BUL 1081

Understanding Weight Loss of Potato Tuber in Storage

Gustavo Henrique de Almeida Teixeira
Potato Postharvest Specialist, University of Idaho Extension, Kimberly Research and Extension Center

Georgios T. Xanthopoulos
Associate Professor, Agricultural University of Athens, Department of Natural Resources Management and Agricultural Engineering, Greece

Samuel Paytosh
Research Associate, University of Idaho Extension, Kimberly Research and Extension Center

Nora Olsen
Potato Specialist, University of Idaho Extension, Kimberly Research and Extension Center

Contents

University of Idaho Extension

Introduction

WATER IS A MAJOR COMPONENT of potato tubers (78%–88%), followed by starch (8.9%–18.8%), protein (1.5%–2.4%), ash (0.8%–1.4%), crude fiber (0.3%–0.8%), and fat (0.3%–1.0%) (Figure 1). As expected, the primary cause of weight loss in stored potatoes is water loss, mainly through transpiration and to a lesser extent through respiration (Czerko et al. 2023). Water loss decreases a potato's sellable weight, degrades appearance (shrinkage and shriveling), and changes texture (softening), ultimately resulting in less profit. It is advantageous to understand the conditions that cause water loss in stored potatoes.

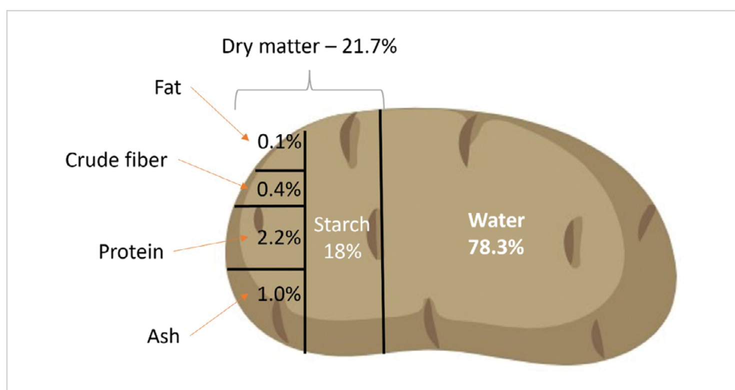

Figure 1. Chemical composition of potato tuber (Leonel et al. 2017). Image created in BioRender.com

Potato weight loss varies significantly, depending on cultivar and storage management practices, though some studies have reported more stable numbers (Wang et al. 2016). To understand how potatoes lose weight, it is important to know how water operates in potatoes: how it escapes and the physics (and quantification) of water vapor inside a potato. By understanding the processes more fully, growers and storage managers will be able to estimate potato weight losses and improve their ability to more effectively store their crops.

Water Loss in Potato Tubers

Transpiration and respiration are the most significant mechanisms for water loss in stored potatoes: 97.6% transpires through the skin, while the remaining 2.4% exits through the lenticels, along with carbon dioxide (CO_2) produced by respiration (Burton 1989). Both processes are affected by various biological and environmental factors. Biological factors may include surface-to-volume or surface-to-mass ratio, surface injuries (such as a shatter bruise), morphological and anatomical characteristics (such as suberin and wax, cracks, and lenticels), and the maturity stage of the potato. Environmental factors include storage air temperature, relative humidity (RH), and air velocity (Lentzou et al. 2021).

Estimating the Role of Water Vapor Pressure

Although low temperatures and high RH are key for minimizing water loss, the respiration rate of tubers also plays an important role. Neglecting respiration as a mechanism of water loss may result in erroneous conclusions when saturation is reached and the water vapor pressure deficit (VPD) is zero. In such cases, water loss is expected to be close to zero, but in reality, some amount of water loss is observed due to respiration (Xanthopoulos et al. 2017).

Most of the water vapor in a tuber is located between its cells (intercellular water). As time passes, water moves out of the intercellular space and into the storage space's air. The movement of water from the inner tissue to the tuber's surface is caused by the difference between the water vapor pressure (VP) inside the tuber's intercellular spaces and the VP in the storage space's surrounding (Pringles et al. 2009).

Intercellular air in potato tubers is nearly saturated with water vapor. In fact, the intercellular environment in potatoes experiences close to 100% RH. Thus, at a certain temperature, the VP inside the tubers is similar to the vapor pressure of saturated air (SVP). Water moves from areas of high-water VP to areas with low-water VP, such as the surrounding environmental air, which is closer to 95% RH for most storage spaces (Brecht et al. 2008).

Use Table 1 to estimate the VP in tubers. For example, the internal SVP of potatoes at 68°F is 2.337 kPa and at 50°F is 1.227 kPa. As such, the VP is determined solely by the temperature of the tuber, where low temperatures result in low VP and high temperatures cause high internal VP (Thompson 2002).

Table 1. Saturation vapor pressure (SVP) over water at different temperatures.

Temperature (°F)	Saturated Vapor Pressure (kPa)
41.0	0.872
42.8	0.935
44.6	1.001
46.4	1.072
48.2	1.147
50.0	1.227
51.8	1.312
53.6	1.402
55.4	1.497
57.2	1.598
59.0	1.704
60.8	1.817
62.6	1.937
64.4	2.063
66.2	2.196
68.0	2.337
69.8	2.486
71.6	2.643

Source: Díaz-Pérez (2019)..

Determining VPD

Water VPD is the difference between the SVP inside the tubers and the VP in the surrounding air. Since water vapor moves from areas of higher RH to lower RH, the higher the VPD, the greater the driving force for water loss from potatoes.

VPD can be calculated using the formula,

$$VPD = SVP - VP$$

where SVP is the saturated vapor pressure in the tuber and VP is the vapor pressure of the surrounding air (storage).

At a given temperature, estimate the VP of the air by taking the SVP listed in Table 1 for the temperature of the storage and multiplying it by the RH of the storage. For example, at 48.2°F, the SVP of the tuber is 1.147 kPa (saturated water pressure at 48.2°F, Table 1). If the temperature of the air around the tuber is 48.2°F and the RH is 95%, the VP of the air is approximately (1.147) × (0.95) = 1.089 kPa. The VPD is 1.147 kPa - 1.089 kPa = 0.058 kPa. If the RH of the surrounding air is 90%, the VPD is 0.115 (1.147 × 0.90), which is twice as high as it is at 95% RH.

The Impact of VP on Storage Management

The greater the VPD, the higher the water loss potential from the tuber to the surrounding air. If the VP in the cells of the potato skin (i.e., the SVP) and the VP of the air surrounding the potato are equal, negligible transpiration occurs. To achieve this optimal balance, the RH of the air surrounding the potatoes should be 97.8%, assuming that the temperature of the air is the same as that of the potatoes. That scenario is not always the case for stored potatoes, however. Calculating the VPD using the information in Table 1, along with tuber as well as air and RH measurements from the storage, provides another indication of how storage management influences the potential water loss from a stored crop.

When the transpiration rate is plotted against VPD (regardless of the air RH in storage), the transpiration rate decreases as the air temperature decreases. This highlights the importance of air temperature in the transpiration rate and the consequent water loss. However, biological and anatomical structures can also affect the transfer of water vapor from a tuber to its surroundings.

Measuring Water Loss

Weight Loss

One common and straightforward method for measuring water loss is to determine the change in tuber weight during storage. This can be carried out by placing small samples of tubers into mesh bags at various locations in the storage area. Record the initial weight of the bags, then measure the weight loss at the end of the storage period by calculating the difference in weight using the following formula:

Weight loss (%) = 100 - [(F_w × 100) / I_w]

where

F_w = final weight (lb or kg)

I_w = initial weight (lb or kg)

For example, if the average initial weight (I_w) of the bags is 30 lb and the final weight (F_w) is 27 lb, the weight loss can be calculated as

Weight loss (%) = 100 - [(27 × 100) / 30]

= 100 - [2,700 / 30]

= 100 - 90

= 10%

This formula comprises all sources of weight loss, including sprouting, decay, and water loss from evaporation and respiration.

Estimating Weight Loss (Per ASAE EP475.3)

The American Society of Agricultural and Biological Engineers has proposed a theoretical formula to estimate weight loss. The formula includes more specific information about the tubers and the storage environment. Use the following formula to estimate the weight loss of potatoes stored in piles or bulk storage:

L = (A + 0.1 × S) × D

where

L = estimated percentage of original weight lost per week;

A = 0.7 for first two weeks of storage period; 0.2 for remainder of storage period;

S = percentage of sprouts by weight;

D = VPD in mm of mercury is P_S (1.00 - RH);

P_S = saturation pressure of water at average temperature of potato in mm of mercury; and

RH = average relative humidity of the air entering the potatoes, a decimal.

For example, if we consider nonsprouting potatoes in storage for two weeks at 95% (or 0.95), RH, the A value would be 0.7 and S = 0 (no sprouting). The amount, 7.50062 mm of mercury (mmHg) is equivalent to 1 kilopascal (kPa), so at 59°F the P_S would be 1.704 kPa (Table 1) or 12.7810 mmHg and D = 12.7810 × (1.00 - 0.95) or 0.6390.

Thus, the percentage of original weight lost per week (L) is

$$L = (A + 0.1 \times S) \times D$$
$$= (0.7 + 0.1 \text{ x } 0) \times 0.6390$$
$$= 0.7 \times 0.6390$$
$$= 0.45\%$$

Weight loss may be two times higher than estimated by using this formula if the potatoes are immature or have a high degree of harvest damage. These cases are difficult to objectively estimate and inherently bear significant ambiguity in evaluation. Therefore, empirical formulas, like weight-captured sample bags, always bring a variable degree of accuracy.

Delta T (ΔT) and Weight Loss

The temperature difference from the bottom to the top of a potato storage pile is known as delta T (ΔT). The temperature is usually lower at the base of the pile as cold air is supplied to tubers. Because air moves from the bottom of the pile to the top, the air becomes warmer by removing the heat generated by the respiration process and creating a temperature gradient (ΔT).

High ΔT can lead to weight loss as the heat produced by respiration (vital heat) reduces the RH of the air around the tubers, increasing the water-holding capacity of the air and contributing to water loss through the transpiration of water from the skin. Thus, as warm air rises through a pile of potatoes, it removes moisture from the tuber surface. Therefore, air should be supplied at a sufficient flow rate so as to maintain a ΔT of 0.5°F–2.0°F across the pile to minimize weight loss.

Overall Management Considerations Based on Weight Loss

The weight loss of potatoes varies, depending on various factors such as cultivar, maturity, handling, disease, stress, weather during harvest, growing location, storage conditions (temperature, humidity, and ventilation), disease, sprouting, and postharvest treatments. Nevertheless, some general suggestions include the following:

- Harvest physically mature potatoes since immature ones tend to have higher weight loss.
- Harvest tubers with cooler temperatures to minimize initial VPD.
- Minimize mechanical injuries during harvest to reduce weight loss.
- Whenever curing is recommended, cure potatoes as fast as possible to minimize weight loss.
- Maintain a ΔT of 0.5°F–2.0°F across the pile to minimize weight loss.
- Provide adequate ventilation to cool the tuber, supply oxygen, and remove carbon dioxide, while maintaining proper humidity to minimize weight loss.
- Apply sprout suppressants to control sprout development and to reduce water loss.

Further Reading

ASAE EP475.3. 2018. "Design and Management of Storages for Bulk, Fall-Crop, Irish Potatoes." ASABE. https://elibrary.asabe.org/abstract.asp?aid=48715&t=3&dabs=Y&redir=&redirType=, accessed 25 January 2024.

Brecht, J. K., M. A. Ritenour, N. F. Haard, and G. W. Chism. 2008. "Postharvest Physiology of Edible Plant Tissues." In *Fennema's Food Chemistry* (4th ed.), edited by S. Damodaran, K. L. Parkin, and O. R. Fennema. Boca Raton, FL: CRC Press.

Burton, W. G. 1989. *The Potato*. 3rd ed. Harlow, UK: Longman Scientific and Technical. 742 p.

Czerko, Z., K. Zarzyńska, and D. Boguszewska-Mańkowska. 2023. "Postharvest Physiology and Storage of Potato." In *Potato Production Worldwide*, edited by M. E. Çalişkan, A. Bakhsh, and K. Jabran. London: Academic Press.

Díaz-Pérez, J. C. 2019. "Transpiration." In *Postharvest Physiology and Biochemistry of Fruits and Vegetables*, edited by E. M. Yahia. Cambridge, UK: Woodhead Publishing.

Hunter, J. 1986. "Heat of Respiration and Weight Loss from Potatoes in Storage." In *Engineering for Potatoes*, edited by B. F. (Burt) Cargill. St. Joseph, MI: American Society of Agricultural Engineers.

Lentzou, D., G. Xanthopoulos, C. Templalexis, and A. Kaltsa. 2021. "The Transpiration and Respiration as Mechanisms of Water Loss in Cold Storage of Figs." *Food Research* 5(6): 109–18.

Leonel, M., E. L. Carmo, A. M. Fernandes, R. P. Soratto, J. A. M. Ebúrneo, E. L. Garcia, and T. P. R. Santos. 2017. "Chemical Composition of Potato Tubers: The Effect of Cultivars and Growth Conditions." *Journal of Food Science and Technology* 54(8): 2372–78.

Pringles, B., C. Bishop, and R. Clayton. 2009. *Potato Postharvest*. Wallingford, CT: CABI. 417 p.

Thompson, J. F. 2002. “Psychrometrics and Perishable Commodities.” In *Postharvest Technology of Horticultural Crops* (3rd ed.), edited by A. A. Kader. Oakland: University of California.

Wang, Y., T. L. Brandt, and N. Olsen. 2016. “A Historical Look at Russet Burbank Potato (Solanum tuberosum L.) Quality under Different Storage Regimes.” *American Journal of Potato Research* 93: 474–84.

Xanthopoulos, G. T., C. G. Templalexis, N. P. Aleiferis, and D. I. Lentzou. 2017. “The Contribution of Transpiration and Respiration in Water Loss of Perishable Agricultural Products: The Case of Pears.” *Biosystems Engineering* 158: 76–85.

UI PEER REVIEWED

BUL 1081 | Published December 2024 | © 2024 by the University of Idaho