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Effect of Time and Temperature on Respiration Rate of *Pomegranate arils* (cv. 'Bhagwa')

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The effect of time and temperature on the respiration rate (RR) of fresh-cut produce is critical towards the development of a suitable modified atmosphere packaging (MAP) system. This requires an adequate mathematical model for prediction of RR as a function of both time and temperature. This study investigated the effect of temperature (5, 10 and 15 °C) and storage time of 1 to 5 days on the RR (RO_2 and RCO_2) of two pomegranate cultivars (cv. 'Bhagwa' and'Ganesh') fresh arils. RO_2 and RCO_2 were within the range of 2.54 to 8.36 ml/kg.h and 2.76 to 10.04 ml/kg.h, respectively for both cultivars. RO_2 and RCO_2 were3-4 folds significantly higher with increased temperature from 5 to 15°C, reducing storage temperature of arils from 15 to 5°C decreased RO_2 and RCO_2 by about 67 and 70%, respectively. Temperature had the greatest influence on RR and the interaction of time and temperature also significantly affected RO_2 and RCO_2. The dependence of RR on temperature and time was accurately described with a combination of an Arrhenius-type and power equation model for RO_2 and RCO_2 of fresh pomegranate arils and fruits.

Introduction

Modified atmosphere packaging (MAP) technology extends the shelf-life and maintains quality of fresh-cut produce by lowering the respiration rate and retarding the development of physiological disorders and proliferation of spoilage pathogenic microbes (Artés *et al.*, 2000). MAP is the dynamic process of altering gaseous composition within a package to extend storage life and optimize fresh produce quality. It relies on the interaction between the RR of the produce, and the transfer of gases through the packaging material, with no further control exerted over the initial gas composition (Caleb *et al.*, 2012). However, a quantitative description of RR of fresh produce via mathematical modelling is essential for the design of MAP (Fonseca *et al.*, 2002). When fruit respiration does not correlate to the permeability properties of packaging film, increase in the concentration of CO_2 will build up beyond acceptable levels, leading to anaerobic respiration and ethanol accumulation inside the fresh produce package. This results in the development of off-flavours, odours and decay (Caleb *et al.*, 2012). Although, some studies have reported information on the RR of arils of selected pomegranate cultivars (Ersan *et al.*, 2010), there is no predictive model on the RR of fresh *Pomegranate arils* describing the effect of time and temperature. Therefore, the objectives of this study were (i) to investigate the effect of temperature and time temperature on RR of whole pomegranate fruit and fresh arils cultivars of ‘Bhagwa’ and ‘Ganesh’), thereby provide valuable information on the design of MAP for pomegranate fruit.

Produce and sample preparation

Produce and sample preparation

Fully ripe pomegranate (*Punica granatum* L.) fruit cvs. ‘Bhagwa’ and ‘Ganesh’ were procured from koyambed fruit market, Chennai to the Food science and Technology Laboratory, College of Food and Dairy Technology. The duration of transportation was about 2 hours. On arrival, fruit were immediately stored at 5°C until the next day, when they were peeled manually in a clean cold room at 5°C by carefully removing the arils to avoid damage. Samples of arils were weighed (≈ 150 g each sample), and each sample was placed inside a glass jar of about 500 ml, and equilibrated at the desired storage temperature (5, 10 or 15°C) for at least 1 hour prior to experiment.

Experimental setup

Respiration rates measurement using flow through system is technically difficult, since it requires highly accurate analytical equipment (Cameron *et al*., 1989). A closed system is the convenient way of measuring the respiration of fresh produce (Hagger *et al.*, 1992). Hence the respiration rate data was experimentally generated for different temperatures using the closed system method. The respiration rate measurement of pomegranate was done as per the method adopted by Singh (2011). A closed system is used to measure the respiration rate of pomegranate arils. A known weight of mature pomegranate fruit and arils 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°C, 10°C, and 15°C at 75 % RH in an Environmental chamber (Remi Laboratory Instruments, India; Model: CHM-10) and time was recorded (Fig. 1). The O_2 and CO_2 concentrations in the headspace was measured and recorded after every 0.5 h directly by piercing syringe inside closed glass chamber through septum by a Headspace gas analyser. To ensure a hermetic seal, Vaseline was incorporated into the gap between lid and jar for all the glass jars.

The gas composition within the glass jars was monitored over time with an O_2/CO_2 gas analyser with an accuracy of 0.5% (Checkmate 3, PBI Dan sensor). Gas samples were taken at an hourly interval from the jar head space through the rubber septum. An additional set of experiments was performed at 8°C in order to validate the mathematical model. RO_2 and RCO_2 were determined by fitting experimentally obtained data on yO_2 and yCO_2 with Eqs. (1) and (2), respectively,

$$Ro_2 = \frac{(yo_2^{ti} - yo_2^{tf}) \times V}{m \times (tf - ti)} \quad \text{-- (1)}$$

$$Rco_2 = \frac{(yco_2^{tf} - yco_2^{ti}) \times V}{m \times (tf - ti)} \quad \text{--- (2)}$$

where,

Ro_2 and Rco_2	-	Respiration rate, in terms of O_2 and CO_2 evolved respectively, m^3/kg/h
V	-	Free volume inside the package
yo_2^{ti} and yo_2^{tf}	-	volumetric concentration of O_2 at initial and final time respectively, %
yco_2^{ti} and yco_2^{tf}	-	volumetric concentration of CO_2 at initial and final time respectively, %
m	-	Mass of the stored product, kg
ti and tf	-	Initial and final time respectively, h

Where $yiO_2$and yO_2 are, respectively, O_2 concentration (%) at the initial time ti (hours, h) (time, zero) and at time t (h) and $yiCO_2$ and yCO_2 are, respectively, CO_2 concentration (%) at the initial time ti(h) (or time zero) and at time t (h). RO_2 and RCO_2 are RR in mL/kg hand W is the total weight of the product (kg). Vf is the free volume inside the glass jar (mL), which is the total volume of the glass jar minus the volume occupied by the sample.

Additionally, in order to characterise the effect of time on respiration rate of the arils, periodic gas samples were taken hourly over a period of 5 hours from the hermetic sealed jars, after which the glass jars were opened slightly to minimize rapid moisture loss and also to avoid built-up of sub-atmospheric gases. Following overnight storage time the jars were closed hermetically and gas samples were taken. This cycle was repeated over a 5 day storage period and no spoilage was observed over this period. The gas samples taken during 5 hour measurement period were used to calculate RO_2 and RCO_2 using Eqn. 1 and 2.

Statistical analyses

Response surface methodology (RSM) was used with two factors (time and temperature) each at three levels of temperatures 5, 10 and 15 ◦C at 95% confidence interval to assess the effects of time and temperature, and the interaction between time and temperature on the RR data. One-way analysis of variance (ANOVA) at the95% confidence interval was applied to evaluate the effect of time and temperature on RR and respiratory quotient (RQ). All experiments were carried out in triplicate and data were analysed using Statistical software (SPSS, 10.0).

Results and Discussion

Rate of respiration

The O_2 concentration decreased and CO_2 increased with time inside the container at all the temperature. The respiration data corresponding to the different temperature indicated that as the temperature increased the respiration progressed at a faster rate. The rate of respiration was higher at the start of the experiment and gradually declined as the storage period prolonged, before becoming almost constant.

Effect of temperature on the respiration rate

The influence of temperature on the O_2 consumption (RO_2) andCO_2 production (RCO_2) of both whole pomegranate fruit and fresh arils for the two cultivars was significant, as shown in figure 1. RO_2 and RCO_2 were within the range of 4.58±0.34–15.21±1.16 mL/kg h and 5.72±0.28–18.74±1.62 mL/kg h, respectively, for whole fruit, and in the range of 2.52±0.20–8.36±0.60 mL/kg h and 2.72 ± 0.12–10.12±0.26 mL/kg h, respectively, for fresh arils. Reducing temperature from 15 to 5 ◦C decreased RO_2 and RCO_2 by about68 and

67% for whole fruit and, 67 and 70% for fresh arils, respectively. This significant reduction in fruit respiration rate at lower storage temperature corroborates the findings reported for other types of fresh produce (Nie *et al*., 2005; Tano *et al*., 2007). For instance, Torrieri *et al*., (2010) reported a decrease in RR by 88and 84% for RO_2 and RCO_2, respectively, when the storage temperature of minimally processed broccoli was reduced from 20 to 3◦C. The slightly lower percentage reduction in respiration rates of both whole fruit and fresh arils found in the present study compared to other types of fresh produce such as broccoli may be attributed to the non-climacteric nature of pomegranate fruit and differences in temperature regimes tested.

There was no significant difference in RR of the two cultivars (‘Bhagwa’ and ‘Ganesh’) at all experimental temperatures ($p > 0.05$) studied. However, irrespective of cultivar, the RR of whole fruit was significantly higher than those of fresh arils, as shown in figure 1.

The RR of whole fruit was two to three folds higher, in comparison to those of the fresh arils across all experimental temperatures. Contrary to other fresh-cut fruit in which membranes and cells are damaged, resulting in increased tissue metabolic processes such as enzymatic browning, increased rate of water loss and respiration rates due to the increased surface area in contact with atmospheric oxygen (Zagory, 1998; Iqbal *et al*., 2009; Torrieri *et al*., 2009), *Pomegranate arils* have a protective membrane which prevents direct tissue or cellular interaction of its succulent portion with atmospheric conditions after the husk is carefully removed.

Effect of time and temperature on the respiration rate

Changes in respiration rate for *Pomegranate arils* during storage at different temperatures (5, 10 and 15◦C) are summarized in figure 2. The influence of both time and the interaction between temperature and time on the RO_2 and RCO_2 of fresh arils were significant ($p < 0.05$). These effects were adequately described by the fitted surface plot, which are summarized in figures 3 and 4, respectively.

The observed effect of temperature on RR of arils as shown in figure 2, is similar to those reported by Gil *et al*. (1996), who reported respiration rates of 1.94, 1.30,and 0.53 mL CO_2/kg h for *Pomegranate arils* (cv. ‘Mollar’) stored at 8, 4, and 1◦C, respectively. However, the difference between the responses of the two cultivars in this study at 15◦C highlights the possible influence of physiological differences between cultivar responses to storage condition (Al-Mughrabi *et al*., 1995).

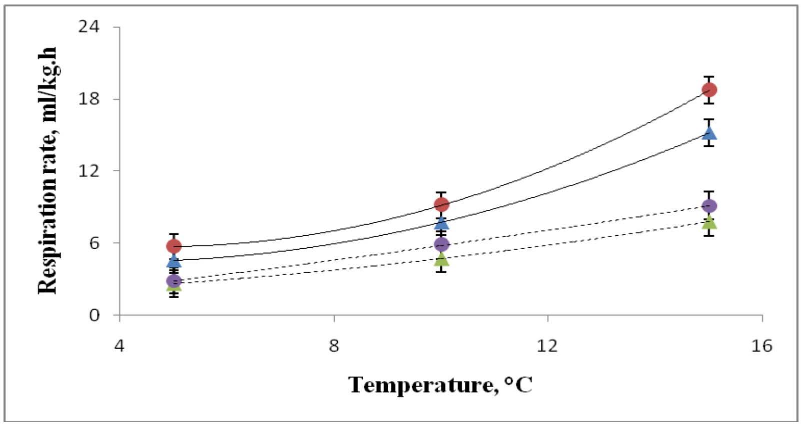
Furthermore, the spike observed in RR at 15 ◦C (Fig. 2), suggests the possible influence of ethylene. Devlieghere *et al*., (2003) found a linear relationship when RR at a specific temperature was plotted against the ethylene production rate for different O_2 and CO_2 concentrations for climacteric and non-climacteric fruit.

In terms of relevance to MAP design, the pattern of RR of *Pomegranate arils* in relation to storage temperature and time as shown in figure 3. Can serve as guiding tool towards other MAP parameters such as package volume to packed arils volume, type of packaging material, barrier properties and temperature sensitivity of packaging material (Fonseca *et al*., 2002).

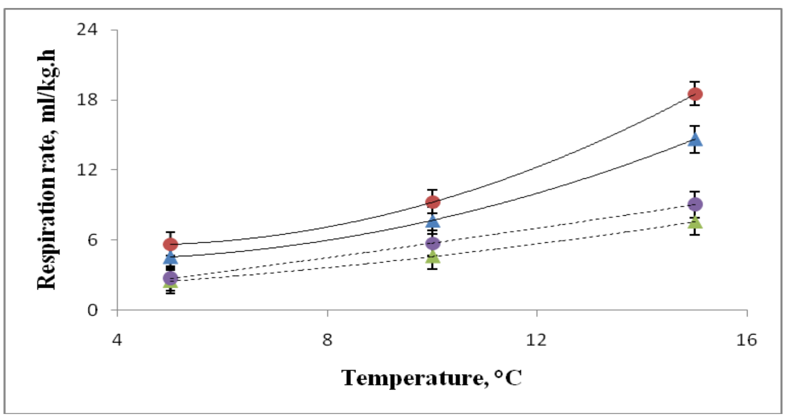
For instance at15◦C, if the permeability property of a packaging film does not correlate with the respiration rate observed. This can lead to excessive accumulation of CO_2, resulting in cell membrane damage and physiological injuries to the product (Caleb *et al*., 2013).

Fig.1 Effect of storage temperature on respiration rate of pomegranate fruit and arils of two Indian cultivars: (a) Bhagwa and (b) Ganesh. Continuous and dotted lines represent the respiration rate of pomegranate whole fruit and arils, respectively. Circle and triangle represents the O_2 consumption rate and CO_2 production rate, respectively. (c). Relationship between experimental and predict respiration rate values of pomegranate whole fruits and arils

(a)



(b)



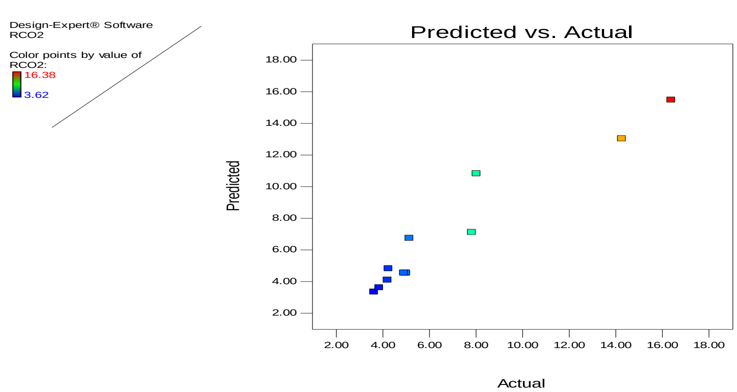
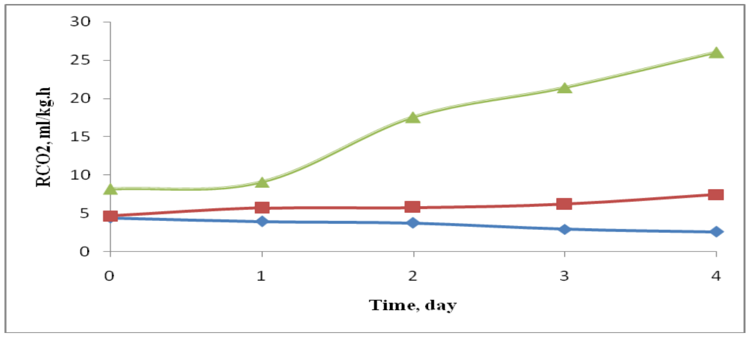
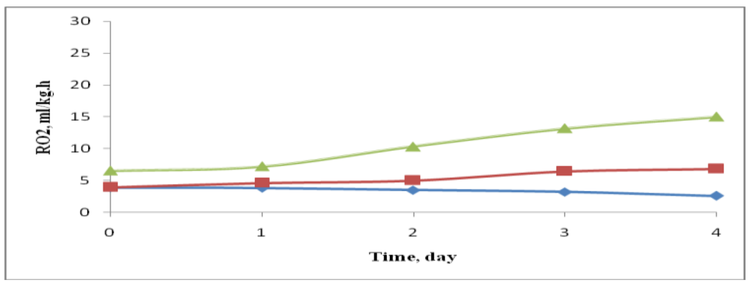


Fig.2 Changes in respiration rate of arils with time at different temperatures: (a) and (b): RCO_2 and RO_2 of arils ("Bhagwa'); (c) and (d): RCO_2 and RO_2 of arils (cv. 'Ganesh') with (♦) representing 5 ◦C, (□) for 10 ◦C and (Δ) for 15 ◦C

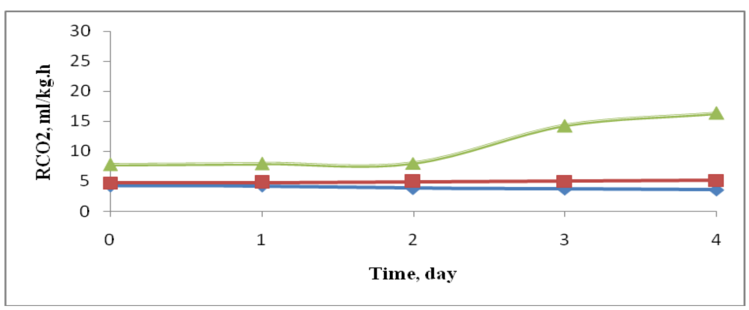
(a)



(b)



(C)



(d)

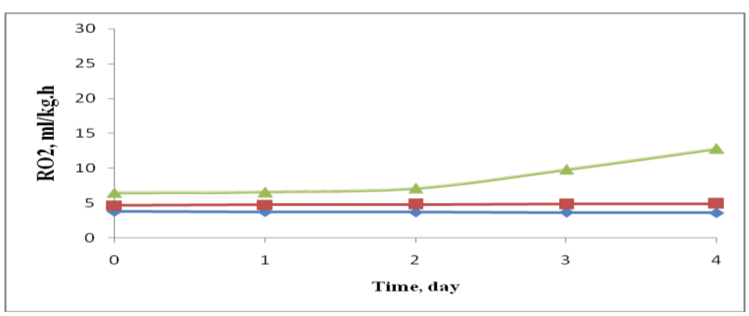


Fig.3 A fitted surface plot showing the effect of temperature and time on RO2 (mL/kg h) for *Pomegranate arils* ('Bhagwa')

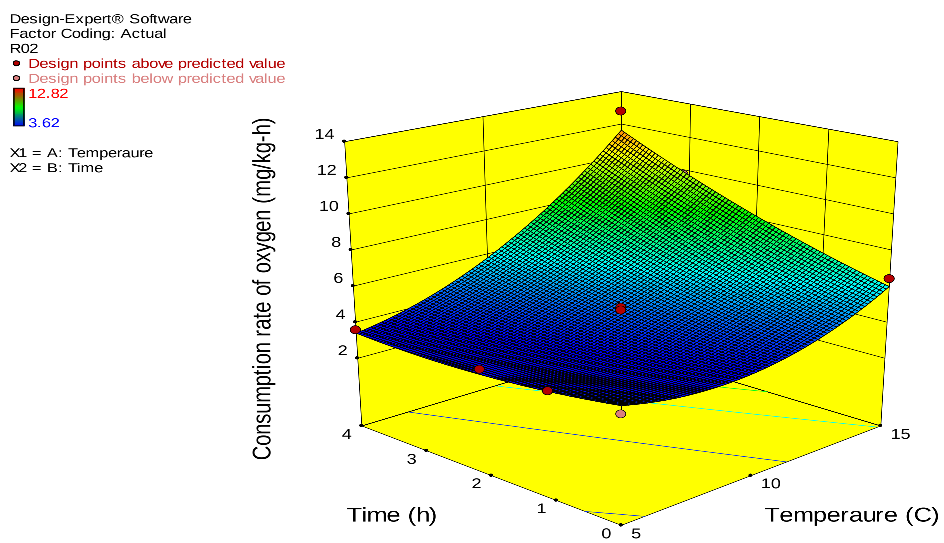
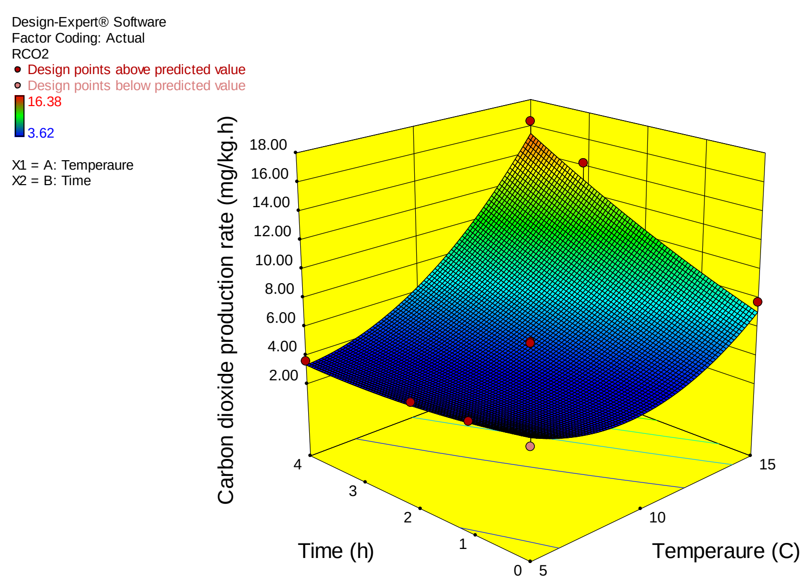


Fig.4 A fitted surface plot showing the effect of temperature and time on RCO_2 (mL/kg h) for *Pomegranate arils* ('Bhagwa')



Furthermore, at 5◦C storage temperature, the respiration rate was at its lowest and appeared to be relatively constant over time. Thus, if an inappropriate ratio of package volume to packed arils volume or packaging material is used the gas equilibrium level at steady-state required inside the package for passive-MAP will take a longer time to establish. MAP has been reported to strongly reduce water loss and chilling injuries without incidence of decay in pomegranate fruit (Artés *et al.*, 2000), and to maintain arils pigments (anthocyanins) better in comparison to samples packed without MAP (Gil *et al.*, 1996).

RQ of *Pomegranate arils* ranged between 1.08 ± 0.06 and 1.64 ±0.08 for cv. 'Bhagwa' and 1.26 ± 0.06 to 1.36 ± 0.08 for cv. 'Ganesh'. The RQ value of arils estimated by linear regression of RCO_2 vs. RO_2 was 0.98 ± 1.14 (*R2* adj = 98 %) at 95 % significant level. These values compares favourably with normal RQ limits (0.7 to 1.3) for aerobic respiration (Kader *et al*., 1989), with the exception of *Pomegranate arils* (cv. 'Bhagwa') at 15 °C. However, experimental evidence suggests that the significant ($p <$ 0.05) influence of time and temperature on the observed high RQ for *Pomegranate arils* (cv. 'Bhagwa') occurred under aerobic conditions, similar to the findings reported by Wang *et al*., (2009) for guava fruit.

In conclusion, based on the experiments, it was concluded that the steady-state respiration rates were found to be decreasing with storage time. Temperature had the most significant impact on the RR of arils of both pomegranate cultivars (cv. 'Bhagwa' and 'Ganesh') and the RR were 3-4 folds significantly higher with increased temperature from 5 to 15 °C. The influence of time, and the interaction between temperature and time also had a significant influence on the RR of fresh arils. This highlights the importance of maintaining optimal cold-storage condition for fresh produce along the supply chain. The RQ was dependent on both temperature and time as the RQ value increased with rising temperature from 5 to 15 °C towards the end of the storage time. An Arrhenius type equation accurately predicted the effect of temperature on RR of fresh pomegranate arils. The power function equation combined with Arrhenius-type equation adequately predicted the influence of time and temperature on RR of fresh *Pomegranate arils* for both cultivars. These models would be useful towards the design of appropriate modified atmosphere package for freshly processed pomegranate arils.

References

Ahmed, D.A., Yousef, A.R.M., Sarrwy, S.M.A. 2011. Modified atmosphere packaging for maintain quality and shelf life extension of persimmon fruits. *Asian J. Agric. Sci.*, 3: 308–316.

Alighourchi, H., Barzegar, M., Abbasi, S. 2008. Anthocyanins characterization of 15 Iranian pomegranate (*Punica granatum* L.) varieties and their variation after cold storage and pasteurization. *Eur. Food Res. Technol.*, 227: 881–887.

Arendse, E., Fawole, O.A., Opara, U.L. 2014. Effects of postharvest storage conditions on phytochemical and radical scavenging activity of pomegranate fruit (cv. Wonderful). *Sci. Hortic.*, 169: 125–129.

Artés, F., Gomez, P.A., Artés-Hernandez, F. 2006. Modified atmosphere packaging of fruits and vegetables: a review. *Stewart Postharvest Rev.*, 2: 1–13.

Artés, F., Villaescusa, R., Tudela, J.A. 2000. Modified atmosphere packaging of pomegranate. *J. Food Sci.*, 65: 1112–1116.

Ayhan, Z., Estürk, O. 2009. Overall quality and shelf life of minimally processed and modified atmosphere packaged "ready to eat" pomegranate arils. *J. Food Sci.*, 74: C399–C405.

Bai, J., Saftner, R.A., Watada, A.E. 2003. Characteristics of fresh-cut honeydew (Cucumisx *melo* L.) available to processors in winter and summer and its quality maintenance by modified atmosphere packaging. *Postharvest Biol. Technol.*, 28: 349–359.

Banks, N.H., Cleland, D.J., Cameron, A.C., Beaudry, R.M., Kader, A.A. 1995. Proposal for a rationalized system of units for postharvest research in gas exchange. *Hort Sci.*, 30: 1129–1131.

Bhatia, K., Asrey, R., Jha, S.K., Singh, S., Kannaujia, P.K. 2013. Influence of packaging material on quality characteristics of minimally processed Mridula pomegranate (*Punica granatum*) arils during cold storage. *Indian J. Agric. Sci.*, 83: 872–876.

Brandenburg, J.S., Zagory, D. 2009. Modified and controlled atmosphere packaging technology and applications. In: Yahia, E.M. (Ed.), Modified and Controlled Atmosphere for Storage, Transportation and Packaging of Horticultural Commodities. CRC Press, Boca Raton, pp. 73–92.

Cameron, A.C., Beaudry, R.M., Banks, N.H., Yelanich, M.V. 1994. Modified atmosphere packaging of blueberry fruit: modelling respiration and package oxygen partial pressures as function of temperature. *J. Am. Soc. Hort. Sci.*, 119: 534–539.

Charles, F., Sanchez, J., Gontard, N. 2003. Active modified atmosphere packaging of fresh fruits and vegetables: modeling with tomatoes and oxygen absorber. *J. Food Sci.*, 68: 1736–1742.

Devlieghere, F., Jacxsens, L., Tatay, M.S., Debevere, J., Meirlaen, J., Vanrolleghem, P. 2003. Modelling the relation between ethylene production rate, respiration rate and their influence on climacteric and non-climacteric fruits. *Acta Hort.*, 600: 647–651.

Ersan, S., Gunes, G., Zor, A.O. 2010. Respiration rate of *Pomegranate arils* as affected by O2 and CO2, and design of modified atmosphere packaging. *Acta Hort.*, 876: 189–196.

Farber, J.N., Harris, L.J., Parish, M.E., Beuchat, L.R., Suslow, T.V., Gorney, J.R., Garrett, E.H., Busta, F.F., 2003. Microbiological safety of controlled and modified atmosphere packaging of fresh and fresh-cut produce. *Compr. Rev. Food Sci. Food Safety*, 2: 142–160.

Fonseca, S.C., Oliveira, F.A.R., Brecht, J.K. 2002. Modelling respiration rate of fresh fruits and vegetables for modified atmosphere packages. *J. Food Eng.*, 52: 99–119.

Gil, M.I., Artes, F., Toma-Barberan, F.A. 1996. Minimal processing and modified atmosphere packaging effects on pigmentation of pomegranate seeds. *J. Food Sci.*, 61: 161–164.

Caleb, O.J., Mahajan, P.V., Manley, M., Opara, U.L. 2013. Evaluation of parameters affecting modified atmosphere packaging engineering design for pomegranate arils. *Int. J. Food Sci. Technol.*, 48: 2315–2323.

Caleb, O.J., Opara, U.L., Witthuhn, C.R. 2012a. Modified atmosphere packaging of pomegranate fruit and arils: a review. *Food Bioprocess Technol.*, 5: 15–30.

Caleb, O.J., Mahajan, P.V., Opara, U.L., Witthuhn, C.R. 2012b. Modelling the respiration rates of pomegranate fruit and arils. *Postharvest Biol. Technol.*, 64: 49–54.

Lakakul, R., Beaudry, R.M., Hernandez, R.J. 1999. Modeling respiration of apple slices in modified atmosphere packages. *J. Food Sci.*, 64: 105–110.

López-Rubira, V., Conesa, A., Allende, A., Artés, F. 2005. Shelf life and overall quality of minimally processed *Pomegranate arils* modified atmosphere packaged and treated with UV-C. *Postharvest Biol. Technol.*, 37: 174–185.

Mahajan, P.V., Oliveira, F.A.R., Macedo, I. 2008. Effect of temperature and humidity on the transpiration rate of the whole mushrooms. *J. Food Eng.*, 84: 281–288.

Mahajan, P.V., Oliveira, F.A.R., Montanez, J.C., Frias, J., 2007. Development of user friendly software for design of modified atmosphere packaging for fresh and fresh-cut produce. *Innov. Food Sci. Emerg. Technol.*, 8: 84–92.

Manolopoulou, H., Papadopoulou, P. 1998. A study of respiratory and physicochemical changes of four kiwi fruit cultivars during cool-storage. *Food Chem.*, 63: 529–534.

Nie, D., Uchino, T., Sakai, N., Tanaka, S. 2005. Effect of high temperature on the apparent activation energy of respiration of fresh product. *Postharvest Biol. Technol.*, 37: 277–285.

Tano, K., Oulé, M.K., Doyon, G., Lencki, R.W., Arul, J. 2007. Comparative evaluation of the effect of storage temperature fluctuation on modified atmosphere packages of selected fruit and vegetables. *Postharvest Biol. Technol.*, 46: 212–221.

Torrieri, E., Cavella, S., Masi, P., 2009. Modelling the respiration rate of fresh-cut Annurca apples to develop modified atmosphere packaging. *Int. J. Food Sci. Technol.*, 44: 890–899.

Torrieri, E., Perone, N., Cavella, S., Masi, P. 2010. Modelling the respiration rate of minimally processed broccoli (*Brassica rapa* var. sylvestris) for modified atmosphere package design. *Int. J. Food Sci. Technol.*, 45: 2186–2193.

Wang, Z.W., Duan, H.D., Hu, C.Y. 2009. Modelling the respiration rate of guava (Psidiumguajava L.) fruit using enzyme kinetics, chemical kinetics and artificial neural network. *Eur. Food Res. Technol.*, 229: 495–503.

Zagory, D. 1998. An update on modified atmosphere packaging of fresh produce. *Pack. Int.*, 117: 1–5.

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