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Effect of Storage Temperatures on Respiration of Moringa Pods (PKM-1)

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Information on the respiration rate of moringa is essential in designing suitable packaging and storage systems for moringa. Air tight PVC chambers of size (70 x 15cm) to hold one kg of moringa (PKM-1)were used to study the respiration rate at three temperatures namely 14, 21 and 28°C. Generally there was progressive reduction of O_2 concentration and a steady increase in CO_2concentration, in all tests. The respiration rate of oxygen was 8.75 ml kg $^{-1}$hr $^{-1}$at 14ºC, 12.01 ml kg $^{-1}$hr $^{-1}$at 21ºC and 66.04 ml kg $^{-1}$hr $^{-1}$at 28ºC. The respiration rate of carbon dioxide was 8.31 ml kg $^{-1}$hr $^{-1}$at 14ºC, 12.01 ml kg $^{-1}$hr $^{-1}$at 21ºC and 34.61ml kg $^{-1}$hr $^{-1}$at 28ºC. There was a 1.5 fold increase in respiration as measured by the value of respiration rate of oxygen from 14 to 21ºC and a four fold increase in respiration from 14 to 28ºC.

Key words: Moringa pods, respiration rate, temperature studies

India is the largest producer of moringa, with an annual production of 1.1 to 1.3 million tones. Moringa is grown for its nutritious pods, leaves and flowers, which are rich sources of proteins, vitamins and minerals.

To design and implement successful controlled atmosphere (CA) regime for fruits and vegetables, their respiration rates are important as they have a direct bearing on shelf life. Respiration can be defined as the metabolic process that provides energy for plant biochemical processes. It involves oxidative breakdown of organic reserves to simpler molecules, including $CO_2$and water, with the release of energy. Respiration rate, which is commonly expressed as rate of O_2consumption and/or CO_2production per unit mass of the commodity, reflects the metabolic activity of the fruit tissue in the form of biochemical changes associated with ripening (Fonseca *et al.,* 2002). The organic substrates broken down in this process includes carbohydrates, lipids or organic acids. The process consumes O_2 in a series of enzymatic reactions. Respiration can be expressed as production of CO_2(RCO_2) and consumption of O_2(RO_2).

A study was conducted to determine the respiration rate of moringa at temperatures 14, 21, and 28 ºC which will be very useful in designing the handling and storage systems for moringa.

Materials and Methods

Moringa

Moringa (PKM-1) pods of uniform maturity and size harvested in August 2012 were washed with water to remove the adhering dirt.

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Respiration chambers

Respiration chambers for moringa were designed using PVC pipes, 75 cm long and of 15 cm diameter (13 L capacity) were enclosed at the bottom with an end cap and at the top with a specially designed PVC flange. A rubber gasket between the top flange and the pipe section ensured air tightness achieved by means of 12 bolts and nuts. Two septums were provided on the top flange for drawing gas samples for analysis.

One kg of moringa was used with a free volume of 12.5 L determined by volume displacement method. The $O_2$and CO_2readings were taken at an interval of 24 h for 14 and 21ºC, and 3 h intervals owing to rapid rate of respiration at higher temperature (28ºC).

Gas analysis

Storage gas sample was analyzed quantitatively for $O_2$and CO_2concentrations using a gas analyzer (MAP check combi model of PBI-Dansensor) that uses, a zirconium sensor for O_2determination and an infrared detector for CO_2. During spot measurement of gas composition, the sampling needle was inserted through a silicon disc septum on the respirometer to get the concentration of O_2 and CO_2.

Respiration rate estimation

The respiration rate was estimated using the following equations (Cameron *et al.,* 1989):

$$RRO_2 = \frac{(Y_{O_2}^{t_i} \quad Y_{O_2}^{t_f}) \cdot V}{100 \cdot M \cdot (t_f \quad t_i)} \qquad \text{------- (1)}$$

$$RRCO_2 = \frac{(Y_{CO_2}^{tf} \quad Y_{CO_2}^{ti}) \cdot V}{100 \cdot M \cdot (t_f \quad t_i)} \qquad \text{-------- (2)}$$

RRo$_2$and RRco $_2$- Respiration rate (ml.Kg $^{-1}$h^{-1}), in terms of $O_2$and CO $_2$respectively,

Yo$_2^{ti}$ and Yo $_2^{tf}$ - Volumetric concentration (%) of O_2at initial and final time respectively

Yco$_2^{ti}$ and Y co $_2^{tf}$ - Volumetric concentration (%) of CO_2at initial and final time respectively

$t_i$and t $_f$- Initial and final time (h) respectively

M - Mass of the stored product (kg)

V - Free volume (L)

Results and Discussion

The respiration rates of moringa pods were measured at three levels of storage temperature namely, 14, 21 and 28°C as a function of time. The temperature and relative humidity were maintained at a fixed level and recorded using a data logger. The respiration rate generally increased with temperature. The respiration rate of oxygen and carbon dioxide were high initially and gradually decreased with time.

Change in oxygen concentration profile due to respiration

Initial oxygen concentration in the chamber was found to be 19.5 % at 14ºC (Fig.1), 19.8 % at 21ºC and

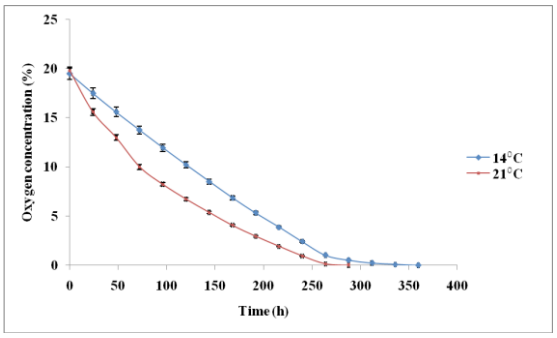

Fig. 1. Oxygen concentration of moringa stored at 14 and 21°C

19.6 % at 28ºC (Fig.2.). The oxygen concentration in all the chambers continued to decrease with time, and oxygen was completely depleted in 360 h at 14ºC, 264 h at 21ºC and 60 h at 28ºC. In these experiments, oxygen consumption rate increased with temperature as shown in Fig.2.

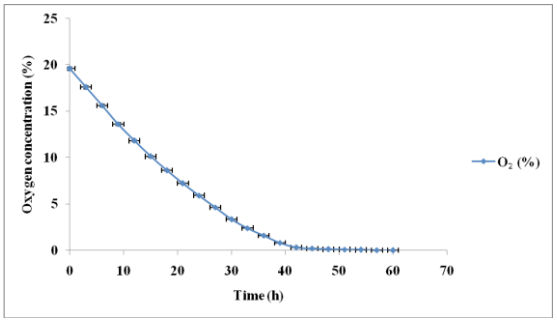

Fig. 2. Oxygen concetration of moringa stored at 28°C

At 14,21 and 28C the initial respiration rates were

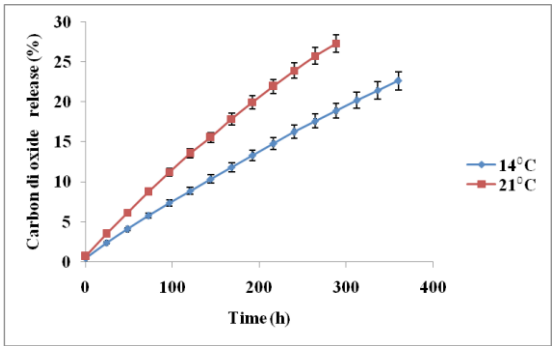

Fig. 3. Carbon di oxide release of moringa stored at 14 and 21°C

8.75,12.01 and 66.04 ml kg $^{-1}$h $^{-1}$, respectively. The average respiration rate was 7.46 ml kg^{-1}h $^{-1}$ at 14º C for first 144 h and it reduced to 4.7 ml kg^{-1}h $^{-1}$ for the next 216 h (Fig.5). At 21ºC the average respiration rate was 11.04 ml kg $^{-1}$h $^{-1}$, for first 72 h and 3.75 ml kg^{-1}h $^{-1}$ for 144 h (Fig.6) . The respiration rate at 28ºC was 56.46 ml kg^{-1}h $^{-1}$, for 27 h and reduced to 16.28 ml kg^{-1}h $^{-1}$ for 30 h (Fig.7). At 14 º C, the respiration rate reduced from 8.75 to 6.74 ml kg $^{-1}$h $^{-1}$ (168 h) and gradually to 2.19 ml kg^{-1}h $^{-1}$. The concentration of oxygen dropped from 19.6 to 2 percent within 33 h at 28ºC and 192 hat 21ºC, where as it took 240 h to drop to 2 per cent at 14ºC. The experimental data revealed that as respiration rate increased with the increase in temperature, aerobic respiration is reduced with

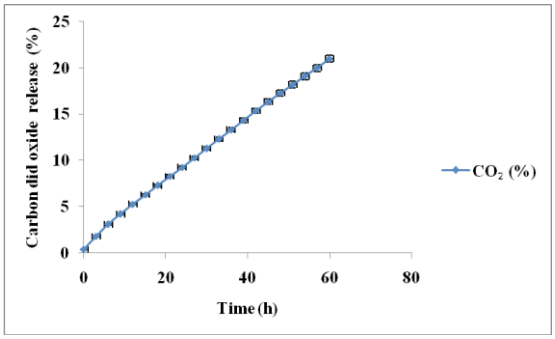

Fig. 4. Carbon di oxide release of moringa stored at 28°C

decreasing available O $_2$, but only to a critical level below which anaerobic respiration increases.

These data suggest that in all these cases the rate of respiration is constrained by the progressive depletion of oxygen within the chamber. Therefore true value of respiration rate is reflected only in the initial spell before reaching a peak value. Respiration rates obtained at the latter periods do not reflect the true respiration. Generally high temperature hastens the respiration process, with subsequent increase in substrate breakdown. Considering the fact that survival of plant cells depends greatly on the energy generated by the respiration process (Ramaswamy and Raghavan, 1995), respiration is widely assumed to be slowed down by decreasing available O $_2$as a consequence of reduction of overall metabolic activity. The reduction of respiration rate is due to

a decrease in the activity of other oxidases, such as polyphenoloxidase, ascorbic acid oxidase and glycolic acid oxidase, whose affinity is much lower (Kader, 1986).

Temperature has been identified as the most important factor influencing the respiration behavior of fruits and vegetables (Saltveit, 2004). The data shows that the respiration was low at low temperatures. It is noticeable that there was more than eight fold

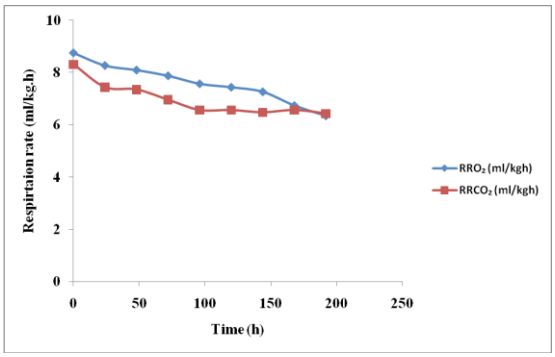

Fig. 5. Respiration rate of moringa stored at 14°C

increase in the respiration rate when temperature increased from 14°C to 28°C and increased 1.5 times when temperature was increased from 14°C to 21°C. Such a behavior signifies that low temperature is desirable to gradually slow down the respiration process and allow the minimum possible respiration rate that could keep the tissues alive for longer periods. The fast decline in the respiration rate at high temperature could also attribute to the malfunctioning of the enzymes, which catalyses the respiration process. Enzymes are made of protein compounds, which are easily denatured if the temperature is high.

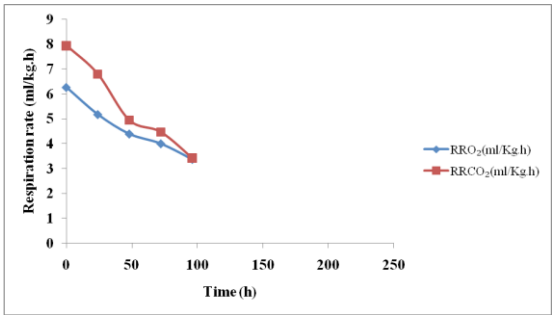

Fig. 6. Respiration rate of moringa stored at 21°C

A similar trend was observed for the respiration of banana by Bhande *et al.,* (2008).

Menon and Goswami (2008), studying with mangoes at different temperatures reported that, as temperature increased, the respiration rate increased. At 5° C, the initial respiration rates recorded were 14.5 and 16.5 mlkg^{-1}h^{-1}for $RO_2$and RCO_2, respectively and 59.7 and 55 mlkg^{-1}h^{-1}for $RO_2$and RCO_2at 30°C.

Spinach, like many leafy vegetables, has limited reserves of substrates (Burton, 1974), therefore the respiration rate is likely to start declining just a few hours after storage. The high temperature hastens

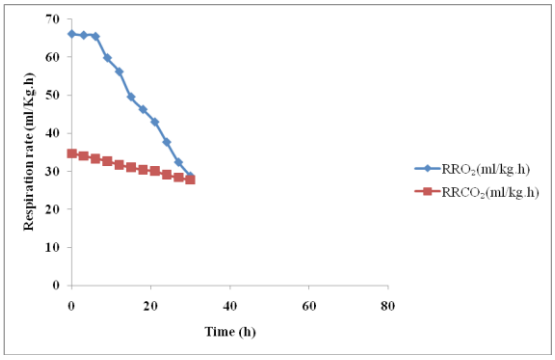

Fig. 7. Respiration rate of moringa stored at 28°C

the respiration process, with subsequent increase in substrate breakdown. Considering the fact that survival of plant cells depends greatly on the energy generated by the respiration process (Ramaswamy and Raghavan, 1995), a zero respiration rate in storage is not desired, because it indicates death of the plant cells. The respiration rate decreased gradually at 14°C. Such a behaviour signifies that low temperature is desirable to slow down the respiration process, and allow the minimum possible respiration rate that could keep the tissues alive for longer period (Wills *et al.,* 1981 and Burton, 1982).

Limited oxygen could reduce the respiration rate by interfering with the enzymatic activities that occur simultaneously with the respiration process. In the glycolytic pathway, the enzyme which catalyses conversion of fructose-6-phosphate to fructose biphosphate is reported to be inhibited by ATP and citric acid. Both compounds are formed in an oxygen dependent TCA cycle (Burton, 1982 and Kays, 1991).

Effect of carbon dioxide concentration profile

At 14ºC, the initial carbon dioxide concentration was 0.5 % (Fig.3). Initial and final respiration rates were 8.31 ml kg^{-1}h^{-1}and 5.25 ml kg^{-1}h^{-1}, respectively (Fig.5) . At 21ºC, it was 0.7 % (Fig.3) with initial and final respiration rates being 12.01 ml kg^{-1}h^{-1}and 6.61 ml kg^{-1}h^{-1}, (Fig.6). At 28ºC, it was 0.4 % with the initial and final respiration rates of 34.61 ml kg^{-1}h^{-1} and 17.83 ml kg^{-1}h^{-1}, respectively (Fig.7) . The gas concentrations reached their upper limit (CO_2> 18%) after 288 h at 14ºC, 192 h at 21ºC and 51 h at 28ºC. At 14ºC, the CO_2evaluation was 6.46 ml kg^{-1}h^{-1}, at 21ºC it was 9.51 ml kg^{-1}h^{-1}and at 28ºC it was 27.65 ml kg^{-1}h^{-1}. Respiration rate decreased with the increase of carbon dioxide concentration. High temperature increased the impact of high carbon dioxide on the respiration rate of moringa pod.

The high carbon dioxide may have impeded the forward reaction, which would have resulted in the breakdown of sugars. Some researchers have also attributed the effect to the increase in the cell sap concentration of CO_2, which normally changes the balance of reactants and products of other subsidiary metabolic pathways prevailing in the plant cells (Kays, 1991).

Peiris *et al.,* (1997) conducted a study using immature pods of moringa at four different storage temperatures namely, 0,5,10 and 20ºC. The carbon dioxide release rate of moringa was 28, 58, 141 and 301.6 mg/kg. h at 0,5,10 and 20ºC, respectively. Comparatively in this study, the value is lower which might be due to respiratory climacteric and substantial genetic diversity in the crop. Therefore it is concluded that the individual crop respiration rate changes due to maturity, cultivar, growing and handling conditions.

Vegetables include a great diversity of plant organs (roots, tubers, seeds, bulbs, fruits, sprouts, stems and leaves) that have different metabolic activities and consequently, different respiration rates. Even different varieties of the same product can exhibit different respiration rates (Fidler and North, 1967; Gran and Beaudry, 1992; Song *et al.,* 1992). Alban *et al.,* 1940 stated that respiration rate changes because of cultivar, maturity difference, production environment and preharvest crop management practices.

Conclusion

The respiration rate was low at lower temperatures, which in turn increases the shelf life of the moringa. Hence, moringa pods can be best stored at 14°C.

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