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# Comparison of the Respiration and Dry Matter Loss in Stored Wheat and Rice Crop at Different Temperatures and Water Activities

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**ABSTRACT:** The experiments were conducted to investigate the Respiration and Dry matter loss in the stored Wheat and Rice crop at Different Temperatures and Water activities in the Post harvest and Mycology laboratories, Cranfield University Silsoe, UK, during the year 2002-3. The results of this study are individual in one area, whereas, in agreement with the other previous researches. May be these were expected due to the variety (Cantone *et al.,* 1983) and location of the grain origin as there seems not much difference between wheat and rice data (Magan *et al.,* 2003). Respiration and Dry matter loss (DML) of wheat and rice grain were compared over 7 and 14 days at 0.80-0.98 $a_w$ for three different temperatures; 15, 25 and 35ºC. The Respiration data for both; $O_2$ and $Co_2$ might be more reliable as analysed by Gas Chromatograph (GC) with compare to Lacey et *al.,* (1994) due to procedure adopted. The respiratory quotient (RQ) of wheat is higher than rice, amounting almost double. For 7 days at 0.80$a_w$, highest RQ was found at 15°C and at 0.98 $a_w$, highest RQ at 25°C followed by 35 and 15°C. For 14 days at 0.80$a_w$, highest RQ was found at 25°C and at 0.98 $a_w$, highest RQ was observed at 35°C followed by 25 and 15°C. The results also showed that DML became linearly increasing at higher temperatures and water activities and the calculated DML was more stable for wheat than the rice crop.
**Key words:** Dry matter loss, respiration, wheat, rice

## INTRODUCTION

Since long the regimes of safe storage for agricultural post harvest material have predominantly concentrated on cereal grain due to its nutritional value, prevention of quality deterioration and potential threat from dry matter loss (DML) and fungi spoilage (Willock and Magan, 2001). Environmental conditions are playing an important role during storage. The temperature of the stored grain, availability of the moisture and relative humidity are the key parameters to control the conditions and responsible for the significant losses (Lacey et al., 1994). In the result of favourable conditions, different processes are taking place, causing mould development and dry matter loss, which ultimately deteriorate the quality of grain. Hence the dry matter loss is focused to calculate from respiration and visible moulding data as the availability of water is playing vital role in respiration and ultimately the attack of fungus (Griffin 1981, Lacey et al., 1991 and Cook and Whipps 1993).

The process of respiration has been found to be one of the major parameter to measure the metabolic activity in grain storage (Hamer et al.,1993). The respiration rate is governed by availability of water, temperature, carbon di oxide/ oxygen concentration, microbial contamination, mechanical damage, condition and storage period (Baily, 1940). It appear to increase exponentially with temperature and moisture content (Srour, 1988).

This study determines the DML of grain by $Co_2$ production rather then $O_2$ utilisation and gas chromatograph is used as the prime instrument to analysis the samples.

The following objectives were identified for this study:

- Compare the respiration of wheat and rice and determine the pattern of respiration for both of them.
- Evaluate the water activity ($a_w$) and temperature effects
- Correlate the dry matter loss with visible moulding

## MATERIAL and METHODS

### Instrumentation

All the experimental steps; initial level of the grain, sample preparation, experiment design, sample storage and sample analysis, involve instrumentation. In this connection, different scientific instruments; like Gas Chromatograph and Water Activity Meter/Monitor were used during the observations in the Post harvest and Mycology laboratories, in order to maintain the scientific procedures and accuracies. The GC was calibrated while running standard samples of the gases; $O_2$ and $Co_2$ individually, before analysing the gas samples from grain and Aqua lab meter (Model CX-2, Washington, USA) was used to confirm the Water activity ($a_w$) of all grain treatments. A part from these, some other instruments like; electric oven, blender and dispenser were also used during the experimentation, directly or indirectly.

### Handling of Grain Samples

Wheat and Rice grain samples, brought from two experimental stations, i.e: Tandojam and Dokri, Sindh, Pakistan were used in the experiments. After observing their initial water activity and moisture content level, grain was stored in 4°C.

Water activity was determined by Aqua Lab Water activity Meter, placing the 5g sub-samples (in triplicate) in it, equilibrating the samples at 25°C for about 1 hr.

For determination of MC, three best known methods in literature (Pixton, 1982 and Reed, 1987) were reviewed and finally the first one used by Pixton, (1982) and Hamer, (1993) was selected to determine the MC. The samples of 5g whole grain (in triplicate) were used to dry at lower temperature of 105°C for 16 hrs and the following formula was used to calculate the MC (wet basis):

$$\text{Moisture Content} = \frac{MC_f - MC_d}{MC_f} x100$$

Where: $MC_f$ =fresh weight, $MC_d$= dry weight (g)

In order to determine that how much water was needed to add for particular $a_w$, the following formula was used to hydrate the grain (Hamer, 1993):

$$\text{SSDW required} = \frac{MC_1 - MC_0}{100 - MC_1} xS_f$$

Where: SDDW = sterile distilled deionised water (ml), $MC_1$= required moisture content (%),
$MC_0$ = initial moisture content of grain (%), $S_f$ = sample's fresh weight (g).

The calculated SDD water was then added to the pre weighted grain samples in conical flasks and were shaken gently to ensure its uniformity. The flasks were sealed air tight with rubber foam and parafilm layer before placing them at 4°C overnight with thorough and regular mixing of grain in the flasks. Moisture content of the hydrated grain samples was confirmed by oven drying.

In order to determine the quantities of water necessary to hydrate the grain to use in subsequent experiments, water activities ($a_w$) during adsorption of different amounts of water, were determined for both grains, i.e: wheat and rice. Sterile water (SDDW) was added in volumes of 0.0, 0.1, 0.2, 0.5, 0.7, 1.0, 1.5, 2.0, 2.5, 3.0 ml to 5 g samples and three replicates were prepared for each treatment. After 24 hrs equilibration at 4°C, the water activity ($a_w$) and moisture content (MC) of each sample was determined by Aqua Lab meter at 25°C and oven drying at 105°C for 16 hrs, respectively. The $a_w$ was plotted against MC to give an adsorption isotherm for each grain. The MC for a given $a_w$, was then be determined from the fitted curve (Figure 1).

### Data Measurements

In order to check respiration, the experiments were designed to measure $Co_2$ production and $O_2$ consumption. Initial levels of $Co_2$ and $O_2$ for each grain were checked before placing the universals in boxes. To do this, five treatments (i.e.: 0.80, 0.90, 0.95 & 0.98 Aw), in triplicate were considered for about two weeks (14 days). After the interval of 48 hours, a set of four universals (four replicates) from each box/ treatment were taken out to get the samples for both gasses. Then the universals were tighten with tops having a rubber hole and were left for 2 and half hrs to generate a gas at different temperature (15, 25 and 35C). The gas sample was taken out while injecting the syringes, which were directly injected in GC to analyse the samples.

All the universals having grain samples at different $a_w$ and corresponding glycerol solutions were placed in the centre of the boxes (10x 14x14in) to control equilibrium relative humidity (ERH) at different temperatures for two weeks period.

Dry matter loss is calculated from the $Co_2$ data. All the equations and procedures were adopted from Hamer (1993) study.

After GC analysis of gas samples, the grain samples in universals were observed for moulding and all replicates, $a_w$ and temperatures were observed visibly and microscopically. The measuring scale was fixed as 0 = no moulding, 1= very light, 2 = light, 3 = medium, 4 = heavy moulding.

## RESULTS

The results of this study are shown in figures 1-6 and displayed in tables from 1-7. Wheat and Rice crops brought from Sindh, Pakistan were under investigation. Table1 show the initial moisture contents at different water activities from the isotherm of the wheat and rice crops.

**Table 1. The moisture contents at different water activities.**

| Water activity, $a_w$ | Wheat | Rice |
|---|---|---|
| 0.80 | 11.0 | 11.5 |
| 0.85 | 13.0 | 13.0 |
| 0.90 | 17.5 | 15.25 |
| 0.95 | 20.0 | 18.5 |
| 0.98 | 24.5 | 21.5 |

Tables 2&3 present the respiratory quotient of wheat and rice 7 and 14 days. The values are compared at each temperature showing the standard error of mean for both crops. The RQ calculated is very small as compared to Hamer (1993) may be because the volume of the Co2 production is much lowers than the $O_2$ consumption. The volume of the $O_2$ can be attributed to the considerable visible moulding. It looks that RQ is linearly increasing with Aw, however increased at 25 then both at 15 and 35ºC for lower $a_w$ of 0.80 and 0.85. Later on it seems to be linearly increasing with temperatures at higher $a_w$ for both crops. With a close look of results, it is observed that as the temperature is increasing, difference of Wheat and Rice respiratory quotients is widening.

**Table 2. Comparison of the Respiratory quotients (RQ) affected by different Temperatures and Water activities at 7days for Wheat and Rice**

| Water activity $a_w$ | Wheat, Day 7 Hammer, 93 | 15C Wheat (± SEM) | 15C Rice (± SEM) | 25C Wheat (± SEM) | 25C Rice (± SEM) | 35C Wheat (± SEM) | 35C Rice (± SEM) |
|---|---|---|---|---|---|---|---|
| 0.80 | 0.45 | 0.0041 (0.00092) | 0.0061 (0.00296) | 0.0039 (0.00221) | 0.0033 (0.00091) | 0.0026 (0.00023) | 0.0029 (0.00069) |
| 0.85 | 0.54 | 0.0034 (0.00075) | 0.0037 (0.00024) | 0.0036 (0.00011) | 0.0032 (0.00041) | 0.0042 (0.00032) | 0.0044 (0.00026) |
| 0.90 | 0.54 | 0.0061 (0.00081) | 0.0038 (0.00021) | 0.0051 (0.00027) | 0.0046 (0.00043) | 0.0692 (0.0129) | 0.0055 (0.00049) |
| 0.95 | 0.59 | 0.0121 (0.00169) | 0.0081 (0.00044) | 0.0531 (0.00324) | 0.0132 (0.00131) | 0.1699 ( 0.0378) | 0.0187 (0.00099) |
| 0.98 | | 0.0471 (0.0028) | 0.0157 (0.00155) | 0.0948 (0.211) | 0.0311 (0.00504) | 0.7781 (0.2224) | 0.0447 (0.00532) |

**Table 3. Comparison of the Respiratory quotients (RQ) affected by different Temperatures and Water activities at 14 days for Wheat and Rice.**

| Water activity, $a_w$ | Wheat, Day 7 Hammer, 93 | 15C Wheat (± SEM) | 15C Rice (± SEM) | 25C Wheat (± SEM) | 25C Rice (± SEM) | 35C Wheat (± SEM) | 35C Rice (± SEM) |
|---|---|---|---|---|---|---|---|
| 0.80 | 0.45 | 0.0026 (0.00016) | 0.0038 (0.00009) | 0.0049 (0.00122) | 0.00667 (0.00133) | 0.00273 (0.00028) | 0.00311 (0.00069) |
| 0.85 | 0.54 | 0.0027 (0.00036) | 0.0039 (0.00032) | 0.0047 (0.00041) | 0.0016 (0.00042) | 0.0077 (0.00131) | 0.00301 (0.00026) |
| 0.90 | 0.54 | 0.0049 (0.00025) | 0.0037 (0.00007) | 0.0086 (0.00159) | 0.0058 (0.00177) | 0.0558 (0.00639) | 0.0405 (0.00049) |
| 0.95 | 0.59 | 0.0119 (0.00046) | 0.0076 (0.00023) | 0.0788 (0.00921) | 0.0102 (0.00264) | 0.2210 (0.0311) | 0.0184 (0.00099) |
| 0.98 | | 0.0461 (0.00253) | 0.0136 (0.00082) | 0.1094 (0.00958) | 0.0305 (0.00372) | 1.396 (1.3388) | 0.0406 (0.00532) |

Tables 4 & 5 mirror the comparison of dry matter loss for wheat and rice in 7 and 14 days at different temperatures. Previous results of dry matter loss for 7 days from Hamer (1993) have also been compared, in the table. Almost increasing trend of DML is found in table 5. Apart from a drop at $a_w$ 0.85 and 25ºC in rice, both crops have linear DML with temperature and water activity.

Tables 6 & 7 represent the moulding affected by water activity and temperature. Tables show the visible as well as microscopic moulding in 7 and 14 days for both; wheat and rice crops. The values shown are the mean values of all replications for each treatment

**Table 4. The effect of different Temp and Water activity on Dry matter loss (DML) in Wheat and Rice crops after incubation of 7 days.**

| Water activity, $a_w$ | 15C | | | 25C | | | 35C | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ham | This study | | Ham | This study | | Ham | This study | |
| | Wheat | Wheat | Rice | Wheat | Wheat | Rice | Wheat | Wheat | Rice |
| 0.80 | 0.007 | 0.0231 | 0.0386 | 0.039 | 0.0240 | 0.0206 | 0.133 | 0.0156 | 0.0184 |
| 0.85 | 0.018 | 0.019 | 0.0242 | 0.130 | 0.0234 | 0.0204 | 0.372 | 0.0252 | 0.0282 |
| 0.90 | 0.085 | 0.0359 | 0.0249 | 0.436 | 0.0341 | 0.0304 | 0.774 | 0.4006 | 0.0362 |
| 0.95 | 0.517 | 0.074 | 0.0189 | 1.21 | 0.3468 | 0.0898 | 1.239 | 0.9791 | 0.1266 |
| 0.98 | | 0.303 | 0.1114 | | 0.6339 | 0.2106 | | 2.9902 | 0.3018 |

**Table 5. The effect of different Temp and Water activity on Dry matter loss (DML) in Wheat and Rice crop after incubation of 14days.**

| Water activity, $a_w$ | 15C | | 25C | | 35C | |
|---|---|---|---|---|---|---|
| | Wheat | Rice | Wheat | Rice | Wheat | Rice |
| 0.80 | 0.016 | 0.0238 | 0.029 | 0.0427 | 0.016 | 0.0196 |
| 0.85 | 0.017 | 0.0255 | 0.031 | 0.0413 | 0.048 | 0.0193 |
| 0.90 | 0.033 | 0.0243 | 0.058 | 0.0384 | 0.359 | 0.0265 |
| 0.95 | 0.082 | 0.0515 | 0.504 | 0.0702 | 1.349 | 0.1297 |
| 0.98 | 0.326 | 0.0950 | 0.722 | 0.2137 | 4.456 | 0.3035 |

**Table 6. The Effect of Water activity and Temperature on Moulding of Wheat grain.**

| Water Activity | | 15C | | 25C | | 35C | |
|---|---|---|---|---|---|---|---|
| | | Visible | Mic. Scope | Visible | Mic. Scope | Visible | Mic. Scope |
| | | (Mean of all Rep) | | (Mean of all Rep) | | (Mean of all Rep) | |
| **0.80** | **07 days** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | **14 days** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 |
| **0.85** | **07 days** | 0.00 | 0.00 | 0.00 | 0.25 | 0.00 | 0.00 |
| | **14 days** | 0.00 | 0.25 | 0.00 | 0.50 | 0.00 | 0.50 |
| **0.90** | **07 days** | 0.00 | 0.00 | 0.00 | 0.25 | 0.50 | 1.00 |
| | **14 days** | 0.00 | 0.50 | 0.25 | 0.75 | 1.00 | 1.25 |
| **0.95** | **07 days** | 0.25 | 1.00 | 1.00 | 1.50 | 1.25 | 2.00 |
| | **14 days** | 1.00 | 1.50 | 1.50 | 1.75 | 1.50 | 2.25 |
| **0.98** | **07 days** | 1.50 | 2.00 | 1.75 | 2.00 | 2.50 | 2.75 |
| | **14 days** | 1.75 | 2.00 | 2.00 | 2.75 | 3.00 | 3.50 |

0 = no moulding, 1= very light, 2 = light, 3 = medium and 4 = heavy moulding

**Table 7. The Effect of Water activity and Temperature on moulding of Rice grain**

| Water Activity | | 15C | | 25C | | 35C | |
|---|---|---|---|---|---|---|---|
| | | Visible | Mic. Scope | Visible | Mic. Scope | Visible | Mic. Scope |
| | | (Mean of all Rep) | | (Mean of all Rep) | | (Mean of all Rep) | |
| **0.80** | **07 days** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | **14 days** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **0.85** | **07 days** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | **14 days** | 0.00 | 0.50 | 0.00 | 0.25 | 0.00 | 0.50 |
| **0.90** | **07 days** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.25 |
| | **14 days** | 0.00 | 0.00 | 0.00 | 0.25 | 0.25 | 0.50 |
| **0.95** | **07 days** | 0.00 | 0.50 | 0.25 | 0.50 | 0.75 | 1.00 |
| | **14 days** | 0.50 | 0.75 | 0.25 | 1.00 | 1.00 | 1.25 |
| **0.98** | **07 days** | 0.50 | 1.00 | 1.00 | 1.25 | 1.50 | 1.75 |
| | **14 days** | 1.25 | 1.50 | 1.00 | 1.50 | 1.50 | 2.50 |

0 = no moulding, 1= very light, 2 = light, 3 = medium and 4 = heavy moulding

## DISCUSSION

Three major experiments at different temperatures and water activities were conducted including with some small scale studies for both wheat and rice crop. This study is of unique interest as the grain used in this experiment is from other location of the world having different environmental conditions. It is more likely possible for this grain to behave differently in UK environment (Cantone et al. 1983) and have different rate of respiration depending on different factors including with the conditions and previous storage period (Baily 1940, Milner and Gedds 1945 and Steele et al, 1969). The results of this study are individual in some areas, however, agreeing with previous researchers in others. May be these were expected but could not be said unusual. It might be due to the variety (Cantone et al. 1983) and location of the grain origin as there seems not much difference between wheat and rice data (Magan et al., 2003). Hamer (1994) has reported higher results, which are mostly calculated on the basis of $O_2$, where as in this study, $Co_2$ data is used.

It is generally found that there are some discrepancies in results in between different studies, which could be due to the different cultivars, ages, sizes and qualities and methodologies applied (Hamer, 1993). This study could be connected in the same chain of differences as the grain used, is imported from the other region for the world and is expected to be affected accordingly. The shape of the curves are bit different showing the decrease of $O_2$ consumption at high water activity, however, $Co_2$ production increased, which could also be attributed towards the initial moisture content of the grain.

In case of Lacey at al (1994), they consumed $O_2$ data assuming more correct than $Co_2$ which was not reliable due to its procedure adopted, however, the data here for both; $O_2$ and $Co_2$ could be more reliable as analysed by GC.

### Respiration

Respiration of wheat and rice grain were compared over 7 and 14 days at 0.80-0.98 $a_w$ for three different temperatures; 15, 25 and 35ºC.

Baily & Gujar (1918) reported the $Co_2$ production increased with the increasing MC and found that some varieties of wheat had different respiration rates than others. Hummel et al., (1954) pointed out that even at high MCs, mould free grain showed low respiration rate. In this case, respiration rate seems to be smaller whereas the visible as well as microscopic moulding bit greater.

Hamer (1993) suggested that gas chromatography could be appropriate for the determination of the $Co_2$ (White et al, 1982) as the collection of the $Co_2$ in alkali and Na OH were not more accurate. In connection to respiratory quotient (RQ), Magan (1993) opined regarding the findings of the White et al., (1982) that use of RQs of 1.00 from this study may not be accurate to use for the safe storage periods.

The smaller production of the $Co_2$ in these experiments could be due to many reasons but one of them may be as suggested by Lacey et al., (1994) that $Co_2$ is utilised very much by fungi and not released, which was supposed to be produced and expected to be released, in reality. The method used for $Co_2$ determination is well recognised by different researcher (Hamer, 1993) hence, its accuracy may not be doubtful.

### Respiratory Quotients

It could be differed due to many complex reasons in wheat grain (Hamer, 1993).

### Dry Matter Loss

In case of wheat crop, DML is varying at lower water activities (0.80 and 0.85), however in case of rice, it varies with all water activities at 15ºC. The results show that DML becomes bit stable and linearly increasing at higher temperatures and water activities. Overall, it could be said that calculated DML in this study is more stable for wheat than the rice crop. May be it is due to its structure and lack of adaptability in different conditions.

### Moulding

The lowest moulding is shown at lower temperature and water activity ($a_w$), whereas the higher moulding is seen at highest temperature and water activity. The studies of Muck et al (1991) showed that the growth rates of yeast and fungi increased linearly with $a_w$ below 0.99 $a_w$ but more slowly from 0.99 to 1.00 $a_w$ . It is employed sense that table represent high values however; the corresponding DML is seemed smaller than expected according to the values. May be possible, it is due to:

1) the more oxygen consumption in moulding than the $Co_2$ production, 2) it is also possible that the proper production of $Co_2$ needed more incubation time in universals than the given one.

**CONCLUSION**

The experiments were conducted to study in the Respiration and Dry matter loss in stored Wheat and Rice crop at Different Temperatures and Water activities at the Post harvest and Mycology laboratories, Cranfield University Silsoe, UK, during the year 2002-3. The results of this investigation are individual in one area, whereas, in agreement with previous research in others. May be these were expected due to the variety (Cantone et al. 1983) and location of the grain origin as there seems not much difference between wheat and rice data (Magan et al., 2003). The data for both; $O_2$ and $Co_2$ could be more reliable as analysed by GC with compare to Lacey at al (1994) due to procedure adopted. The results show that DML becomes bit stable and linearly increasing at higher temperatures and water activities. Overall, it could be said that calculated DML in this study is more stable for wheat than the rice crop. May be it is due to its structure and lack of adaptability in different conditions.

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