Study on changes of maize respiration rate under different temperature conditions

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Abstract

The purpose of the study was to examine variation of maize respiration rate by determining O_2 content in percentage released due to respiration under hermetic storage conditions, based on three different moisture contents of maize (low moisture 11.8% safe moisture 13.3% and high moisture 16.3%) at four different temperatures (15°C, 20°C, 25°C and 30°C). The results obtained from the 20L-scale experiments have demonstrated that respiration rate of maize has a nonlinear relationship to storage time and oxygen concentration in self-regulated environments, the maize of higher moisture content has faster respiration rate at the same temperature, for the same moisture content of maize, higher respiration rate was observed at higher temperature. The maize at 15°C showed changes in respiration rate: low moisture 0.047~0.431 mL.g-1.d-1, safe moisture 0.059~0.574 mL.g-1.d-1 and high moisture 0.071~0.707 mL.g-1.d-1; the maize at 20°C exhibited changes in respiration rate: low moisture 0.143 ~0.520 mL.g-1.d-1, safe moisture 0.183 ~0.734 mL.g-1.d-1 and high moisture 0.173~0.707 mL.g-1.d-1; the maize at 25°C exhibited changes in respiration rate: low moisture 0.199~0.910mL.g-1.d-1, safe moisture 0.192~1.170 mL.g-1.d-1 and high moisture 0.241~1.197 mL.g-1.d-1; the maize at 30°C showed changes in respiration rate: low moisture 0.194~1.360 mL.g-1.d-1, safe moisture 0.203~1.541 mL.g-1.d-1 and high moisture 0.256 ~1.964 mL.g-1.d-1. Regression analysis was performed on trends of maize respiration rate due to changes in time and oxygen concentration and to obtain the equations with different moisture contents in different temperature conditions. The prediction model can be employed to determine respiration rate of stored maize under hermetic condition and to provide basic parameters for rational utilization of a controlled atmosphere storage environment.

Keywords: different temperature, different moisture content of maize, grain respiration, respiration rate

1. Introduction

Hypoxia grain storage is one of the developing directions of green grain storage. It has practical meaning for stored grain quality-keeping and energy-saving and emission-reduction to use of grains self-respiration to decrease the O_2 concentration. Respiration has long been used to measure metabolic activity in stored produce (Laccy et al., 1994). Considerable work about respiration rate has been done on fruits and vegetables, but relatively little has been done on grains (Weinberg et al., 2008; Wang et al., 2009; Wang et al., 2008; Tian, 2003. The present study was to examine variation of maize respiration rate by determining O_2 content in percentage released due to respiration consuming O_2 under hermetic storage conditions, based on three different moisture contents of maize in four different temperatures.

2. Materials and methods

2.1. Preparation of the maize grain samples

Maize cobs were brought to the laboratory from a local farmer's field. After threshing and removing impurities and moldy kernels by hand, the maize was divided into three batches, which were then sun-dried to the targets of low moisture (11.8% m.c.), safe moisture (13.3% m.c.) and high moisture(16.3% m.c.).

2.2. Experimental conditions

The maize from the same moisture treatment was thoroughly mixed. Then maize at each m.c. was placed in 20-L glass jars with 6.56-L freedom porosity, about 16.8kg per jar. The jar were sealed with a gas-tight lid and special clamps. Four jars were prepared for each m.c., each of which was stored at 15°C, 20°C, 25°C and 30°C for analysis. To enable gas sampling, a silicon-rubber tube was used.

2.3. Analytical procedures

The amount of O_2 that consumed by maize grain respiration in the sealed jar was used to calculate the maize grain respiration rate. Respiration rates were expressed as mL O_2 consumed by each g of maize grain for each day (mL.g-1.d-1) and they were calculated by the following equation:

$$R_{O_2} = \frac{(C_{O_2}^{t_i} - C_{O_2}^{t_f}).V}{M.(t_f - t_i)} \qquad (1)$$

where RO_2 is respiration rates, it is starting time of measurement, it is ending time of measurement, $C^{t_i}_{O_2}$ is starting O_2 concentration, $C^{t_f}_{O_2}$ is ending O_2 concentration, V is the volume of freedom porosity in the sealed jar, M is the weight of maize grains.

Atmospheric gas composition in the free space was determined by withdrawing gas samples with a 1-ml gas-tight syringe. The concentrations of O_2 and CO_2 were determined in an analiser (FOXBOX-CTM Sable System International, Las Vegas, USA). Three replicates were drawed for each jar. N_2 as carrier gas at a 600 mL min-1 flow.

2.4. Statistical analysis

The variation trend of the respiration rate were analysed by EXCEL software. The statistical analysis of variance were analysed by using GLM procedure of SPSS 17.0.

3. Results and analysis

3.1. The changes of respiration rate at different moisture content in maize under different temperature conditions

3.1.1. The changes of respiration rate in different moisture corn at 15°C

Fig. 1 shows the change trend of the respiration rate within the sealed containers of maize at different m.c. at 15°C.

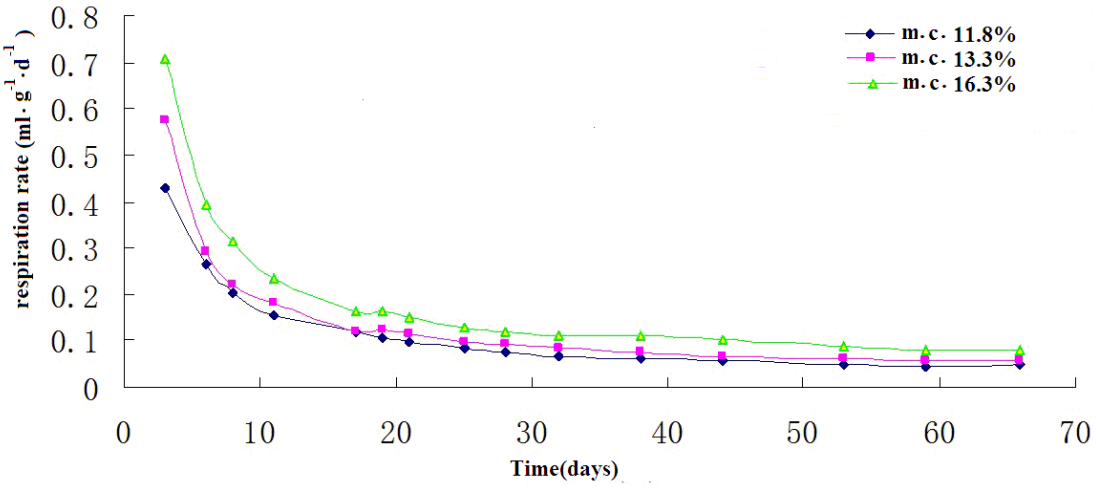

Figure 1 The change trend of the respiration rate of maize at different m.c. at 15°C.

Respiration rate of m.c. 11.8%, 13.3% and 16.3% declined gradually with time. The difference of respiration rate was significant between low moisture and safe moisture, low moisture and high moisture, safe moisture and high moisture. Regression analysis were performed according to trends of maize respiration rate due to changes in time and (Table 1). On the basis of corresponding regression equations obtained, the prediction model can be employed to determine respiration rate of stored maize under hermetic conditions.

Table 1 The regression equations of respiration rate (RO_2) changed with the time at 15°C.

Moisture(%)	Regression Equations	R
11.8	$R_{O_2} = 0.9772t^{-0.7543}$	0.9979
13.3	$R_{O_2} = 1.0886t^{-0.7331}$	0.9929
16.3	$R_{O_2} = 1.3474t^{-0.7049}$	0.9924

3.1.2. The changes of respiration rate in different moisture corn at 20°C

Fig. 2 shows the change trend of the respiration rate within the sealed containers of maize at different m.c. at 20°C.

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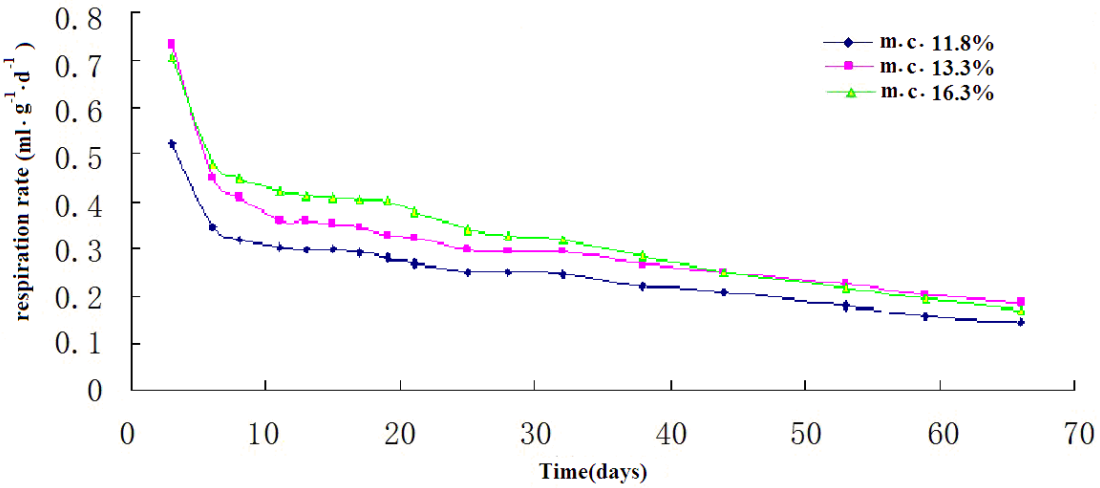

Figure 2 The change trend of the respiration rate of maize at different m.c. at 20°C.

Fig. 2. shows that the respiration rate of m.c. 11.8%, 13.3% and 16.3% at 20°C declined gradually with time, similar to results for 15°C.

Table 2 The regression equations of respiration rate (RO_2) at 20°C.

Moisture(%)	Regression Equations	R
11.8	$R_{O_2} = 0.9023t^{-0.5128}$ (0<t<11)	0.9898
	$R_{O_2} = -0.0029\,t + 0.3339$(t≥11)	0.9964
13.3	$R_{O_2} = 1.4231t^{-0.6152}$ (0<t<11)	0.9911
	$R_{O_2} = -0.0033\,t + 0.3943$(t≥11)	0.9936
16.3	$R_{O_2} = 1.1805t^{-0.4775}$ (0<t<11)	0.9892
	$R_{O_2} = -0.0049t + 0.4765$(t≥11)	0.9936

3.1.3. The changes of respiration rate in different moisture corn at 25°C

Fig. 3 shows the change trend of the respiration rate within the sealed containers of maize in different m.c. at 25°C.

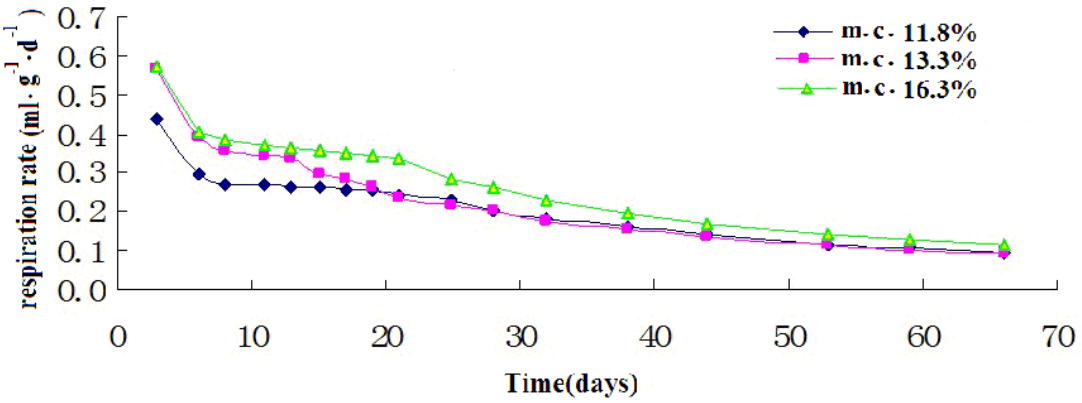

Figure 3 The change trend of the respiration rate of maize in different m.c. at 25°C.

Fig. 3. Shows similar results to the previous temperatures.

Table 3 The regression equations of respiration rate (RO_2) changed with the time at 25°C.

Moisture(%)	Regression Equations	R
11.8	$R_{O_2} = 0.7555e^{-0.021t}$	0.9804
13.3	$R_{O_2} = 0.9403e^{-0.0263t}$	0.9805
16.3	$R_{O_2} = 1.0587e^{-0.0236t}$	0.9867

3.1.4. The changes of respiration rate in different moisture corn at 30°C

Fig. 3 shows the change trend of the respiration rate within the sealed containers of maize in different m.c. at 30°C.

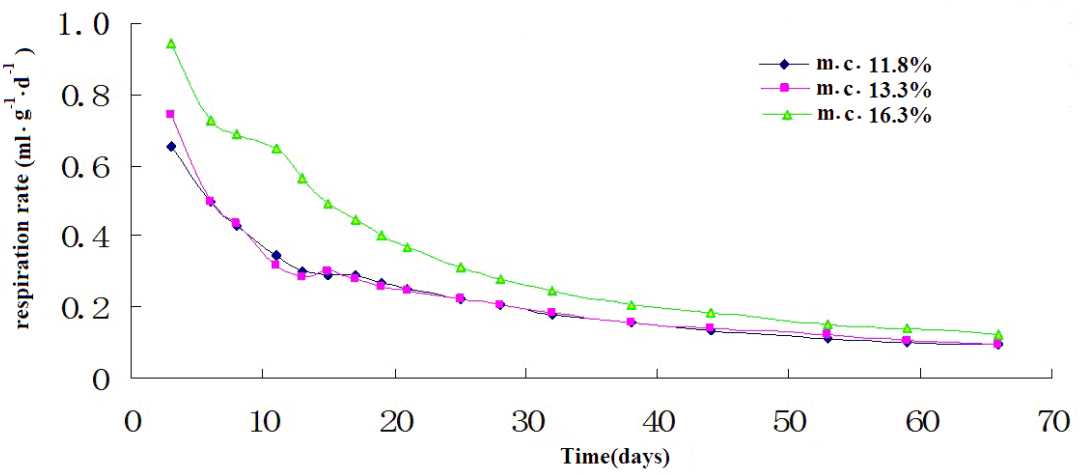

Figure 4 The change trend of the respiration rate of maize in different m.c. at 30°C.

Regression analysis was performed as previously described (Table 4).

Table 4 The regression equations of respiration rate (RO_2) changed with the time at 30°C.

Moisture(%)	Regression Equations	R
11.8	R_{O_2} = -0.3645Ln(t) + 1.6523	0.9881
13.3	R_{O_2} = 3.3507$t^{-0.6419}$	0.9930
16.3	R_{O_2} = -0.5833Ln(t) + 2.6014	0.9914

Respiration rate based on three different moisture contents of maize in four different temperatures is presented in Table 5.

Table 5 Respiration rate based on three different moisture contents at four different temperatures.

Temperature (°C)	Moisture (%)	Range of respiration rate (mL.g^{-1}.d^{-1})	Average of respiration rate (mL.g^{-1}.d^{-1})
15	11.8	0.047~0.431	0.124
	13.3	0.059~0.574	0.148
	16.3	0.071 ~0.707	0.196
20	11.8	0.143 ~0.520	0.269
	13.3	0.183 ~0.734	0.334
	16.3	0.173 ~0.707	0.363
25	11.8	0.199~0.910	0.462
	13.3	0.192~1.170	0.521
	16.3	0.241~1.197	0.613
30	11.8	0.194~1.360	0.556
	13.3	0.203 ~1.541	0.562
	16.3	0.256 ~1.964	0.847

The results showed that the higher the moisture content the faster the respiration rate at the same temperature for maize. The difference of respiration rate was significant between each f different moisture contents at the same temperature except low moisture and safe moisture at

30°C, the difference of respiration rate was significant between each two of different temperature to the same moisture content maize.

3.2. The relationship between respiration rate and the change of oxygen concentration

3.2.1. Respiration rate of low moisture maize with the change of oxygen concentration

Fig. 5 shows the change trend of the respiration rate of low moisture maize with the change of oxygen concentration at four different temperature 15°C, 20°C, 25°C and 30°C.

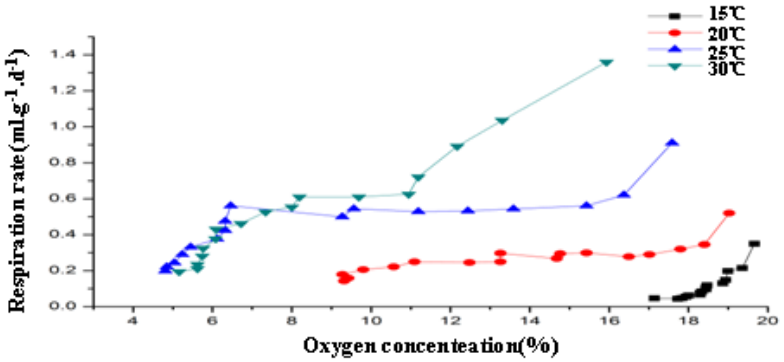

Figure 5 The change trend of the respiration rate of low moisture maize with the change of oxygen concentration at four different temperature.

Fig.5 showed that the difference of respiration rate was not significant between 25°C and 30°C when oxygen concentrations were below 8% under the test conditions. Regression equations are listed in Table 6.

Table 6 The regression equations of respiration rate (RO_2) of low moisture maize changed with oxygen concentration in different temperatures.

Temperature (°C)	Regression Equations	R_{O_2} (x=15%)	R
15	$R_{O_2} = 0.032x^3 - 1.5349x^2 + 24.543x - 130.57$	/	0.953
20	$R_{O_2} = 0.0012x^3 - 0.0395x^2 + 0.4427x - 1.3155$	0.488	0.936
25	$R_{O_2} = 0.0017x^3 - 0.0455x^2 + 0.3781x - 0.1684$	1.003	0.974
30	$R_{O_2} = 0.0037x^3 - 0.0864x^2 + 0.6244x + 0.1297$	2.543	0.990

3.2.2. Respiration rate of safe moisture maize with the change of oxygen concentration

Fig. 6 shows the change trend of the respiration rate of safe moisture maize with the change of oxygen concentration at 15°C, 20°C, 25°C and 30°C.

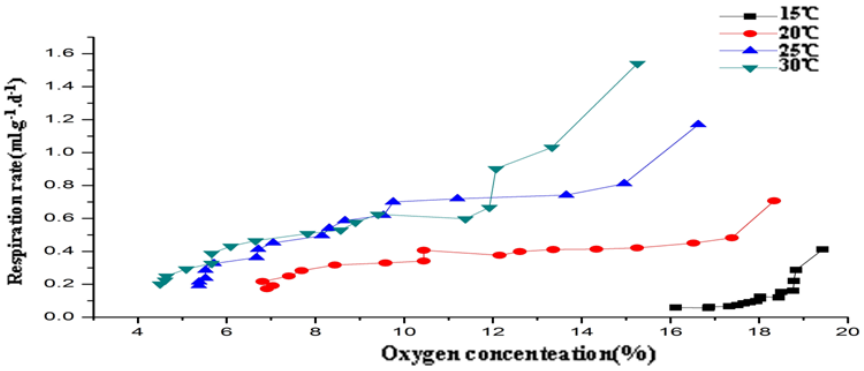

Figure 6 The change trend of the respiration rate of safe moisture maize with the change of oxygen concentration at four different temperature.

Regressions are listed in Table 7.

Table 7 The regression equations of respiration rate (RO_2) of safe moisture maize changed with oxygen concentration in different temperatures.

Temperature (°C)	Regression Equations	R_{O_2} (x=15%)	R
15	$R_{O_2} = 0.0189x^3 - 0.9522x^2 + 16.020x - 89.802$	/	0.970
20	$R_{O_2} = 0.0013x^3 - 0.0466x^2 + 0.5704x - 1.9403$	0.518	0.973
25	$R_{O_2} = 0.0018x^3 - 0.0594x^2 + 0.6729x - 1.9664$	0.837	0.988
30	$R_{O_2} = 0.0027x^3 - 0.0694x^2 + 0.6369x - 1.4949$	1.556	0.988

3.2.3. Respiration rate of high moisture maize with the change of oxygen concentration

Fig. 7 shows the change trend of the respiration rate of high moisture maize with the change of oxygen concentration at four different temperature 15°C, 20°C, 25°C and 30°C. Regressions are listed in Table 8.

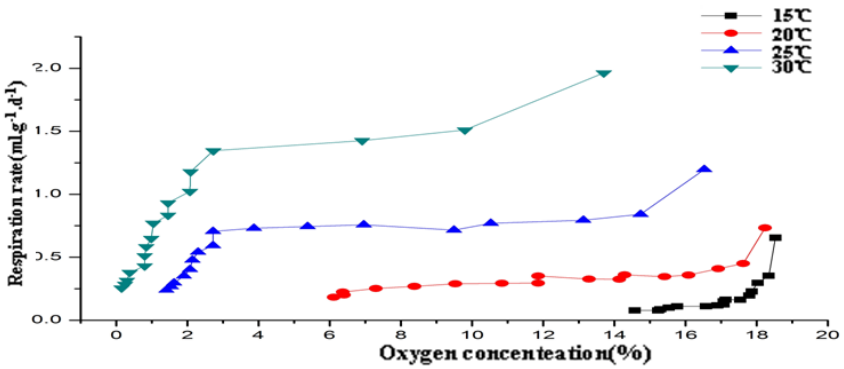

Figure 7 The change trend of the respiration rate of high moisture maize with the change of oxygen concentration at four different temperature.

Table 8 The regression equations of respiration rate (RO_2) of high moisture maize changed with oxygen concentration in different temperatures.

Temperature(℃)	Regression Equations	R_{O_2} (x=15%)	R
15	$R_{O_2} = 0.0153x^3 - 0.7834x^2 + 13.354x - 75.871$	/	0.982
20	$R_{O_2} = 0.0016x^3 - 0.0660x^2 + 0.9031x - 3.8191$	0.2774	0.949
25	$R_{O_2} = 0.0019x^3 - 0.0640x^2 + 0.6855x - 1.8182$	0.4768	0.973
30	$R_{O_2} = 0.0017x^3 - 0.0516x^2 + 0.5761x - 1.6301$	1.1389	0.984

4. Conclusions

The respiration rate of maize with the same moisture contents decreases with reducing oxygen concentration. Regression models can be used for predictive analysis.

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