Storage of Chestnuts in Michigan

Dennis W. Fulbright
Vice President, Chestnut Orchard Solutions
info@chestnuthelp.com
Professor Emeritus, Michigan State University

Postharvest decay of edible chestnuts reduces nut quality and can lead to severe economic losses. In Michigan, postharvest decay was identified as one of the major problems that negatively impacts fresh chestnuts, and in 2006 it accounted for up to 25 percent of losses after harvest.[9] Since that time, a better understanding of chestnut storage enlightened the process of storage in Michigan and lead to the discovery of a new physiological problem associated with pollen parents. Today, Michigan can harvest nearly a quarter million pounds of chestnuts with only a minimal amount of nut rot.

There are generally four types of decay or nut rot associated with chestnut production: 1) Common storage molds; 2) Environmentally-induced storage molds; 3) Pathogen-associated nut rots; and 4) Physiological kernel breakdowns. Each requires an understanding of its symptoms and causes if they are to be recognized and managed.

Biology and Physiology of the Chestnut

The chestnut fruit or nut is obviously a living organism and its natural biological purpose is to germinate and grow into a new tree. Since the new tree will come up in the spring, the nuts need to be able to survive intact for several months, buried in the soil without rotting even though they are surround by soil-borne microorganisms that normally rot plant parts in a matter of weeks. The time it takes from falling out of the tree to germinating into a new tree is basically that time that growers and marketers call "storage". To successfully make it through that time interval, the chestnut has evolved natural defense mechanisms against rot and the genetics of the nut is the most important in expressing that defense mechanism.[8] Therefore, it must be understood that the nut should be considered a new plant which has half the genetics of the mother and father tree. Like our own children, each one will be different even though they are normally named after their mother tree from which they are collected. That is, for example, nuts collected from a Colossal mother tree are erroneously called Colossal nuts even if pollinized by cultivars Precoce Migoule or Labor Day. The part of the nut that germinates in the spring is the embryo nested near the point of the nut under the shell. The remainder of the material under the shell is primarily the kernel which supports the early growth of the embryo.[9] The embryo and the kernel are genetically the same and, again, a unique genetic combination of each parent. Therefore, each nut is an individual and will respond uniquely to its environmental surroundings. In nature, the nut is vulnerable to at least two scenarios while waiting for germination processes to occur. The first is temperature as it cannot be too hot or too cold. The second is humidity and it cannot be too wet or too dry. Finally, they are also the victims of their novel genetic makeup. The mother and/or father cultivars (trees) can donate superior or inferior genes that will influence each nut's storage (storage=the wait till germination or that moment when animals consume them) and help them make it through that ardous time from nut drop to germination or what we call "storage".

Types of Nut Rots

1) Common storage molds

When chestnuts are in limited numbers, molds associated with storage are not very common. But once the environment is altered by an abundance of chestnuts, molds begin to grow, first on the genetically compromised nuts, then finally on the shells and kernels of healthy nuts. Insect damaged nuts including those with weevil holes are very vulnerable to introduced decay fungi. The white mold in the photo below is probably *Coniphora puteana* a wood rotting fungus that grows across the chestnuts during storage. It finds one poor quality nut, infects it, and then spreads to other poor quality nuts in the bin giving the pocket effect. The mold occurs in pockets where the environment is conducive for the fungus and/or less conducive for the health of the nut. Surprisingly, you can clean some of this off the healthy chestnuts, if you have the time and inclination.

Storage improvements, which include sanitizers, can enhance the quality of stored chestnut as they wait for packaging and markets. Treatments should allow the nuts to maintain health through January.

A diverse range of fungi including *Penicillium* sp., *Aspergillus* sp., *Fusarium* sp., *Phomopsis castanea*, *Acrospeira mirabilis*, and *Sclerotinia pseudotuberosa* (syn. *Ciboria batschiana*, *S. batschiana*; anamorphic from *Rhacodiella castanea*, syn. *Myrioconium castanea*) have commonly been found responsible for postharvest decay of the shell and kernel in France, Italy, Australia, Chile, United States and elsewhere. Recently, several fungal species, were isolated from fresh healthy Michigan chestnuts and chestnuts experiencing

postharvest shell mold and kernel decay, including *Penicillium* spp., *Acrospaeria mirabilis*, *Botryosphaeria ribis*, *Sclerotinia sclerotiorum*, *Botrytis cinerea*, *Gibberella* sp., and *Coniphora puteana*.[1,3,9] Some of these fungi may simply grow across the shells of healthy chestnuts while seeking less healthy, senescing nuts. Some fungi simply grow in small colonies leaving a dark spot on the hilum (the light spot on the shell of the chestnut). In some situations, the chestnuts covered with the white mantle of *Coniphora* can be washed off and put into sanitizers and the kernels will remain good. Others fungi invade the shell and kernel and spoil the chestnut which can even lead to mycotoxin production.[5]

2) Environmentally-induced storage molds

The nuts of chestnuts can die if the temperatures are too hot during harvest or storage. Death doesn't occur until the nuts dehydrate. Once dried, the nuts will mold as no active defense mechanisms will be functioning. The same is true if the nuts freeze. If the nuts experience temperatures below 27 F, the nut may freeze and die. This can happen in Michigan during harvest as the nuts from northern orchards ripen late and are subject to frosts while the nuts are still on the tree or on the ground. More often, freeze damage occurs when coolers malfunction or in the corners of coolers with poor circulation and where chestnuts may be stored in bags or bins. It is not the freezing that ruins the chestnut as you can store chestnuts frozen in the shell. The chestnuts die during the freezing event and when they thaw, they become water soaked and grey colored and infested with bacteria, yeast and fungi that give the chestnuts off smells and flavors. If you purposely freeze chestnuts in the shell, you must use them immediately after thawing. Generally, malfunctioning refrigeration units may freeze the chestnuts without the manager's knowledge.

3) Pathogen-associated storage molds

Worldwide, there are two major chestnut kernel pathogens—both fungal in nature. One is called black rot and it is caused by *Sclerotinia pseudotuberosa* and the other is called brown rot and it is caused by *Gnomoniopsis smithogilvyi*. They both occur in Europe and only brown rot is of concern in Australia and New Zealand. They are considered serious pathogens that actually threatens the industry where they are found. These are not just fungi that grow on senescing nuts in storage, they appear to directly invade the kernel as it develops during the summer months and begin the rot process before the nuts are harvested.

In North American there is currently only one chestnut kernel disease epidemic on chestnut and it is called blossom end rot.[10] It is a relatively new disease first observed in Ohio only a few years ago. Not much is known about it at this time. It is caused by the fungal pathogen *Colletotrichum gloeosporioides* (asexual stage) or *Glomerella cingulata* (sexual stage). This fungal pathogen is known to cause diseases on plants in the warmer, more humid southeastern USA where is causes disease on a broad array of hosts including bitter rot of apple, leaf anthracnose of magnolia, anthracnose on mango fruits, and anthracnose on numerous, mostly tropical, fruits and vegetables. In Ohio, it followed an epidemic of Asian chestnut gall wasp. So far, it has only caused problem on Chinese chestnuts and other species such as European X Japanese hybrids appear to be more tolerant to infection. This is the first nut rot pathogen found on North American-grown chestnuts.

In all cases for these pathogen-induced nut rots, sanitation protocols in the orchard is key. Sanitation reduces the amount of the pathogen available for infection. Old burs, kernels and dead branches must be removed from the orchards each year and destroyed to help eliminate the pathogen inoculum.

4) Physiological kernel breakdowns

In Michigan where we grow both Chinese and European X Japanese hybrid cultivars, there can be a physiological breakdown of the kernel that is not associated with microorganisms.[6,7] We call it internal kernel breakdown (IKB). It appears to be due to an incompatible reaction between these tree species when one pollinizes the other. Up to 30 percent of the kernels show IKB in cross pollination studies which was similar to that found by growers where these trees are mixed. Internal kernel breakdown can be observed in the kernels of nuts in early September and can be found in both the Chinese chestnuts and European X Japanese hybrid chestnuts. To eliminate this problem plant only Chinese or European X Japanese hybrid cultivars, but not both (photo below).

A typical European X Japanese hybrid cultivar pollinized by a Chinese tree. No microorganisms are associated with this physiological breakdown.

Follow these Protocols to Help Reduce the Effects of Rots in Stored Chestnuts

To reduce nut rot requires setting protocols and guidelines for receiving chestnuts from your own orchard or from members of a cooperative. Bad and decaying chestnuts must be sorted from the healthy chestnuts before storage and at times during storage. The number of poor chestnuts in a storage bin must be reduced to reduce the amount of mold.

1. Grow the highest quality chestnuts using best growing practices including the highest quality cultivars for your area.

2. If dealing with pathogenic nut rot fungi, the orchard must be cleaned of burs and any culled chestnuts after harvest the prior year (not applicable in Michigan, yet).

3. Before harvest starts, the facility in which the chestnuts are to be stored must be thoroughly cleaned with food safe chemicals that will reduced microorganisms. Obviously dirt, soil, and oily grime must be scrubbed from the walls and ceilings. Power washing is not enough, but it is a good start. Wash down with sanitizers periodically.

4. Keep the trees as strong and as healthy as possible for the entire growing season providing water, nutrients and protectants at appropriate times. That does not mean adding an abundance of fertilizer as that can cause too much leggy growth. But it does mean adding appropriate amounts of fertilizer.

5. Recognize that the the first chestnuts to drop may be somewhat compromised. Harvest is a bell-shaped curve, with some falling early and late. The best quality is usually found in those nuts that fall in the middle of the bell-shaped curve.

6. Harvest the nuts everyday or at least within 48 hours of drop. wash and float. The ones that float might be good, but they are usually more compromised than the sinkers. But remember, there are bad nuts within the sinkers, too. As you move the chestnuts during the storage, you may need to float them again. Cut open some of the sinkers and determine why the majority are floating. Air pockets, extra shell invaginations in the kernel, or rot? If you cut a few open, you will get a sense as to why they float.

7. The temperature in the storage unit must be kept as close to 30 F as possible. This reduces the respiration of the chestnuts (less water loss therefore less free moisture for microorganisms to grow). The chestnuts do not freeze below 32 F due to their sugar content and temperatures set at 30 F can reduce the number and amount of actively growing mold. The higher the temperature, the more respiration by the nuts. The more respiration by the nuts, the more moisture is released. The more moisture that is released creates an environment beneficial for mold growth. However, if the temperature accidentally slides below 28 F, the chestnuts will freeze and when they thaw they will be dead and accumulate water-soaked off tastes and smells. They will be spoiled. Do not allow the chestnuts to freeze in their shells. Place thermometers around the the facility. The best thermometers to use are those that mark the lowest and highest temperatures of the day. Understand that the bins holding chestnuts will be experiencing much warmer temperatures due to the respiration of nuts.[9]

8. After the facility is cleaned and the temperature reduced and set, find bins in which to store the chestnuts that offers some type of air flow. The alternative and best practice is to move each chestnut in the facility at least once a week. This can be accomplished by "pouring" the chestnuts from one bin to another. The larger the bins holding the chestnuts, the more sophisticated the equipment must be. Frequent movement of the nuts will give

better results. This will also stop the molds from developing in pockets. Think about the type of bins you will need. Most large growers in Michigan use apple bins that hold 800 to 1000 pounds of nuts. But smaller orchards might use crates that hold small fruit. Air movement is critical to healthy storage.

9. While washing and floating the next step is sizing. This can be done many ways. There are small drum graders with holes or you can make your own. If you make your own, try not to use materials that can scratch the shells.

10. Before bringing the chestnuts into the clean storage refrigeration unit, treat them with a sanitizer. There are several products that have reputations for sanitizing the chestnuts such as bleach or Chlorox™, but surprisingly, these were not as effective as hydrogen peroxide (also called hydrogen dioxide) or ozonized water.[2,3,4] The materials most growers are using now is called StorOx™ or SaniDate™ and the company producing them is BioSafe™ which manufactures both materials. It is organically certified. Do not expect it to be safe to handle, hydrogen peroxide is a strong oxidizer and it will burn your skin. You will need to mix it and follow the instructions. Here is a description from the web for SaniDate:

***"SaniDate 5.0** from BioSafe Systems is an OMRI Listed, commercial sanitizer and disinfectant that contains hydrogen peroxide and peroxyacetic acid. This product is recommended for cleaning equipment, fruits, vegetables and various hard surfaces on farms, dairies, in beverage plants, food processing plants, greenhouses, etc. There are no dumping or run-off restrictions. Use SaniDate 5.0 for control of: mold and mildew, bacteria and fungi including Staphylococcus aureus, Klebsiella pneumoniae, Aspergillus fumigatus, Salmonella enterica."*

Peroxyacetic acid is a preservative for the material and is not involved in the sanitation procedure itself.

SaniDate™ kills microorganisms on the chestnuts thereby sanitizing the chestnuts. It does not stop the chestnuts from becoming infested again from other sources once it has been used on the chestnuts. You may need to re-treat the chestnuts several times in a season depending on how well you keep the facility clean, the quality of the chestnuts, the temperature at which you hold the chestnuts and the ability to move the chestnuts.

Ozonized water was also shown to be effective. If it was available, ozonized water

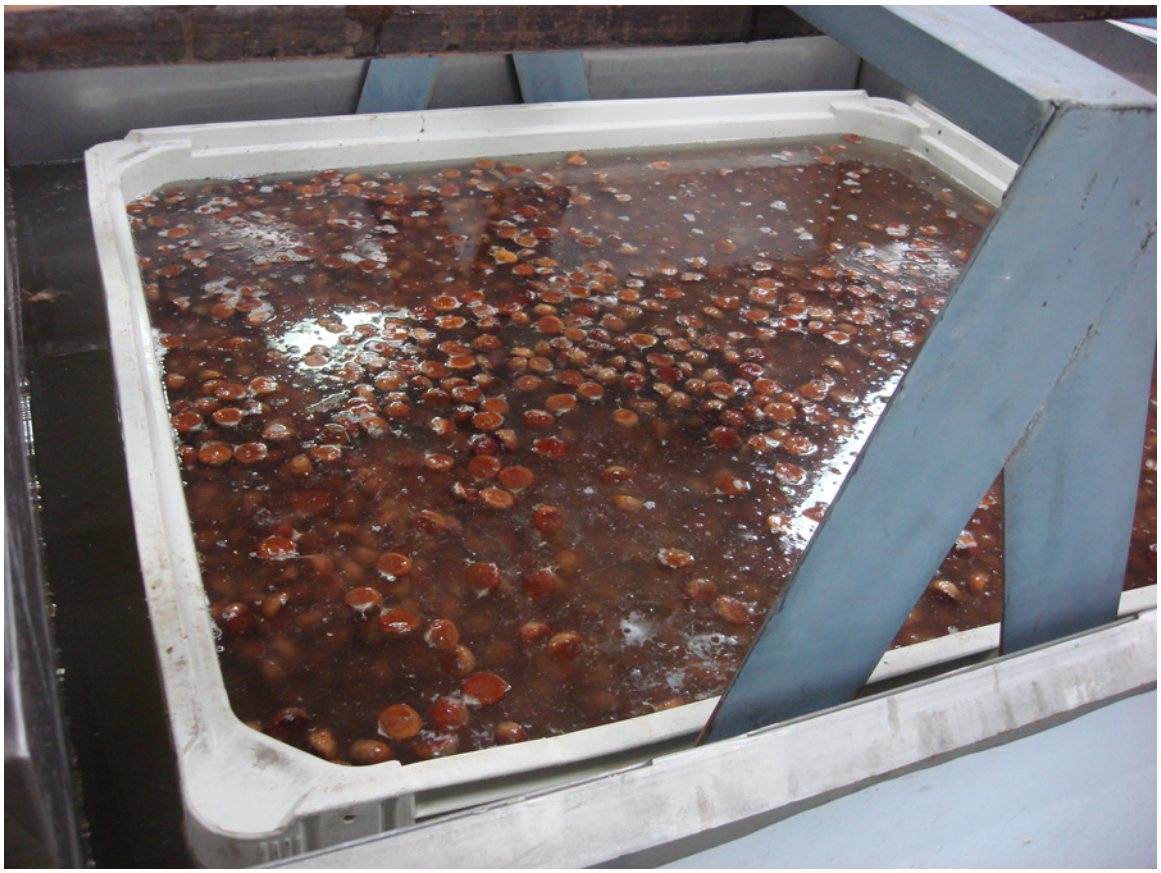
might also be effective to lower contaminating bacteria and fungi.

Remember, these materials will not stop the growth of pathogenic fungi that infect the kernels in the orchard. Nor do they stop physiological kernel breakdown. However, they may be able to help stop secondary molds that grow on and spread from damaged, compromised and field infected chestnuts.

Summary

Cleanliness and efficient application, monitoring and examination for microbial spoilage are the most important aspects of chestnut production. If you are storing chestnuts in your own facility, you must develop strategies to to keep the storage area clean while maximizing product coverage and efficacy. Hydrogen peroxide in combination with peracetic acid (Storox™; SaniDate™), has been adapted by chestnut producers, to better reduce postharvest mold and kernel decay. The Michigan chestnut cooperative Chestnut Growers, Inc. was set up to help the growers market their chestnuts, but one of the most important services they provide is science-based storage. They utilize all of the 10 steps listed above for more than 40-100 tons of chestnuts each year. If you are finding that the number of chestnuts you are harvesting is larger than you can handle, do not compromise the quality of the chestnuts. The rots will get worse and the value of the nuts will be reduced.

Chestnut Growers, Inc. storage facility for chestnuts brought in by members. This facility is cleaned, sanitized and the temperature lowered each year before the chestnuts are brought in to the facility. These chestnuts will have been treated with the sanitizer before entering this refrigeration unit. Also, the chestnuts in each bin are periodically poured into empty bins.



Chestnuts being treated with SaniDate. An apple bin is dropped into a vat of SaniDate at the Chestnut Growers, Inc. receiving facility. Floating chestnuts will skimmed off and removed.

References

[1]Donis-González, I. R., Guyer, D. E., & Fulbright, D. W. 2016. Quantification and identification of microorganisms found on shell and kernel of fresh edible chestnuts in Michigan. Journal of the Science of Food and Agriculture 96: 4514–4522. doi: 10.1002/jsfa.7667

[2]Donis-González, I. R., Jeong, S., Guyer, D. E., & Fulbright, D. W. 2016. Microbial contamination in peeled chestnuts and the efficacy of post processing treatments for microbial spoilage management. Journal of Food Processing and Preservation. doi: 10.1111/jfpp.12874

[3]Donis-Gonzalez, I. R, Ryser, E.T., Guyer, D., and Fulbright, D.W. 2010. Shell mold and kernel decay of fresh chestnuts in Michigan. Acta Horticulturae 866: 353-358.

[4]Donis-Gonzalez, I. R, Ryser, E.T., Guyer, D., and Fulbright, D.W. 2010. Efficacy of postharvest treatments for reduction of molds and decay in fresh Michigan chestnuts. Acta Horticulturae 866: 563-569.

[5]Donis-Gonzalez, I. R., Mandujano, M., Medina-Mora, C., and Fulbright, D. W. 2009. Presence of mycotoxins after 90 days of storage in fresh chestnuts. Acta Horticulturae 844: 69-74.

[6]Fulbright, D.W. 2013. Internal kernel breakdown (IKB) of chestnut appears when European × Japanese hybrid cultivars are pollinized by Chinese chestnut. Annual Report of the Northern Nut Growers Association 103: 3-11.

[7]Fulbright, D.W., Stadt, S., Medina-Mora, C., Mandujano, M., Donis-Gonzalez, I.R., and Serdar, U. 2014. Kernel breakdown appears when hybrid *Castanea* cultivars are pollinized by *C. mollissima*. Acta Hort 1019: 91-97.

[8]Hao, J.J., Liu, H., Donis-Gonzalez, I.R., Lu, X.H., Jones, A.D., and Fulbright, D.W. 2012. Antimicrobial activity of chestnut extracts for potential use in managing soilborne plant pathogens. Plant Dis. 96: 354-360.

[9]Irwin Donis Gonzalez. 2008. Post-harvest diseases of chestnut. M.S. thesis. Michigan State University.

[10]Miller, G. 2017. Blossom end rot of chestnut: A small problem becomes a big problem. The Chestnut Grower 18 (1): 1-4.