Computers and Electronics in Agriculture 121 (2016) 347–353

Contents lists available at ScienceDirect

Computers and Electronics in Agriculture

journal homepage: www.elsevier.com/locate/compag

Original papers

Development of a small and flexible sensor-based respirometer for real-time determination of respiration rate, respiratory quotient and low O_2 limit of fresh produce

Pramod V. Mahajan [a,b], Alexandru Luca [a], Merete Edelenbos [a,*]

[a] Aarhus University, Dept. of Food Science, Kirstinebjergvej 10, 5792 Årslev, Denmark
[b] Department of Horticultural Engineering, Leibniz Institute for Agricultural Engineering, Potsdam, Germany

ARTICLE INFO

Article history:
Received 10 November 2015
Received in revised form 19 December 2015
Accepted 27 December 2015
Available online 15 January 2016

Keywords:
Fresh produce
Sensors
Respiration rate
Respiratory quotient
Low O_2 limit
Modified atmosphere packaging

ABSTRACT

Information on the respiration rate and the low O_2 limit (LOL) is important for optimization of packaging and storage systems for fresh fruit and vegetables. In this study, a small and flexible sensor-based respirometer was developed for real-time determination of the respiration rate, respiratory quotient (RQ), and LOL of fresh produce. The respirometer consisted of a wide mouth 1-L glass jar with a screw-type metal lid and an electrochemical and an infra-red sensor mounted directly on the lid of the glass jar to take continuous and non-invasive measurements of the O_2 and CO_2 contents. Data from the respirometer was compared with data obtained from two fluorescence-based spot sensors (OpTech and PreSens) and a headspace gas analyzer (CheckMate). A test with strawberry showed that similar respiration rates (14.1–16.2 mL O_2 kg^{-1} h^{-1} and 13.4–16.4 mL CO_2 kg^{-1} h^{-1} at 10 °C) were obtained with all instruments. Further on, a Savitzky–Golay smoothing filter was implemented on the data from the respirometer to estimate the real-time respiration rate. The result showed that the respiration rate could be acquired in 2–3 h after filling of the respirometer or even after 1 h if the produce was equilibrated to the target storage temperature before the measurements. Detailed information on the respiration rate of wild rocket, strawberry, and carrot showed that the respiration rate decreased with time as the O_2 content decreased; however, the RQ remained almost constant throughout storage until the LOL was reached. Information on the RQ and the LOL value is rare in the literature; however, the RQ and the LOL could easily be determined by the use of the respirometer. The RQ was 1.0, 1.0–1.5, and 0.5 for wild rocket, strawberry, and carrot, respectively, during storage under an O_2 content above >2.0 kPa. As the O_2 content dropped to 0.5, 1.0 and 2.0 kPa O_2, for wild rocket, strawberry, and carrot, respectively, the RQ values increased sharply. The described respirometer made it easy to analyze the impact of a dynamic temperature and O_2 content on the respiration rate, the RQ, and the LOL as handling was limited and real-time data could be obtained. With such detailed information, a knowledge-intensive design of packaging and storage systems for fresh horticultural produce is enabled.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

Information on the respiration rate and the low O_2 limit (LOL) content is important for optimization of packaging and storage systems of fresh fruit and vegetables as fruit and vegetables remain alive and continue to respire to produce biochemical energy after harvest. When fresh produce is stored above the LOL in an atmosphere with sufficient O_2 the respiration processes involve consumption of O_2 and production of CO_2 in an almost equal rate (Saltveit, 2003) and the respiration rate is aerobic. Below the LOL, more CO_2 is produced than O_2 consumed and the respiration rate is anaerobic. The respiration rate is defined as the amount of O_2 consumed (RRO_2) or CO_2 produced ($RRCO_2$) per unit mass of fresh produce per unit time.

The respiration rate is a key parameter in postharvest technology for the design of modified atmosphere packaging (MAP) solutions for fresh fruit and vegetables (Mahajan et al., 2007; Cagnon et al., 2013; Guillard et al., 2015). Once the RRO_2 and $RRCO_2$ are known, the respiratory quotient (RQ) can be determined as $RRCO_2/RRO_2$. The RQ will vary around one above the LOL content and it will increase dramatically ($RQ \ggg 1$) at the LOL content or below (Fonseca et al., 2002; Kader and Saltveit, 2003). As the LOL can

* Corresponding author. Tel.: +45 8715 8334; fax: +45 8715 4812.
E-mail address: merete.edelenbos@food.au.dk (M. Edelenbos).

http://dx.doi.org/10.1016/j.compag.2015.12.017
0168-1699/© 2016 Elsevier B.V. All rights reserved.

be reached easily with inappropriate designed MAP solutions it is a paramount to prevent LOL in successful MAP not to impair produce quality (Kader and Saltveit, 2003; Løkke et al., 2012).

Once the RRO_2 or $RRCO_2$ is determined, important parameters such as the size of package, the amount of produce and the size and number of micro-perforations can be optimized (Mahajan et al., 2007). The respiration rate can be determined in a static or closed system or in a dynamic or flow-through, open system containing fresh produce (Fonseca et al., 2002) and the initial gas composition can be similar or different from that of air.

In most of the studies published before 2001, measurement of the O_2 and CO_2 content was based on using a gas chromatograph. This was time consuming, laborious and expensive (Fonseca et al., 2002). Since 2002, there has been a growing interest to employ simple and easy-to-use O_2 and CO_2 gas analyzers for measurement of the gas content (Caleb et al., 2013). These analyzers are based on electrochemical (O_2) and infrared (CO_2) sensors and are commercially available in the CheckMate (Dansensor, Ringsted, DK), the PacCheck (MOCON, Minneapolis, USA), the Dualtrak (Quantek Instruments Inc., Grafton, USA), and the GasSpace Advance instrument (Systech Instruments Ltd, Oxfordshire, UK). The gas analyzers, although simple and easy-to-use, all produce discrete data based on headspace sampling. A headspace sample of 3–15 mL gas is taken for every reading. With many readings, this can create under pressure in the static system (Fonseca et al., 2002). Also the points for measurements should be chosen with great care to be representative for the changing respiration rates, as respiration, like many other biological processes, is a dynamic and continuous process, and the O_2 and CO_2 contents continuously change (Fonseca et al., 2002). Recently, non-invasive O_2 sensors emerged on the market for continuous O_2 measurements (OpTech, Mocon, Minneapolis, USA; PreSens, PreSens – Precision Sensing GmbH, Regensburg, Germany). These sensors are based on monitoring an oxygen-dependent fluorescence signal on a spot stuck to the inside of a transparent container, however, these sensors are expensive and measure only the O_2 content of the container.

Information is available on continuous measurements of O_2 and or CO_2 contents in flow-through systems filled with fresh produce (Bower et al., 1998; Herppich et al., 1999; Calegario et al., 2001). However, information from the flow-through systems are not representative for the gas conditions inside MAP with fresh produce where the gas exchange is restricted during storage. Løkke et al. (2011) and Seefeldt et al. (2012) applied a wireless sensor network (WSN) for on-line, non-invasive measurement of O_2 content in a respirometer containing fresh produce without gas exchange. The sensor could measure the O_2 content in the range from 6.3 to 20.9 kPa and could give on-line, continuous reading of the O_2 content in the vicinity of the produce. However, the RQ could not be determined as the CO_2 content was not measured.

It is well-known that storage temperature is the most critical parameter for fluctuations in the respiration rate and it has been demonstrated that the respiration rate increases at elevated temperatures (Kader and Saltveit, 2003; Caleb et al., 2012). In experimental storage conditions it is assumed that the temperature is strictly controlled during gas sampling. However, Seefeldt et al. (2012) reported that the removal of a respirometer with a wireless O_2 sensor from a climate chamber to a laboratory bench for discrete gas measurements with a CheckMate instrument had large and long-lasting effects on the respiration rate as determined with a wireless O_2 sensor. Such data are rare in the literature because it is difficult to measure minute changes in the respiration rate due to short-time temperature fluctuations by the use of traditional gas analysis. Even measurements with an on-line, fluorescence-based equipment would not be possible as these systems require constant illumination of the in-side spot to give continuous readings of the O_2 content.

The aim of the present work was to obtain non-invasive, reliable and continuous data on the changes in the O_2 and CO_2 contents during storage of fresh produce in a closed container and from these data determine the RRO_2, $RRCO_2$, RQ, and the LOL of fresh produce under varying storage temperatures and O_2 contents. A sensor-based respirometer was developed and from the obtained data, real-time respiration rate, RQ and LOL were calculated. The results were compared with those obtained with traditional gas analyzers and fluorescence-based spot sensors. Wild rocket, strawberry and carrot were used for the experiments.

2. Material and methods

2.1. Plant material

Three products were selected for the experiments; wild rocket (*Diplotaxis tenuifolia* L.), strawberry (*Fragaria X ananassa* Duch, 'Elsanta') and carrot (*Daucus carota* L., 'Brasilia'). These products represented fresh produce with different geometry and respiration rates; wild rocket with high, strawberry with medium, and carrot with low respiration rates. Wild rocket was harvested at a Danish grower (Yding Grønt A/S, Yding, Denmark), packaged and brought to Aarhus University in Årslev (Denmark). Strawberry and carrot were obtained from a local supermarket in Årslev and brought to the University after purchase. All commodities were stored in their original packages at 1 °C until being used for the experiments. On the day of experimental start, the products were allowed to equilibrate for at least one hour to reach the test temperature. All experiments were carried out in walk-in cold rooms kept at the target temperature.

2.2. The respirometer

The respirometer (Fig. 1) consisted of a wide mouth 1-L glass jar with a screw-type metal lid and an O_2 sensor (CiTiceL®, City Technology Ltd, Portsmouth, UK) and a CO_2 sensor (ICB sensor, SenseAir, Delsbo, Sweden) mounted on the top of the lid through holes. These sensors are nominated lid sensors. The lid sensors were tightened with O-rings to avoid gas leakage between the lid and the sensors, and extra holes were drilled through the lid when needed for inlet and outlet tubing or for headspace gas sampling through a septum. The O_2 sensor consisted of an electrochemical cell for measurement in the range 0–100 kPa with a resolution of 0.01 kPa. The CO_2 sensor was a non-dispersive, infra-red sensor. It measured the CO_2 content in the range 0–25 kPa with an accuracy of ±0.2 kPa. The lid sensors were exposed to the gas content inside the respirometer through the holes in the lid and the sensors

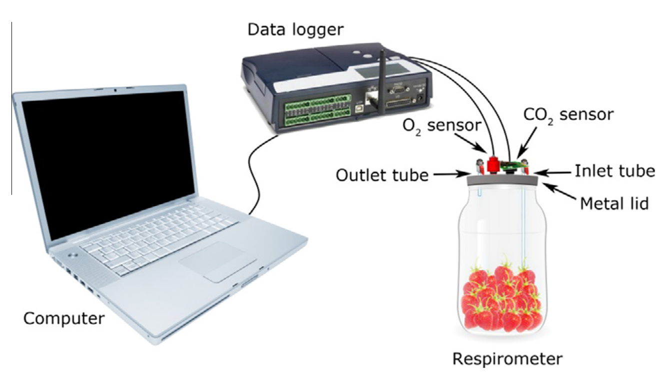

Fig. 1. The experimental setup for measuring changes in the O_2 and CO_2 content in a respirometer.

Download English Version:

https://daneshyari.com/en/article/84015

Download Persian Version:

https://daneshyari.com/article/84015

Daneshyari.com