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CO_2 respiration rates of einkorn wheat at different temperature and moisture contents

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Abstract: Temperature and grain moisture content are the main factors affecting grain spoilage in storage. These factors have a significant impact on the maintenance of quality, insect, fungus, and pest development. The main objective of this study was to determine the CO_2 concentration and respiration rate of hulled einkorn wheat in different temperatures (5, 10, 15, 20, 25, 30, and 35 °C) and grain moisture contents (9.1%, 11.5%, 13.8%, and 15.9%, wet basis) by means of CO_2 sensors. Multiple polynomial regression equation was developed to predict respiration as affected by temperature and grain moisture content. The CO_2 concentrations and respiration rates of wheat increased with an increase in temperature and grain moisture content. The highest mean cumulative CO_2 concentrations of 5461.4 ppm and respiration rate of 12.38 mg CO_2 kg^{-1} h^{-1} were found with temperature at 35 °C. Minimum respiration rates were determined at 5 and 10 °C in all moisture contents. Adjusted R-square value of the multiple polynomial prediction equation depending on storage temperature and grain moisture content was found to be 0.76. According to these results, ambient temperature and grain moisture content were found to be extremely effective on respiratory rate. This study showed that 9.1–13.8% moisture content and 10–20 °C are suitable conditions to store einkorn wheat without a decrease in nutritional properties for long-term periods.

Key words: Wheat, respiration, storage, temperature, moisture

1. Introduction

Einkorn wheat (*Triticum monococcum* L.) is one of the oldest wheat species. Nowadays, it is grown in limited areas in Turkey, Spain, the Balkan countries, Switzerland, Germany, and Italy within the north transition regions (Serpen et al., 2008). This type of wheat has advantages in terms of quantities of protein and nutrients compared to commercially produced emmer wheat (Yılmaz, 2012). The most important advantages are the high nutritional qualities of einkorn wheat and the low cost of its agriculture. Its adaptability, resistance to diseases and pests, and the development of organic agriculture have caused an increased interest in this wheat. Due to the high nutrient content, the use of it in the food industry has become widespread. However, it is not consumed immediately after harvest and is preserved in storage bins.

Respiration is a metabolic process where oxidative breakdown of complex molecules such as sugars or carbohydrates takes place (Ubhi and Sadaka, 2015). It results in the formation of heat, CO_2, and water (Forcier et al., 1987). Environmental conditions are important for maintaining grain quality and biological activity. Depending on the environment conditions of the storage bin, some functional deterioration may occur in the wheat. The most important key factors for this deterioration is the temperature, relative humidity (RH), and CO_2 and O_2 levels in the storage environment. The increase in grain moisture content (MC) and temperature is the main cause of nutritional and quality spoilages in wheat (Kibar, 2019). The temperature and MC of stored grain are the main factors affecting their spoilage (Fonseca et al., 2002 and Gonzales et al., 2009). Bunce (2004) reported that low temperature decreased respiration rates while high temperature increased respiration rates. Ubhi and Sadaka (2015) reported that the highest respiration rate of 2.63 g/kg^{-1} was observed with moisture content of 18.8% and a mean temperature level of 35 °C after 9 days. Again, the level of O_2 and CO_2 in the storage structure is important for maintaining grain quality. Reduction of O_2 in the storage structure decreases grain respiration as reported by Herner (1987). The respiration rate as affected by different moisture contents (12%, 14%, 16%, 18%, and 20%) and temperatures (10, 20, 30, and 40 °C) for chickpea, pinto bean, and green lentil stored for 30 days as cited by Chidananda et al. (2014). Maier et al. (2010) reported that fungus, grain metabolism, and insects cause the high CO_2 concentrations in storage bins. Thus, the monitoring of CO_2 concentrations helps in detecting spoilage early. On

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the other hand, the maturity and type of grain have an effect on the respiration rate. Here, as the maturity of the grain increases, respiration decreases (Ubhi and Sadaka, 2015).

The respiration rate of the grain can be measured directly or indirectly. Chemical and physical measurements are the foundation for the direct measurements. Direct measurement techniques are used to determine the amount of CO_2 in grain storage. However, indirect techniques measure some properties associated with the crop, such as volumetric or pressure changes within a closed flask (Ubhi and Sadaka, 2015; Raudiene et al., 2017).

The interior of the storage structure can be rapidly affected by weather changes in atmospheric conditions. Depending on this change, sudden changes such as spoilage, mold, or infestation may occur in the stored grain. A quick measurement should be made to avoid deteriorating the quality of the stored product. In this case, indirect measurement methods can be used instead of direct CO_2 measurement methods. CO_2 sensors can be used and due to the rapid results of these sensors, demand has increased in recent years (Neethirajan et al., 2009; Raudiene et al., 2017).

Grain and legume respiration rates were reported for soybean (Ochandio et al., 2012; Jian et al., 2014; Sood, 2015; Ochandio et al., 2017) and prediction correlations for CO_2 concentrations based on storage temperature and grain moisture content were proposed for corn (Bern et al., 2002; Huang et al., 2013; Ubhi and Sadaka, 2015) and wheat (White et al., 1982; Lacey et al., 1994; Raudiene et al., 2017) for the typical range of storage conditions. In the literature, there is no research on the changes of the effects of different storage temperatures and grain moisture contents on CO_2 concentration and respiratory rates in hulled einkorn wheat. The purpose of this research was to investigate: (1) the respiration rates of hulled einkorn wheat by measuring CO_2 concentrations at seven storage temperatures (5, 10, 15, 20, 25, 30, and 35 °C) and four grain moisture content (9.1%, 11.5%, 13.8%, and 15.9%); (2) the mathematical equation related to respiration rates of hulled einkorn wheat.

2. Materials and methods

2.1. Einkorn wheat and its preparation

In this study, hulled einkorn wheat grains were used. The reason for this is that they are readily available in storage until processed in Turkey. The wheat grains were obtained from the İhsangazi district of Kastamonu Province, Turkey. The residual and foreign materials were found in the einkorn grains collected. Accordingly, the materials such as soil, deformed wheats, split, and different grains were cleaned before the experiment.

2.2. Determination of moisture contents

The einkorn wheat moisture content was determined according to ASABE standards for grains (ASABE, 2012). For wheat, around 10 g of sample was unground and dried at 130 °C for 19 h. The grain moisture content was calculated using the drying oven (Mikrotest, MST120, Turkey). The grain moisture content percentage on a wet basis (w.b.) is expressed. The grain moisture measurements were performed in three replications. Four grains with different moisture content were used in the experiments. The reason for using different moistures is to demonstrate the effect of possible spoilages in storage bin on respiration rates of einkorn wheat grains. The initial moisture content of the einkorn wheats was found to be 8.8% (w.b.). The wheat grains were conditioned to required moisture levels (9.1, 11.5, 13.8, and 15.9% w.b.) by adding calculated (Eq. 1) amounts of distilled water and thoroughly mixing for 30 min (Kibar, 2019). All seed lots at the desired each moisture content were packed in separate air-tight high density polyethylene packages (180 × 300 mm) and stored in a temperature-moisture test cabin (2 ± 1 °C) for 2 days to equilibrate the moisture contents. The packages were locked for air tightness. The analysis was carried out at different temperatures in 5, 10, 15, 20, 25, 30, and 35 ± 1 °C and a constant relative humidity of 65 ± 3% with four moisture contents (9.1%, 11.5%, 13.8%, and 15.9% w.b.). For each temperature analysis, 12 sealed polyethylene packages with 300 g wheat seed in each were used for each moisture content. A total of 84 polyethylene packages were prepared for all experiments. Three of them were used in each analysis period (9.1%, 11.5%, 13.8%, and 15.9% moisture content at 5, 10, 15, 20, 25, 30, and 35 °C temperatures). Each package represented a replication. The surfaces of grains were sterilized with 5% NaCIO solution to remove microfora such as fungus and bacteria (Özdemir et al., 2016). Polyethylene packages were prepared separately for each moisture and temperature. Polyethylene packages were stored for a maximum of 1 week at 2 ± 1 °C to prevent CO_2 increase, deterioration, and development of insects and molds in the experiments (Christensen and Kaufmann, 1969). Thus, no deterioration was encountered.

$$Q = \frac{W \times (M_f - M_i)}{100 - M_f} \quad (1)$$

where;

W: grain weight, g,

M_i: initial moisture content of hulled wheat grain, %,

M_f: final moisture content of hulled wheat grain, %.

2.3. Experimental setup

Around 200 g of hulled einkorn wheat grain was placed in 2000 mL glass flasks. Two holes with 2 cm diameter were drilled in the plastic lids of the glass flasks (Arias Barreto, 2016). One of these holes has a temperature-humidity sensor (MS6505, Mastech, USA) and the other one has a CO_2 measuring sensor (Testo 535 CO_2 Meter, Germany) (Figure 1). The measurement range of the CO_2 sensors was 0 to 5000 ppm (parts per million volumetric) (accuracy ± 75 ppm ± 3% of measurement value) and 5000 to 9999 ppm (parts per million volumetric) (accuracy ± 150 ppm ± 5% of measurement value). The response time of the CO_2sensors was 30 s. The temperature and relative humidity measurement range of the sensors was from –20 to 50 °C (accuracy ± 0.7 °C) and from 0 to 100% RH (accuracy ± 2.5%). The temperature and humidity response time of the sensors was 40 s and 75 s, respectively. To prevent CO_2 leakage, the sensors and lid were sealed with parafilm (Huang et al., 2013). The flasks were kept at seven different temperatures 5%, 10%, 15%, 20%, 25%, 30%, and 35 ± 1 °C and a constant relative humidity of 65 ± 3% with four moisture contents (9.1%, 11.5%, 13.8%, and 15.9% w.b.). All experiments were carried out in an environmental chamber with adjustable temperature and relative humidity. The temperature and relative humidity changes during the experiments were continuously monitored by a temperature-humidity sensor.

The respiration measurement method of the hulled einkorn wheat in this study was similar to that described by Dillahunty et al. (2000) and Raudiene et al. (2017). In the study, the raw CO_2 concentrations measured for 24 h at all temperatures and seed moisture contents are shown in the graphs. The CO_2 respiration rate (RR) was calculated from the raw CO_2 concentration measurement results (Eq. 2). The respiration rate of wheat grains was calculated based on the amount of CO_2 concentration as:

$$RR = \frac{\Delta_{CO_2} \times M_{CO_2} \times V_h}{V_m \times m \times \Delta t} \quad (2)$$

$$\Delta_{CO_2} = CO_{2(t2)} - CO_{2(t1)} \quad (3)$$

$$V_m = \frac{R \times T}{P} \quad (4)$$

where;

RR : respiration rate, mg CO_2 kg^{-1} h^{-1},
Δ_{CO2} : CO_2 volumetric concentration, ppm, 10^{-6} L L^{-1},
M^{CO2} : molecular weight of CO_2 gas, 44.01 g mol^{-1},
V^h : flask volume, L,
m : the weight of hulled einkorn wheat, kg,
Δ_t : duration of the experiment, h,
$CO_{2(t2)}$: CO_2 concentration in the initial, ppm, 10^{-6} L L^{-1},
$CO_{2(t2)}$: CO_2 concentration at the end of experiment, ppm, 10^{-6} L L^{-1},
Vm : molar volume of gas, L mol^{-1},
R : gas constant, 0.08206 L^{-1} mol^{-1} K^{-1},
T : temperature, K,
P : pressure, atm.

2.4. Statistical analysis

The entire experiment was performed in triplicates. Data were collected after 24 h at each temperature and grain moisture content. However, data were collected after a duration of less than 24 h at a high temperature and grain moisture content. The normality distribution was performed using the Kolmogorov–Smirnov test at P < 0.05 significance level. The homogeneity of group variances was performed with a Levene's test at P < 0.05 significance level. The P-values for the Kolmogorov–Smirnov test and the Levene's test were larger than 0.05; therefore, normality and homogeneity of group variances should be satisfactory. One-way ANOVA was used to analyze the impact of temperature and grain moisture content on the respiration rates of hulled einkorn wheat. Differences among means were evaluated by the Tukey honest significant difference (HSD) test and the significance

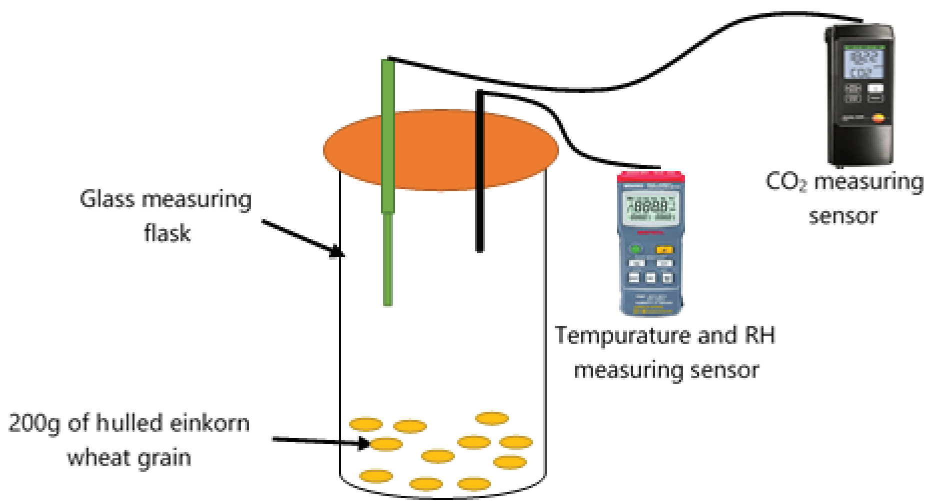

Figure 1. Experimental setup.

was accepted at $P < 0.05$ level. The ANOVA analysis and multiple polynomial regression equation were performed using JMP13.2 software (SAS Institute Inc., Cary, NC). The CO_2 concentration, respiration rate graphs, and their exponential and polynomial equations were performed with Microsoft Excel 2013.

3. Results

3.1. Respiration rates

The CO_2 concentrations and respiration rates of hulled einkorn wheat with moisture content of 9.1% at different temperatures (5, 10, 15, 20, 25, 30, and 35 ° C) are given in Figure 2. The cumulative CO_2 concentrations increased as temperature increased. The lowest and highest CO_2 concentrations were 451 ppm at 5 °C at the end of 24 h and 9999 ppm at 35 °C at the end of 15 h, respectively. Accordingly, the lowest respiration rate was determined at 5 °C (the mean 0.99 mg CO_2 kg^{-1} h^{-1}) and the highest at 35 °C (the mean 8.61 mg CO_2 kg^{-1} h^{-1}). Despite low grain moisture content, the planned 24 h measurement period could not be reached due to the high respiration of wheat grain at 35 °C. The wheat grain respiration rate increased (1%, 45%, 113%, 241%, 290%, and 770%) as temperature increased (from 5 to 10, 15, 20, 25, 30, and 35 °C, respectively). Mathematical equations of respiration rates obtained at different temperatures depending on measurement times are shown in the graphs. When the graphs were examined, R^2 values varied between 0.93 and 0.97. As a result of statistical analysis, a statistically significant relationship was found among respiration rate values (df = 6470; F = 93.06; $P < 0.01$).

CO_2 concentrations and respiration rates increased at all temperatures with moisture content of 11.5% (Figure 3). At the end of 24 h, the lowest CO_2 concentration (497 ppm) and respiration rate (0.29 mg CO_2 kg^{-1} h^{-1}) were obtained at 5 °C. However, the highest respiration rate was 11.69 mg CO_2 kg^{-1} h^{-1} at 35 °C at the 12th h of the measurements. The graphs show a cumulative increase in CO_2 concentrations and a parabolic decrease in respiration rates. Mathematical relations obtained at the end of the experiments are given in the graphs. The highest R^2 values were obtained at 5 and 10 °C.

To get higher R^2 values, some equations are expressed exponentially and some are expressed polynomially. Their mathematical relationships were determined as exponential and polynomial equations. As a result of statistical analysis, a statistically significant relationship was found among respiration rate values (df = 6461; F = 151.19; $P < 0.01$).

CO_2 concentrations and respiration rate changes showed higher values at high temperature levels in 13.8% grain moisture content (Figure 4). However, the lowest CO_2 concentrations and respiratory rate values were observed at low temperature values. The measurements were taken at 5, 10, 15, 20, 25, and 30 °C for 24 h. Furthermore, the measurements were taken at 35 °C for 11 h. When all graphs are examined, there is an overall increase with the increase of temperature. The hulled einkorn wheat grain respiration rate increased (13, 126, 203, 374, 411, and 995%) as temperature increased (from 5 °C to 10, 15, 20, 25, 30, and 35 °C). According to these results, there was a significant increase at a high temperature. This situation has been revealed as a result of statistical analysis. As a result of statistical analysis, a statistically significant relationship was found between respiration rate values (df = 6458; F = 132.37; $P < 0.01$). Polynomial and exponential mathematical relationships of respiration rate values obtained from measurement time are given in Figure 4. When Figure 4 is examined, high R^2 values varied between 0.91 and 0.99.

Respiration rate values calculated by CO_2 concentrations measured at seven different temperature levels increased due to increasing temperature change (Figure 5). The highest mean CO_2 concentrations were determined at 35 °C. The high moisture content had the highest respiration rate for hulled einkorn wheat, but peaked at a temperature of 35 °C. High respiration rate was determined until the 4th h at 35 °C, while low respiration rate was determined after the 4th h. The hulled einkorn wheat grain respiration rate increased (15%, 123%, 218%, 399%, 460%, and 1015%) as temperature increased. The resulting high increases showed that there was a statistically significant difference among the data (df = 6455; F = 137.62; $P < 0.01$). The R^2 values of mathematical relations varied between 0.93 and 0.99 and the highest R^2 values were determined at 5 and 10 °C.

3.2. The prediction model of respiration rate

The mean respiration rate values for all temperature and grain moisture contents are given in Figure 6. We can see that the respiration rate increased polynomially as temperature and grain moisture content increased. This would indicate that temperature and grain moisture content has a major effect on the respiration rate of the einkorn wheat. Based on temperature and grain moisture content, a multiple polynomial regression equation has been developed and given below (Eq. 4). Adjusted R-square of polynomial equation was found to be 0.76. As a result of the analyses, the highest adjusted R-square value was obtained in polynomial regression.

The multiple polynomial regression equation for hulled einkorn wheat is given below (Eq. 5). This equation contains some boundaries (measurement time = 24 h, wheat samples = 1, container size or headspace volume = 2 L).

$$RR = -4.409 + 0.175MC + 0.242T + [(T - 18.846) \times ((T - 18.846) \times 0.011)] \quad (5)$$

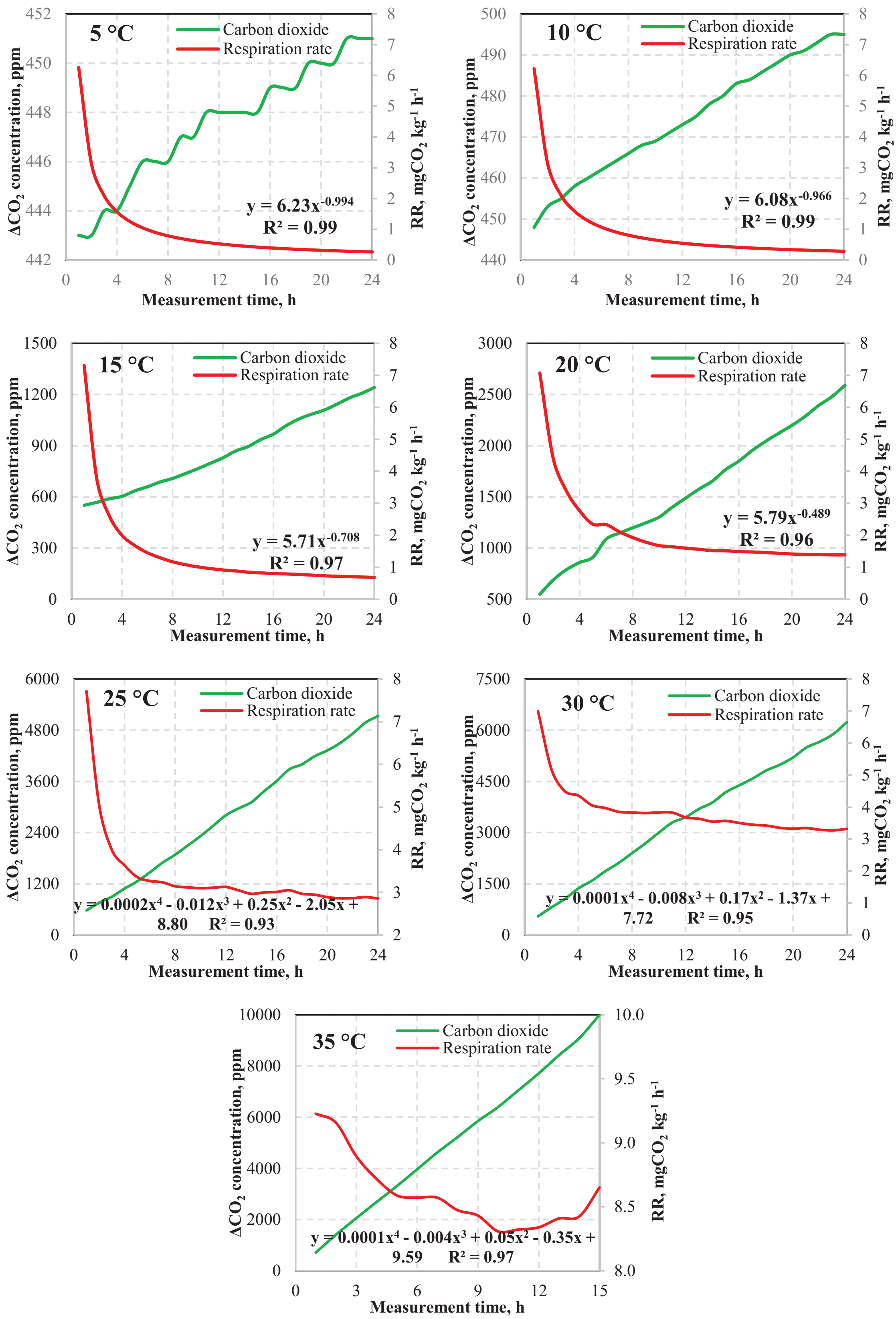

Figure 2. CO_2 concentrations and respiration rates as affected by 9.1% moisture content and temperature.

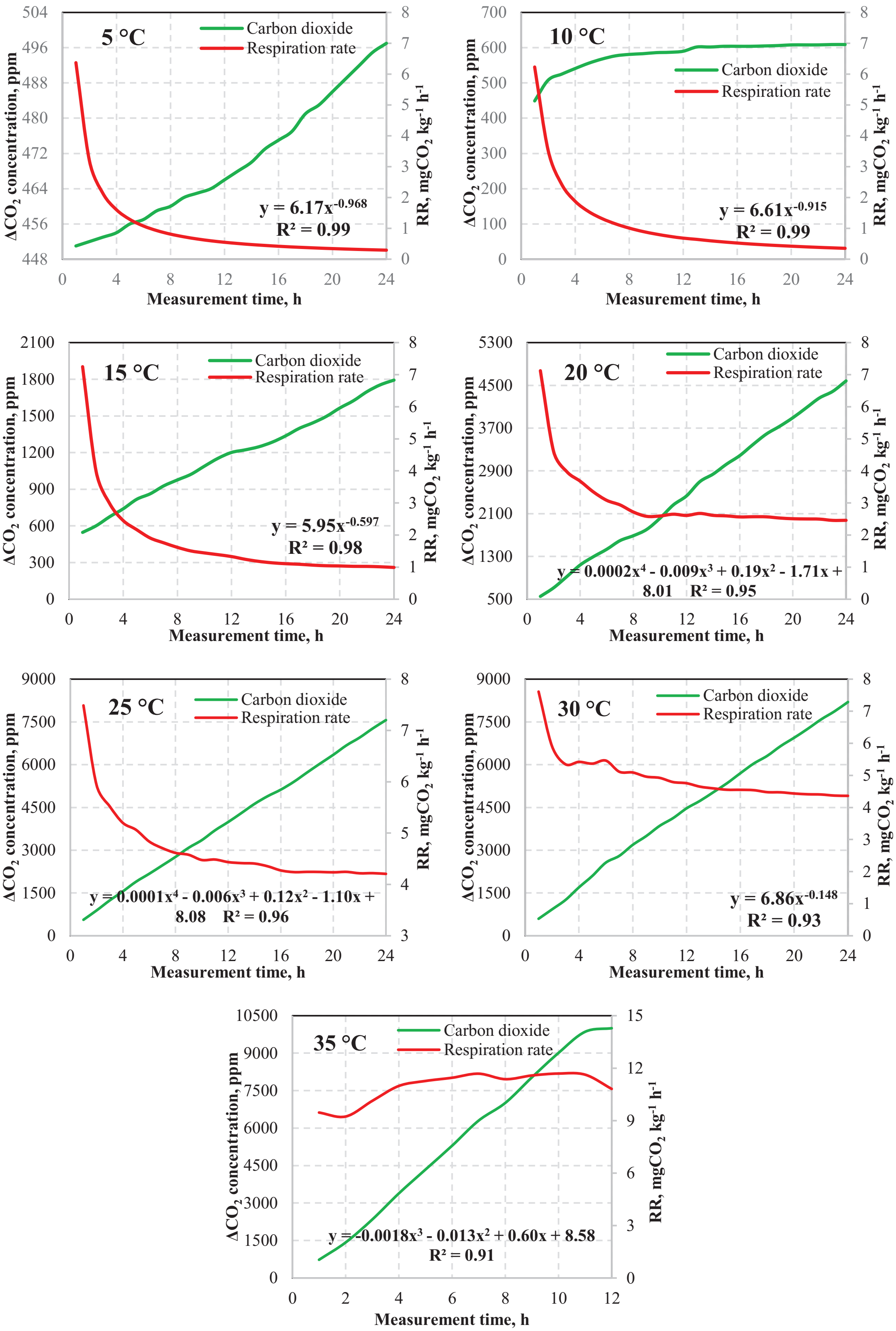

Figure 3. CO_2 concentrations and respiration rates as affected by 11.5% moisture content and temperature.

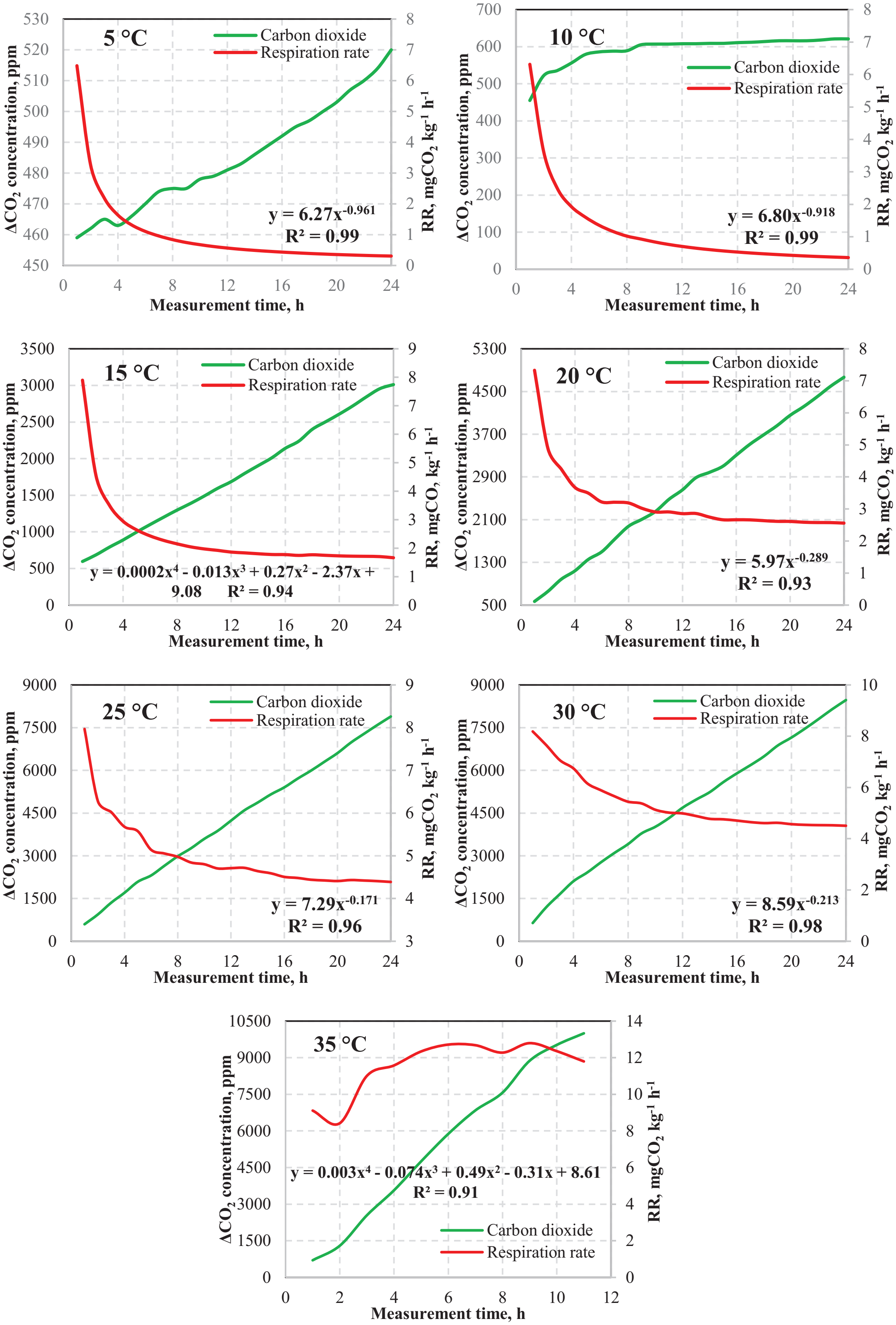

Figure 4. CO_2 concentrations and respiration rates as affected by 13.8% moisture content and temperature.

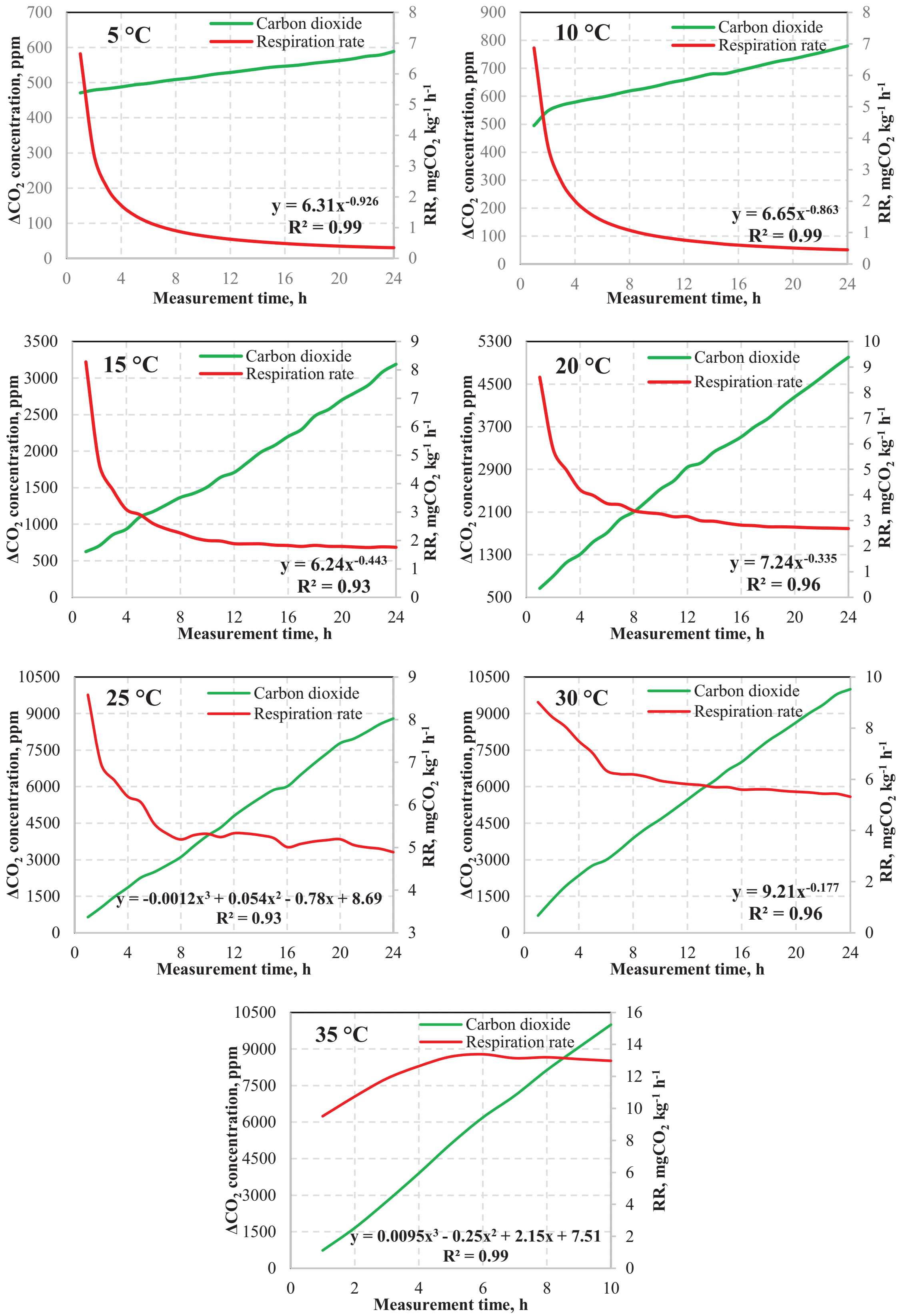

Figure 5. CO_2 concentrations and respiration rates as affected by 15.9% moisture content and temperature.

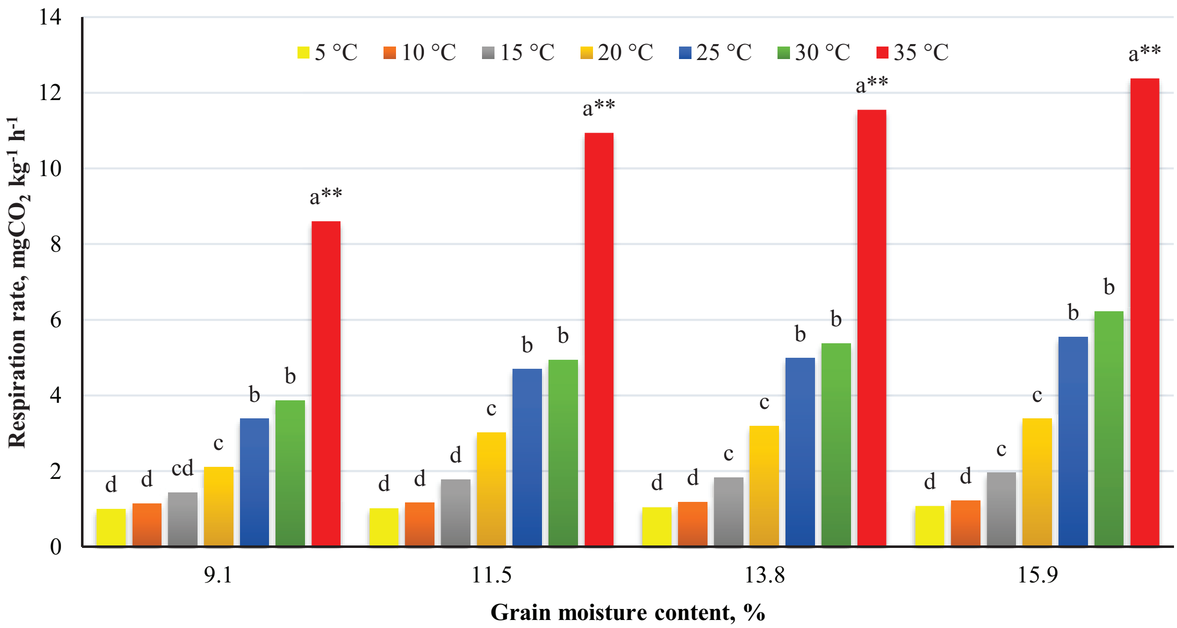

Figure 6. Respiration rates after 24 h depending on different temperature and grain moisture content (means were separated by using Tukey HSD multiple range test).

where;

RR : grain respiration rate, mg CO_2 kg^{-1} h^{-1},
MC : grain moisture content, % w.b.,
T : storage temperature, °C.

4. Discussion

The respiration rate of grains is affected by changes in the moisture content, temperature, CO_2, and O_2 concentrations of the storage environment. Therefore, these environmental conditions must be kept under control of the storage. On the other hand, the first harvest moisture content of the grain, maturity level, physical damage, disease, and infestation status may affect the respiration rate. Physically damaged seeds promote higher respiration rates, possible due to increased microbiological activity. Bern et al. (2002) proposed a correlation to predict CO_2 evolution and dry matter for shelled corn, including a multiplier to account for the effect of visible mechanical damage. Ochandio et al. (2017) demonstrated that different maturity levels of soybeans have an effect on respiratory rate. Navarro et al. (2012) investigated the respiration rate of the seeds with the level of physical damage of peanut seeds. As a result, it was observed that the peanut respiration rate was low in the absence of broken or damaged peanut seeds. In this study, the effect of physical damage on the respiratory rate was not detected, since physical cleaning of the seeds was carried out before the experiments. Moreover, respiration rates are an important factor that may help in decision-making for the programming of the ventilation system.

All grain moisture contents and temperatures showed an increase in CO_2 concentrations and respiration rates. This study showed that the temperature of 35 °C resulted in the highest values of mean CO_2 concentrations and respiration rates. Accordingly, it was essential to illustrate the mean respiration rates as affected by the temperature and grain moisture content. However, the rates of increase in low grain moisture content (9.1%) and high temperature (35 °C) are lower than the increase in other grain moisture contents and temperatures. This would indicate that temperature and moisture content of the grain is extremely important. These effects of grain moisture content and temperature on respiration rates had been observed by other authors for different grain materials. Hamer et al. (1991) reported that respiration rate of wheat increased with grain moisture content and temperature. The rise in moisture content of all grains may be the result of water being released during respiration (around 0.409 g of H_2O released per gram of CO_2 evolution) (Chidananda et al., 2014; Rukunudin et al., 2004). Diawara et al. (1986) reported similar effects of grain moisture content on respiration rate of paddy rice. Lacey et al. (1994) reported that respiration rates of wheat between 53 and 474 mg CO_2 (kg DM d)$^{-1}$ at a storage temperature of 20 °C. On the contrary, Jian et al. (2014) reported higher respiration rates of soybean (from 116.7 to 126.7 mg CO_2 (kg DM d)$^{-1}$ than wheat (from 66.0 to 134.3 mg CO2 (kg DM d)$^{-1}$. Karunakaran et al. (2001) reported respiration rates between 23 and 463 mg CO_2 (kg DM d)$^{-1}$ for stored wheat in the range of 12.7–19% moisture content and 25 °C. Pronyk et al. (2004) reported that CO_2

concentrations increased with the increase in storage duration, grain moisture content, and temperature. Moog et al. (2010) reported a similar effect where the temperature had a higher effect than grain moisture content on fungal susceptibility measuring during the storage of shelled corn cereals. Huang et al. (2013) reported that respiration rate increased when storage temperature and grain moisture content increased. Sood (2015) reported a soybean CO_2 production rate of 15.7 mg CO_2 (kg DM d) $^{-1}$ for storage conditions of 14% seed moisture content and 35 °C, in the range of what is reported in the present study. Raudiene et al. (2017) reported that CO_2 concentrations and respiration rates of wheat grains at moisture contents of 13%, 15%, 17%, and 19% and temperatures of 16, 20, 25, 30, and 35 ° C. As a result of the study, it has been reported that the increase in temperature and grain moisture content, CO_2 concentration increased, and respiration rates decreased. The results obtained in this study were similar to those of other researchers.

Lacey et al. (1994) cited that respiration increased linearly with temperature up to 35 °C and that it also increased with time and seed moisture content in barley, wheat, rapeseed, and linseed. Gomez et al. (2014) and Ubhi and Sadaka (2015) mentioned that the high temperatures accelerate chemical reactions and respiration rates as well as expediting the occurrence of peak. In this study, respiration rates peaked at 35 °C in each grain moisture content. A similar situation is cited in Chidananda et al. (2014). In this study, it was reported that the respiration rates of pinto bean, chickpea, and green lentil reached peak values at 20% grain moisture content and 40 °C. Ubhi and Sadaka (2015) reported maximum respiration rate values for corn grain at temperatures of 35 and 45 °C with grain moisture content of 20.7%. In this study, respiration rates were more affected by storage temperature. Across all treatments, CO_2 release increased for each 1% point of increase in seed moisture content. On the other hand, for each 1 °C of increase in storage temperature, respiration rate was modified. Coincidently, Ochandio et al. (2017) concluded that respiration increased linearly with temperature.

Minimum CO_2 concentrations and respiration rates at 5, and 10 °C with all moisture contents were determined. It can be emphasized that these values are negligible. A similar result was presented by Huang et al. (2013) who cited that corn respiration rates were almost negligible at storage temperatures of 10, 20, and 30 °C and 14.0% moisture content.

As a result, CO_2 production slows down when approaching 24 h at all temperatures and seed moisture contents. Accordingly, the respiratory rate started to slow down. In all cases, the highest grain respiration rate was during the first hours of each experiment, and then it decreased. It was considered that at the beginning of the experiment, after moistening grain with distilled water, most of the water is still on the grain surface. After that, moisture penetrates into the grain's kernel and the activity of the grain respiration process decreases (Raudiene et al., 2017).

Mathematical models developed for respiration rates can provide fast results. Thus, necessary precautions can be taken to prevent the deterioration of grain in the storage environment. Dillahunty et al. (2000) found that the respiration rate of two different rice varieties could be predicted by polynomial and exponential equations. Bern et al. (2002) improved a series of mathematical modeling to predict CO_2 concentration of stored corn as a function of temperature, grain moisture content, and mechanical damage level. Their mathematical models could be used to predict CO_2 concentration from stored corn. These mathematical models are valid under the grain moisture contents of 15% to 34%, temperatures from 0 to 49 °C and mechanical damage of 2% to 41%. Waghmare et al. (2013) cited that the equation is used for prediction of respiration rates as a function of both measuring time and temperature. They reported that the temperature and the interaction of time had significant effects on respiration rates. Similar mathematical models were reported by Chidananda et al. (2014) for stored pinto bean, chickpea, and green lentil, Ubhi and Sadaka (2015) for corn grain, and Ochandio et al. (2017) for soybean. In the present study, the improved polynomial equation is valid at temperatures from 5 to 35 °C and grain moisture content from 9.1 and 15.9% w.b. for hulled einkorn wheat.

5. Conclusion

Important results were obtained in this study regarding the respiration rates of stored hulled einkorn wheat. In the present study, both grain moisture content and storage temperature have a significant effect on respiration rate. The respiration rate of einkorn wheat stored at 5 and 10 °C in all moisture contents were minimal. However, it was found that high temperatures such as 30 and 35 °C significantly increased respiration rate. For this reason, the storage environment should be kept at low temperatures during storage. The results of this work showed that CO_2 sensors can be used for rapid results in determining respiration rate. Thus, grain deterioration during storage may be prevented at an early stage. The findings of this study will provide useful information on the storage of einkorn wheat for researchers and the food industry.

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