Effects of Mechanical Damage and Temperature on Potato Respiration Rate and Weight Loss

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Abstract: In order to take full advantage of stored potatoes, especial attention has to be paid to storage conditions. Respiration rate is an indicator of the physiological activity in storage and is characterized by O₂ consumption and CO₂ and heat production. The goal of this study was to investigate the effects of these two factors, temperature and mechanical damage levels on respiration rate and weight loss of potato. Therefore a factorial experiment with two factors included mechanical damage with 4 levels (control, hit, scratch and heavy scratch) of tubers and temperature with 3 levels, (5°C, 10°C and 15°C) was arranged in a completely randomized design with three replications. Duration of experiment was one week. Respiration rate was measured by monitoring the flow of oxygen in and out of the tuber containers using a NOA analytical system. Weight loss was measured from different of tubers weigh before and after the experiment. The results indicated that weight loss and respiration rate significantly affected by both temperature and mechanical damages levels. The lowest respiration rate and weight loss were observed at 5°C and the highest values were observed at 15°C. The highest respiration rate and weight loss were observed for the tubers with scratched skin and pulp level of mechanical damage, followed by tubers with scratched skin, bruised tubers and undamaged tubers in that order.

Key words: Potato • Respiration rate • Storage temperature • Mechanical damages • Weight loss

INTRODUCTION

The need for food constitutes a major concern for the people of the world. Potatoes are the fourth most important agricultural crop worldwide after wheat, corn and rice and play a key role in feeding the growing world population [1]. Potatoes are a versatile food that are consumed throughout the world because of their high yield, relatively low cost of production and adaptability to a wide variety of soil and climate types [2]. Most of the harvested potato is put into storage for a while before being used or distributed in the market. While in storage, potato tubers undergo gradual chemical decomposition, involving the breakdown of starch, resulting in significant weight and quality loss. Moreover, pests and tuber sprouting can cause further harm to the stored tubers. A variety of factors such as ambient temperature, light and air moisture, as well as mechanical damage of the potato tubers can accelerate this degradation [3,4].

Mechanical damage to the potato tubers may occur during harvest or transportation. Mechanical damage can appear as minor skin abrasion, bruises, or deeper damages. Hemmat & Taki (1997) reported that mechanical damage to potato tubers accounted for 48% of the wastage from harvest to consumption in Iran [5]. Other studies have shown that 65% to 75% of all the damage to potato tubers is due to mechanical harvest; in other word, they occur before storage [1].

Proper storage should aim at minimizing the weight loss and quality degradation by preventing excessive respiration during storage [6]. As indicated by Eq. 1, respiration converts the valuable starch, by oxygen expenses, into carbon dioxide, water and heat [7].

\[ C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + \text{Energy(Heat)} \] (1)

In addition to the overall health condition of the tubers, variety, growth conditions in the field and maturity level of the tubers, the storehouse temperature is a major factor influencing the respiration rate and weight loss of the tubers during storage [8,9]. In general, based on the intended use of the tubers, variety and mechanical damages to tubers, the temperature range of the storehouse is recommended to be between 5 and 20°C.

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The storage period is divided into three phases: (a) the heating phase, during which tuberose tissues develop at the spots on the tuber surface that are damaged during harvesting, (b) the longer phase of stability and (c) the warming phase before transportation (1). For example, some studies suggest that the storehouse temperature be increased to 15°C during the first month of storage, so that the injured spots of the tubers heal, although such high temperatures are likely to increase the respiration rate [10]. Raghani (2009) suggested that the storage temperature has to be between 10 and 12.7°C for fresh use and 8.9°C for later use and that the temperature should not drop below 5.5°C [8]. For healthy and mature tubers that are to be used for making potato chips, the storage temperature should be between 10 and 15°C, while if mature potatoes with high sugar content are to be used for the same purpose, 15°C. For long-term storage, the recommended storehouse temperature is 2 to 4°C for seed potatoes, 3 to 5°C for regular sale, 7 to 9°C for halffinished frozen potatoes and 7 to 10°C for potato chips [11]. The present study was conducted to investigate the effect of mechanical damage and storage temperature on the respiration rate and weight loss of potato tubers.

MATERIALS AND METHODS

Selection of Potato Tubers: The tubers were of potatoes (*Solanum tuberosum*, L., cv. Marco) with fully matured, uniform shape and size of an average mass of 150 gram. On average each tuber contained 3.7 gram protein, 37 gr carbohydrates and 2.7 gr of fiber. Each experimental unit used 2 kg of potato.

Treatments: Four form of made up mechanical damage included control, hit, Scratch and heavy Scratch which were created a follow:

- Undamaged tubers; this treatment is referred to as “Control” in the rest of this manuscript.
- 2) Tubers were hit with a rubber mallet with a mass of 0.8 kg. The mallet was dropped forty times from a height of 0.25 m in free fall. This treatment will be referred to as “Hit”.
- 3) An area of 3 cm² on the tuber skin was scratched without damaging the pulp. This treatment will be referred to as “Scratch”.
- 4) The tuber skin and a thickness of 2 mm of the pulp were removed over an area of 3 cm². This treatment will be referred to as “Heavy Scratch”.

Three different temperature included 5, 10 and 15°C were tested in the experiment.

Respiration Rate and Weight Loss Evaluation: ANOA analytical system (model 402 AS-24) was used to measure the amount of oxygen as an indicator of respiration rate base on Eq. 1 [1]. The system, fundamentally, included 12 cylindrical receptacles, all with the same capacity (24.4 L) and adjustable temperature, an analyzer for O₂ measurement and a PC for record the data (Figure 1). Before each test, the equipment was calibrated, the analyzer on 20.9% for O₂ and of the receptacles were adjusted for temperature according to the treatments. The pre weighted tubers (2 kg) were put into the cylindrical receptacles as experimental unit and the lids were put on. The inputs and outputs of the 12 receptacles inside equipped with celluloid valves were connected to the analyzer. The O₂ measurements by

Fig. 1: The experimental setup showing the gas analyzer and PC equipment (a) and the receptacles (b)
the analyzer were recorded by a PC every 10 min during the experiment. The duration of the experiments was one week and mean of the last day recorded data for each experimental unit was used in analysis.

Upon the completion of the experiment, the cylindrical receptacles were opened, tubers were visually inspected and carefully weighed to determine the amount of weight loss by calculate difference of tubers weight before and after of experiment. Taking into account the oxygen decrease rate measured during tests.

**Statistical Analysis:** A factorial experiment with two factors included mechanical damage with 4 levels and temperature with 3 levels, which explained above, was arranged in a completely randomized design with three replications. Analysis of variance was done on weight loss per Kg of tubers and oxygen consumption as indicator of respiration rate using Statistical Analysis System (SAS), General Linear Models (GLM) procedure [12]. difference of the analyzer oxygen calibrate at the experimental initiate (20.9%) and the mean of the last day recorded O2 data by PC was calculated as expensed oxygen. Fisher's LSD was used to compare factors means and also interaction means when at least one interaction effect was significant at the 0.05 probability level.

**RESULTS AND DISCUSSION**

The analyses of variance revealed significant differences ($P<0.01$) due to both mechanical damage and temperature factors effect on weight loss and oxygen consumption (Table1). Interaction of mechanical damage and temperature was significant for oxygen consumption.

Hence, potato transpiration rate regarding the damages was dependent on environmental condition, in this experiment, temperature.

Comparison of mean square (and also sum of square) indicate that mechanical damage explain a large fraction of the weight loss variation compare to temperature, while temperature is more important in explain variation of oxygen consumption and it indicates role of this factor in transpiration rate.

Oxygen consumption means of mechanical damage and temperatures combination also comparison of mean levels of each factor are shown in Table 2. At the lowest temperature (5°C), there was no significant different between control and any of mechanical damages levels. At 10°C temperature just heavy scratch treatment significantly increased the oxygen consumption (0.641%) compare to control (0.528%). While for the higher temperature (15°C), all of the four mechanical damage types were significantly different. Heavy Scratch treatment resulted in the highest respiration rate (4.689% reduction in existent oxygen in the cylindrical receptacles); respiration rate for scratch treatment was higher than Hit treatment and the Control treatment (0.591%) showed the lowest respiration rate. Moreover, considering the mean of oxygen consumption over four types of mechanical damage, showed that the respiration rates increased by heighten of temperatures (Table 2). However this characteristic for 5°C and 10°C were not statistically different, but it significantly increased for 15°C. This results agreement with Hide & Boorer (1991), who report high temperatures are increase the respiration rate. Different levels of mechanical damage (control, hit, scratch and heavy scratch)

<table>
<thead>
<tr>
<th>Source of variation</th>
<th>df</th>
<th>Weight loss</th>
<th>Oxygen consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>2</td>
<td>11.215**</td>
<td>0.021**</td>
</tr>
<tr>
<td>Mechanical Damage (MD)</td>
<td>3</td>
<td>147.415**</td>
<td>3.881**</td>
</tr>
<tr>
<td>Temperature (T)</td>
<td>2</td>
<td>78.116**</td>
<td>7.396**</td>
</tr>
<tr>
<td>MD * T</td>
<td>6</td>
<td>12.971**</td>
<td>3.464**</td>
</tr>
<tr>
<td>Error</td>
<td>24</td>
<td>5.978</td>
<td>0.004</td>
</tr>
</tbody>
</table>

ns, *, **: Non significant, Significant at the 0.05 and 0.01 probability levels, respectively

<table>
<thead>
<tr>
<th>Factors</th>
<th>5°C</th>
<th>10°C</th>
<th>15°C</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.488</td>
<td>0.528</td>
<td>0.591</td>
<td>0.535d</td>
</tr>
<tr>
<td>Hit</td>
<td>0.557</td>
<td>0.565</td>
<td>0.799</td>
<td>0.640c</td>
</tr>
<tr>
<td>Scratch</td>
<td>0.569</td>
<td>0.579</td>
<td>1.601</td>
<td>0.916b</td>
</tr>
<tr>
<td>Heavy Scratch</td>
<td>0.583</td>
<td>0.641</td>
<td>4.689</td>
<td>1.971a</td>
</tr>
</tbody>
</table>

mean 0.549b 0.578b

Levels means of each factor followed by the same letter are not significantly different at Fisher's LSD0.05. Fisher's LSD0.005 for comparison of two factors interaction means is 0.106.
caused 0.535, 0.640, 0.916 and 1.971 percent reduction in the existent oxygen, respectively and all differences between these levels were significant (Table2) [10]. Rastovski and van Es (1987) believed that respiration is like breathing and potatoes respire to provide their cells with oxygen and the energy needed to maintain health [6]. However, fast respiration causes fast spoilage and short shelf life. For slow respiration and have long storage lives, potatoes tubers should be healthy and storage in suitable condition like low temperatures. On the other hand, respiration is necessary, but there are two concerns. One is that managers may need to remove heat caused by potato respiration. The other is that respiration contributes to shrink the loss of salable weight [11].

Visual inspection of the potato tubers showed that the appearance of the tubers stored at 5°C did not undergo any observable change. Also, the tubers stored at 10°C did not show any undesirable change in their appearance. At this temperature, a corky layer was formed at the scratched areas on the tubers' surface. However, at 15°C, depending on the severity of the mechanical damage, significant changes to the appearance of the tubers were observed. For example, all the tubers in the heavy scratch treatment were spoiled.

Temperature is the most important storage management tool and high temperatures accelerate biological deterioration [11]. In our study, the weight loss mean had a significant positive correlation with the temperature and as shown in Figure 2, the lowest weight loss was observed at the lowest tested temperature (i.e., 5°C) and increasing temperature caused to weight loss climbing till the 15°C showed 13.6 g/kg reduction of potato tubers. Figure 3 shows the mean weight loss for different types of mechanical damage. Hitting treatment did not affect the tuber weight compared to control treatment and mean weight loss of these two treatments...
were statistically the same. However, the scratch and heavy scratch treatments showed more enormous weight losses compared to control and hit treatments. Overall potato bruises and cuts cause storage problems. Damaged tubers alone are unsightly and undesirable to consumers. Injuries also accelerate water loss, which caused to weight loss and also open the tuber to disease infection [9] Harvest and handling equipment usually damage some potatoes. Wound healing is essential for storage potatoes. This is done by controlling storage temperature and humidity during a two-week curing period. The curing temperature is higher than that used after wound healing [7]. In this study formation of corky layer at the scratched areas of the tubers surface at the low temperatures probability help to reduce water and weight losing.

Means potato weight loss of mechanical damage types and temperature levels combination are shown in Figure 4. It show the interaction of these two factors on the losing weight of the tubers. In such way largest weight loss was observed for intensely damaged potatoes (i.e. heavy scratch) and at the highest temperature tested (i.e. 15°C). At this temperature level, weight loss is significantly different for mechanical damage types. However it seem that mechanical damage, specially scratching of tubers, is more important than the studied temperature levels on weight loss. Since mean weight loss of different levels of temperature at the control and even in hit treatments statistically were the same. Hence in this study positive correlation between weight loss mean and temperature levels which shown in Figure 2 is more affected by the scratch and heavy scratch damage treatments. This study showed that scratched tubers should be stored at low temperatures to avoid high respiration rates and rotting of the tubers. Previous studies have suggested that, provided appropriate storage conditions, skin scratches can heal in the storehouse, but more severely damaged potatoes should be used immediately [13].

**CONCLUSION**

- Our results indicate that respiration rates and weight loss both affected by, temperature, mechanical damage.
- Transpiration rate is more influence by temperature and weight loss is more influence by mechanical damage.
- This study showed that scratched tubers should be stored at low temperatures to avoid high respiration rates and rotting of the tubers.
- It is difficult to identify bruised potato tubers by visual inspection. Bruised tubers can easily end up in the storehouse as healthy tubers and especial precautions should be undertaken in harvesting and transportation in order to minimize bruising.

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**REFERENCES**


