RESEARCH PAPER
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Study on respiration rate and respiration quotient of green mature mango (*Mangifera indica* L.) under aerobic conditions

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Accurate measurement of respiration rate is an important aspect in designing and operating systems such as controlled and modified atmosphere storage that will extend the shelf life of the perishable produce. The respiration rate and respiratory quotient of fresh mature green mango cv. Mallika were determined under closed system at 5, 10, 15, 20, 25 and 33^{0}C (ambient) temperatures. The respiration rate based on carbon dioxide production in aerobic condition decreased about 20 per cent relative to air atmosphere. However, the oxygen consumption sharply reduced to 25-30 per cent relative to air atmosphere at 25^{0}C temperature. The results suggest that, the respiration rate of mango increased with temperature and decrease with storage time. Results of the study can be applied to the MAP design for extending shelf life of mango.

Key words : Mango fruit, Physico-chemical properties, Respiration rate, Respiratory quotient

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INTRODUCTION

Respiration can be defined as the metabolic process that provides energy for plant biochemical processes (Del and Baiano, 2006). It involves oxidative breakdown of organic reserves to simpler molecules, including CO_2 and water, with the release of energy. The significance of respiration in extending the shelf-life of fresh fruits and vegetables stems from the fact that there exists an inverse relationship between respiration rate and the shelf-life of the commodity (Lee *et al.*, 1991). Respiration rate, which is commonly expressed as rate of O_2 consumption and/or CO_2 production per unit weight of the commodity, reflects the metabolic activity of the fruit tissue in the form of biochemical changes associated with ripening (Lee *et al.,* 1996). Another important parameter associated with respiration is the respiration quotient (RQ). Depending on the organic reserve being oxidized, the RQ values for fresh produce normally range from 0.7 to 1.3 (Fonseca *et al*., 2002). Very high values of the RQ or a sudden shift in RQ value indicate a shift in the respiration cycle to the anaerobic cycle (Saltveit, 1997). This helps select appropriate packaging materials when designing modified atmosphere (MA) packaging systems, identifying the vital heat in calculation of refrigeration load, select fan size and location for optimal air flow within controlled atmosphere (CA) facilities and formulate appropriate process control for ventilating storage facilities (McLaughlin and Beirne, 1999). Thus, the accurate measurement of respiration is an important step in the successful design and operation of storage techniques for horticultural produce like mango. Keeping in view the above advantages and shelf life enhancement of mango, the present study was undertaken to study the respiration rate of mature green mango 'Mallika' caltivar under aerobic condition at different temperatures.

RESEARCH METHODOLOGY

Fruit material:

Mango cv. Mallika was procured from fruit farm of Central Institute of Agricultural Engineering, Nabi-Bagh, Berasia Road, Bhopal for experimentation and study. The mangoes were graded manually to remove damaged, infested and non-uniform fruit. Fruits were selected to insure uniform size, shape and weight for further experimentation

The parameters such as unit fruit weight, pulp, peel and stone fraction, length, width, thickness, sphericity, fruit volume, true density, TSS, acidity, pH, colour and firmness were determined objectively in the lab for mature green mango before start of the respiration rate study as per the method adopted by Singh (2011) and Mangraj and Goswami (2011).

Measurement of rates of respiration:

The respiration rate measurement of mango was done as per the method adopted by Singh (2012). A closed system is used to measure the respiration rate of the green mature mango (Fig. 1). A known weight (1kg) of green mature mango was filled into air tight glass container of known volume. The container was sealed carefully using vacuum grease. A single hole covered with silicon septum was made in container for measurement of gas concentrations. After packaging, container was kept at different temperature *i.e.* 5^0C, 10^0C, 15^0C, 20^0C , 25^0C and 33^0C (ambient temp.) at 75 per cent RH in an environment system (Systec instruments , Draihan LabTech Co. Ltd, UK; Model: GS3/P-898C) and time was recorded (Fig. 1). The initial atmosphere inside the sealed container is ambient. But, atmosphere alteration occurs soon after every 0.5 hours the respiration of green mature mango anaerobic condition.

Fig. 1: A closed system for respiration rate measurement of the green mature mango

Respiration rates in terms of O_2 consumption and CO_2 evolution and respiratory quotient (RQ) were determined according to the equations 1 and 2 below:

$$R_{O_2} = \frac{(p_{O_2}{}^{in} - p_{O_2}{}^{f})\, V_V}{100 \times W \times (t^f - t^{in})} \quad \text{and;} \quad R_{CO_2} = \frac{(p_{CO_2}{}^{f} - p_{CO_2}{}^{in})\, V_V}{100 \times W \times (t^f - t^{in})} \quad (1)$$

where,

P_{O2} and P_{CO2} = partial pressure of oxygen and carbon-dioxide gas, %

Vv= Void volume, ml

W= weight of the sample, kg

t= time, h

Superscript in and f= initial and final

and $$RQ = \frac{R_{CO_2}}{R_{O_2}} \quad (2)$$

where,

RQ = respiratory quotient, dimensionless

R_{O2}= Respiration rate of oxygen gas, ml/kg-h

R_{CO2}= Respiration rate of carbon-dioxide gas, ml/kg-h

RESEARCH FINDINGS AND ANALYSIS

The experimental findings of the present study have been presented in the following sub heads:

Rate of respiration:

The respiration data corresponding to the different temperature indicated that as the temperature increased the respiration progressed at a faster rate.

The calculated values for RO_2 and RCO_2 during the steady state at the same interval are plotted in Fig. 2. The rate of respiration gradually increased and was higher at the start of the experiment and gradually declined as the storage period prolonged, before becoming almost constant. The steady-state respiration rate for O_2 consumption were observed to be 3.46, 0.77, 0.38. 1.92. 1.8 and 3.08 ml.$kg^-1.h^{-1}$ at 5^0C, 10^0C, 15^0C, 20^0C, 25^0C and 33^0C (ambient) , respectively. Similarly the steady-state respiration rate for CO_2 evolution were observed to be 3.38, 0.38. 0.77, 2.31, 1.44 and 2.3 ml.$kg^-1.h^{-1}$ at 5^0C, 10^0C, 15^0C, 20^0C, 25^0C and 33^0C (ambient) , respectively. In the temperature range tested (5 to 25^0C), increase in the temperature increased O_2 consumption and CO_2 evolution by more than 3.31 to 3.46 degree folds, respectively. From temperature range 5-15 ^{0}C, O_2 consumption decreased by 2.2 -folds. But, when temperature was increased from 20-25^{0}C, the O_2 consumption again decreased and set at 0.77 folds with respect to ambient temperature.

For similar temperature increments, increase in CO_2 evolution rate was observed to be approximately 3.31 folds. It is observed from Fig. 3, that the difference in O_2 consumption and CO_2 evolution rate decreased in production. The steady-state respiration rates for CO_2 evolution were 3.38, 0.38, 0.77, 2.31, 1.44 and 2.3 ml/kg-h at 5^0C, 10^0C, 15^0C, 20^0C, 25^0C and 33^0C (ambient sample), respectively. It can be suggested that, moisture condensation may take place at higher temperature leading to spoilage of produce. At all temperatures, the O_2 consumption rate remained higher than the CO_2 evolution rate giving steady-state respiration quotient values as 0.293, 0.187, 0.264, 0.264, 0.969 and 1.142 at 5^0C, 10^0C, 15^0C, 20^0C, 25 ^{0}C and 33^0C (ambient), respectively.

RCO_2 at 10^0C observed in this steady was slightly higher with the respiration range suggested by Kadder (2003) which is about 42-45 ml CO_2.kg^{-1}.h^{-1}. it should be noted that, these values of RO_2 and RCO_2 during respiration rate that were, as previously mentioned calculated by using normal air rather than using the gas concentration values of modified atmosphere and for the reason, they are more than the respiration rate in previously modified atmosphere under

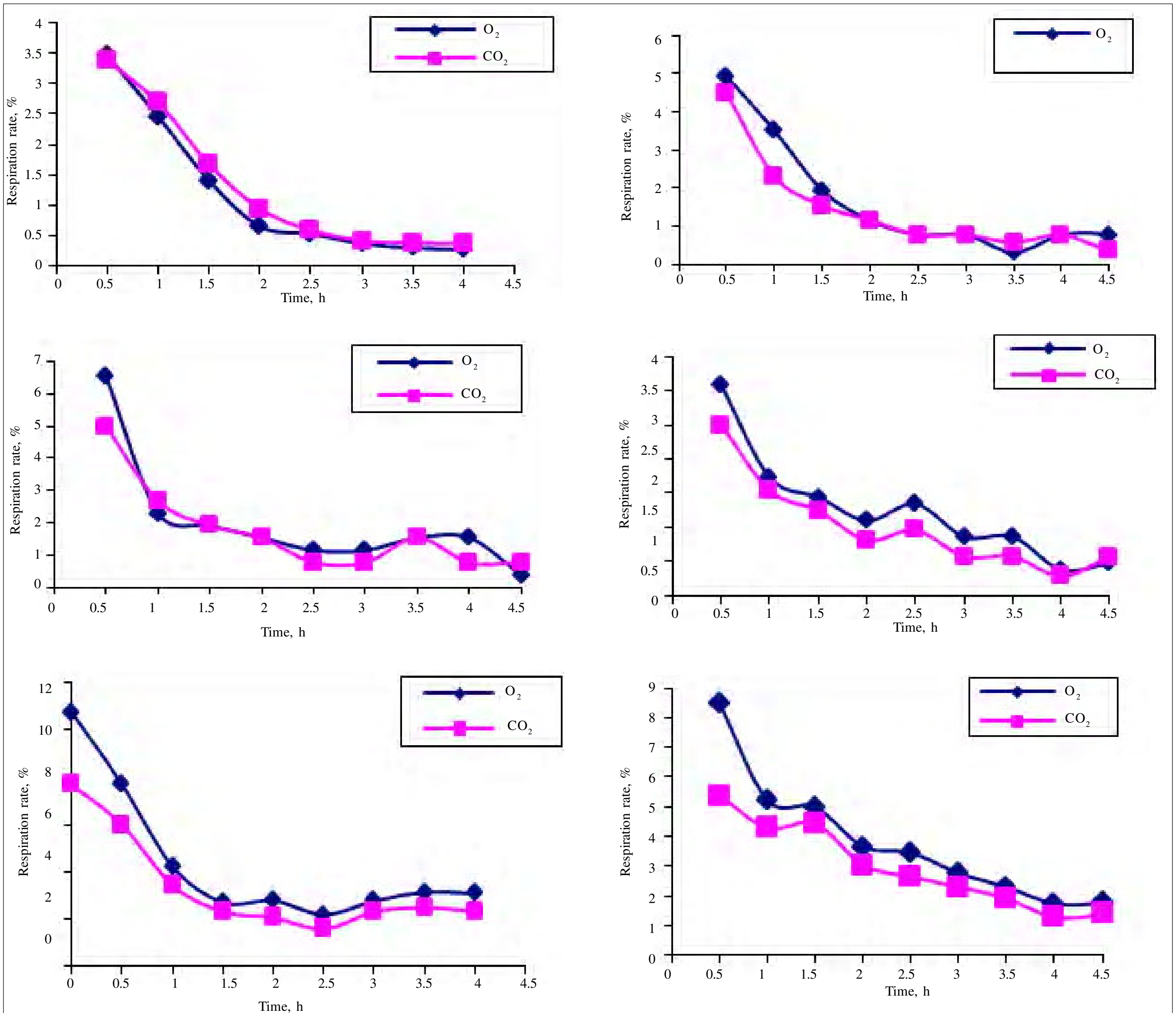

Fig. 2: Respiration rate for mature green mango (Mallika) at 5, 10, 15, 20, 25 and 33^{0}C (Ambient) temperatures

identical temperature.

Respiratory quotient:

Respiratory quotient (RQ) depicts the ratio of the volume of carbon dioxide released to the volume of oxygen consumed by a body tissue of chickpea sprouts in a given period (Deepak and Shashi, 2007). The ratio of carbon dioxide generation to oxygen consumption will be close to unity when substrate used in the metabolic process is carbohydrate and sufficient amount of oxygen is available. The respiratory quotient exhibited minor fluctuations during the initial stage of respiration rate experiments. The respiratory quotient stabilized as the experiment achieved steady state condition.

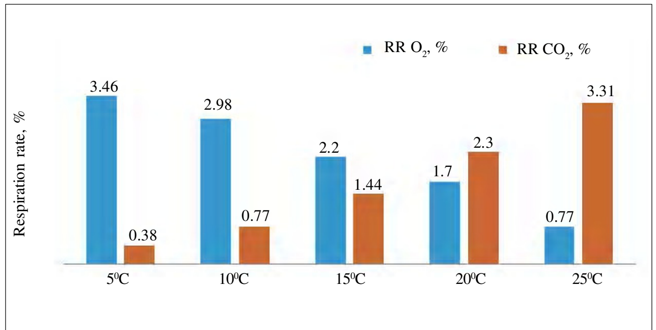

Fig. 3: Degree-fold increase/decrease in RRO$_2$/RRCO$_2$ of mango fruit CV (Mallika) at different temperature with ambient temperature as reference (33^{0}C)

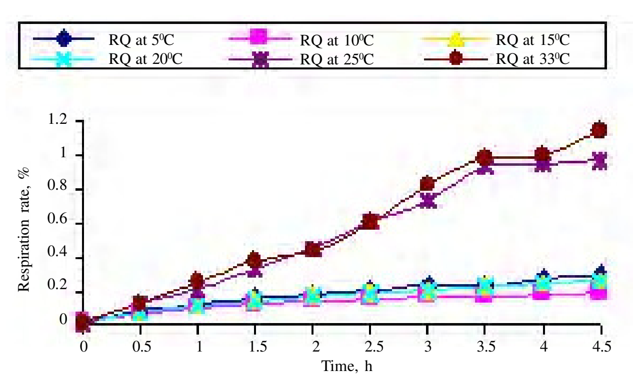

Fig. 4: Respiratory quotient (RQ) of mango (Mallika) at different temperature

It was observed that, the RQ indicated gradual decline at lower temperature in the early stage of experimentation. But, at 15^{0}C and 20^{0}C temperatures, it achieved relatively linear increase and at temperature 25^{0}C fluctuation observed in RQ was very low. These resulted phenomena may be due to the fact that at lower temperature reduces the metabolic activity consequently results in decreasing respiration rate. It was observed that higher temperature enhances the respiration rate and substrate (O_2) is dissolved at a faster rate resulting in production of more CO_2 leading to a faster accumulation of more CO_2 within the package and causing an increase in the respiratory quotient even at the early stage of experiment.

At a given temperature condition, RQ was found varying with the time under aerobic condition. With respect to temperature series investigated, a gradual increase in RQ value was observed with the rise in temperature. This phenomenon corresponds to some other fresh produce reported by Fernanda *et al.* (2002), Liu and Li (2004) and, Toshitaka and Daisuke (2004). RQ is less than unity; the O_2 consumption was always higher than the oxidative CO_2 production. A change in the respiratory quotient at different temperature is shown in Fig. 4.

Conclusion:

The present study was undertaken to measure the respiration rate of mango fruits under different temperature using closed system experiment. Based on the experiments, it was concluded that the steady-state respiration rates were found to be decreasing with storage time. The respiration rates were also found to be increasing with increasing storage temperature. At all temperatures, the O_2 consumption rate remained higher than the CO_2 evolution rate giving steady-state respiration quotient values between 0.29-1.14 at different temperatures. At a given temperature condition, RQ was found varying with the time under aerobic condition.

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