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Mathematical Modeling of Respiration Rate of Mango (*Magnifera indica*)

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ABSTRACT

Respiration rates (RR) have been used as an index for the metabolic activities of Mango during ripening and senescence. A knowledge on respiration rate will be very much needed for enhanced shelf life of Mango particularly during Modified Atmosphere Storage. Hence a work was carried out to determine respiration rates of three varities of mango (*Magnifera indica*) *viz*., Malgoa, Banganapalli and Neelum stored at three different tempertautres (Ambient, 24°C and 14°C). Known weight of fruits were kept under air tight condition in the plastic container fitted with a silicon septum. Every day three gas samples of 5 ml volume were drawn from the chamber through silicon rubber septum using a needle and the oxygen concentration was found out using MAP analyzer. The oxygen concentration was determined for 13 days of storage at all temperatures. The respiration rates were determined using experimentally and the values were substituted in formulae method for prediction. The value of the constants were determined using non-linear regression using Sigmaplot 8.0 software. The development of the mathematical model for the prediction of Respiration Rates were found to be useful for further reference.

Key words: Cold storage, Mango, Mathematical Model, Respiration Rate.

INTRODUCTION

Respiration is a process of oxidative breakdown of organic matter present in the cells such as starch, sugars, acids, fats, proteins into simpler molecules such as carbon dioxide and water along with concurrent production of energy and other molecules which can be used by the cell for synthetic reactions (Wills *et al*., 1989). Though it is necessary to maintain the metabolic process, it hastens senescence which is undesirable for shelf life extension. The extent of respiration can be measured by determining the amount of substrate loss, oxygen consumed, carbon dioxide liberated, heat produced and energy evolved (Pantastico *et al.,* 1975). Respiration of climacteric fruits plays a major role in determining their shelf-life.

Mango has a very special place in diet low in fats, cholesterol and high in calories. Being a tropical climacteric fruit, keeping quality of mango as a whole fruit for long time is not feasible due to its poor shelf life quality. Due to these reasons, surplus production in peak season cannot be taken quickly enough to market and export zones resulting in 25 to 40 per cent of post harvest loss from harvest to consumption stage (FAO, 2003).

Hence, knowledge on respiration rate of Mango will pave a way for Modified Atmosphere Storage of the fruits for enhanced shelf life.

The principle behind modified atmosphere packaging is reduction in respiration rates of fruits by modifying the gas composition of the storage atmosphere and thus enhancing the shelf life of the fruits. If the availability of oxygen is restricted, the rate of respiration could be slowed down; thereby quality of the commodities is preserved with enhancement of shelf life (Labuza and Breene, 1989). The appropriate atmosphere is made to evolve within the storage chamber by the respiration of the produce and maintaining that atmosphere by selective permeability of the gases (Ratti *et al.,* 1998; Zagory and Kader, 1988).

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MATERIALS AND METHODS

The study was conducted on three varieties of mango *viz*., Mulgoa, Banganapallai and Neelum. The freshly harvested mangoes of commercial (90 per cent) maturity were procured from a nearby farm at Anamalai area of Coimbatore district. The fruits of uniform size were selected and washed in tap water to remove latex, soil particles, floral remains etc and shade dried. The Experimental design is given in Table 1.

Measurement of respiration rate

Known quantities of fruits were kept under air tight condition in the plastic container fitted with a silicon septum (for sampling of gases). The samples were kept at three different storage temperatures *viz*., Room Temperature, 25°C and 14°C for measurement of respiration rates. The samples were treated with fungicide before keeping them inside the container. The mass of each fruit was weighed individually and volume of fruits were determined by employing water displacement method (Mohsenin, 1980). The free volume of the container was determined by deducting the fruit volume from the total container volume. Every day three gas samples (replications) of 5 ml volume were drawn from the chamber through silicon rubber septum using needle and the oxygen concentration was found out using MAP analyzer (Make: PBI Dansensor Model: Checkmate). The MAP analyser is shown in Plate 1.

The respiration rate was calculated by the change in oxygen concentration with time when the commodity was stored in a closed chamber (Cameron *et al.,* 1989) using the following formulae.

$$r = \frac{dC_{o2}}{dt}\frac{V_f}{m_s} \qquad \text{..........(Eqn. 2.1)}$$

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

The average of three values of oxygen concentration was used to determine the respiration rate.

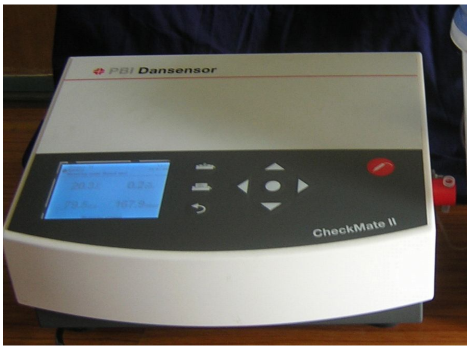

Plate 1: MAP Analyzer.

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

$$r = \frac{aC_{o2}}{b + C_{o2}} \qquad \text{.......(Eqn. 2.2)}$$

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 (Eqn 3.2) 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 respiration rates (RR) of the three varieties of mango stored in three different temperatures *viz*., were determined experimentally as per the procedure described in the Section 2.1 and the values of respiration rates were used in the mathematical model (Eqn. 2.2) and the value of constants 'a' and 'b' were obtained and presented in Table 2. The actual and predicted respiration rate values for different mango varieties are presented in Table to Table 5. From the Table, it is obvious that as the time proceeded both the actual and predicted respiration rate values decreased with oxygen concentration as well as with storage temperature. Among the mango varieties chosen for the study, Neelum showed higher respiration rate at ambient and 24°C storage. Mulgoa showed almost same respiration rate during ambient storage as that of Neelum but the values under 14°C was found to be higher among the three varieties. In all the storage temperatures, Banganapalli had minimum respiration rate values.

The decrease in oxygen concentration with storage temperature is in accordance with the results of Wen *et al.* (2006), who observed the same trend for two different

Table 1: Experimental Design of Respiration Rate of mango.

Factors		Levels
Variety	(3)	Mulgoa, Banganapalli and Neelum
Temperature and humidity	(3)	Ambient (27-33°C, 50-70 per cent RH) 24 ± 1°C, 90- 95 per cent RH and14 ± 1°C, 90- 95 per cent RH

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

Variety	Parameters	Storage temperature		
		Ambient	24°C	14°C
Mulgoa	a	19.36	13.994	12.16
	b	0.0347	0.013	0.5393
Banganapalli	a	15.74	12.44	8.77
	b	0.0219	0.0082	0.0187
Neelum	a	19.602	17.03	9.92
	b	0.017	0.0198	0.0257

Table 3: Actual and predicted RR (mg O_2/kg h) values for Mulgoa at different storage temperatures.

Time(hr)	Ambient			24°C			14°C		
	O_2 (%)	RR Actual	RR Predicted	O_2 (%)	RR Actual	RR Predicted	O_2 (%)	RR Actual	RR Predicted
24	14.5	24.16	19.31	15.3	21.3	13.98	16.7	15.00	11.78
48	9.6	22.29	19.29	12.7	16.18	13.97	13.4	14.37	11.69
72	5.6	20.41	19.24	10.8	13.49	13.97	12.3	11.11	11.65
96	2.1	18.95	19.04	8.60	12.46	13.97	10.9	9.79	11.58
120	1.04	16.05	18.73	6.43	11.81	13.96	7.8	10.41	11.37
144	0.72	13.59	18.47	2.31	12.77	13.91	6.7	9.44	11.25
168	0.102	12.02	14.45	1.21	11.61	13.84	4.5	9.40	10.85
192	0.07	10.53	12.94	0.09	10.76	12.22	2.3	9.37	9.85
216	0.02	9.38	7.08	0.06	9.58	11.50	1.2	8.84	8.39
240	0.018	8.45	4.33	0.02	8.63	8.48	0.98	8.05	7.84
264	0.015	8.32	4.23	0.017	7.85	6.08	0.78	7.39	7.19
288	0.014	7.45	4.12	0.017	6.76	5.43	0.65	6.82	6.64
312	0.011	6.43	4.11	0.014	6.12	5.32	0.54	6.33	6.08

Table 4: Actual and predicted RR (mg O_2/kg h) values for Banganapalli at different storage temperatures.

Time (hr)	Ambient			24°C			14°C		
	O_2 (%)	RR Actual	RR Predicted	O_2 (%)	RR Actual	RR Predicted	O_2 (%)	RR Actual	RR Predicted
24	15.4	20.41	15.71	16.9	14.16	12.43	17.4	12.08	8.75
48	11.2	18.95	15.70	13.6	13.95	12.48	15.4	10.20	8.75
72	7.8	17.36	15.69	11.2	12.63	12.43	13.2	9.86	8.75
96	4.5	16.45	15.66	6.7	14.16	12.42	11.6	9.06	8.75
120	2.3	15.00	15.59	8.4	9.91	12.42	9.8	8.75	8.75
144	1.2	13.26	15.45	3.7	11.52	12.41	8.7	8.05	8.74
168	0.87	11.56	15.35	1.2	11.36	12.35	7.2	7.79	8.74
192	0.5	10.31	15.07	0.08	10.53	11.28	6.5	7.18	8.74
216	0.03	9.38	9.09	0.03	9.38	9.76	3.2	7.91	8.71
240	0.02	8.45	7.51	0.02	8.45	8.81	1.6	7.79	8.66
264	0.016	7.98	6.78	0.015	7.68	6.82	0.54	7.48	8.47
288	0.013	6.75	5.65	0.014	6.89	5.87	0.03	7.03	5.39
312	0.011	6.43	4.32	0.012	5.43	5.32	0.07	6.48	6.91

Table 5: Actual and predicted RR (mg O_2/kg h) values for Neelum at different storage temperatures.

Time (hr)	Ambient			24°C			14°C		
	O_2 (%)	RR Actual	RR Predicted	O_2 (%)	RR Actual	RR Predicted	O_2 (%)	RR Actual	RR Predicted
24	13.2	29.58	19.57	14.5	24.16	17.00	16.5	15.83	9.90
48	8.9	23.77	19.56	10.2	21.04	16.95	12.2	16.87	9.90
72	7.5	17.77	19.55	9.9	14.44	16.99	11.4	12.36	9.89
96	3.2	17.81	19.49	5.9	15.00	16.96	9.8	10.93	9.89
120	1.3	15.83	19.34	3.2	14.25	16.92	7.8	10.41	9.88
144	0.6	13.68	19.06	1.1	13.33	16.72	7.2	9.09	9.88
168	0.075	12.03	15.98	0.07	12.04	13.26	6.5	8.21	9.88
192	0.02	10.56	10.60	0.03	10.55	10.24	5.4	7.76	9.87
216	0.01	9.39	7.26	0.03	9.38	10.24	4.6	7.26	9.86
240	0.01	8.45	7.26	0.02	8.45	8.54	3.2	7.12	9.84
264	0.01	7.65	7.12	0.01	7.68	5.70	2.1	6.89	9.80
288	0.01	6.54	6.23	0.03	6.78	4.56	1.2	6.63	9.71
312	0.01	6.21	6.43	0.01	5.76	3.21	0.09	6.47	7.71

varieties of mango. This may be due to less metabolic activities at lower temperatures and oxygen concentration which resulted in reduction of respiration rates. Similar observations were recorded by Bhande *et al* (2008) for banana and Iqbal *et al* (2009) for shredded carrot slices.

CONCLUSION

The respiration rates of the mango stored in three different temperatures were determined experimentally and also predicted Respiration rates decreased with oxygen concentration as well as with temperature. Among the mango varieties chosen for the study, Neelum showed higher respiration rates at ambient and 24°C storage whereas Mulgoa had higher respiration rates at 14°C. In all the storage temperatures, Banganapalli had minimum respiration rate values. The development of the mathematical model for the prediction of respiration rates were found be useful for further reference.

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