Guide to Yellowbud Hickory Nut Oil Production in the United States

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Guide to Yellowbud Hickory Nut Oil Production in the United States by Sam Thayer was last updated in June 2026.

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Introduction

In the forests of eastern North America, from Georgia and Texas north into Canada, grows one of the world's most promising underutilized food trees: the bitternut or yellowbud hickory. Although these nuts have been used by Indigenous people for thousands of years, the tradition almost completely disappeared within a few centuries of the upheaval of European arrival. A small but devoted group of enthusiasts are dedicated to reviving this lost tree crop, which offers a delicious, healthy oil that is ideal for sustainable production in agroforestry systems. This document is intended to serve as a welcome and an introduction for growers interested in this exciting and amazing resource.

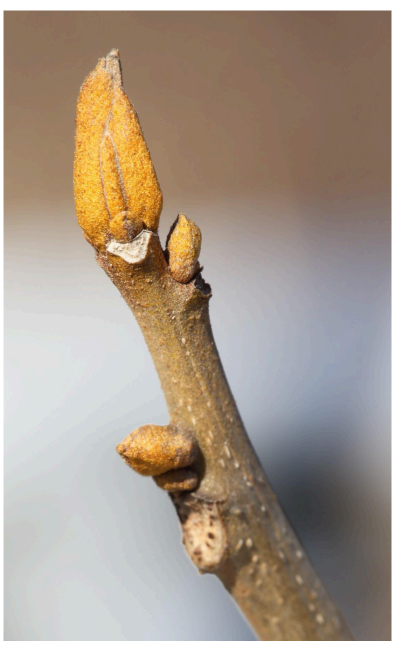
The hickories (genus *Carya*) are a group of trees in the walnut family (Juglandaceae), found in Southeast Asia, eastern North America, and Mexico. Twelve species are native to North America and six to Asia. All hickories have alternate, pinnately compound leaves with a prominent terminal leaflet. Unlike walnuts, the fleshy husk surrounding a hickory nut separates along predetermined lines of dehiscence when ripe. Hickories flower in late spring, the individual flowers being tiny and wind-pollinated. Male flowers are borne in drooping catkins 3–11 centimeters long, the catkins usually in clusters of three. Female flowers are in separate, short, compact clusters on the same tree.

Yellowbud hickory (*Carya cordiformis*), also commonly called bitternut hickory, smooth-bark hickory, thin-shelled hickory, and pignut hickory (see note below), is the most widespread and abundant of North America's 12 hickory species. Of the common hickories it is most closely related to the pecan (*Carya illinoinensis*), with which it frequently hybridizes. (It is actually closest to a rare Mexican endemic species, *C. palmeri*.) Yellowbud also hybridizes with shagbark (*C. ovata*), shellbark (*C. laciniosa*), and reportedly other species.

It must be noted that the most common name used by farmers, loggers, and rural people for *Carya cordiformis* is "pignut hickory," while most written sources such as field guides and tree books use "pignut hickory" for two entirely different species, *C. glabra* and *C. ovalis*. This confusion appears to have originated with Freidrich Wangenheim, a German botanist who assigned the common English name "pignut" to the wrong species in a highly influential 1787 German publication (Sargent, 1918). Before this, multiple authors had reported "pignut" as the common English name of the tree we today call *Carya cordiformis*. It appears that all authors after Wangenheim adopted his mistake, and today we are stuck with the confusion: Professionals call this tree bitternut, but most laypeople still use the customary English name "pignut" that, according to Pehr Kalm, had been well established before 1750 (Larsen, 1945). Anyone communicating about yellowbud hickory with rural landowners is likely to run into confusion if unaware of this name problem. To avoid alienating people, I advise not correcting them for using the customary name "pignut," but rather just suggesting the use of "yellowbud" as a less confusing name.

Description

Yellowbud hickory is a medium to large tree, commonly reaching heights of 60–90 feet and a diameter of 12–28 inches. The smooth gray bark of youth is retained much longer in this species than in other hickories—often until it reaches a diameter of 9–14 inches. The oldest trees have narrow ridges separated by shallow fissures, but never become shaggy. The crown is narrow and the branches are ascending and more sinuous than those of other hickories, with thinner twigs. The leaves are 6–12 inches long and typically have seven or nine leaflets, but sometimes 11 or even 13. The leaflets are lanceolate, 2–4 inches long, and generally narrower than those of shagbark. However, the two most diagnostic features of yellowbud hickory are the buds and the nuts.



The characteristic yellow bud of Carya cordiformis

This species is the only tree in eastern North America with a sulfur-yellow bud that appears naked (i.e., appears to lack bud scales covering the embryonic leaves). There are actually two bud scales that look like embryonic leaves (resembling seal flippers), which fold back when the true leaves emerge. The unique yellow buds make this species easy to tell from all other hickories in its range, even without leaves or nuts, so long as one can reach the branches.

Like other hickories, the nuts of yellowbud are borne singly or in clusters of up to three (rarely more), each surrounded by a green husk that normally splits into four (but often five) sections. However, yellowbud nuts can be distinguished from those of all other hickories by having *all three* of the following characteristics:

- Ridges or wings where the husk sections meet
- Very thin husks (usually less than 3 millimeters in the thinnest area)
- Very thin shells (usually less than 1 millimeter in the thinnest area)

The husks do not fully separate or fall off upon ripening. The nuts are highly variable in size, from 11–38 millimeters long. They are usually almost as wide as long, and sometimes equally wide, but other specimens have narrow nuts. The nuts are usually slightly flattened. The Latin species name, *cordiformis*, means "heart-shaped," but only a minority of yellowbud trees have heart-shaped nuts.


Yellowbud nut and leaves

Yellowbud nuts most strongly resemble those of "pignut" (*C. glabra* or *C. ovalis*), which also have husks that may cling to the mature nut. However, pignuts have slightly thicker and stiffer husks, and much thicker and stronger shells. Pignut shells often have faint lengthwise ridges—yellowbud shells never do, and are often slightly wavy or "lumpy." Yellowbud nuts have very bitter kernels—while those of pignut do not have bitter kernels. (The common belief that pignuts are bitter derives from the use of the name "pignut" for yellowbud hickory.) The only other bitter hickory nut in North America is water hickory (*Carya aquatica*), which has unmistakably different nuts (flattened with a corrugated dark shell) and shaggy bark.

Range and Habitat

Yellowbud is the most widespread hickory in North America, found from the Gulf Coast states to northern New England, southern Canada, and northern Minnesota. It is distributed from the eastern edge of the Great Plains to the Atlantic Coast. Yellowbud hickory is a versatile tree found in many forest types, but does best in rich, deep soil that is high in calcium. It is generally absent from areas of thin soil over volcanic bedrock, low-fertility moraines or till composed primarily of sand and gravel, and sand outwash plains. It does not tolerate long-term inundation, but often grows in the upper parts of floodplains, smaller floodplains, swamp margins, lower slopes, and stream valleys—where seasonal inundation is brief. Flood tolerance needs further study.

It is most common on well-drained alluvial soils in higher parts of floodplains, on lower slopes in hilly regions (especially limestone regions), all aspects of rich glacial till, and areas of ground moraine or old alluvial deposits. In wild stands yellowbud hickory is most highly associated with elms, white ash, northern red oak, bur oak, black walnut, butternut, sugar maple, basswood, beech, yellow birch, hackberry, boxelder, buckeye, tulip poplar, and shagbark hickory. In the South, where it is less common due to the generally less fertile unglaciated soils, yellowbud is mostly limited to the fertile alluvial and colluvial soils. Here it is associated with swamp chestnut oak, cherrybark oak, Shumard oak, tulip poplar, elms, sweet gum, red mulberry, and sugarberry.

Ecology

Yellowbud hickory is considered a gap-phase regeneration species—one that takes advantage of periodic death in the forest canopy for regeneration. Seedlings are more shade tolerant than those of other hickories, sometimes allowing for heavy regeneration after shelterwood or select logging cuts. They are also very effective at colonizing abandoned fields. The primary dispersal agents are squirrels and gravity, although jays and woodpeckers also play a role. Many other rodents eat and transport the seeds, but cache them where germination is unlikely. Trunks may be killed by fire, but seedlings produce a large taproot and resprout readily after mowing, browsing, or burning. Saplings and young mature trees will resprout vigorously from the base when cut or burned. Compared to most other hickories, yellowbuds are fast-growing but shorter-lived (although the potential longevity is still centuries).

Yellowbud hickory is a very important source of food for wildlife. Despite frequent claims to the contrary in the literature, the nuts are avidly eaten by squirrels, chipmunks, white-footed mice, deer, black bears, and jays.

History and Current State of the Hickory Oil Industry

Any prospective grower must be aware that the yellowbud hickory oil industry in North America is in its infancy. At the time of this writing I am aware of only four very small commercial producers, producing a collective total of 100–200 gallons of oil per year.

Nevertheless, we believe there is enormous potential for growth, and the reasons for that optimism are outlined in this document.

Current producers of oil include Levi Geyer of Fancy Twig Farm in Parnell, Iowa; Keystone Tree Crops Cooperative in Pennsylvania; Northern Forest Foods in Vermont; and Samuel Thayer (this author) at Wildwoods Orchard in Weyerhaeuser, Wisconsin. A few other parties have purchased equipment and may begin production soon.

After learning about Chinese hickory oil production in 2001, I identified yellowbud hickory as the best candidate among North American hickories. I first made a small experimental batch of oil in 2002. I was so excited by the results that I purchased acreage with hickory trees in 2007, and a commercial oil press in 2012. Over the last decade I have produced 30–70 gallons of hickory nut oil per year, with most of the supply coming from a network of farmers who allow me to pick on their land. However, my production has been limited by the relatively low abundance of hickory in my area, due to a severe outbreak of hickory wilt from 2006–2010.

Two hickory species are already grown and processed for oil on a larger commercial scale: the pecan (*Carya illinoinensis*) and Chinese hickory (*Carya cathayensis*). Chinese hickory production reached 40,000 metric tons in 2017 and is steadily increasing (Huang et al, 2019), with an economic value of 413 million USD reported in 2014 (Li et al, 2014). I was unable to determine the percentage of the Chinese hickory crop allocated to oil production, but the existence of Chinese research on hickory nut oil (for example, Zang et al, 2016), and the occasional commercial availability of the product, indicate an established market. Worldwide pecan production in recent years has averaged about 600 million pounds (270,000 metric tons), primarily in the U.S. and Mexico. However, due to the high value of extracted nutmeats, only a very small portion of harvested pecans are pressed for oil.

Hickory nut oil has an ancient history in eastern North America. Several early European colonists noted that it was manufactured by Native Americans. There are also numerous historical documents referring to the making of hickory nutmilk by pounding the nuts and boiling them. (Indeed, the name "hickory" is derived from an Indigenous word for this nutmilk.) Unfortunately, many archaeologists and historians have conflated hickory oil and hickory milk. They are definitely not the same, and both were produced. Several accounts, including Thomas Ash (1682), from what is now North Carolina, make it clear that the product being described was an oil rather than a nutmilk. This oil was produced by boiling the pounded nuts and skimming the oil from the surface. It was an item of trade between the colonists and the Indigenous people. Hickory nut shells are among the most frequent plant remains found in archaeological sites throughout their distribution, dating back 10,000 years (Fritz, 2001). The antiquity of oil production is uncertain, but presumably extends for millennia before European contact.

Why Yellowbud Hickory?

Because yellowbud has bitter nuts, those familiar with them often assume that the oil would be bitter. This is not the case. Tannin, which produces the bitterness of yellowbud kernels, is not oil soluble, and is thus not present in the oil. (Note that olives are also high in tannin, and are inedible straight from the tree due to their bitterness.) The oil pressed from yellowbud nuts is tannin-free and just as palatable as that from other hickory species.

Colonial accounts of hickory oil production did not specify which species was being used by Native Americans. This is not surprising, since English speakers were just coming into contact with hickories and had no established nomenclature for the various species. Unfortunately, archaeologists generally lump hickory species together. I have found only one archaeologist (Nancy Asch Sidell, 2008) who has separately identified yellowbud hickory nutshells from those of other species, but the data is limited. Because yellowbud has bitter kernels, it is not suitable for hickory milk; the nuts found were probably being used for making oil.

Yellowbud is the only species of hickory specifically mentioned in the literature as a source of oil among American colonists. Numerous sources claim that early white settlers pressed the nuts for oil—but they generally claim that the oil was used for oil lamps and rheumatism. I have not been able to trace these claims to an original source; the earliest appearance that I have found is Peattie (1948). I suspect that the details about oil lamps and rheumatism may have been added as a post-hoc explanation by authors who believed that the oil must be too bitter to consume.

I have extensively gathered and utilized all of the widespread hickory species in the United States. Shellbark (*C. laciniosa*), mockernut (*C. tomentosa*), and black hickory (*C. texana*) all have extremely thick shells and a very low kernel percentage. Pignut or red hickory (*C. glabra/ovalis*), shagbark (*C. ovata*), and water hickory (*C. aquatica*) have somewhat thinner shells (but still thicker than those of yellowbud or pecan) and much lower kernel percentages, still making them impractical for expeller pressing with the shells included. Oil could be extracted from any of these species if a portion of the shells were mechanically separated, but this entails significant additional costs in time and equipment.

Yellowbud and pecan are the two species that have proven most conducive to oil production with an expeller press. These species have the thinnest shells and highest kernel percentage of all hickories, and I have been able to effectively press both with the shells included. This gives them a significant economic advantage over all other hickory nuts. Since the pecan is an established oil crop, and the nut qualities of yellowbud are similar in terms of oil production, the commercial pressing of yellowbud for oil should be feasible. The same thin shells that make yellowbud nuts ideal for pressing in an expeller also make them easier to mash in a wooden mortar for oil extraction by boiling and skimming, as was formerly done by Native Americans.

Besides ease of pressing, yellowbud has additional advantages over other hickory species. One is productivity. Large, open-grown yellowbuds often produce crops of 40–70 gallons of clean nuts (200–350 pounds) in a mast year. This exceeds the yields that I have witnessed for similar-sized trees of any other hickory species. This observation matches theoretical expectations based on biomass allocation: Higher potential yields of clean nuts are to be expected for bitternut due to the smaller investment in the husk.

Yellowbud nuts on the ground with fresh green husks

Shen (1973), reported, for example, that yellowbuds in his sample invested 36.3% of their fruit energy into husk and shell, while pignut invested 74.1%, shagbark invested 78.8%, and mockernut invested 87.2%. This leaves a greater portion of energy to invest in the kernels: Shen reported that yellowbud in his sample invested 64% of their fruit energy into kernels, while pecans invested 41%, pignuts invested 27%, shagbarks invested 21%, and mockernuts invested 13%. A small portion of this difference in kernel percentage is offset by the fact that yellowbud kernels appear to contain a slightly lower percentage of oil than those of other hickories—probably due to their tannin content. Nevertheless, yellowbud still yields more oil per unit of whole-nut volume or weight than the other hickories. In my experience it takes about 135 pounds of shagbark nuts to yield the same amount of oil as 100 pounds of yellowbud nuts, and the disparity would be even greater for pignut, mockernut, and black hickories.

Another advantage of yellowbud is its lower susceptibility to pecan weevil (*Curculio caryae*) and hickory weevil (*Conotrachelus affinis*). These pests can destroy 70% or more of the nut crop of most other hickory species. The infestation rates for yellowbud nuts are usually very low, and in my experience the losses to pecan weevil in particular are extremely low—rarely exceeding 2%, even when nearby hickories of other species are experiencing severe crop losses from weevils. However, yellowbud nuts in some regions may have high levels of pecan weevil infestation, comparable to that seen with other hickories. Possible reasons for this are discussed later in Insect Predators of Hickory Nuts.

Yellowbud nuts do have one disadvantage for oil production: adhering husks. With most hickory species, the valves surrounding the nuts detach from each other and from the nut shell upon ripening, facilitating the separation of clean nuts from their husks. The valves of yellowbud, however, only partly separate from each other, and envelop the nut even upon ripening. Husk removal is an extra step in processing. However, in my experience the advantages of yellowbud nuts outweigh the disadvantages of the adhering husks.

In light of the advantages listed above, and the fact that yellowbud is archaeologically known to have an ancient use, and the fact that its bitter kernels are not suitable for making hickory milk, I think that yellowbud was one of the species—and probably the primary species—used by Indigenous people for producing hickory oil. I also think it is the best choice for making hickory oil today using modern equipment.

However, I believe that we should consider other species, particularly shagbark, and shagbark-bitternut hybrids, as candidates for oil production. Using my equipment I have been able to successfully press some hybrids, and I have been able to press shagbarks after about a third of the shell volume is removed. With the right pressing equipment we might be able to run shagbark nuts with all of the shell. While it would be mechanically difficult to fully separate the shagbark's shells and kernels, automated separation of only a percentage of the shell pieces should be much easier to achieve.

Suitable Growing Conditions

Rich soils on landscapes that already support yellowbud hickory are recommended for planting. Yellowbuds tolerate a wide latitude of drainage conditions: They are often seen on dry hillsides and ridges, while in my orchard I have found that they thrive in sites that are a little too moist for apples. Moderate drainage is probably ideal. Like any tree, yellowbud hickory under orchard conditions can be successfully grown outside of its natural distribution. The range of this tree appears to be limited in the North by soil fertility rather than cold. Native stands in north-central Minnesota and northwestern Wisconsin have been exposed to temperatures colder than –50°F without noted mortality. The northernmost known stand is near Cass Lake, Minnesota; the record low temperature from the closest weather station (Federal Dam at Leech Lake) is –59°F. The tree's western distribution appears to have been limited by a combination of low soil moisture and frequent fire in pre-European ecology. Understanding these limits, experimental plantings that slightly expand the native range seem reasonable.

Yellowbud hickory tree in Arkansas

Establishment and Care

Grafted trees or seedlings should be transplanted when fully dormant, preferably in early spring, but fall transplanting is also acceptable. Success is best with small trees, generally less than 4 feet (1.2 meters) tall and 0.5 inches (12 millimeters) in diameter. Hickories produce disproportionately large taproots, and they are difficult to transplant without breaking or damaging these. Root damage can stunt top growth and make transplants more susceptible to moisture stress and competition.

Transplants should be watered regularly for their first season unless there is ample rainfall. They should be immediately protected by individual fences or tree tubes, or significant browsing losses are likely in spring and early summer, especially to cottontails. Trees should be planted in full sun, and best growth will be achieved if the area around is mowed at least three times per growing season to prevent shade and reduce root competition. We have noted substantially increased growth rates from heavy high-nitrogen mulch such as grass clippings and hay. Apply mouse guard around the trees by September 1 to prevent girdling by voles.

The taproots of young hickories store a large quantity of carbohydrate and are therefore attractive to voles. Zach Elfers of Keystone Tree Crops reports losses from voles eating yellowbud roots in Pennsylvania and recommends burying hardware cloth cages around seedlings to prevent subterranean depredation. I have not had this problem in Wisconsin. This could perhaps be due to different soil conditions, hard freezing of the soil, or different vole species. (My area has only meadow voles (*Microtus pensylvanicus*), but Pennsylvania also has woodland voles (*Microtus pinetorum*).)

Yellowbud likes neutral to slightly alkaline soil and may benefit from the application of lime. If the leaves curl, develop necrotic margins, and fail to grow normally (mouse-ear disorder) this may be caused by a nickel deficiency (Miller, 2022). Several sources claim that yellowbud is the fastest-growing hickory (e.g. Kurz, 2003). In my experience it grows much faster than shagbarks under similar conditions. In northern Wisconsin we have seen yearly growth of 22–66 inches between years 4 and 6 in open, sunny conditions, with nut production commencing at 7–11 years of total age. Growth slows significantly with the onset of heavy nut production.

Optimum planting density has not been determined, but due to the narrower crown, yellowbuds should probably be planted somewhat closer together than pecans.

Cropping Systems

Yellowbud has potential in a variety of agroforestry production systems. It can be a component of a managed, pre-existing native food forest, similar to the management of a maple grove for syrup, or native pecan groves. In some existing commercial sugarbushes, yellowbud hickory is the most abundant tree competing with the sugar maples. Managing for both species could spread risk and increase forest value for syrup producers. Many organic certification agencies require maple groves to contain other tree species to maintain diversity—yellowbud hickory could fill that role. The potential economic yield, per tree or unit of area, appears greater for hickory nuts than maple syrup. And the timing of the harvest seasons for the two crops do not interfere with each other. From the hickory grower’s perspective, sugar maple is an ideal companion tree, because its seeds do not support dense populations of nut predators like squirrels.

Where the forest is managed for yellowbud hickories alone, the ideal spacing appears to be 20–40 trees per acre, depending on size. Hickory nut production responds very well to full sun on all sides of the canopy, which suggests that growers should err on the side of fewer trees. In managing a pre-existing stand containing yellowbuds, I suggest an initial cut to free up canopy space for the hickories, followed by monitoring the nut production and nut characteristics of individual trees for 5–7 years, and then a follow-up cut to remove the less productive hickories.

After canopy thinning to favor hickory in a woodlot, the re-growth of dense or thorny shrubs can be problematic because it interferes with nut harvest and provides cover and alternative food sources for nut predators. Such re-growth could be managed by establishing or encouraging a subcanopy of large shrubs or small trees that are thornless, spreading, and which cast a heavy shade. Such a subcanopy would compete with hickories for soil resources and water, but might compensate for this by creating better harvest conditions. Four native species that fit these criteria are pawpaw, redbud, mulberry, and witch hazel. All of these are common associates of yellowbud and will thrive under a sparse, thinned hickory canopy; and all but redbud produce a potentially marketable non-timber forest product.

A canopy of yellowbud hickory is also ideal for another edible forest product, ramps or wild leeks (*Allium tricoccum*). Ramps thrive in calcium-rich topsoils (Lapointe et al, 2018), and yellowbud hickory leaf litter is among the highest in calcium of major northeastern trees (Chandler, 1939). Ramps grow larger and seed more heavily under the canopy of trees that leaf out later, such as hickory and ash, than under early-leafing species such as maple, basswood, and elm (Dion et al, 2017). This makes yellowbud stands one of the best forest types under which to grow ramps. Yellowbud stands with a thin canopy would also be suitable for growing ginseng (*Panax quinquefolia*) and goldenseal (*Hydrastis canadensis*), both high-value herbs with established markets. Other potentially marketable native forest herbs that can thrive under a yellowbud hickory canopy include mayapple (*Podophyllum peltatum*), eastern yampa (*Perideridia americana*), and eastern camas (*Camassia scilloides*).

In multi-cropping or alley-cropping agroforestry systems, yellowbud hickory would be compatible with a number of fruit-producing shrubs or marketable herbs. As the hickories mature, these smaller plants will lose productivity due to shade; at the appropriate time they could be removed and replaced with a more shade-tolerant ground cover.

Yellowbud hickory would also be ideal for a silvopasture system. Widely spaced trees planted into an existing pasture or hayfield would have negligible effect on forage production when young. As trees mature they increase their shading of forage, but compensate for this by an increase in nut production. Heavy grazing or mowing just prior to nut fall would facilitate harvest. It is important to note that cattle, and perhaps other livestock, will avidly eat yellowbud nuts. Decreasing nut harvest is not desirable if hickory oil is the main product, but in a silvopasture system focusing on livestock production, yellowbud hickory nuts could be an interesting feedstock. Not only is it calorie dense and high in fat, but the tannins can help with bloat prevention, parasite control, methane reduction, and feed efficiency.

Intensely-managed yellowbud orchards could also be established. These would presumably be managed similarly to pecan orchards. As of yet we have no such mature orchards upon which to model new plantings. Tree density, ground covers, pest control, soil augmentation, and pruning (if any) are all experimental at this juncture. Chinese hickory might be a better analog than pecan, due to greater ecological similarity, but I have been unable to find practice-based planting recommendations for that species.

Pecan orchards are generally planted with one or two planned thinnings. Higher initial density results in higher per-acre yields in the early years of orchard establishment. As the growing trees crowd each other, they are thinned to reduce competition. Traditional densities often started at 16–40 trees per acre, being eventually thinned to 7–18 trees per acre, and sometimes as few as four. The recent trend in pecan production is toward higher-density initial plantings of 40–100 trees per acre (but not all varieties are productive at such high densities). These high-density plantings must be thinned aggressively at about 20 years of age to prevent detrimental effects from crowding; overcrowding from neglected thinning is a common problem with pecans, and tree crops in general.

Pecan trees are larger and more spreading than yellowbuds, and also less shade and drought tolerant, so higher densities of yellowbuds should be feasible. Yellowbud Farm is currently observing an array of superior trees from which cultivars will be selected, and is selling seedlings from these superior trees. However, at this stage there is not an array of named and selected cultivars of yellowbud hickory, and few if any grafted trees are available. Growers will be initially constrained to use seedlings unless they find and propagate superior trees themselves. Seeds should be sown from genetically superior parents. We do not currently know to what extent, if any, yellowbud produces apomictic clones by seed, as is the usual case with Chinese hickory, and sometimes occurs with pecan (Zhang et al, 2012).

Seedling plantings at this early stage of yellowbud culture will provide a large gene pool with diverse characteristics from which genetically superior individuals can be discovered and selected for future generations of plantings. Genetically diverse seedling plantings will also increase resilience to pests, disease, and environmental stresses. Once growers have access to cultivars with superior characteristics, they will have to weigh seedling resilience against the higher production and reduced harvesting and processing costs of cultivars. Because the shape, size, and crackability of nuts will not affect the quality of the final oil, the nut crop from seedling trees is unlikely to be discounted in value the way it is with pecans. Seedling orchards are unlikely to become rapidly obsolete once superior cultivars are found.

For seedling orchards, Jesse Marksohn of Yellowbud Farm recommends initial plantings of 54–145 trees per acre. At these higher densities, bearing characteristics should be carefully monitored for several growing seasons of early production. Beginning at roughly 12–16 years of age, lower quality trees should be culled aggressively to prevent crown competition. This thinning should continue through the life of the orchard. Optimal densities at 30 years are probably no higher than 30 trees per acre. Maintaining optimal spacing through the life of the orchard will require disciplined and emotionally difficult culling of trees. If neglected, this will not only result in productivity decline, but will make the orchard susceptible to decimation from hickory wilt. However, if done well, higher-density planting followed by heavy culling will give early high yields, result in strong selection for the best-quality trees in the mature orchard, and improve breeding stock.

Growers wishing to minimize initial investment, experimental growers for whom early returns are less crucial, or those uncertain of their commitment to active early management, may want to start with lower initial planting densities of 20–50 trees per acre, perhaps lower still in silvopasture systems.

Productivity and Yield Patterns

Yellowbud hickory, like most nut trees, exhibits a production cycle known as *masting*—that is, production from year to year is highly variable and partly random, resulting in "boom and bust" production. Growers of nuts seek to minimize this yearly variation. With pecans, kernel fill and nut quality usually go down in years of high production. Four factors combine to determine a season's nut crop: flower investment, pollination success, favorability of the growing season, and insect pests.

Flower investment is largely determined by the previous nut crops; if recent crops have been low, food reserves in the tree will be high, allowing for (or stimulating) a higher investment in flowers. Conversely, heavy recent nut crops deplete the tree's resources, resulting in low flower production the following year.

Yellowbud catkins

Pollination success is largely determined by the weather at the time of flowering. Hickories are wind-pollinated, with pollination occurring in late spring or early summer just before the leaves reach full size. This ranges from late March in the South to early June in the North. Optimal weather is warm and dry, 70–80°F, with a moderate wind. Pollination failure can be caused by a period of cool or wet weather, excessive heat, or from a frost that kills the flowers. Shortly after the male catkins drop in early summer, one can observe the female flowers to estimate pollination success: Ovaries that have been retained on the twigs and which begin to swell are developing nuts (although some portion of them will be later aborted).

The growing season has a lesser effect on nut production—the deep roots and drought tolerance of hickory normally allow the tree to ripen most of its crop. However, in years of drought the nuts may be reduced in size, resulting in lower yield. Insect pests such as pecan shuckworm and pecan weevil have a significant impact on the number of nuts successfully ripened by the tree. Pest pressure on yellowbud nuts appears to be somewhat lower (see Insect Predators of Hickory Nuts).

Our production records for yellowbud hickory are extremely limited and not very reliable. I am aware of multiple individual trees that have yielded in excess of 50 gallons of clean nuts in mast years (yielding 7 gallons or more of finished oil). Although I have monitored the productivity of three individual trees for 6–8 years, this is a small sample, in terms of both trees and time. The productivity numbers indicated are problematic because a portion of the nuts in each growing season either went uncollected due to time constraints, or were eaten by rodents. In most of the years where no nuts were collected, there was a nut crop that was 100% expropriated by wildlife, so the productivity of these three trees is significantly underrepresented. Additionally, it is impossible to accurately extrapolate per-acre or per-tree yields in an orchard setting from the productivity of a few isolated trees. This is a classic blunder in assessing new tree crops, as was well noted in the early pecan industry (Jones and Childs, 1932). The difficulty lies largely in the fact that isolated trees are typically under less competition than orchard trees, and so yield more.

It is probably safer and more accurate to estimate productivity based on that of pecan and Chinese hickory. This is not to say that such comparisons are accurate, but that they are currently the best information that we have to go on. Within the genus *Carya*, yellowbud hickory is closely related to both of these species, and shares several characteristics with both (thin shells and husks with pecan, thin husk and naked buds with Chinese hickory). Pecan and Chinese hickory are both subject to a wide range of cultural practices—from managed native stands to mono-crop orchards—and this can give us some idea of the extent to which yields might be improved over time through selection and more intensive management.

Pecans have been used as food for as long as people have lived among them. Extensive post-colonial management of commercial groves began in the late 1800s, primarily in Oklahoma, Texas, Arkansas, and Louisiana. This management consisted primarily of removing competing species from native forests containing pecan, thinning pecans for optimum spacing with a mind to preserving and favoring the trees with better production and cracking qualities, and clearing brush to facilitate nut harvest and reduce competition. Cattle were commonly grazed in these native pecan groves, providing additional income as well as vegetation control. These practices parallel those recommended for yellowbud hickory in this document.

Such native pecan groves based on unimproved wild genetics and small nuts averaging about 45% kernel accounted for about 64% of U.S. pecan production in 1928 (Jones and Childs, 1932) and continued to dominate pecan production until about 1965 (Grauke et al, 2016). However, such systems are still economically viable today, accounting for millions of pounds of production annually. In 2014, Oklahoma State University estimated that native pecan groves still accounted for 80–90% of production in that state, or 14–15 million pounds of nuts.

Pecan orchards relying on selected and grafted cultivars planted into cleared agricultural fields were first planted on a significant commercial scale in the 1880s, mostly in areas east of the pecan's native range (Wood et al, 1990). By the early 1900s southern Georgia had established itself as the leading production area for orchard-grown pecans, and it remains so today. Large numbers of pecan orchards also exist in Florida, South Carolina, Alabama, Mississippi, Texas, Louisiana, Oklahoma, New Mexico, Arizona, California, and Mexico. These orchards account for the majority of production today.

Average production for managed native pecan groves is about 400–600 pounds per acre per year (Carroll, undated; Ares et al, 2006). Intensively managed orchards of selected cultivars may average 1–2 tons of pecans yearly, at about 55% edible kernel (Noperi-Mosqueda et al, 2020). This is impressive, considering that the cultivars result from no more than five generations of selection and breeding.

Chinese hickory (*Carya cathayensis*) has been actively cultivated for about 500 years (Wu et al, 2014), although most hickory production in China was from minimally managed wild groves until the last few decades (Wu et al, 2014). Today there are both managed wild groves and planted orchards. However, there are still no true cultivars of Chinese hickory; instead there are "landraces." This is due to the peculiar fact that Chinese hickory reproduces primarily through apomictic seeds—that is, the seeds are usually clones of the parent tree (Zhang et al, 2012). This allows growers to collect nuts from superior trees and plant orchards from seedlings, being assured that almost all of their trees will carry the superior traits of the parent. Production of Chinese hickory has risen from about 400 kilograms per hectare (360 pounds per acre) in the early 1980s to 1,000 kilograms per hectare (900 pounds per acre) in 2010 (Wu et al, 2014).

Having harvested yellowbud hickory nuts and pecans by hand in a variety of settings, my intuition and experience leads me to believe that the inherent per-area productivity of yellowbud is equal to or somewhat greater than that of pecan. 400–600 pounds of nuts per acre seems like a reasonable and conservative estimate for a managed yellowbud hickory grove, with perhaps twice that yield in an orchard. As cultivars are selected and distributed, and growing methods are refined, I expect this productivity to increase. Every 100 pounds of clean nuts (dry weight) will yield roughly 3.1 gallons of filtered oil.

Characteristics for Tree Selection

Development of yellowbud hickory as an oil crop will entail selection of superior trees as seed sources and eventually grafted cultivars. The most important characteristic to look for in such trees is heavy average bearing. Trees with an annual cropping tendency are probably preferable to those trees that alternate prodigious crops with barren years. In the pecan industry alternate bearing is considered a disadvantageous trait, because during the heavy crop years the nuts are often smaller and the kernels are not filled out. With certain cultivars, some orchards shake trees early in the season to thin the nuts, reducing these severe swings in productivity. However, pecans are sold primarily in the form of kernels; with yellowbuds pressed for oil, annual cropping may not be as important, and such measures are less likely to pay off.

Late appearance of flowers is likely to result in more stable production, because frost is one of the most important factors causing crop failure. Growers may want to observe flowering phenology as a potential proxy for annual bearing—followed by observation to confirm the strength of the relationship between these factors.

Large nuts are another advantageous trait—they decrease the labor of harvesting, husking, and sorting. They also increase the effectiveness of mechanical harvesting. Although theoretically large nuts should have a higher kernel-to-shell ratio, this is not always the case, because exceptionally large nuts appear to have a tendency to not completely fill their shells.

Thin shells, thin husks that readily detach, and higher oil content are additional advantageous traits. (However, extremely thin shells that crack during dehusking might promote spoilage during drying.) Round nut shape seems to facilitate husking. Very late and prolonged or reluctant nut drop are disadvantageous; we want trees with their full nut drop in a short time period. On the other hand, early ripening nuts are more susceptible to pecan weevil (Mulder et al, 2012). It is not uncommon in my area to get persistent snow before many of the yellowbud nuts drop. The optimum ripening time appears to be after hard frost, but there is no benefit to nuts that cling into December or beyond.

Although it seems counterintuitive, there may be an advantage to nuts with higher tannin content, since this may confer resistance to pecan weevils and other pests (see Insect Predators of Hickory Nuts). Higher tannin content most likely would be associated with lower oil content, so the trade-off may or may not be advantageous.

Advantageous or Potentially Advantageous Traits:

- Heavy average bearing
- Annual cropping tendency
- Large nuts
- Thin shells
- Thin husks that readily detach
- Higher oil content
- Round nut shape
- Full nut drop in a short time period
- Ripening time after hard frosts (in colder climates)
- High tannin content or other traits conferring genetic weevil resistance

Disadvantageous Traits:

- Low yield
- Small nuts
- Alternating prodigious crops with barren years
- Prolonged, very late, or reluctant nut drop

Hickory Wilt and Other Diseases

Yellowbud hickory is generally free of persistent endemic diseases such as pecan scab—although minor afflictions might become problematic in monoculture settings. (It should be noted that pecan scab is most destructive where pecans are grown outside of their native range, in areas with more humid summers.)

However, yellowbud hickory is occasionally subject to local mass die-offs; these have been reported for more than a century from numerous locations (New York, North Carolina, Vermont, Nebraska, Ontario, Georgia, Wisconsin, and Minnesota). Although these events have been uncommon, they are obviously of great concern to growers. I have personally been deeply affected. In 2007 I purchased 30 acres of forest in the Blue Hills of Rusk County in northwestern Wisconsin to develop a food forest with yellowbud hickory as its most important crop. At the time there were more than 250 mature yellowbud hickories in the canopy. By 2010 only two of these survived (although saplings to about 4 inches in diameter were generally unscathed).

By the early 1900s it was recognized that these die-offs were associated with elevated numbers of hickory bark beetles (*Scolytus quadrispinosus*) (Hopkins, 1912), which were in turn caused by drought (St. George, 1929). Park (2011) refined our understanding of this syndrome in yellowbud hickory in particular, recommending the name of "hickory wilt." Hickory wilt is caused by the synergistic interaction of two organisms—a fungus, *Ceratocystis smalleyi*, and the hickory bark beetle, *Scolytis quadrispinosus*.

Hickory wilt entry wound on Carya cordiformis. *Photo courtesy of USDA Forest Service.*

Damage indicative of hickory wilt on Carya cordiformis. *Photo courtesy of USDA Forest Service.*

In Park's study (2011) the fungus spread longitudinally (vertically) along the grain of the sapwood up to 64 centimeters (about 2 feet) from the point of inoculation within a year; however, lateral spread was limited to a few centimeters or less. The infection is indicated by lesions of dead bark at the point of entry and much larger reddish-brown discoloration of the underlying sapwood revealing the extent of infection above and below. The trees fight this infection by producing chemical defenses, and by producing tyloses to stop vascular flow and compartmentalize decay. This reaction causes localized restriction of upward sap flow. It appears that hickory trees are typically successful in stopping the spread of infection within a growing season.

Because of the limited lateral spread of *C. smalleyi* infections, a single lesion is insufficient to cause hickory wilt syndrome. However, multiple concurrent infections can severely impede sap flow, causing moisture stress in the crown, inducing wilt and die-back. Compromised trees are likely more attractive to bark beetles, attracting additional infections. Infections of stressed trees will on average be more successful, creating more viable offspring to infect nearby trees. This syndrome usually results in tree death in 1–2 growing seasons, and can decimate entire stands in only 3–5 years. (As happened to mine!)

The hickory bark beetle is native, and the fungus *C. smalleyi* is believed to be native as well. Both organisms attack yellowbud hickory in the absence of the other, and both independently cause damage. Hickory bark beetles are known to carry spores of *C. smalleyi*, but mechanical injury, other bark beetles, and sapsucker holes are all possible entry points for this fungus. However, neither organism appears likely to kill a healthy hickory by itself, and circumstantial evidence indicates that hickory bark beetles are the primary vectors for the fungus in large-scale outbreaks of yellowbud hickory wilt.

There appears to be a strong relationship between long-term drought and explosions in the population of hickory bark beetles. The beetles are attracted to stressed yellowbud hickory (Goedner and Morris, 1964). Hickories under moisture stress are more favorable to brood success (St. George, 1929). Conversely, rain during the feeding, mating, and oviposition period in May and June increases adult mortality and decreases egg-laying (St. George, 1929). High levels of moisture within hickory tissue, resulting from heavy rainfall, increases mortality of bark beetle larvae (Blackman, 1924). This explains why severe outbreaks of hickory bark beetle, and hickory wilt, have tended to occur after multiple consecutive years of below-average rainfall.

Observing the severe outbreak of hickory wilt in my home area between 2006 and 2010, we can draw some important conclusions about the factors affecting susceptibility and survivorship.

First, only mature trees were affected; seedlings and saplings smaller than 3 inches were not killed. Some trees between 3 and 7 inches in diameter survived; mortality increased as the size increased. Second, mortality struck first and most severely in crowded stands of relatively tall and lanky canopy trees with narrow crowns, especially in clumps of pure or nearly pure hickory. The next trees to succumb to hickory wilt were less crowded individuals with wider crowns. This took 1–3 additional years.

The only mature hickories that survived fit one or more of the following categories:

- Isolated trees in full sun in pastures, fencerows, yards, and parks. (In fact, I observed NO mortality on such trees, in stark contrast to the forest interior.)
- Trees on forest edges which had reduced competition and full sun on one side.
- Trees beside bodies of water. (A few forest-interior trees beside streams survived.)
- Forest interior trees that were isolated in expanses of forest in which hickory was generally absent or rare.

My observations match those of a research team studying yellowbud hickory mortality in a northern hardwood stand in the Flambeau River State Forest, about 40 miles east of my property, from 2010–2016. Bakken et al (2021) found total mortality of 84% on yellowbud hickory larger than 10 centimeters. Mortality was highest on larger trees: 23% of trees 10–15 centimeters died, and 40% of trees 15–20 centimeters died. Among trees larger than 30 centimeters in diameter, mortality was around 95% per year, which almost completely eliminated large yellowbuds from the study site. These researchers recommended that, to prevent hickory decline, yellowbuds should be thinned to no more than 20% of the basal area in a stand.

Of course, this would not be compatible with the management of a nut forest, but the available information suggests that it should be possible to mitigate wilt outbreaks by reducing tree density. High tree density causes stress through competition, limiting each tree's access to light, soil nutrients, and water. Thinning forest trees sufficiently to allow vigorous growth of yellowbuds should not only reduce susceptibility to wilt, but also maximize nut production. Since individual trees can be highly productive, it may be possible to maintain scattered individual hickories on larger farms as a source of supplemental income. Orchard, silvopasture, or alley-cropping plantings should be kept at densities that allow full sun and vigorous growth.

The severity of the die-off in the Blue Hills appears to have been directly related to the abnormally high density of yellowbud hickories prior to 2006.

The impressive survivorship of full-sun yellowbuds, even within areas of very severe yellowbud outbreaks, may be due to more than the reduction of competition. In avocado orchards affected by laurel wilt, a disease with similar etiology, it has been shown that increased sunlight from pruning and reduced tree density creates a microclimate unfavorable to flight activity of the ambrosia beetles that facilitate infection (Menocal et al, 2022). The behavior of hickory bark beetles should be investigated to determine if they have a similar aversion to an increase in light, heat, or wind.

Any hickory grower should monitor their trees carefully for any signs of wilt, especially after multiple years of below-average rainfall. Wilt-affected trees can be removed and burnt promptly before the mature beetles are able to emerge and infect additional trees. Growers should familiarize themselves with the feeding scars of adult beetles, and the cankers caused by *C. smalleyi* infection. Some authors have suggested that hickory bark beetles can be controlled by spraying oil or other substances on the bark of infected trees to suffocate the eggs or larvae. Such methods have not been practiced enough for me to comment on their effectiveness.

Another common disease of yellowbud hickory, of less concern, is *Phomopsis* galls. These deformed gobs of wood affect several tree species, but are uniquely prevalent on yellowbud hickory. (Park [2011] points out that the organisms causing these galls have been little investigated, and might not actually be *Phomopsis*.) The unsightly galls rarely, if ever, kill the trees, but they reduce competitive vigor and nut production.

Phomopsis *galls on yellowbud hickory*

Insect Pests of Hickory Vegetation

A number of insects damage yellowbud hickory trees, but these tend to be incidental and minor. One of the better known is the hickory horned devil (*Citheronia regalis*) a large caterpillar of one of our largest moths. The less photogenic walnut caterpillar (*Datana integerrima*) is a more significant defoliation threat. Other minor insect pests include the painted hickory borer (*Megacyllene caryae*) and hickory leaf roller (*Argyrotaenia juglandana*).

A pest that may sometimes become more serious is the fall webworm (*Hyphantria cunea*), which defoliates numerous deciduous species toward the end of the growing season, and is sometimes a serious pest of pecan. Fall webworms overwinter in cocoons in bark crevices and other natural shelters. Mature caterpillars are about 1.2 inches long and have a broad brown stripe down the back and yellow sides flecked with black. These caterpillars can be controlled by destroying nests and application of *Bacillus thuringiensis.* For treatment and natural history of fall webworm, see Showalter and Ring, 2017.

Another more serious pest is the hickory gall aphid (*Phylloxera caryaecaulis*). These unsightly, roundish galls, 0.25–1 inch in diameter, form mostly in May on leaf stems, midveins, and new shoots. After the aphids (phylloxerans) leave in June, the galls dry out, darken, and often persist on the tree for a year or more. This insect has a complex and interesting life cycle. A female known as a fundatrix or stem-mother emerges from an overwintering egg in mid-spring and begins feeding on new leaf or stem growth, which stimulates a gall to grow around her. Inside the gall the fundatrix will asexually reproduce numerous clones of herself. Upon maturity these female clones will exit the gall, continue to clonally reproduce, and then lay eggs on the underside of hickory leaves. These eggs, mostly males, hatch and mate, with the female minority then laying a single overwintering egg each, in an old gall or a bark crevice, to renew the cycle. (see Caldwell and Schuder, 1979, and Hamilton, 2019). Phylloxerans damage hickory trees but rarely if ever kill them. They may be controlled by removing and burning infected twigs, or by spraying—although I have no experience with either method.

Minor pests of hickories might become problematic if the trees are grown on a large scale in reduced-diversity settings. Growers will have to develop strategies for these problems if and when they arise. Interestingly, there are multiple species of Phylloxera that attack hickories, and some of them require alternate host trees to complete their life cycle, including *Phylloxera castaneae*, which infects chestnut (Hamilton, 2019). This may have implications for growing hickory and chestnut together, and in such situations monoculture might actually be less prone to this particular problem.

Insect Predators of Hickory Nuts

Two species of snout-beetles (weevils) are the primary insect predators of hickory nuts in North America: *Conotrachelus affinis* and the much larger *Curculio caryae.* Both species will lay multiple eggs per nut—but it is rare that more than six larvae survive.

The hickory weevil (*Conotrachelus affinis*) emerges in spring, mates, and lays eggs in late spring or early summer in crescent-shaped scars on the sides of developing nuts. The larvae (grubs) feed on the nuts for about a month. Infected nuts or grubs drop from the trees in midsummer, after which the grubs chew an exit hole and burrow into the soil, where they pupate in late summer. Adults hibernate until emerging the following spring—making for one generation per year (Shen, 1973).

The pecan weevil (*Curculio caryae*) adult emerges in summer, the adult feeding upon and destroying multiple nuts during its active period. This species mates mostly in late summer, and lays eggs from August through September. Rather than oviposit on the nut surface like the hickory weevil, the pecan weevil chews through the husk and shell, oviposits, and then uses her long snout to push the egg into the nut and place it on the kernel. From oviposition to grub emergence takes 5–6 weeks. Mature larvae chew an exit hole through the shell; after emergence they burrow 4–12 inches into the soil and hibernate for one or less often two years. After this they pupate into their adult form, but remain dormant in the soil for another year before emergence. This means that each generation takes two or, less often, three years (Mulder et al, 2012).

There may be other weevils that occasionally infect hickory nuts. Most of the research on pecan weevil has focused on its effect on pecans in commercial production settings. It infects all hickories, but we know very little about its interaction with species other than pecan. *Conotrachelus affinis* has been much less studied, although we know that it is fed upon by various parasitic flies and wasps.

Yellowbud has a distinct advantage over other hickories in its resistance to these pests. Both of these weevils infest yellowbuds at much lower rates than shagbark, pignut, mockernut, black hickory, and pecan (Shen, 1973). Shen noted that the percentage of nuts with weevil-infested kernels (both species) across the non-bitter hickory species generally reflected their investment in protective physical defenses (husk and shell combined). That is, the hickory species with the thickest shell and husk had the lowest rates of infection. However, this relationship did not hold true for the two species with bitter kernels, yellowbud and water hickory. These species had the lowest infestation rates among the species sampled, despite having the thinnest husks. This supports the belief that tannins and physical defenses are alternative strategies to reducing insect predation.

What appears to be feeding scars and partially damaged kernels from hickory weevils

Among these two pests of yellowbud hickory, *Conotrachelus affinis* appears to be worse. Because larvae of this species mature in July or August, most infected nuts are aborted 6–14 weeks before normal nut drop. Such premature drops exhibit characteristics signaling their infected status (early darkening, small size, thin and dry husk, and lack of the partial split between valves), and so are usually left behind by experienced harvesters. However, infestation rates of greater than 10% are rare. In locations where yellowbuds grow beside heavily-infested hickory species, it is common to find a large portion of the yellowbud nuts having raised scars on the shell surface. I suspect that these are unsuccessful hickory weevil oviposition sites; they match the shape and distribution of *Conotrachelus affinis* oviposition sites. This suggests that yellowbuds have a chemical or mechanical means of defending themselves against hickory weevil attack, which other sympatric hickory species lack. Research should be conducted to confirm this.

The pecan weevil, *Curculio caryae,* is limited by cold autumn temperatures in northern areas (Shen, 1973) and appears to be absent from parts of the northern distribution of shagbark and yellowbud hickory. It can also be limited by soil conditions (Mulder et al, 2012), which may account for its enigmatic absence from some warmer regions. The late ripening of some yellowbuds probably helps them avoid weevil infestation. Where I live, yellowbud is the only native hickory, and pecan weevil is not present. However, in regions further south where I gather yellowbuds growing beside other species that are heavily infested with pecan weevil, the pecan weevil infestation rate among yellowbud nuts generally remains very low. I have often picked yellowbud nuts with almost no weevil damage that were intermingled with shagbark, mockernut, and pignut that had 50–80% infestation rates. In many northern portions of the range of yellowbud, pecan weevils are absent. Being able to grow yellowbuds with little or no crop losses from insect pests is a significant advantage.

However, in certain circumstances yellowbud nuts have high infestation rates from pecan weevils. Zach Elfers reports this in parts of Pennsylvania, and John Godar at a site in Tennessee (personal comments), and I trust both of them to have identified the trees correctly. A few possible explanations seem plausible for this, and they are nut exclusive.

First, hybrids between yellowbud and shagbark hickories are fairly common in many areas where the two grow together. Some of these hybrids appear to be more susceptible to pecan weevil than either parent. One particular hybrid tree that I have picked from in Wisconsin (named 'Sky View', which appears morphologically to be an F1 hybrid) for more than ten years has consistently high pecan weevil infestation rates, at least once exceeding 50% and always exceeding 10%. In this area, where I have picked yellowbud and shagbark nuts for 35 years, totaling thousands of gallons from hundreds of trees, I have never seen shagbarks with infestation rates higher than 5% (and usually only 0–1%), and I have never seen yellowbuds with infestation rates even at 1% (usually 0%). Two other hybrid trees in the area have demonstrated elevated pecan weevil infestation rates like this. It seems plausible that certain shagbark genes which control the morphological, phenological, or chemical factors facilitating weevil susceptibility have entered the yellowbud gene pool through introgression in some yellowbud populations with a robust history of interbreeding with shagbarks. Yellowbuds fight weevils chemically, while shagbarks fight them mechanically, through thicker shells and husks. In a hybrid population, certain trees that are morphologically yellowbuds, but with a small amount of shagbark genetics, might exhibit the worst-case strategy of lowered chemical resistance and a thin husk and shell, resulting in greater weevil susceptibility.

Additionally, pecan weevils have highly variable regional populations. Mynhardt et al (2007) identified five major haplogroups of the pecan weevil in eastern North America, each of which has potentially fixed behavioral characteristics. They believe that the dominant lineage of the Upper Midwest separated from the lineage east of the Appalachians during a previous glacial episode more than 800,000 years ago. The subpopulations appear to be specialized in the infestation of particular hickories under certain phenology and climate conditions. For a tiny beetle to get inside a hickory nut is a tall task, and the hickories have been waging an evolutionary battle against them for millions of years. Small differences in genetics, climate, or soil seem to have a great effect on the weevil's ability to succeed.

A well-known example of this regional specialization and adaptive reaction in pecan weevil occurred when pecan cultivation was introduced to Florida. For several decades of early pecan cultivation in Florida, the pecan weevil was rarely observed, and infected the nuts at negligible rates (Hill, 1938). However, within 70–80 years, this changed dramatically, and today pecan weevils are a serious pest in Florida pecan groves. Genetic work (Mynhardt et al 2007) suggests that these weevils were from local populations. The weevils were presumably adapted to water or pignut hickory, but eventually adapted to the new pecan resource.

What all of this means in the long-term for hickory oil remains to be seen. Some areas may be at a distinct disadvantage if local yellowbud populations are more susceptible to pecan weevil, for whatever reasons. Growers may want to avoid hybrids to reduce short-term weevil pest loads in mixed orchards, but also because growing hybrids may facilitate adaptive change in weevil populations that allows them to become serious pests of non-hybrid trees. It also suggests that oil producers might want to source locally, to avoid transporting nuts, which may contain weevils from different haplogroups, to new areas where they may have an enhanced ability to infest yellowbuds.

The current reality, that yellowbuds naturally grow in areas where pecan weevil is absent, and appear largely naturally resistant to both pecan weevil and hickory weevil, provides a significant economic advantage for growing these nuts over those of other hickories. Cleaning up and destroying all bad nuts in infected orchards is nevertheless suggested, to break the breeding cycle of the weevils.

Rodent Control

In the wild, the majority of the yellowbud hickory nut crop will be eaten or hoarded by rodents. I have personally witnessed them being eaten by flying squirrels, chipmunks, white-footed mice, and gray, red, and fox squirrels—as well as deer and black bears. In wooded environments, squirrels can easily clean up 20–40 gallons of nuts from one tree in a few weeks. This is the reason that it is difficult to gather appreciable amounts from forest trees in most years. Only one to four times a decade, when there is a bumper crop of nuts, is it possible to harvest efficiently in a forest site. Isolated trees in fields and pastures are generally better for harvesting because they are less accessible to rodents.

In orchards, rodent control is advised to increase yields. In managed forests, rodent control is absolutely necessary to get reasonable yields—without reduction in rodent numbers, a hickory woodlot will only provide a surplus of nuts in occasional years. There are several complementary strategies to accomplish this. These methods may interfere with other goals, such as timber production and maintaining wildlife habitat, so landowners will have to make decisions by weighing their particular values.

The first is to eliminate alternative food sources. Oaks, hickories, and walnuts with nuts that go unharvested will provide alternative food sources that will maintain high populations of nut predators. Because different nut species do not all mast in the same year, a diversity of species tends to stabilize nut production and result in higher average rodent numbers. A single-species nut forest will maintain a lower average rodent population because the synchronized crop failures cause population crashes, making for lower rodent numbers in the following years of heavy bearing. Thinning out other nut species accomplishes this. Promptly and thoroughly harvesting fallen yellowbud nuts will further lower rodent populations. Maple, birch, aspen, tulip poplar, and sweet gum are associated trees that provide little alternative rodent sustenance.

A related strategy is to reduce the denning sites and cover for rodents by removing rock and wood piles and brush. This especially reduces the numbers of white-footed mice. Old hollow trees that provide squirrel den sites can be removed. The lack of den sites for white-footed mice is one of the great advantages of yellowbud trees in an orchard setting. Fencing to keep out deer and turkeys will also reduce crop losses.

Hunting is a labor-intensive but effective way to reduce squirrel numbers, but it may be possible to open your property to recreational hunters who do some of the work for free. Trapping squirrels is more labor-efficient, if you can find an effective means of trapping them. In large forested areas an influx of squirrels from nearby forests can perpetually replenish the population. But it cannot be overemphasized that high rodent numbers will rapidly and completely eliminate the crop of yellowbud nuts in all but the best years.

Harvest

Yellowbud nuts ripen in autumn. Peak nut drop occurs from about October 15 to November 10. Some trees will begin their primary nut drop as early as mid-September; other trees will hold their ripe nuts into February. Most collectors currently just pick up fallen nuts from the ground by hand. My typical rate of hand collection in wooded areas is 3–8 gallons per hour, with 10–12 gallons being exceptional. In lawn-type environments 6–12 gallons per hour is typical, reaching 15–20 gallons per hour under the best conditions. These numbers represent green, in-husk nuts; the volume after husk removal will be 45–60% of the in-husk volume.

Freshly harvested yellowbud nuts

Mechanical harvesters like Bag-A-Nut and Nut Wizard can significantly increase collection rates, but I have not used them enough to obtain meaningful averages. However, they can only be effectively used in areas with a smooth, mowed surface free of obstructions. In modern pecan orchards nuts are typically harvested from the ground by sweeping and blower or vacuum machines, often after mechanical tree shaking. Currently there are no productive, manicured yellowbud orchards large enough to justify such expense, but similar processes will presumably be employed in a mature hickory oil industry. Early growers and gatherers of yellowbuds will use hand-harvest or less costly mechanical harvest systems.

Eventually, as hickory nut harvest shifts to orchards, mechanical harvesting will likely take over the industry, as it has with pecans. In my experience, the supply of accessible yellowbud nuts is limited enough that the portion of nuts missed by mechanical harvesters is usually too large to justify their use except in well-manicured lawns. Mechanical harvest often requires significant post-harvest sorting to clean out bad nuts and debris.

Tree shakers will eventually have a place in hickory nut harvest. Even with hand harvest I often use heavy throwing sticks to dislodge nuts, which can be surprisingly effective. Climbing to shake down nuts is also effective, but more difficult and dangerous.

The very long and variable dropping period of yellowbud nuts appears to be part of a multi-modal dispersal system. The nuts are avidly eaten by nut-eating mammals (despite frequent claims to the contrary in the literature) and, like other hickory nuts, they are scatterhoarded in large numbers by gray and fox squirrels. Their thin shells make them more susceptible to consumption by large mammals such as deer and bear, and they are avidly eaten by cattle—which generally avoid thicker-shelled hickory nuts. However, as with pecans, their thin shells make them more accessible as a food source for birds (primarily corvids and woodpeckers), which also appear to be an important dispersal agent, especially for late-clinging nuts.

It is best to harvest the nuts as soon as possible after they fall. So long as they are ripe and sound, the moist husks detach readily. Freshly fallen nuts have had less time to "burrow" into the grass or litter, less time to be contaminated with feces or covered by falling leaves, and less time to be collected by wildlife. It is also easier to spot the difference between good and bad nuts when they are freshly fallen. The longer the nuts remain on the ground, the more of them will have spoiled kernels from bacterial action and mechanical damage.

Nuts that ripen and fall before leaf drop or soon thereafter have yellow-green husks. These darken within 2–12 days of falling. Under moist conditions the husks turn black and soften. The husks of nuts that cling late into the fall or winter will turn brown and desiccate on the tree. Removal of such dry husks is more difficult. Harvesters need to recognize that nuts with husks of all three colors—green, black, and brown—can be good and sound.

Nuts that have been aborted before full ripening (often due to insect infestation) are often abundant and can be recognized by many subtle cues that are learned by experience, but the most reliable indicator is their tightly sealed husk sections. The husk sections of sound nuts partly separate on the distal end at ripening. This separation is usually 20–50% of the length of the seam. On dry nuts it is wide enough that a small section of shell is visible. However, when husks remain moist and plump, the detached portions often remain in contact, making the separation hard to see. The tightly clinging husks of aborted nuts are reluctant to loosen, even in dehusking machinery; these nuts should be recognized and removed by processors.

New harvesters should crack many nuts, and all questionable nuts, until the criteria for selection are well understood. The kernel should be clean-looking with light-colored flesh within sound nuts. Keystone Tree Crops Cooperative has produced this online guidebook for new harvesters.

Post-Harvest Storage

Until husking, nuts should be stored in breathable bags or open bins in a cool location out of direct sun. The longer one waits before dehusking, the more nuts will spoil, but losses will be minimal during the first two weeks. A temperature between 30–50°F is ideal, for this retards spoilage of nuts. Temperatures this low are not necessary if dehusking is prompt, but it is always best to keep nuts in the husk at less than about 85°F. Depending on moisture levels in the storage environment, the husks may dry and shrink (which makes them harder to remove) or blacken and soften (which makes the removal process messy, and makes it harder to spot bad nuts).

A nut is a living organism that will only survive in a certain range of conditions. Temperatures in excess of about 120°F will kill them. Excessive cold will kill them, but I have not determined the threshold—it seems to be somewhere below 10°F. Nuts can also be killed by long-term soaking, lack of air flow, desiccation, mechanical damage, or pathogenic microorganisms. Nuts that die will spoil in a few weeks at room temperature if not dehydrated. You want to keep the nuts alive until they are dehusked. After dehusking, as the nuts dry, they will eventually die. However, if they die from desiccation, their moisture levels will be low enough to prevent most forms of spoilage.

Prevent rodents from stealing your nuts! Gray, fox, red, and flying squirrels; chipmunks, rats, and white-footed mice—all of these will steal and hoard many gallons of yellowbud nuts, and additionally create a food safety hazard. These rodents have a powerful sense of smell. They will know that you have nuts in your building, and will travel a long distance to get there. It is common for gray or fox squirrels in particular to circle a building trying to find their way in. Store your nuts in a rodent-proof facility, and set numerous traps as assurance and for monitoring.

Dehusking

Yellowbud hickory nuts are surrounded by a thin husk of four or sometimes five sections. At maturity these husk sections break apart near the tip, but do not fully separate from each other, or from the nut. I remove this husk before pressing for oil. Drying does NOT make the husks easier to remove, as some might suspect—the effect is generally the opposite. Therefore, husks are removed before drying. I have rehydrated dried nuts before dehusking by spraying water into the gunnysacks or dipping and draining, followed by leaving them for a few days so the husks can reabsorb moisture. However, this is a cumbersome step that is best avoided, and any fine cracks that form during initial drying can serve as water entry points that might facilitate nut spoilage.

Yellowbud nuts in drying husks

Some people have argued that husk removal is an annoying extra step that is unnecessary. Several people, myself included, have pressed oil from nuts from which the husks had not been removed. Although this is possible, I believe that husks should be removed for the following reasons:

- The oil tastes better when the husks are removed.
- Husks begin to decompose on the nuts under field conditions and in storage; having this material in the oil press constitutes a food safety hazard.
- Husks included in pressing increases the volume of material to be pressed by 20–40%, slowing the rate of press operation commensurately.
- The soft and fibrous dried husks absorb oil in the press, thereby reducing extraction efficiency and lowering oil yield. (I have not done sufficient experimentation to determine the percentage of this loss, but it is definitely significant.)
- Retaining the husks slows down nut desiccation, meaning more time, more energy, and more rack surface is required for drying nuts with the husk on.
- Husk removal makes bad nuts more evident and facilitates their removal before pressing.

For the above reasons, I consider husk removal a required step in preparing yellowbud hickory nuts for oil pressing.

Removing the husks from yellowbud hickory is tricky because of the thin, brittle nutshells; applying too much force in dehusking will crack the shells or break the nuts. Breaking nuts during dehusking results in the loss of small kernel pieces that fall through the holes in the machinery. Nuts that are cracked or damaged while still moist are more likely to mold or spoil while drying. For these reasons it is necessary to use a medium of force that removes the husks while leaving the shells intact.

When I first began making hickory nut oil, I removed the husks manually. This is slow and results in sore thumbnails after a few hours. I started putting about 1.5 gallons of nuts into a gunnysack and rolling the sack under one foot, applying moderate pressure (far less than my body weight) for a few minutes per batch. After this the nuts would be dumped onto a tray and sorted manually. With the help of my family, I dehusked thousands of gallons over several years this way. I eventually designed, and with help built, a dehusking machine that is reasonably effective and can serve as a prototype for better designs.

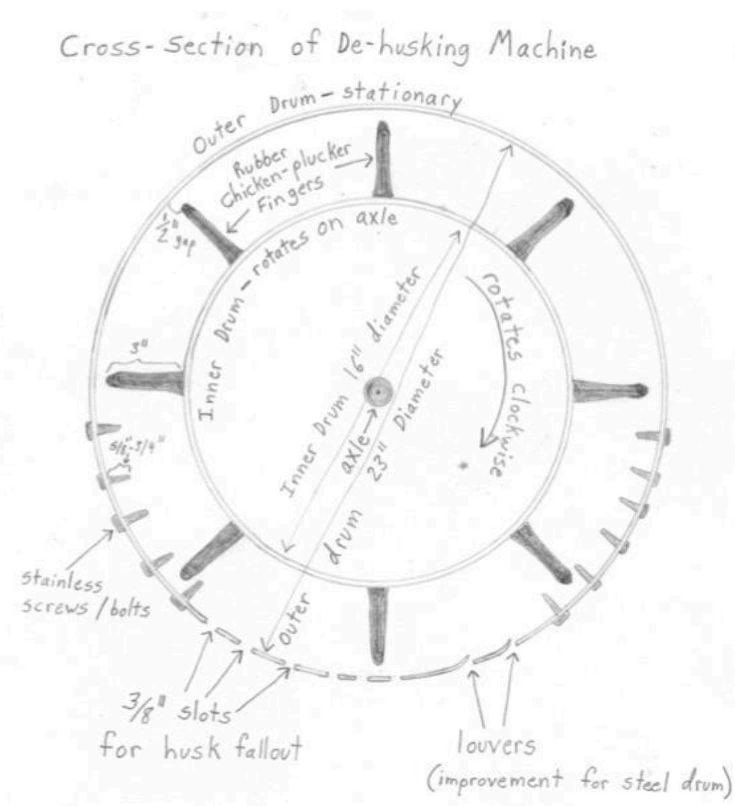


Diagram of dehusking machine

The body of the dehusker consists of a modified 55-gallon food-grade plastic drum, to which stainless screws are attached, the tips on the interior, for abrading and shearing off nut shells. Inside is a smaller barrel made from another plastic drum by cutting off the ends, cutting down the side, and overlapping the sides until a diameter of 16 inches is achieved. This inner drum is made rigid by fastening a 16-inch pizza pan on each end, both perforated in the center to fit around an axle. Chicken-plucker fingers are attached to the inner drum to move the nuts across the abrading and fallout areas of the outer drum. The motor was repurposed from a small cement mixer. (Fast rotation will crack many nuts.) The chicken-plucker fingers are arranged in rows, with gaps of about half an inch between them. It is important that the component pushing the nuts is not too hard or rigid, or it will crack or break them. The husk fallout slots must not be too large, or entire nuts will be lost. 5/16-inch might be a better size for these. The stainless screws are also in rows, with about 1 inch between them. Screws can be backed out if the machine has too much friction. My machine does not have louvers as are shown in the diagram. Louvers would require a metal drum, but I believe they would be a great improvement, because they would simultaneously shear off pieces of husk and direct them outside of the drum. Thus the abrasion mechanism and fallout system would be unified, allowing one to double the area of each and speed up the dehusker's function. If louvers were used, rubber flaps attached to an axle could replace the drum and chicken-plucker fingers for agitating the nuts more effectively.

Chicken-plucker fingers on dehusking machine

My machine dehusks a batch of 2.5 gallons of nuts in 7–10 minutes (unless the husks are dry, in which case it takes much longer), resulting in about 6 quarts of clean nuts. This includes the time necessary for the operator to empty the machine and put in a new batch. While the machine is running, the operator can sort the previous batch and place clean nuts on drying trays. A small number of nuts will have husks that appear sound, but which will cling tenaciously during the dehusking process. These adhering husks indicate an empty or bad nut. Producers should learn to recognize them so that such nuts can be discarded without wasting additional time. If nuts are in good condition, an operator with this dehusking machine can get 8–12 gallons of cleaned nuts per hour. There is substantial room for improvement in this process. In providing the details of the machine here I am giving permission for others to reproduce it and improve upon the design.

Levi Geyer at Fancy Twig Farm has successfully used a pistachio sheller from Kaidoglu, a company in Turkey, to remove yellowbud husks. He's been running batches of 8 gallons of nuts for about 20 minutes. The operation of this machine requires a water supply and floor drain. Zach Elfers at Keystone Tree Crops Cooperative has been using a potato peeler although they will be incorporating the same pistachio sheller from Kaidoglu. It is likely that various pre-existing machines can be effectively used for dehusking yellowbud nuts, but the greatest efficiency will probably be achieved eventually with a machine designed specifically for this purpose.

Washing and Floating

I used to wash and "float" the nuts after husk removal. Floating refers to putting batches of nuts into water and determining, by whether nuts float or sink, if they are full or empty. It is often said that good nuts float and bad nuts sink, but the reality is more complex. When kernel fill is poor, many or most of the good nuts on a particular tree may float. In this case, one has to separate "high floaters," which are actually empty, from "low floaters," which have good kernels, but are not totally filled out. Similar problems can develop when nuts lay on sunny, dry ground under the tree for an extended time prior to harvest; desiccation can make the good nuts float.

This is a lot of work for little benefit. The empty nuts don't cause major problems unless they are a large proportion of the batch, and usually they are less than 5%. What I worry more about are nuts with full but spoiled kernels. These are *not* detected by floating; in fact, floating might create them. I believe that immersing the nuts in water after dehusking increases spoilage. Small cracks or nicks in nut shells inevitably occur during mechanical dehusking, and immersion allows water to penetrate these openings, which sometimes induces spoilage. Therefore I have stopped using floating as a regular step in sorting. If the nuts seem particularly dirty after dehusking, I spray them off in a basket before drying.

Drying

Nuts should be laid out for drying immediately after dehusking. I use 3 foot × 3 foot racks made with aluminum or stainless mesh stretched over a wooden frame. The wooden members are 1.25 inches × 2 inches. There is nothing special about this size: Larger trays were harder to handle. At each corner is a wooden brace at a 45° angle, which reinforces the corners and simultaneously acts as a spacer to facilitate air flow when the trays are stacked. On each tray I spread 3–4 gallons of nuts, keeping them mostly one layer of nuts deep, and never more than two layers.

After filling, I stack these trays about 7 feet high in a drying room. The room has a small fan to circulate air and can be heated (depending on the outside weather conditions). The temperature is maintained at about 75°F. Nuts are not stirred during drying, because my trays are too close together to allow it—but stirring would not be a bad idea. In this system, nuts are adequately dried for pressing in 4–5 weeks. By raising the temperature to 80–85°F, they are ready in 2–3 weeks.

Drying rack for yellowbud nuts

Stacked drying racks

There are other effective options. To save time and space, Levi Geyer dries his nuts in a small grain bin, using a repurposed furnace fan to blow air up through the perforated bin floor, moving it evenly through the nuts in a level pile up to 6 feet deep. He turns the fan on during the day when the relative humidity tends to be lower (unless it is foggy or rainy).

By increasing the temperature and air flow and decreasing humidity, drying time could be substantially reduced. (Drying space has not been a limiting factor in my practice, so I have not pushed to speed up the drying time.) For pecans, drying temperatures of 90–95°F are considered optimal, and it is recommended to never exceed 100°F. Experimentation should be done to determine the optimum temperature range for rapid drying of yellowbud nuts without inducing rancidity or spoilage, but temperatures slightly lower than those used for pecan seem advisable.

When nuts are sufficiently dried for pressing, the kernels shrink back slightly from the shell interior and the shells become brittle rather than pliable. I do not use a moisture meter to determine dryness—just the sound and feel of the nut as it cracks. Producers will learn through experience the look and feel of nuts at an optimum level of dryness. The Kern Kraft manual suggests moisture content of 7–9% in pressed seeds. Levi Geyer of Fancy Twig Farm has made a limited number of moisture measurements and tentatively concludes that about 10–11% moisture is optimal. If the nuts are too moist, the press cake moves through easily and it is hard to build pressure; the oil may come out gummy with lots of particulate and some moisture mixed in, which creates a food safety hazard. If the nuts are too dry, they run through the press with more difficulty, generate excessive heat from friction, and make jams more likely.

If dry nuts are stored at room temperature, I press them all for oil by April 10 in my climate (northern Wisconsin). Beyond this time, rancidity begins to negatively impact the flavor of the oil. I prefer to get my oil pressed by the end of February. Lowering of the storage temperature greatly slows rancidification, but whole nuts are bulky for long-term cold storage.

Dried nuts are susceptible to infestation by meal moths (*Plodia interpunctella*) or almond moths (*Cadra cautella*). These moths do not seem able to penetrate the shells and are absent from uncracked nuts, but once the nuts are cracked or pulverized, the larvae can infest them. Small amounts of meal in crevices, or uncleaned press parts in the offseason, can harbor these pests. They can also live in the press cake. The processing of nuts for oil during the season is generally fast enough to circumvent the life cycle of meal moth populations, but all traces of nutmeat and press cake should be cleaned carefully at the end of the pressing season so that meal moth numbers cannot build up during the off season.

Sorting and Inspection

Before milling the nuts should be inspected to ensure that they are of adequate quality for pressing. If previous steps have been carried out well this should not be an issue. When good, sound nuts dehydrate, the kernels die. Dead kernels will eventually rancidify due to oxidation and decompose due to some combination of bacterial and fungal agents. This is why prompt pressing is important. Separation of the oil from the kernel speeds up rancidification on the one hand, but on the other hand it deprives potential spoilage organisms of other nutrients (protein, carbohydrate) found in the kernel.

Rancidity can be detected by tasting a piece of kernel. Although rancidity is difficult to describe, and with yellowbud nuts it is somewhat masked by the bitterness of the kernel, rancid nuts taste clearly different from fresh ones. Again, if you are pressing within a few months of drying, this will not be an issue.

Fungal spoilage is evident often through color change of the kernel, sometimes to whitish, yellowish, or bluish, usually accompanied by the presence of mold or a thin film over the kernel's surface. This has been infrequent in my experience, and seems to be the result of drying insufficiently or too slowly. Mold on the surface of nuts often, but not always, indicates mold on the interior.

What appears to be bacterial spoilage is most common. This is a presumption—based on the observation of consistent spoilage syndromes that are not accompanied by signs of fungal growth—but has not been confirmed through observation under a microscope. We do not know which kinds of bacteria are involved, or of the level of potential dangers of their byproducts.

In the most common pattern of presumably bacterial spoilage, the opaque, whitish flesh of the kernel first begins to clarify. This is eventually accompanied by a darkening or "moist" look to the shell's exterior, which we call "oil spoil." I believe this to be caused by a breakdown of the kernel's structure, causing oil to be released and soak into the shell from the inside. Given enough time, these kernels turn grayish, then black. Other times spoiling nuts develop dark yellowish kernels.

I take random handfuls from throughout a batch of nuts until I have about half a gallon, then spread them on a sorting tray to inspect. Crack any nuts that look abnormal in color, and a few of the normal ones too. If few to none of them are spoiled, the batch is good and ready for milling. Occasionally I find a batch with a large proportion of bad nuts. Then I sort them to separate good from bad nuts. I may put some of them through my Davebilt nutcracker, which breaks them in half or in large pieces, to facilitate inspecting and sorting the batch. This adds a lot of time. The goal is to perform all of the previous steps so that this sorting is not necessary. I always have a hand-held nutcracker handy if I need to check nuts for quality.

No batch of raw agricultural product is in perfect condition. We don't really know what is the appropriate quality threshold for yellowbud nuts to be pressed for oil. I have noticed only minor differences in taste and color between the most and least spoiled batches of nuts that I have inspected. The differences caused by rancidity of the whole batch are more obvious.

Levi Geyer and Alex Tanke pressed oil from a batch of nuts of which 20% were deemed bad—exhibiting "oil spoil" or discolored kernels. The oil's flavor was passably good. Alex and Levi submitted this oil to Eurofins Food Chemistry Testing in Madison, Wisconsin, for a mycotoxin test. There were no mycotoxins detected in the sample. They tested for:

Aflatoxin B1 <0.300 ppb
Aflatoxin B2 <0.300 ppb
Aflatoxin G1 <0.300 ppb
Aflatoxin G2 <0.300 ppb
Aflatoxin M1 <0.300 ppb
Aflatoxin M2 <0.300 ppb
Deoxynivalenol <56.0 ppb
T-2 Toxin <5.60 ppb
HT-2 Toxin <56.0 ppb
Fumonisin B1 <14.3 ppb
Fumonisin B2 <14.0 ppb
Ochratoxin A <1.00 ppb
Zearalenone <16.7 ppb
Sum of Aflatoxins B1, B2, G1, and G2 <1.20 ppb
Sum of Fumonisins <28.3 ppb
Sum of HT2 and T2 <61.6 ppb

This is promising, and suggests that I've been sorting nuts more stringently than necessary, but these results do not preclude the presence of other toxins. Nut quality is nevertheless very important. I pressed one batch of nuts that was brought to me, and which contained many spoiled nuts, and the resulting oil had a strong, unpleasant flavor—I deemed it non-consumable. One publicized food safety problem has the potential to destroy the image of an entire fledgling food industry, and also to raise institutional barriers such as permitting difficulties and other red tape. Considering the uncertainties with hickory oil, I advise any producer to err on the side of caution and quality during the final stage of inspection before pressing begins.

Milling

The kernels of most hickory nuts, including yellowbuds, are prohibitively difficult to separate from their shells. Oil pressing would not be economical or practical if shelling was a prerequisite. Oil is expelled from the full nuts, shells included. However, I have not been able to get yellowbud nuts to run through an oil expeller *whole*. These presses are designed for smaller seeds such as canola, sunflower, soybean, and hemp. Hickory nuts are too large to fit into the grooves in the screw that move material through the press. Therefore the nuts must be broken into smaller pieces before pressing.

In my early years of pressing, I ran the yellowbud nuts through a Davebilt nutcracker. This machine is designed to crack hazelnuts, and it effectively breaks yellowbud nuts open, many of them in halves or quarters. These pieces are small enough to run through the press, but for me they did not run smoothly; the machine still ran erratically with gaps that led to slow and uneven pressing and frequent jams. I decided that the nuts needed further comminution.

I then put batches of about 7 quarts of nuts into a food-grade 5-gallon plastic bucket and smashed them with a large wooden pestle to get a smaller average particle size. Each batch takes about a minute of pounding. The resulting milled nuts form a heterogenous mixture of particle sizes, ranging from sand-sized bits to quarters and a few halves. This mixture feeds effectively through the machine and presses well.

Pounding nuts by hand with a wooden pestle is a reasonable proposition for small production runs in the early stages of establishing a shop, but the need for a better mechanical means of milling will soon be felt. The solution that I found was a small hammermill. However, *hammermills have the tendency to break up the nuts too finely*, creating a fluffy material that does not feed well through the press. To prevent this, I removed the screen that holds material near the mill hammers, allowing the nuts to fall rapidly past them to avoid excessively fine milling. Achieving this will depend on your specific mill.

We later discovered that by cracking with the Davebilt on a smaller setting, satisfactory flow was achieved, especially using an agitator in the press hopper. Levi Geyer has designed a roller mill that breaks the nuts to an appropriate consistency for pressing, and he is offering those for sale. Using Levi's roller mill is simpler than my hammermill, and it is quieter and easier to clean.

Along with a conveyor table, it facilitates inspection and removal of occasional bad nuts as they are being cracked.

Roasting

Some producers may want to roast hickory nuts before pressing for oil, as is sometimes done with other nuts, such as walnuts, hazelnuts, and almonds. I do not have experience doing this, although I have tried the oil from roasted nuts pressed by others. I prefer the flavor of oil from unroasted nuts. Roasting will lower the moisture content of the nuts and may require different press settings and techniques. Also, shelf stability of the oil pressed from roasted nuts may differ. I am not discouraging producers from pursuing this as an option, but I have little relevant information. If you choose to go this route, it is important to clearly distinguish the oil pressed from roasted nuts on the label, so that customers know what to expect from the product.

The Expeller Press

Edible oils are commercially extracted either mechanically or using a solvent.

Solvent extraction is the most efficient, removing 97–99% of the oil, but it requires a much higher capital investment. For solvent extraction, the oilseeds are first ground into a paste, then heated and mixed with the solvent (normally hexane). The hexane-oil mixture is then drained from the paste, after which the hexane is evaporated and collected (distilled) for reuse, leaving the oil behind. Solvent-extracted oils are generally less flavorful than mechanically pressed oils, and due to concerns over possible residual hexane (a neurotoxin) are considered less healthy by consumers.

Mechanical extraction methods include batch (stamp or bladder) presses, centrifuges, and expeller presses. Batch presses use mechanical force to pressurize a batch of ground material, usually in a cylinder, or a mesh bag or "bladder." This is a labor-intensive process with a low extraction efficiency, generally confined to small operations in regions with low labor costs. Bladder presses are used primarily for soft, oily fruits such as olives and avocadoes, but also sometimes with ground seeds. However, today most olive oil is extracted with centrifuges. Stamp and bladder presses and centrifuges are ideal for mechanical extraction at low temperatures.

Expeller presses use a rotating screw to force a continuous stream of material through a perforated cylinder (called a barrel or sieve). Flow is impeded at the distal end of the sieve (the "press head"), enough to cause pressure ("back pressure") to build up inside of it. This pressurization causes oil to flow out through the perforations in the sieve. Material from which oil has been extracted flows continuously out of the impeded end of the sieve. Expeller pressing removes about 80–95% of the oil from pressed material.

Consumers who want local, fresh oil from a tree crop generally do not want a solvent-extracted oil. We already have an ample supply of cheap, old, flavorless, solvent-extracted oil; hickory will not fill that niche. Stamp presses with small cylinders would probably work for pressing hickory oil, but these machines are very difficult to obtain in North America, and the added labor costs would make it hard to price oil competitively in the U.S. market. Bladder presses and centrifuges, such as are used for olives, require soft mash to extract oil. Hickory nuts would need to be shelled and ground to a paste to work in such apparatuses, which would be impractical.

Therefore, an expeller press appears to be the right option for commercial production of hickory nut oil.

I own and use two expeller presses: a Kern Kraft KK20 and KK40. These are manufactured in Germany and sold by Circle Energy of Dodgeville, Wisconsin. (I have no relationship to this company other than as an occasional customer.) I have also tried the M70 press made by Oilpress.co (formerly Agoilpress), which is made not far from me in Wisconsin. In my trials the representatives from the company were unable to get the M70 to effectively press hickory nuts with the shells included (although I have heard of one other party that has used this press for hickory nuts with limited success). The M70 press internally generated excessive heat from friction, causing the machine to jam. Certainly there are other presses that would work for hickory nuts, but trying them out is a difficult and expensive proposition. The specific instructions given for press operation in this manual refer to my experience operating the KK20 and KK40.

Operation of Kern Kraft Expeller Presses with Hickory Nuts

Expeller pressing is an inherently difficult process. One has to build up sufficient pressure to squeeze oil out of a semi-woody matrix of material, which requires the formation of a hard "puck" of press cake at the end of the sieve. Yet this puck must remain pliable and fluid enough to flow out continuously through a constrained opening. If the puck is too soft, pressure remains low and oil extraction is inefficient. If the puck is too hard, it won't flow and the machine jams. The operator must find the narrow zone between these extremes where pressure is as high as reasonably possible without jamming the press head. The settings and conditions at which a press functions effectively differ widely between machines, and between different seed types. Small adjustments can make a big difference. Troubleshooting is common, especially in the beginning.

Press Assembly

Refer to your owner's manual for instructions and a detailed diagram of your press.

There are a few things I would like to emphasize. Make sure the machine oil in the crankcase is food-grade. Many of these presses are used for biodiesel. It's okay if biodiesel has a trace of machine oil in it, but you don't want this in anyone's food. Also, make sure you coat the threaded parts with a generous amount of non-polymerizing food-grade lubricant as they are assembled. Tighten the parts, but do not pound or overtighten them, which can make it difficult to disassemble the machine.

There is some additional paraphernalia you will need to run the press. A **nozzle changing tool** is composed of two parts, and comes with the press. A small **steel pick** is good for removing bits of press cake from the nozzle area when you change output nozzles, and for cleaning the machine after disassembly (especially for popping the long slivers of press cake out of the barrel grooves). An **agitator stick** is a clean piece of soft wood used to break up bridges in the hopper, or push milled nuts down into the screw in moments where it is not feeding well. You will need a **tub** or **box** for the press cake falling out of the end of the head. The **oil pan** comes with the press. The oil will drip mostly out of the last row of holes in the sieve. Make sure to place your pan accordingly. A **tub** or **bucket** for oil collection (larger container into which the pan drips) should be made of food-grade material, and have a lid available.

After each pressing session, the threaded parts should be disassembled and washed. Even though you lubed it with non-polymerizing machine oil to start, pressure during operation will force hickory oil into some of the threads. To prevent build-up of partially polymerized oil, which can lead to sticking parts later, thoroughly clean these parts with hot, soapy water, wiping the threads with a cloth to remove oil residue. I spray water forcefully into the sieve holes, sometimes reaming them with a small pick, to clean out the press cake.

Press Settings for the KK20/40

I purchased my first press after just a brief demonstration at the dealer. There were no pre-existing guidelines for pressing hickory nuts. Hickory nuts with the shells included are especially difficult to press. The percentage of woody material is higher than is ideal, making the machine more likely to jam, and more prone to generating heat by friction. After many hours of intermittent frustration and occasional jams, some of which resulted in damaged press parts needing replacement, I have settled upon press settings and procedures that reliably achieve good oil extraction and smooth press operation with yellowbud hickory nuts. These I share below.

Screw type: Standard

Speed: 27 RPM to start (maximum 34, minimum 19)

Pre-heat: Press head should be about 125°F, sieve 115°F.

Puck thickness (gap): 2–15 mm (see notes below)

Output nozzle: None to start, down to 10 mm in operation, if necessary

With expeller pressing in general, increased screw speed is usually accompanied by a slight decrease in oil extraction efficiency, ranging to about 5% loss in some scenarios. I don't have the data to give estimates for pressing hickory nuts, but there does seem to be some loss of efficiency at higher speeds. This loss of extraction efficiency must be weighed against the increased labor efficiency of faster press rates. Within the range of speed given here the decrease in press efficiency is likely to be almost negligible. When everything is running smoothly, I sometimes speed up the press in small increments. Conversely, if I am running multiple press heads, and I'm having trouble keeping them fed, I slow them down, congratulating myself on the tiny increase in efficiency that I'm probably achieving. The main reason I slow the press down, however, is when it is generating too much friction. This most often happens with nuts that are dried slightly below optimum moisture levels.

KK20 press in operation. Photo by Jesse Marksohn.

I have used the "standard" screw for most of my pressing. I have also used the "screw for oil-rich seeds" and the accompanying high-oil sieve/barrel, but found this setup less effective. The instructions here refer to the standard screw. There is also a "hard seed screw" and accompanying sieve/barrel. I have not used this configuration, but it might allow pressing of shagbark nuts with the full shell volume included, and it might reduce trouble with yellowbud nuts. (The names of the screws cause confusion, since the standard screw is "for soft seeds" but "oil-rich seeds" are softer still, so the "standard screw for soft seeds" is for harder seeds than the oil-rich seeds, while the "hard-seed screw" is for low-oil seeds, not necessarily harder seeds.)

The press comes with a heating collar matching the diameter of the sieve. Before pressing, I slide this on and preheat the press head to about 125°F, and the sieve to about 115°F. These precise temperatures are not vital—preheating is important, but inexact and not always essential. I go mostly by feel: I should be able to comfortably keep my hand on the press head for 1–2 seconds, but not 5. After pressing begins, the heating collar should be turned off and removed; the running press will generate its own heat through friction.

Producers have pressed successfully with puck thicknesses (the distance between the end of the screw and the breaker, referred to in the manual as the "gap") ranging from 2–16 millimeters. (Follow the manual's instructions for determining gap width.) I have done most of my pressing with a gap of 14–15 millimeters, but Levi Geyer has done most of his at 2 millimeters. I'm not sure why we have achieved such similar results with great variation in this variable. I weakly recommend starting with a gap of 3 millimeters.

In the beginning of pressing, the output hole should be "open"—that is, there should not be a nozzle screwed into its end. This is unusual, and again, it is necessary due to the woody nature of hickory nuts with the shells included. Sometimes the press is run open for the entire session, but usually, once it is running smoothly, output nozzles are installed. The press can sometimes be started with a large nozzle installed, but I recommend waiting to do this until you have more experience running the machine.

Startup

Close the gate on the hopper, and initially put just a small amount of milled nuts (mash) in it, perhaps half a gallon. If you have problems, they are most likely to occur at startup, and it's difficult to empty a full hopper. Turn on the press, then open the gate. It will take a couple minutes to fill the screw and have pressure build. The first oil will drip out the end of the press head through the exit hole rather than through the sieve. Hold a clean cup to catch this oil, which you can feed back into the mash later. It will take a few seconds for the puck to form, and for pressure to build behind it. After this happens, the exiting press cake will be dry, and oil will begin dripping out of the sieve and into the oil collection pan.

If, after 3–4 minutes, no oil has dripped out, and the press cake is not exiting the bung, something is wrong. It could be:

- The nuts are milled too finely and are so fluffy that pressure is not building up.

- The nut pieces are too large to fall into the screw's grooves, and thus are not feeding into the press head.
- The milled nuts are too cold. They should be at room temperature, not refrigerated.
- The press head is too cold or too hot.
- You forgot to open the hopper, or milled nuts are not running through the mouth of the hopper for some reason. Agitate the nuts, or push them into the screw threads with a softwood agitator stick.
- Your batch of nuts had too many empties, so the shell ratio is too high.
- Your nuts were some other species or hybrid, and the shell ratio is too high.
- Your press was set up incorrectly.

You may have to stop and take the press apart to diagnose the problem. If the head is smoking or steaming or any part is screeching, stop the motor and take the press head apart immediately.

But let's pretend that the machine runs smoothly for a few minutes, with press cake exiting the bung, and oil dripping from the sieve. If the press cake sticks together for a few inches before breaking off and falling, you probably have a good puck. The oil dripping into the pan should be almost, but not quite, a continuous stream. It will often pulse a little due to the alternating pattern of metal and mash in the screw. Run the machine like this for a while, and celebrate with high fives: You are pressing!

As the machine runs, things tend to get smoother and smoother, literally. The press cake burnishes and polishes the inner parts of the machine, and scrapes off any film of old polymerized oil from previous pressings. Eventually, as smooth operation causes the pressure to be reduced, the puck may get loose, and the exiting press cake may crumble immediately without sticking together. The amount of dripping oil may decrease. Now you have to stop celebrating and do something.

It is time to put in an output nozzle to constrict the flow of press cake, to increase the pressure behind the puck. Start with the largest output nozzle, 16 millimeters. Shut off the machine, clean out the exit bung with a metal pick, screw in the output nozzle, and restart the machine—all of this as fast as you can—and then pray that it doesn't jam. If all goes well, after 10–20 seconds the press cake will begin to flow out of the bung, this time cohering in a solid mass. Now you are "up and running."

However, if no press cake comes out within about 20 seconds, turn the machine off, unscrew the output nozzle, and turn the machine back on, letting it run with no output nozzle. If you wait too long to turn the machine off, it may jam (meaning the press cake in the puck has become too hardened to flow out of the press head). A jam requires disassembling the press head and removing all of the hardened material inside it.

Running the Press

The press needs little tending once it is running smoothly, but being present is important, so that one can notice changes in sound that might indicate problems. While the press is running, one can perform tasks like sorting, milling, filtering, bottling, and cleaning—but every few minutes you should check the press for:

Overheating. Overheating, caused by excessive friction, is indicated by smoking or steaming at the end, hissing or screeching, or darkening of the press cake. This is more likely with excessively dry nuts, or batches with a high shell percentage. Carefully feel the press head or find its temperature. Overheating is remedied mostly by slowing down the rotation of the screw, changing to a larger output nozzle, or running nuts with a higher kernel percentage. I sometimes wipe the outer part of the press head with a wet cloth to cool it down as I make these changes.

Press cake quality. If there is oil on the surface of the press cake, you may want to slow the press a little bit, reducing the temperature and giving the oil more time to move through the sieve. If the cake becomes soft and crumbly, you may want to go to a smaller output nozzle. I recommend changing nozzles in increments of 1 millimeter—don't skip nozzles until you are experienced enough to know when it is appropriate to do so.

Hopper fill and flow. Make sure there is mash in the hopper, and that it is moving steadily into the screw.

Agitation and Bridging

These presses are designed for material such as canola seed, which consists of many small, dense units, each of similar size and shape, with a smooth surface. Such seeds move past each other readily, and therefore flow smoothly from the hopper into the opening to the press screw. Milled hickory nuts are not like this—they are much lighter, and they are heterogenous in size, shape, and density. This material does not flow smoothly and often forms “bridges” in the hopper. A bridge occurs when material falls into the screw, but the pile above the fallen material does not collapse, resulting in an invisible air pocket in the hopper, which stops the flow of material into the press. This slows down the work, but more importantly, when pressurized and heated press cake remains in the puck for too long with no flowing material to push it through, it will harden to the point where it will no longer flow when new material starts pushing against it. Thus, if a bridge is undetected for several minutes, it can result in a jam.

To prevent bridges, the milled nuts need to be agitated every few minutes. That is, they need to be stirred or disturbed by an object causing the material to fall into the air gaps, thereby maintaining a continuous flow through the screw. The Kern Kraft presses do not come with a built-in agitator. Producers will want to rig up some apparatus to slowly stir the material in the hopper to prevent bridging. Until you have an agitator set up, you will need to manually agitate the hopper every 2–3 minutes while pressing. I have done this for years with a wooden stick, made of soft wood thin enough to not cause the press to jam if it accidentally falls or becomes caught in the screw.

Dealing with Jams

When heated, unsaturated fatty acids polymerize, turning to plastic. Pressure speeds up this process and often results in longer-chain polymers. This means that an expeller press head is a good place for polymerization to happen. Mechanical compression of the material in the press, combined with polymerization, can cause the material to harden to the point that it can no longer flow out of the expeller. This is a jam. Jams are bad. They can take a long time to get out of, and they might damage your press, your tools, your morale, and your fingers.

Most jams occur during one of the following scenarios:

- Changing to a smaller output nozzle
- The hopper running empty
- An undetected bridge
- Trying to run material that is too woody (too much shell, not enough kernel)

Jams can be identified by the refusal of the press cake to exit the machine even when the screw is turning and full of material. This is often accompanied by smoke, steam, hissing, or screeching in the press head. The motor may make a labored sound, and under extreme stress, it might shut off on its own. When you know you have a jam, turn the machine off immediately. Running the press longer makes the jam worse.

If you have an output nozzle installed, remove it *quickly*, then turn the press back on. If you are lucky, the cake will begin slowly exiting the bung. Watch to see that it speeds up and normalizes. If you are lucky enough to solve the jam by just removing the output nozzle, the press cake will slowly speed up, then run very rapidly for a time, followed by another slowing (but not full stoppage) before the pressure and speed normalize. That was a "little jam."

If you have no output nozzle screwed in, or you remove the output nozzle and there is still no movement, or faint movement begins and then slows to a complete halt, you have a full-blown jam. A "big jam." This is the dread of every oil expresser.

Close the hopper gate and begin disassembling the press immediately—waiting increases polymerization, which causes the parts to bond together. No matter what, the jammed press parts will take a lot of force to unthread. Start with the outermost part, the threaded breaker assembly. Use a wooden mallet to pound the press wrench, but be very careful. Make sure you are pounding in the right direction. Once the cutter piece is removed and the puck is visible, turn the machine back on. Hopefully it will push the puck out. You may have to break the puck with a tool to get it out. Once the puck is out, run out all the semi-hard material in the screw, until the stuff coming through is normal, uncompressed nut mash. Then reassemble the press and start up again.

If you absolutely cannot get the breaker receiver bolt (or breaker assembly) off, then you have a "really bad jam." You will be tempted to kick things, curse, and quit. Do not. If you leave those parts together, under this much pressure, they will bind, and might never come apart. Try to remove the cover nut. Make sure all the face bolts holding the press head onto the body of the machine are snug. Apply the wrenches and pound *carefully*. It will be hard. Make sure you are going the right direction—the threads *do not all disassemble counterclockwise*! You might need help. You might need additional tools, like pipe wrenches or an air hammer.

At this point, you are on your own. You will understand why a jam is so dreadful. I have a small pile of broken press parts attesting to the worst of them.

Filtering

15–20% of the oily mixture that runs out of the sieve will consist of solid particulate. This includes everything from granular bits of shell to super-fine clay-like fragments of kernel. This particulate needs to be separated from the oil through filtering or decanting. I have used several different processes and am not fully satisfied with any of them.

When I began pressing, I let the particulate settle at room temperature for a week or so and then decanted the clear oil off the top. Leaving it at room temperature this long caused the oil to lose quality—while rancidity was not evident in the flavor, there was a notable loss of "freshness" and aroma, and a change of color. The settled layer clearly contained a lot of good oil, but I didn't want to leave it settling at room temperature for longer.

After a couple years I purchased a small vertically-oriented pressurized cylinder filter from Kern Kraft, to speed up the filtering process. The oil is filtered through this with compressed air and the aid of diatomaceous earth. (Diatomaceous earth is derived from the fossilized remains of diatom shells. It is whisked into unfiltered oil to prevent the finest particles from clogging the filter and preventing oil flow.) This cylindrical filter was too slow to keep up with my oil production, and it was laborious to clean and disassemble with every small batch. I had to put tubs of oil in the cooler to wait for their turn in the filter, and during this waiting, ended up separating most of the oil by settling and decanting anyway.

After looking at larger filter presses from Kern Kraft, I noticed that they were mechanically almost identical to the filter presses manufactured for maple syrup production, but were 3–4 times as expensive per unit of filtering capacity. So I purchased a maple syrup filter press and used it for filtering hickory oil. I had to adjust the batch size and my expectations of speed, since maple syrup is filtered while hot (and I did not want to expose the oil to any unnecessary heat), and because maple syrup has a much lower percentage of particulate than hickory oil. The maple filter press is much faster than the pressurized cylinder filter. But it is very difficult to clean. This is very important because traces of rancid oil in the hosing or other filter parts can catalyze rancidification of oil in the filter, leading to rapid deterioration in flavor quality.

I have now moved back to settling the particulate and decanting the clear oil off the top. I do this in large Cambro clear plastic tubs in a refrigerator or cooler. I let the oil settle for 3–5 weeks before decanting, sometimes longer. The loss of quality during this time frame at 36–38°F is negligible. The biggest downside to this is the time required between pressing and bottling, and the large cooler area required to settle a large quantity of oil. But the better oil quality, the elimination of the expensive filter press, and the decrease in labor cost of filtering more than make up for these downsides, in my operation.

It is claimed by equipment suppliers that a pressure filter will yield about 10% more oil than settling and decanting. This seems like a reasonable ballpark estimate for hickory oil. There is obviously a lot of oil trapped in the sediment. My plan is to purchase a bladder press that is manufactured for pressing olive or avocado pulp, to extract as much oil as possible from the sediment after the clear oil above has been decanted. Hopefully this combination will achieve or exceed the extraction efficiency of a filter press, while avoiding the quality loss and painstaking operation of a filter press.

One might reasonably ask why I've had trouble filtering hickory oil. Perhaps it is due to my limited skills and competence with the filtering equipment. Or perhaps hickory oil has an unusually large amount of particulate, or particulate that is especially fine, or has other difficult physical properties. This remains to be answered.

An additional filtration option is a centrifuge. Levi Geyer uses a stainless steel bowl centrifuge from Algae Centrifuge, a company in California. He reports, "The oil flows directly from the press into the centrifuge. That speed is about right—the slower the fluid flows into the centrifuge, the better it is cleaned. The oil flowing out of the centrifuge is not completely 'clean'—meaning it still has some particulate in it—but it is pretty much completely without bitterness. I like the flavor of this oil better, and so did the chef I gave samples to. For customers last year, I settled the oil after centrifuging, so what they got was completely clear. I saved back the 'cloudy' looking oil and used it for all my cooking. This year I might just bottle the oil directly as it exits the centrifuge, and tell customers the cloudiness is a sign of the raw, unfiltered nature of the oil. The fine particles in the cloudy bottled oil will settle to the bottom before sale, so I might tell customers to 'shake for flavor, leave it settled for cooking'—since I believe the cloudiness reduces the smoke point, and cooking removes most of the flavor anyway."

Hickory Butter as a Potential Byproduct from Settling

When a single batch of hickory oil settles slowly in a tub or bucket, the sediment forms layers according to the fineness of the particles. The ultra-fine upper layer, perhaps a third of the sediment, contains little tannin, and is only slightly bitter, like tahini. (My hypothesis is that the particles are too small to contain tannin vacuoles.) This fine material can be scraped off with a spoon or spatula and used as a nut butter. (These are the same ultra-fine particles that go through Levi's centrifuge filter.) It has a nice nutty flavor and combines very well with sweeteners and fruits in dessert applications. This hickory butter is a delicious byproduct that is discarded with pressure-filtered oil. A similar layer forms when settling shagbark oil, and interestingly, its bitterness level is almost the same as that of the yellowbud.

The Press Cake

I have given tours or demonstrations of hickory oil pressing to hundreds of people, and most people who observe the process are far more interested in the press cake exiting the machine than in the oil dripping out of the sieve. After a few cursory questions about the oil, the conversation inevitably progresses to the press cake, and usually stays there, punctuated with exclamations like, "There's got to be some use for this stuff!" People usually express these declarations while fondling a piece of press cake in wide-eyed reverie of its endless possibilities. And I must admit, the press cake looks pretty neat.

I assure these people that it's not good for animal feed. It has too much tannin, and too few digestible calories, to be of nutritive value. And the animals figure that out—they may be interested at first by the smell, and eat a small amount, but they soon reject it. It is not good for burning in a pellet stove either. I offer people a bag or bucket of the stuff for whatever purpose they see fit. Only one person, a hide tanner, has asked for more. I have years of press cake composting in a pile in my orchard, hoping that someday it will break down into something that I would want to use for mulch or as a soil additive. If you find a better use for the stuff, please share it.

Some people have tried the press cake for smoking meat; reviews have been mixed. There seems like a potential market here for the press cake as a byproduct, if we can find avid or well-known meat smokers to use and recommend it.

Bottling Oil

Because oil excludes water, it is not hospitable to the growth of bacteria, molds, and other spoilage microorganisms. This makes pure oil one of the safest foods to store and package. Heating and hermetic sealing are not required; oil is generally bottled at room temperature. For very small batches, I just pour the oil from a pitcher into the bottles. For larger batches I use a stainless steel pan (manufactured for bottling maple syrup) with a valve at the base. The caps are screwed on tight by hand. I apply heat-shrunk, tamper-evident seals when the oil is being sold wholesale.

I sell hickory nut oil in 5-ounce, 16-ounce, and 32-ounce clear glass bottles. The oil keeps better in darker glass because it excludes more light, but I like to let customers see the natural color of the oil. However, I may switch bottles in the future. Your choice of packaging should be tailored to the customer base that you envision serving. Most new customers, and those purchasing for gifts, buy 5-ounce bottles. Repeat customers almost always buy the larger sizes. I have grown to dislike the 5-ounce bottles, personally, because they seem to send the message, "Use this sparingly, it's precious and expensive." If people use tiny amounts they don't get to actually notice the oil's exquisite flavor, and they are less likely to become fond of it. I like the message of the larger bottles, which say, "Hickories are generous—pour it on!"

Apply the labels before filling the bottles. Traces of oil that get on the bottle surface during filling can interfere with label adhesion.

The Composition of Yellowbud Hickory Nut Oil

Stone et al (1969) performed a detailed analysis of the fatty acid composition of most species of hickory nut oil. Ripe nuts from multiple trees in different growing conditions were collected and frozen to remain fresh until sampling. The average fatty acid composition from 14 samples of yellowbud hickory (*Carya cordiformis*) were as follows:

Palmitic: 8.77%

Stearic: 2.77%

Oleic: 72.75%

Linoleic: 13.52%

Linolenic: 2.09%

Yellowbud oil was about 11.5% saturated fatty acids (palmitic and stearic), and 88.5% unsaturated. It was the second highest of all hickories tested in oleic acid (pecan was slightly higher). An average of five Shagbark (*Carya ovata*) samples showed 57.72% oleic acid and 29.16% linoleic acid. This profile suggests poorer keeping qualities for shagbark oil, since linoleic acid is more prone to oxidation than oleic acid. However, the fatty acid ratios in the samples for all hickory species were quite variable. The results also show that the fatty acid profile of yellowbud hickory oil is very similar to that of olive oil—useful knowledge in helping consumers accept it.

Fatty acid testing of two yellowbud samples provided by Alex Tanke and performed by Peyton Higgins (2025) at the University of Wisconsin generally corroborated the findings of Stone et al, showing: 12.2% and 13.1% saturated fatty acids (presumably mostly palmitic and stearic); 69.8% and 68.8% oleic acid; 14.3% and 11.7% linoleic acid; 3.7% and 6.4% linolenic acid. (That last linolenic value is believed to be slightly exaggerated by the testing protocol, bringing total values even closer to Stone's average.)

Rancidity and Storage

While oils don't spoil via putrefaction in the same way most foods, they do go rancid. Rancidification is the breakdown of the double bonds in lipids (fatty acids) due to oxidation, resulting in an unpleasant set of flavors known as rancidity. Unsaturated fatty acids are more susceptible to oxidation than saturated fatty acids. The compounds formed from oxidation of fatty acids include hydrocarbons, alcohols, furans, aldehydes, ketones, and various acids (Min and Bof, 2002). As rancidification progresses, the oil eventually becomes unfit for consumption.

Rancidification occurs naturally within oils, and the oxidation is thus called *autoxidation*, but many factors affect the rate of this process. Increasing light, temperature, oxygen exposure, and the presence of metal ions all tend to increase the rate of oxidation; while a decrease in any of these factors, or the presence of antioxidants, tends to decrease oxidation and slow rancidity (Min and Bof, 2002). Rancidity catalyzes further oxidation (Shahidid and Wanasundara, 2002), which is why cleaning equipment between batches, and not mixing older batches with new ones to dilute rancid flavors, is important.

The free oxygen (not bonded to the lipid molecules) in an oil is mostly in the form of triplet oxygen, which despite the name, is a stable form of $O2$ (two bonded oxygen molecules). However, light energy can energize an O2 molecule by altering the electron spin pattern, turning it to *singlet oxygen*, which is much more reactive than triplet oxygen. This energized singlet oxygen reacts with the unsaturated bonds in unsaturated fatty acids, causing degradation of the fatty acid—in other words, rancidification. This process occurs more rapidly at higher temperatures. Metal ions in oils can also catalyze oxidation.

Free radicals are reactive molecules with one or more free electrons in their outer shell. They can be created by oxidation in oils, and their formation is accelerated when oils are heated. Antioxidants slow down the rate of oxidation by "capturing" singlet oxygen and free radicals. Tocopherol, found in many oily seeds, acts as a powerful oil-soluble antioxidant, and this is why it is often added to oils as a stabilizer. Other antioxidants are found naturally in oils.

Most vegetable oil on the market is solvent-extracted. Solvent extraction renders nearly pure fatty acids, leaving behind a number of oil-soluble compounds which might accelerate oxidation. This makes solvent-extracted oils more shelf-stable, but it also removes flavors, aromas, colorants, and mineral micronutrients—all things that consumers of fresh oil want. These cheap oils also may be stabilized with the addition of tocopherol, and through "bleaching," a process to remove impurities that might accelerate rancidity. This is *refining* of vegetable oils. These refined oils have a longer shelf life at room temperature, but they are nearly flavorless, and lack the full nutritional profile of fresh, unrefined oil.

For more detailed information on oxidation, rancidity, antioxidants, and refining, see Min and Boff (2002) and Shahidid and Wanasundara (2002). These are the primary sources for much of the info summarized here.

Hickory producers are probably not going to use solvent extraction, refining, or stabilizing additives in the near future. This leaves us with three ways to halt oxidation (rancidity): Keep the oil from heat, light, and oxygen.

After decanting or filtering my hickory oil, I store it either in a freezer or refrigerator. Freezing does not harm the oil, and completely arrests oxidation. Then, when it is time to bottle the oil, I thaw it until all the fatty acids have liquified, mix it with a whisk, and bottle it. The caps should be airtight, to prevent unnecessary oxygen exchange. I store the filled bottles in a refrigerator or freezer, depending on how soon I anticipate using or selling the oil. If refrigerated for a long period, they should be in a box or otherwise kept out of the light.

I have detailed this information on rancidity and oxidation not only so that hickory oil producers can keep our product fresh, but also so that we are able to communicate effectively with our customers and potential customers about the differences between fresh, unrefined oils such as the hickory nut oil we sell refrigerated, and the refined vegetable oils that dominate the market and are sold at room temperature. It is important that we advise customers to refrigerate their hickory nut oil so that it has the best flavor when consumed.

We and our customers should be proud and excited that our oil needs refrigeration—this means that it is fresh and unrefined, and contains all the micronutrients, flavors, and phytochemicals that it was meant to have!

Smoke Point

Customers often ask about the smoke point of yellowbud hickory oil. I am not aware of any formal testing for this property. However, pecan oil is frequently listed as having a high smoke point of 470°F, making it among the better high-heat frying oils. In my experience frying with pecan and yellowbud hickory oils, I find that the two behave similarly, and I tell customers that I consider the yellowbud oil a good high-heat frying oil. Chinese hickory oil is reported to have a lower smoke point (400–450°F)—although this would still qualify it as a high-heat oil. However, the fatty acid profile of yellowbud hickory oil is much closer to that of pecan than to Chinese hickory, which is about 63% linoleic acid and only about 16% oleic acid (Zhang et al, 2016). Also note that particulate matter suspended in unrefined high-heat oils may smoke at a lower temperature than the oil itself.

Cold Pressing

You will be asked by many customers if your hickory nut oil is "cold-pressed," because many people believe that cold-pressed oils have better nutrition and flavor. However, this term does not have a universally or even widely accepted definition outside of olive-oil production. In the EU, olive oil is allowed to be labeled "first cold pressing" when extracted with a hydraulic stamp press at temperatures below 27°C (81°F). It can be labeled "cold-extraction" if produced with a centrifuge at temperatures below 27°C. Expeller pressing isn't mentioned, because it isn't used for olive oil.

There are a variety of opinions about what "cold-pressed" means in relation to oils other than olive; there is no official or legal definition in the United States. Some claim that cold-pressed means that the oil is pressed at "room temperature," while others insist that the temperature threshold to qualify is 81°F, or 104°F. Other sources extend the threshold to 120°F, 122°F, 125°F, or 140°F. Some say that any time that no heat is added during the pressing to aid extraction, it is cold-pressed. Expeller presses generate considerable heat through friction, and sometimes need supplemental heat. (However, it is the post-pressing cake, not the oil or pre-press material, that is heated). There are some in the industry claiming that expeller pressed oils, by definition, are not cold pressed; while others claim that expeller pressed oils are, by definition, cold pressed. It's a free-for-all—everyone is trying to claim they have the best, coldest-pressed oil they possibly can using the extraction technology they employ.

I think it is reasonable to designate expeller-pressed hickory oil as "cold-pressed," and I answer yes when asked. But I try to be honest and clear with customers, so I like to elaborate by emphasizing the following facts:

- There is no universal definition of cold-pressed oils.
- The term "cold-pressed" is a holdover from the olive oil industry which uses different technology that is not applicable to hickory nuts.
- Unlike olive oil, hickory oil cannot be effectively extracted at low pressure, and therefore is not expressed at room temperature.
- The hickory nut mash is not heated for expeller pressing.
- Friction in the expeller press generates heat, which raises the oil temperature to 115–125°F, but only for 3–8 seconds.
- This is hotter than the pressing temperature for olive oil, but much cooler than the temperature used for solvent extraction of large-scale commercial vegetable oils.
- The oil begins cooling instantly when it drips out of the sieve, and reaches room temperature within minutes. There is very little time for heat-induced degradation.

Producers should note that the temperature of the press head while running is hotter than the temperature of the actual oil as it drips out. Friction and heat increase from the puck to the output nozzle; oil drips out before this point. Because the oil is transient and pulsates on the surface of the sieve, accurate measurement of its peak temperature is virtually impossible.

Labeling

Laws require clear labeling of your product that accurately conveys certain information to the consumer. Before designing a label, read and understand the relevant statutes, which should be provided by your governmental food-safety agency.

It is important to label our oil "hickory nut oil" rather than just "hickory oil." Many consumers, especially outside the natural distribution of hickory nuts, tend to think of "hickory" as a flavoring agent, as in hickory-smoked ham, or "hickory syrup," which is a sugar syrup flavored with hickory bark. Since many flavored or infused oils are sold, it is only natural that some consumers will assume that "hickory oil" is some sort of cheap mainstream vegetable oil infused with hickory flavoring.

Furthermore, leaving "nut" out of the product name may confuse consumers who have nut allergies. These consumers can consume hickory-smoked meats or hickory syrup with no problem. It is important to convey to potential buyers that the oil is derived from hickory nuts. Note, however, that it is NOT required to put "contains hickory nuts" or "contains tree nuts (hickory)," or any such wording on the ingredient list, if the label already contains the product name "hickory nut oil." (Also note that, although hickory nuts were recently removed from the FDA's list of allergens requiring specific warning, they could be added back to the list in the future.)

The nutritional information required on hickory nut oil labels is simple; feel free to copy the label above.

Food Safety Inspection and Workspaces

Because regulations vary from state to state, the information in this section is general. Producers should check with the relevant local authorities to determine the licensing requirements and production regulations in your specific circumstance.

The greatest expense that one will face in setting up to press hickory oil will probably not be the equipment, but the real estate. Depending on your state, producers may be able to take advantage of a "cottage food law" that allows the sale of a limited dollar value of certain food items, or which allows the sale of certain food items directly to consumers, without being produced in a licensed and inspected facility. Because oil is free of water and does not spoil, it may be included under laws that allow the sale of relatively safe food products, such as jams, jellies, pickles, honey, and maple syrup produced at home or on the farm in an unlicensed kitchen. However, since there is very little tradition of small-scale oil production in the United States, oil may have been overlooked on such lists of exempted foods. (This is a problem that organized hickory oil producers may be able to remedy in the long-term.) Even if small-scale production is allowed without inspection in your area, most producers will eventually want to get licensed.

The purpose of the certifying state or local agency is to ensure that the food sold is safe for consumers. Since that is your goal as well, the inspection process should not be seen as a burden. It should be seen as an opportunity to verify, personally and publicly, that we are accomplishing that goal. I see the health inspectors as allies in my attempt to legitimize hickory nut oil as a food product. I welcome them to my shop, give them an enthusiastic tour, and encourage their input. I want to be their favorite inspection of the year.

I want to build up good will in case there is any disagreement down the line. The food code is full of gray areas. The more the inspectors like and trust you, the more likely they are to interpret rules in your favor. This is not a formula for "getting away with things." It's about establishing and maintaining a good working relationship with important allies.

Here's a relevant example: The rules for storing and handling a raw agricultural product differ from those applying to a "processed" food product. The gray area is whether or not the removal of hickory nut husks is "food processing" or a "field operation." Regulations do not make this designation clear. It is in our interest that it be considered a field operation, so that dehusking is not subject to licensing, and can take place anywhere, and be performed by anyone. A grower or harvester should be able to dehusk nuts before delivery to a pressing facility. This speeds up the drying process and reduces delivery costs. For this reason, I do my nut husking in a separate building or outside, and do not store the machine in the licensed production area. My inspector approved of this arrangement. If I was in some other state, dealing with some other inspector, I would make my case something like this:

Hickory nut producers consider husk removal a field operation, as is the case with pecans and walnuts. Some harvesters remove the husks in the field by hand, especially on hybrid trees where they fall off readily. Husk removal with hickory nuts is the equivalent of grain separation in a combine. With corn, soybeans, wheat, oats, and other common crops this is a field operation performed by a machine that is not inspected or licensed by the food safety department. Hammon's (a long-established company processing wild black walnuts) performs similar husk removal at buying stations far removed from the processing plant.

The inspectors are just trying to do their jobs. Help them. Learn the food safety regulations and show them how you are complying. Follow the rules and keep things clean. The inspectors may not have dealt with oil manufacturing before; they may be uncertain or confused. Be the expert who helps them through it. Show them that you have thought through your decisions carefully and reasonably, with food safety in the forefront of your mind. They are likely to agree with you. If not, stay calm and reasonable and ask what accommodations they need.

The inspector is going to look mostly at the configuration of your building and work space. You will need a three-compartment dishwashing sink, and a separate handwashing sink in the production area (in addition to the one in the bathroom). You will need a mop sink and floors that hold up to daily mopping. You will need washable, non-porous work surfaces, walls, and ceilings. You will need good lighting, and the space should be free of pests.

They are also going to look at your processing equipment and your food storage areas. Keep everything clean. They will want to see you actually processing food; do it in a cleanly way. Keep careful production records; they will want to see those. At almost every inspection you will be told to improve some minor thing. Compliance usually won't be a big deal. Occasionally you may encounter an inspector who is being unreasonable. If you honestly feel this is the case, go to their supervisor—not to complain about the inspector, but to ask for clarity about how to achieve compliance. If your inspector is not being reasonable, the supervisor is likely to give you a more achievable route to compliance.

A final concern, specific to hickory oil, is that your refrigeration or freezing of the oil might trigger a concern with a health inspector that the product is susceptible to spoilage. Remind them that, in food safety parlance, oil has "no water-activity." It has no free water available for spoilage microorganisms. Remind them that vegetable oils are customarily stored and sold at room temperature. The purpose of refrigeration is not to prevent spoilage, it is to maintain the color, flavor, and aroma of fresh-pressed oil—the one advantage that you, as a small producer, have over the large manufacturers.

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