BUL 1061

Respiration of Potatoes During Storage

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Contents

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What Is Respiration?

WHEN POTATO TUBERS are harvested, respiration becomes a crucial metabolic process that keeps potatoes alive throughout storage. Respiration involves the breakdown of complex substances like starches, sugars, and organic acids in tuber cells. As a result, simpler molecules are produced, along with energy and other compounds. The equation below illustrates the process, from the oxidation (breakdown) of substrates (carbohydrates or glucose) to the release of energy (mostly in the form of heat), carbon dioxide (CO_2), and water (H_2O).

Glucose + oxygen → carbon dioxide + water + energy

$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + (673\ kcal)$

Typically, the respiration rate of potatoes is determined by measuring the amount of CO_2 (mL or mg = milliliter or milligram) produced relative to the weight of the potatoes (in kg = kilogram) over a specific timeframe (h = hour). The respiration rate is usually expressed as either mL CO_2 kg^{-1} h^{-1} or mg CO_2 kg^{-1} h^{-1}.

Mature potatoes are considered vegetables with a very low degree of perishability. This classification is due to a low respiration rate of less than 2.5 mg CO_2 kg^{-1} h^{-1} when stored at a temperature of 41°F (Kader and Saltveit 2003). Although potatoes have a relatively low respiration rate, the volume in storage plus common potato storage temperatures (42°F–48°F) can create an environment with high oxygen (O_2) demand and a great necessity to exhaust CO_2. This is especially true when storing freshly harvested warm potatoes.

What Impacts Respiration?

Temperature

After being harvested, potatoes produce a significant amount of heat due to the high temperatures of their surroundings, also known as **field heat**. Field heat influences the potato tubers' respiratory rates while in storage (also known as vital

heat). At higher pulp temperatures, potatoes have a higher rate of respiration. For example, Clearwater Russet potatoes have a higher respiration rate at 77°F, reaching up to 4.53 mg CO_2 kg^{-1} h^{-1}, which is 3.5 times greater than the rate at 50°F (Figure 1).

As such, harvest at lower temperatures to avoid high heat load during storage. Not only is it difficult the remove heat from the storage in a timely manner, but warm tubers from the field have higher respiration rates and will likely physiologically age the tubers. The consequences of early aging in storage could be early sprouting, senescent sweetening, and/or greater weight loss. In addition, warm potatoes, typically above 60°F or 65°F depending upon variety and conditions, are more susceptible to disease development and weight loss.

Vital Heat

The heat produced by respiration is referred to as **vital heat**. To calculate vital heat, divide the energy generated (673 kcal or kilocalorie) by the molecular weight of the CO_2 produced during respiration (264 g). Therefore, every gram of CO_2 produced generates 2.55 kcal of energy. The majority of this energy is released as heat, thus linking the respiration rate of potato tubers to the heat generated (Table 1).

If the vital heat produced by potatoes in storage is not removed, the temperature rises. This can lead to higher respiration rates, which in turn increases heat production. Therefore, temperature has the greatest impact on respiration rate. Proper temperature control is crucial to reduce respiration and extend the storage life of potatoes.

Cultivars

Cultivars have varying respiration rates due to genetic variation, which affects their response to storage conditions, particularly temperature (Table 2).

It is important to consider the respiration rate of a cultivar when multiple cultivars are stored together in the same bay, split bay, or storage. Cultivar differences in heat production can impact the storage environment, creating different thermal zones, depending on the vital heat generated (Table 3). For instance, in a two-bay shared plenum storage,

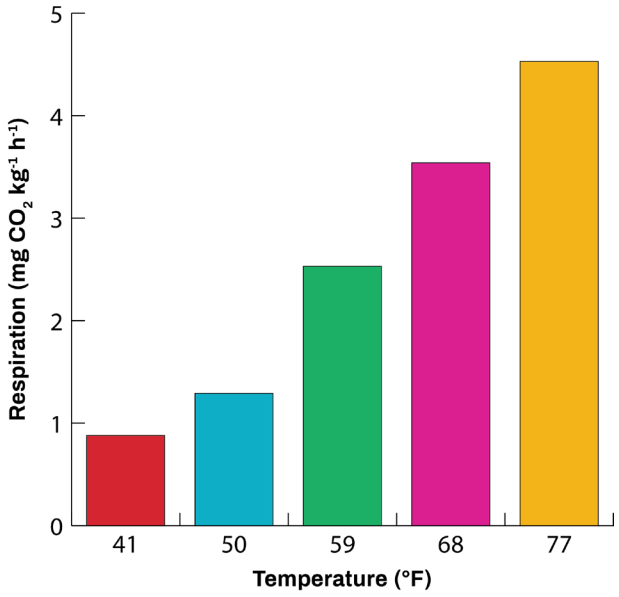

Figure 1. Respiration rate (mg CO_2 kg^{-1} h^{-1}) of 'Clearwater Russet' previously stored at 42°F and 95% relative humidity for seven months and transferred to various temperatures (41°F, 50°F, 59°F, 68°F, and 77°F) for twenty-four hours for respiration rate measurements using a static system.

Table 1. Respiration rate (mg CO_2 kg^{-1} h^{-1}) and vital heat of potatoes stored at different temperatures.

Temperature	Respiration Rate	Heat*	Heat†	Heat‡
	mg CO_2 kg^{-1} h^{-1}	kcal t^{-1} day^{-1}	BTU t^{-1} day^{-1}	BTU cwt^{-1} day^{-1}
42°F	1.5	91.8	364.5	16.6
45°F	1.6	97.9	388.7	17.6
48°F	1.7	104.0	412.9	18.7

*1.0 mg CO_2 kg^{-1} h^{-1} indicates a heat production of 61.2 kcal Mt^{-1} day^{-1} (Saltveit 2003), †kcal to BTU = 3.97, ‡cwt = 45.4 kg. BTU, British thermal units.

Table 2. Average respiration rate (mg CO_2 kg^{-1} h^{-1}) of russet potatoes stored at 42°F, 45°F, and 48°F and 95% relative humidity after eight months in storage and treated with CIPC. CIPC, chlorpropham.

Cultivar	42°F	45°F	48°F
Russet Burbank	0.96	1.29	1.18
Russet Norkotah	0.90	0.96	1.00
Ivory Russet	1.12	1.13	1.26
Rainier Russet	1.21	1.27	1.38

Table 3. Average vital heat (BTU t^{-1} day^{-1}) generated of russet potatoes stored at 42°F, 45°F, and 48°F and 95% relative humidity after eight months in storage and treated with chlorpropham (CIPC).

Cultivar	42°F	45°F	48°F
Russet Burbank	233.2	313.4	286.7
Russet Norkotah	218.6	233.2	242.9
Ivory Russet	272.1	274.5	306.1
Rainier Russet	293.9	308.5	335.2

the ventilation requirements for one bay may vary based on the respiration rates of one stored cultivar compared to others. Respiration rate and heat production also impact the necessary capacity of the refrigeration system needed to remove heat or maintain temperature.

Ventilation

Maintain airflow postharvest to effectively dissipate the significant amount of heat produced by respiration alongside additional field heat. The primary purpose of ventilation is to reduce or maintain respiration by cooling and/or keeping potatoes at the desired temperatures (Pringles et al. 2009).

The ventilation rate recommendation for bulk potato storage varies according to the production region and can range from 10 to 35 cubic feet per minute (CFM) in the United States. Adequate ventilation is necessary to avoid CO_2 buildup, especially early in storage season. Not purging it leads to adverse effects on tuber quality if the CO_2 concentration exceeds the recommended threshold level for the market use of the crop. The maximum CO_2 level can vary from 1,200 to 5,000 ppm. High CO_2 levels have been associated with elevated reducing sugars, darker fry color, and off-flavors, depending upon the duration, cultivar, presence of ethylene, and overall storage conditions. As with any stress in plant tissue, high CO_2 can stimulate a stress-related synthesis of ethylene, which at concentrations as low as 0.25 ppm can increase reducing sugars and darken potato fry color. Thus, high CO_2 and the presence of ethylene detrimentally impact fry color.

Basic Overall Management Considerations

The respiration rate of potatoes varies depending on various factors such as cultivar, maturity, handling, disease, stress, harvest season, growing location, storage conditions (temperature and ventilation), sprouting, and postharvest treatments. Nevertheless, note the following general recommendations:

- Harvest potatoes when mature. Immature potatoes tend to have higher respiration rates.
- Harvest crops during the cooler parts of the day to prevent high heat accumulation during storage.
- During harvest, minimize injuries since they can lead to higher respiration rates.
- Rapidly lower the temperature of potatoes to curing levels.
- Provide adequate ventilation to cool the crop, supply O_2, and remove CO_2, while maintaining proper humidity to minimize weight loss.
- If two cultivars are stored together in a two-bay shared plenum storage, base the ventilation requirements on the respiration rate of the cultivar with the higher rate.
- At holding temperatures, reduce the ventilation rate since it minimizes vital heat production.
- If appropriate, apply sprout suppressants to control sprout development. Sprout growth increases respiration rates.
- Monitor temperature fluctuations, hot spots, ventilation, and overall storage conditions, including air leaks. These can impact respiration rates.
- Warming the crop prior to unloading it from storage increases the respiration rate of the potatoes, so more ventilation may be necessary.

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