Quality of Postharvest Papaya and Prediction of its Sugar Consumption using Chemical Model

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Abstract: Fresh papaya is more susceptible to disease organisms because of increase in the respiration rate after harvesting. The changes of main composition of papaya such as total soluble solids (TSS), total sugars (TS), and sugar-acid ratio (SAR) are studied. The model of the respiration rate of papaya in modified atmospheric environment has been built based on chemical kinetics. The model is parameterized with experimental data obtained at temperatures 8, 18 and 28 °C and evaluated at 13 °C by the closed system method. The indicators of the mean absolute percentage error (MAPE %) and the correlation coefficient *r* are used to verify the performance of the created model respectively. The results indicated that TSS, TS content and the sugar-acid ratio of half-ripe fruits reached the peak on day 16, and then showed a declining trend. Meanwhile the above three elements of the full-ripe ones were decreasing all the time during the storage. The sugar consumption calculated by the respiration model was found to have a good agreement with those obtained experimentally.

Keywords: papaya; quality; sugar consumption; chemical model

1. Introduction (Heading 1)

Papaya (Carica *papaya* L.) is cultivated throughout the tropical area for its fruit. It has been becoming increasingly popular in recent years due to the healthy benefits associated with the excellent nutrient contents. However, most fruits including papaya, even after harvest, still remain active in respiration, ripening and senescence [1]. Respiration is a metabolic process that supplies the required energy for the plant biochemical demand. At the same time, many of the substrates especially sugars and acids are consumed during the metabolic synthesis [2], which can cause quality deterioration of the fruits. Thus, the control of the metabolism of the substrates is important for the design of the modified atmosphere packaging (MAP) storage for fresh produce.

The respiration of the fruits is the oxidative breakdown of complex substrate molecules, such as starch, sugars and organic acids to simple molecules such as CO_2 and H_2O. Although fats and proteins can also be used partially as substrates for respiration, it is assumed that most CO_2 emitted from fruits and vegetables is due to oxidation of sugar for respiration [3-4]. With regard to papaya, some papers showed the trend of sugar consumption or the changes of sugar [5-6], but there was no report on the relationship between the consumption of the substrates and the respirations, or the prediction of sugar consumption based on the respiration model.

Thus, in this work, the sugar consumption was calculated according to the respiration rate (RR) by chemical model put forward by Duan et al. [7]. SAR and quality loss of TSS and TS in papaya after postharvest was obtained too, which would provide guidance for the design of the MAP methods. This study was based on the assumption that the decrease in sugars of the papaya was caused only by oxidation for respiration and the consumption of the sugar was regarded as the decrease of the total sugar.

2. Materials and methods

2.1. Fruit samples

Papaya fruit of local harvest was purchased from the nearby qianshan market at Zhuhai, Guangdong, China and transported carefully to the laboratory within 30min. Samples must be selected with no mechanical and pest damage at two ripe stages. The half-ripe stage was defined as 50% skin yellowing and for papaya in full-ripe stage, it was normally ready to eat [8]. Two groups of full-ripe samples must be prepared. One group and half-ripe samples were used for measuring the changes of sugar at 13 °C . The other was used for creating the model at temperature 8 °C, 13 °C, 18 °C and 28 °C, respectively. Each sample was measured for volume using the method of water replacement, and then it was put into the container and sealed for further use. All the fruits were packaged in boxes (110 × 170 mm)

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made from 60μm-thick polypropylene (PP) and stored at the corresponding temperature in a cooling cabinet.

2.2. Measurement of sugar consumption

Papaya samples were crushed manually with a mortar and pestle to extract the juice. The content of TSS was determined using an Atago ATCI hand-held refract meter (Atago Co., Ltd, Tokyo, Japan). SAR is the ratio of total sugar content (TSC) to total acid content (TAC). The TSC was measured by DNS methods [9]. The TAC must be obtained in order to calculate SAR, which was measured by the neutralization method. In this paper, the total acidity was expressed as mg citric acid per 100g fresh papaya.

The sugar consumption obtained experimentally (SC_E) was regarded as the decrease of the total sugar in this study.The predicted sugar consumption (SC_C) was obtained by the CO_2 production using the following equation:

$$C_6H_{12}O_6+6O_2 \rightarrow 6CO_2+6H_2O+2,816\text{kJ} \quad (1)$$

2.3. Prediction of sugar consumption using the chemical model

2.3.1. Determination of respiration rate

The respiration rate (RR) was measured by a closed system method as suggested by Hagger et al. [10], which was broadly used for generating the respiration data for fruits. In this study, the RR was expressed as the CO_2 production rate which was measured according to Wang et al. [11].

2.3.2. Prediction of sugar consumption with Chemical model

Herein, the chemical model, developed by Duan et al. [8], was applied to calculate the RR as:

$$R_{CO_2} = A\exp\left(\frac{-E_a}{RT}\right)[O_2]^{\alpha}[CO_2]^{\beta} \quad (2)$$

Where the parameter A is pre-exponential factor; E_a is apparent activation energy, kJ /mol; R is universal gas constant, 8.314 J/ (mol · K); T is absolute temperature, K; α and β are called reaction orders. The negative sign before β means the reducing respiration rate of the present of CO_2.

The CO_2 production could be obtained by integrating respiration rates (RRs) calculated from the above model, then the sugar consumption (SC_C) could be estimated and compared with the experimentally derived data.

2.3.3. Model verification

Verification of the regression chemical model for RR was performed at 13 °C. The experimental data of sugar consumption were also obtained using equation (1) and (2). The fitness of predictions and observations was judged by calculating the mean absolute percentage error (MAPE) and the two-tailed Pearson correlation coefficient (r) as suggested by McLaughlin & O'Beirne [12]. Ravindra & Goswami [13] suggested that when the MAPE% was less than 10%, it indicated reasonably good fit. When the MAPE% was within 10~20%, it indicated fairly good fit. However when the MAPE% was within 20~30%, it indicated unsatisfactory fit for all practical purpose.

3. Results and discussion

3.1. TSS

Significant changes in TSS were observed among the papaya with different maturity shown in Fig.1. Half-ripe papaya was found to have the highest TSS values on day 16, and have a decreasing trend after that, while the full-ripe ones typically declined throughout the storage. The decrease in TSS observed was in agreement with the results of Arganosa et al. [14], who found that three-quarters ripe papaya showed decreases in TSS after 18 days of storage at 10°C and they explained this phenomenon on the assumption that sugars were the first substrates used during respiration.

3.2. TSC

Changes of TSC of papaya were shown in Fig.2. For half-ripe papaya, TSC increased until day 16, which was twice as initial values. Afterwards it decreased quickly, which was like the changes of TSS seen in Fig.1. This might be due to the fact that most of TSS was sugar. Meanwhile TSC in the full ripe papaya declined rapidly during the whole storage time. This probably could be related to the RR of papaya. Some researchers confirmed that the faster the RR increased, the faster the substrates decreased [15].

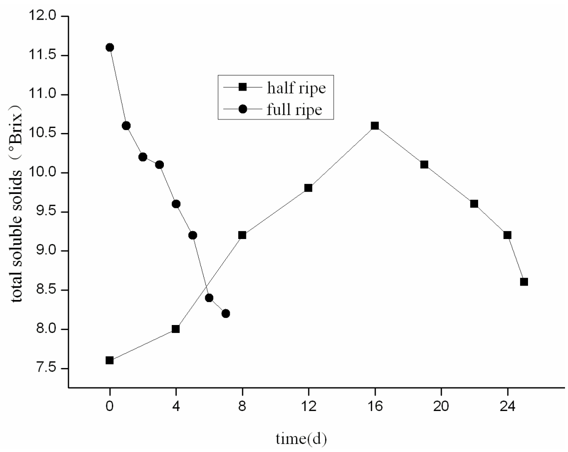

Figure 1. Changes of TSS in postharvest papaya at 13 °C.

3.3. SAR

Flavor is a quality attribute that is critical in determining the acceptability of fruits and vegetables, which is decided mainly by the SAR. Sugar and acid can vary independently leading to the change of flavor [16]. The changes of SAR of the postharvest papaya were shown in Fig. 3. The SAR of half-ripe papaya was very low at the beginning period, and then increased to the highest value (125.15) on day 16, which was in accordance with the report by Arganosa et al. [14]. SAR in the full-ripe fruits was decreasing during the storage and the rate became faster in the last days, which probably due to the deterioration caused by over-ripening.

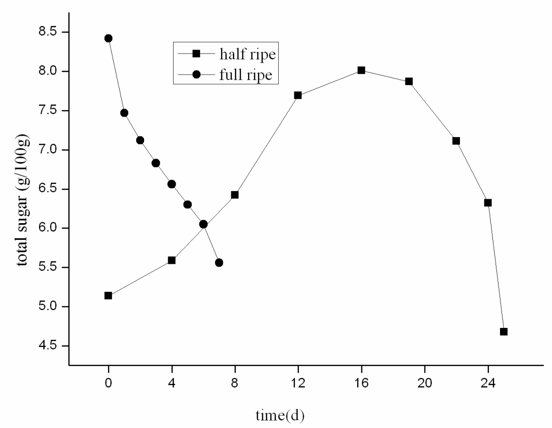

Figure 2. Changes of TSC of postharvest papaya at 13 °C.

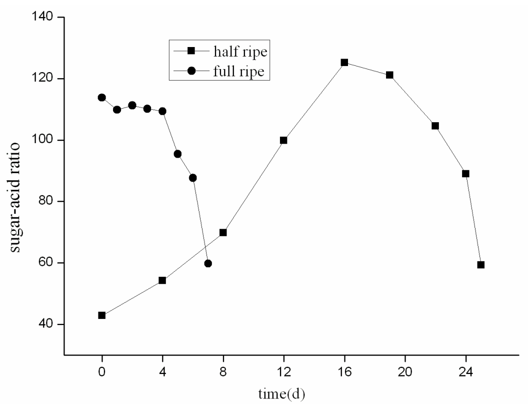

Figure 3. Changes of SAR of postharvest papaya at 13 °C.

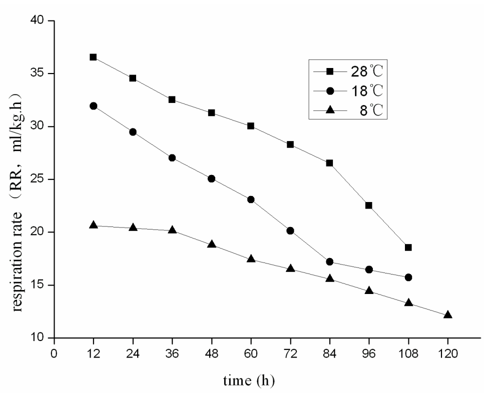

Figure 4. Experimental data for RR of CO_2 at various temperatures and time.

3.4. Prediction of sugar consumption using the chemical model

The changes of the RR of CO_2 of the full-ripe papaya at temperature 8 °C, 18 °C, 28 °C were described in Fig.4, respectively. The RR of CO_2 of papaya decreased with the elapse of time, which was due to the decreasing concentration of O_2 and the increasing concentration of CO_2 in the containers. Similar phenomenon had been reported for many fruits and vegetables [13,17]. The temperature had obvious effect on the RR. The higher the temperature, the higher the RR in papaya, which was in accordance with the respiration pattern suggested by Kader [18].

The above RRs data were put to the chemical model in order to estimate the parameters A, E_a, α and β in equation (2). The final levels of α and β are 1.15 and -0.003, respectively. The pre-exponential factor (A) and the activation energy (E_a) approached by nonlinear regression are 1.47×10^{14} h^{-1} and 78.5 kJ mol^{-1}, respectively. Accordingly, the global chemical model on the RR of papaya was expressed as follows:

$$R_{CO_2} = 1.47\times10^{14}\exp(-9451.3/T)[O_2]^{1.15}[CO_2]^{-0.003} \qquad (3)$$

3.5. Evaluation of results

To verify this model, the data of sugar consumption was calculated at 13 °C and compared with the predicted ones which were evaluated by the chemical model with Eqns. (1) and (3). The comparison between the experimental and predicted values was shown in Fig.5. The values of MAPE% and r obtained from the chemical model were 9.8% and 0.974, respectively. This suggested that the sugar consumption predicted by the chemical model was in good agreement with the experimental data.

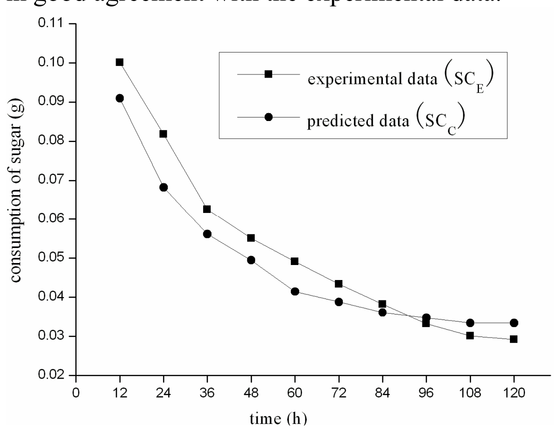

Figure 5. Experimental and predicted sugar consumption for papaya at 13 °C.

4. Conclusion

The effect of TSS, TSC and SAR on the quality of papaya with different maturity was studied. The prediction of the sugar consumption using the chemical model in the full-ripe papaya was proposed. The results indicated that the half-ripe papaya had the best quality during storage at 13℃ for up to about 16 days, which possessed the highest TSS, TSC and SAR. The full-ripe samples showed a declining trend in TSS, TSC and SAR at the beginning period, which meant that the full-ripe papaya should be consumed right after harvest due to its rapid deterioration.

The RR obtained by the chemical model could be used to predict the consumption of sugar in papaya. This chemical model was suitable to predict the sugar consumption in papaya and could probably be used for other produce. However, close attention must be paid that papaya tested in this study must be in maturity level, because the unripe produce has more complicated metabolic processes and the sugar can't entirely participate in the respiratory activity.

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