvest Techology Centre, Tamil Nadu Agricultural Sciences, COIMBATORE (T.N.) INDIA
Email : nvaradharaju@yahoo.co.in

REFERENCES

Barbosa-Cánovas, G.V., Fontana, J.A., Schmidt, S.J. and Labuza, T.P. (2007). Water activity in foods: Fundamentals and Applications. Blackwell Publishing Profesional, Ames, USA.

Basu, S., Shivhare, U.S. and Mujumdar, A.S. (2006). Models for sorption isotherms for foods: a review. *Drying Technol.,* **24** : 917-930.

Cameron, A.C., Boylanpett, W. and Lee, J. (1989). Design of modified atmosphere packaging systems: modeling oxygen concentrations within sealed packages of tomato fruits. *J. Food Sci.,* **54** : 1413-1416.

Chitarra, M.I.F.,Chitarra, A.B. (2005). *Pós-colheita de frutas e hortaliças*: fisiologia e manuseio. 2ed. Lavras: Editora UFLA,783 p.

Emond, J.P., Cartaigne, E., Toupin, C.J. and Desilets, D. (1991). Mathematical modeling of gas exchange in modified atmosphere packaging. *Trans. ASAE,* **34**(1) : 239-245.

Gareipy, P., Raghavan, G.S.V., Castaigue, F., Arul, J. and Willemot, E. (1991). Precooling and modified atmosphere storage of green asparagus. *J. Food Processing & Preservation,* **15** : 215-224.

Lee, D.S., Song, Y. and Yam, K.L. (1996). Application of enzyme kinetics based respiration model to permeable system experiment of fresh produce. *J. Food Engg.,* **27** : 297-310.

Lopez-Galvet, G., Bassuoni, R.E.P., Nie, X. and Castwell, M. (1997). Quality of red and green fresh cut peppers stored in controlled atmosphere. In: J.R.Gorny (Ed.), Proceedings of 7th International Controlled atmosphere research conference. Davis, C.A., USA, Vol I: pp. 152-157.

Mohsenin, N.N. (1980). *Physical properties of plant and animal materials* (1st Edn.). Gordon and Breech Science Publishers, New York pp. : 123-124.

Pinheiro, A.C.M., Vilas Boas, E.V.B., Mesquita, C.T. (2005). Ação do 1-metilciclopropeno (1-MCP) na vida de prateleira da banana 'maça' *Revista Brasileira de Fruticultura,* Jaboticabal, v.27, n.1, 25-28 pp.

Prachayawarakorn, S., Tia, W., Plyto, N. and Somchart, S. (2008). Drying kinetics and quality of low-fat banana slices dried at high temperature. *J. Food Engg.,* **58** : 75-81.

Ratti, C., Raghavan, G.S.V. and Gariepy, Y. (1996). Respiration rate model and modified atmosphere packaging of fresh cauliflowers. *J. Food Engg.,* **28** : 297-306.

Taiz, L. and Zeiger, E. (2004). *Fisiologia vegetal* 3.ed. Porto Alegre: Artmed, 719 p.

Wills, R.B.H., McGlasson, W.B., Grahm, D., Lee, T.H. and Hall, E.G. (1989). *Postharvest*. AVI Van Nostrand Reinhold Publishers, New York, U.S.A.

Zhang, D., Haang, B.Y. and Scoh, K.J. (1993). Some physiological and bio chemical changes of green ripe banana at relative high storage temperatures. *Acta Hort.,* **343** : 81-85.