An automated stripping concept has been under development and evaluation in the Department of Biosystems and Agricultural Engineering at the University of Kentucky for several years. A very high capacity mechanical stripping system has been developed that segments the tobacco plant into sections of stalk with leaf attached (for each grade), and then separates the leaf pieces from the stalk pieces (Day et al., 2012). This system has been field tested for the past three or four seasons for efficiency and industry acceptance. Given the expected costs and complexity of the machine, this concept would likely involve growers bringing bulked tobacco to a central location for custom stripping.

The changeover to big bale packaging for burley production and the accompanying opportunity for putting non-oriented leaf into the bales, led to an initial flurry of interest in various stripping aids that moved the stalks past the workers allowing them to use both hands to more rapidly remove the leaves. Such aids include the stripping wheel and various types of straight-line conveyors. Of these stripping aids, the dual chain conveyor, which moves sticks of tobacco hanging vertically downward past the workers, has gained widespread use, especially in dark tobacco. In one study, the dual chain conveyor had a reported labor productivity of 57-pound per worker-hr for 10.8 workers, meaning an overall capacity of over 600 pounds per hour, quite high for a relatively simple and inexpensive mechanism (Wilhoit and Duncan, 2013). As the size of tobacco operations has increased since the end of the federal quota system, timeliness in getting a crop processed has become more important, meaning high capacity may be a more critical factor for producers than actual labor efficiency when it comes to mechanization innovations.

Interest in these stripping aids seems to have leveled off as growers have tried different ways of incorporating big balers into their stripping system to improve labor efficiency. Some of the things growers are doing include pulling wagonloads of tobacco directly into large stripping rooms, taking portable balers to the barns and stripping on wagons in the barn driveway, using various multi-chambered balers that have become available, powering two balers off a single hydraulic power source, and even stripping directly into the balers. Some growers consider stripping aids to fit well into their systems, while others feel that they are obtaining good efficiency with the setup they are using for organizing the workers and relaying the tobacco stalks.

There continues to be interest in using stalk choppers with the larger-scale stripping operations that are becoming more common. Many farmers have converted forage choppers, powering them electrically, to make tobacco stalk choppers. Several units of a purpose-built tobacco stalk chopper developed in the Department of Biosystems and Agricultural Engineering at the University of Kentucky have also been used on Kentucky farms in the last several years. Stalk choppers that incorporate conveyors, so that they are fed continuously as workers strip the tobacco, offer the best gains in efficiency for stripping operations. These systems eliminate the need for accumulating bare stalks and carrying them out of the stripping room and manually loading them on wagons or in manure spreaders. Labor requirements for spreading chopped stalks are considerably reduced compared to having to throw whole stalks off a wagon manually. Uniformity is much better than if whole stalks are spread with a manure spreader.

**References**


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**TSNAs in Burley and Dark Tobacco**

*Anne Jack, Lowell Bush, and Andy Bailey*

**What Are TSNAs?**

Nitrosamines are nitrogenous compounds, some of which are carcinogenic. They are found in a wide range of food and cosmetic products, as well as in tobacco. Tobacco-specific nitrosamines (TSNAs) are so called because they are formed only from tobacco alkaloids, and found only in tobacco leaves and in the particulate phase of tobacco smoke. With the current emphasis on the health risks of tobacco, TSNAs reduction has become a major issue for the tobacco industry.

Several TSNAs have been identified, but interest has focused on the four most important: NNK, NNN, NAT, and NAB. Of these, NNN is the most important in burley and dark tobacco.

**How Are TSNAs Formed?**

Negligible amounts of TSNAs are present in freshly harvested tobacco. They are mainly formed during curing, specifically during the late yellowing to early browning stage. Typically this occurs over a two-week period between the third and fifth week after harvest, but can be earlier or later depending on curing conditions.

TSNAs are formed by the nitrosation of tobacco alkaloids (addition of a nitrogen and an oxygen atom to the alkaloid molecule). NNN is formed by the nitrosation of the alkaloid nor nicotine. The nitrosating agent in air-cured tobacco is usually nitrite, derived from the reduction of leaf nitrate by the action of microbes during curing. In fire-cured tobacco, the nitrosating agents are both nitrite and any of several nitrogen...
oxides (NOx) formed during the fire-curing process. Both the alkaloid and the nitrosating agent are necessary for the formation of TSNAs. Any practices or conditions that increase the accumulation of either of these groups of compounds would be expected to increase TSNAs.

Factors Affecting TSNA Accumulation

Three main factors affect the amount of TSNA accumulation:

- The amount of specific alkaloid precursor. In the case of burley and dark tobaccos, this is nornicotine, and it is mainly determined by the amount of conversion of nicotine to nornicotine in the seedlot used. Screened or "LC" seed has been selected for low conversion, and we have shown that this results in significantly lower TSNAs.
- The amount of nitrosating agent. Nitrite is the main nitrosating agent for air-cured tobacco and is determined by the microbial populations reducing the leaf nitrate to nitrite. The microbial populations are affected by curing conditions, particularly during the first 35 days of curing. The amount of leaf nitrate, determined by available soil nitrogen, has little direct effect on the amount of leaf nitrite; any effect is probably indirect, through the effect of nitrate on the thickness and drying rate of the leaf. With the levels of nitrate found in the normal production range, the main effect of applied nitrogen fertilizer on TSNAs is through the effect on alkaloid level. During fire-curing, nitrogen oxides (NOx) are the nitrosating agent and are the result of combustion of wood during firing.
- The amount of total alkaloids/nicotine. The relative amount of nornicotine depends on conversion, and the absolute amount depends on the amount of nicotine originally present. The higher the nicotine, the higher the absolute amount of nornicotine (because there is more nicotine available to be converted to nornicotine), and consequently the higher the potential for TSNA accumulation. The amount of total alkaloid is determined partly by environmental conditions, such as rainfall, and partly by agronomic practices, such as fertilization, topping, maturity at harvest, etc.

If any of these factors (conversion, nitrosating agent, total alkaloids) are reduced, TSNAs are reduced (Figure 1).

Seed Screening

Reducing the amount of nornicotine precursor for NNN is the single most effective step in reducing TSNA accumulation. Figure 2 illustrates the difference in NNN between two varieties, a non-commercial high converter and a screened low converter.

There are very low inherent levels of nornicotine in the green plant; it is mainly formed by the conversion of nicotine to nornicotine during curing. The ability of plants to convert nicotine is under genetic control and most modern varieties have been selected for minimum conversion.

In the US, all the public varieties have been screened; i.e., the foundation seed was selected for low conversion, which is indicated by "LC" (low converter) in the variety name (for example, TN 90LC, KT 204LC). Many other varieties also have this designation. Some varieties do not have the LC designation, but "screened seed" is indicated on the seed pack. All seed of commercially viable varieties has now been screened, and there should be no unscreened seed sold in the domestic seed market.

Prior to universal seed screening, many seedlots had relatively high conversion, and consequently the potential for high TSNA formation. There has been a considerable reduction in TSNAs in recent years as a direct result of seed screening.

What the Grower Can Do

The most important step in TSNA reduction, the use of LC or screened seed, has been taken for U.S. tobacco growers. All seed on the domestic market is now screened, and all contracts with major tobacco companies now require the grower to use LC or screened seed.

Variety

To some extent, there seem to be inherent differences between some burley varieties in their potential to accumulate TSNAs, differences that are not explained by conversion levels. These differences are small, but they do appear to be real. For example, it appears that KT 204LC often has lower TSNA levels than some other varieties (Figure 3). We do not yet understand the mechanism for these varietal differences. Like all factors affecting TSNAs, these differences are not always apparent. They are dependent to a large extent on the environmental growing and curing conditions; differences are more likely to be apparent under conditions conducive to higher TSNA accumulation.

To date, no varietal differences in TSNA accumulation have been observed in dark tobacco varieties.
The total amount of applied nitrogen is the critical factor, regardless of whether it is all applied as a pretransplant application or is split between pretransplant and sidedressing. Sidedressing does not appear to cause a significant increase in TSNAs, as long as it is applied at the recommended time. Applying sidedress nitrogen later than six weeks after transplanting could increase TSNL levels under some conditions.

There is no clear link between nitrogen source and TSNAs. Fat stems can increase TSNAs by retaining moisture in the leaf stem. Fat stems can be caused by late uptake of nitrogen (late sidedressing or a dry period followed by rain shortly before harvest) and by the use of muriate of potash fertilizers.

While the amount of applied nitrogen is important, the most important factor is the amount of available nitrogen, which depends partly on the soil type. We have measured large differences in TSNA accumulation between growing locations, where higher TSNAs were associated with heavier, more fertile soil. It is necessary to exercise particular care when fertilizing these heavier soils.

What the Grower Can Do

Judicious fertilizer application is one of the more feasible steps a grower can take to reduce TSNAs.

- Apply no more nitrogen than is necessary for the crop. Apart from minimizing TSNAs, there are many other good reasons to avoid excessive nitrogen—not the least of which is cost. Excess nitrogen can also cause disease problems and contribute to groundwater pollution, and it does not increase yield.
- If sidedressing, apply nitrogen within four to five weeks after transplanting.
- Avoid spring applications of muriate fertilizers. If muriate fertilizers are used, they should be applied in the fall. Chloride also has an adverse effect on quality and causes the cured leaf to be more hygroscopic (moisture absorbing).
- Exercise particular care when fertilizing heavier soils.

Maturity at Harvest

Several studies have shown that TSNAs increase with increased maturity at harvest. Earlier studies used unscreened seed, and we know that conversion increases with increased maturity. Current results show a similar, but smaller, response with the low converter varieties now in use. The increase in TSNAs with increased maturity is due mainly to the higher alkaloids in later harvested tobacco; alkaloids increase steadily after topping.
**What the Grower Can Do**

Weather and availability of labor to cut the crop often limit the grower’s choice of harvest date, but to the extent possible, harvest at the maturity for best yield and quality.

- **Burley.** Typically the best compromise between yield and quality is approximately three and a half to four weeks after topping.
- **Dark air-cured.** Five to six weeks after topping—some early maturing varieties may require earlier harvest.
- **Dark fire-cured.** Six to seven weeks after topping—some early maturing varieties may require earlier harvest.

**Harvesting Practices**

Field-wilting longer than necessary can, under some conditions, increase TSNAs. Figure 5 shows the TSNA accumulation in burley tobacco field-wilted for three and six days. These increases are small and are not always apparent, but it is advisable not to field-wilt burley longer than three days, as this can have a detrimental effect not only on TSNA accumulation, but also on leaf quality.

**What the Grower Can Do**

Weather and availability of labor often dictate when the tobacco can be housed, but house burley tobacco as soon as possible, ideally within a few days of cutting.

**Air-Curing**

Growing season and curing environment play a very large role in TSNA accumulation. Figure 2 shows the effect of season on a high and a low converter variety. At this site, 2005 was a year very conducive to TSNA accumulation; 2004 was not. The more than tenfold difference between years was due solely to environmental differences, as the same seed and growing practices were used in both years. Note that the low converter variety in 2005 (when conditions were highly conducive) still had lower TSNAs than the high converter in 2004 (when conditions were very unfavorable for TSNA formation).

The main factors affecting air-curing in relation to TSNAs are temperature, relative humidity, and air movement.

- Higher temperatures increase TSNAs because biological and chemical reactions are faster at higher temperatures.
- Higher humidity increases TSNAs because it is favorable for the nitrite-producing microbes and the leaf remains alive and active longer during curing, allowing more conversion of nicotine to nornicotine. Thus, with the increased nitrite and nornicotine available, more TSNA is formed.
- Increased air movement decreases TSNAs mainly by increasing the drying rate of the leaf.

High humidity and high temperatures result in high TSNAs and often in house-burn. Low temperatures or low humidity result in low TSNAs but green or piebald tobacco. The conditions best for optimal quality (moderate temperatures and 72 to 75% relative humidity, i.e., a long, slow cure) are also favorable for TSNA accumulation. Under these conditions, TSNAs levels will be unacceptable if there is any appreciable amount of conversion. However, TSNAs will usually be acceptable if conversion is low and curing is well managed. Low converters can have significant amounts of TSNAs in conducive conditions if the curing is not properly managed (see Figure 2, low converter in 2005). The challenge is to produce quality tobacco with acceptable levels of TSNAs.

Tests have shown that TSNAs in outdoor burley curing structures are very similar to those in a conventional barn (Figure 6) if they are in the same vicinity and experience similar environmental conditions.

The location and orientation of a barn can have a considerable effect on TSNAs by affecting the amount of ventilation. There can be big differences in TSNAs between tobaccos cured in different barns. TSNAs will tend to be lower in exposed barns on ridges and higher in barns in protected hollows with limited air movement.

Various barn modifications have been tested, but none have yet resulted in a practical and economical system to consistently reduce TSNAs while producing quality tobacco.

**What the Grower Can Do**

Attention has focused on ventilation, because there is little that a grower can do to control ambient humidity and temperature during air-curing. However, ventilation can be manipulated to a limited extent if quality is to be maintained. Managing curing specifically for very low TSNAs will often result in poor quality tobacco, so the best curing management is a balance between enough humidity for good quality and enough ventilation to minimize TSNA formation. Take the following steps:

- Space plants evenly on sticks, and space sticks evenly on the rails.
• Avoid packing sticks too closely (actual stick spacing will vary with barn design and size of tobacco).
• Manage vents to ensure adequate but not excessive ventilation.

**Fire-Curing**

Fire-curing of dark tobacco involves the burning of hardwood slabs and sawdust on the floor of the barn during curing. Although fire-curing barns have bottom and top ventilators, they are typically much tighter than air-cured barns and most have metal siding. Many fire-cured barns are also equipped with fans in the top of the barn that can be used to increase ventilation early in the cure. Although differences in barn design and the fire-curing process itself allow more control over curing conditions and less influence of outside weather conditions, the growing season and curing environment still play a major role in TSNA accumulation in fire-cured tobacco.

Fire-curing allows more potential for TSNA accumulation than air-curing. Higher temperatures are involved, which increases the speed of biological and chemical reactions, and nitrogen oxide (NOx) gases are produced by the burning of wood, which increases nitrosation of tobacco alkaloids. However, some basic management practices for fire-curing can reduce the potential for high TSNA formation.

Avoid packing sticks too closely in the barn, as this can lead to poor cured leaf quality, losses in cured leaf weight, poor or uneven smoke finish on leaves, and higher TSNA levels.

Ideally, start firing within seven days after housing. Avoid firing the tobacco more or longer than necessary to produce cured leaf with acceptable quality and marketability. Growers should strive to keep barn temperatures below 130°F, even during the drying stage of the cure. Ideally, tobacco should not be kept at 130°F longer than four to five days; by seven days at this temperature, TSNA levels would be expected to increase.

Artificial casing with overhead misting systems or steamers is often required for takedown in dark fire-cured tobacco due to the extremely dry condition of the tobacco after curing is complete. This is particularly true with first cures in double-crop curing, where takedown needs to occur quickly following curing. Research has shown that use of overhead misting systems at takedown may result in lower TSNA levels than steam.

**What the Grower Can Do**

The most effective steps a grower can take are to minimize the effects of high temperatures (which increase the speed of TSNA-forming reactions) and wood combustion (which increases the amount of nitrosating agent). Do the following:

- Fire dark tobacco no more than necessary.
- Ideally, start firing within seven days after housing.
- Strive to keep barn temperatures in fire-cured barns below 130°F.
- Ideally, do not keep temperatures at 130°F for longer than four to five days.
- Space plants evenly on sticks, and place sticks evenly on the rails.
- Avoid packing sticks too closely.
- Use minimal artificial casing.
- Consider using overhead misting systems instead of steam when artificial casing is needed in fire-cured tobacco.

**Control of Microbes**

The nitrite-producing microbes are ubiquitous and cannot be avoided. They are endophytic (inside the leaf), which makes application of any treatment very difficult.

Many chemicals and biological agents have been tested, but none of them has yet resulted in a practical control method. Correct curing will help to control microbes.

**What the Grower Can Do**

At this point, there is no treatment to directly control the nitrifying microbes. Manage curing for production of high quality, full flavor and aroma tobacco, and avoid houseburn conditions that are conducive to microbial activity.

**Moisture and Storage**

Studies have shown that housing wet tobacco can increase TSNA levels, as can storing high-moisture tobacco. It is difficult to control the moisture content of tobacco when using artificial methods of casing, such as steam or water sprays, and over-application of water to cured leaf can result in unsafe moisture levels during storage. For this reason, it is better to use natural casing if possible.

TSNAs generally increase with time in storage, although this is less evident in low converter tobacco. Tobacco should therefore not be left in storage longer than necessary.

**What the Grower Can Do**

The following steps will help to minimize the effects of moisture on the nitrite-producing microbes:

- To the extent possible, do not house tobacco with free moisture on the leaves.
- Allow air-cured tobacco to come into case naturally if possible. If using artificial casing, avoid over-applying moisture.
- Use minimal artificial casing for fire-cured tobacco, and consider using overhead misting systems instead of steam.
- Strip, bale, and deliver tobacco as soon as possible to avoid any extra time in storage.
- Keep moisture in the cured tobacco as low as possible, ensuring that it is below the level specified in the contract.

**Best Management Practices for Minimizing TSNA Formation**

TSNA formation is a very complex process, and one cannot consider any of the factors contributing to it in isolation. All of these factors interact, and that is why different treatments sometimes result in TSNA differences and sometimes do not. These practices will contribute to lowering TSNA levels:

- Use LC or screened seed.
- Choose the most suitable variety with the appropriate disease resistance package—if KT 204LC meets other requirements, the choice of this variety may help to lower TSNA levels. Use no more nitrogen than necessary to optimize yield.
- Avoid spring applications of muriate fertilizers.
- If sidedressing, apply nitrogen within four to five weeks after transplanting.
- Top correctly.
- Harvest at correct maturity, ideally about three and a half to four weeks after topping for burley, about five to six weeks after...
Safety and Health in Tobacco Production

Mark Purschwitz and Bob Pearce

Production agriculture is a hazardous business. While tobacco production may not be especially hazardous in terms of fatalities compared to other crops, the range of operations required for the production of a crop is quite varied. Tobacco production requires significantly higher amounts of manual labor than other field crops, and thus carries a significant opportunity for accidents and injuries. Tobacco harvesting and stripping operations, in particular, typically require large crews of seasonal labor, and it is important that these workers are aware of potential hazards and use safe working practices. Communication can be difficult with large and varied work crews, especially with immigrant laborers who may not understand English well, so farm operators must put effort into promoting safety.

Safety during Tobacco Setting

Tobacco setting is a relatively safe operation. However, protection from heat and sun and proper hydration are important, and will be discussed below in the section “Harvest Field Safety and Health.”

Research has uncovered several cases of carbon monoxide poisoning during setting operations. Although you may think carbon monoxide poisoning is impossible outdoors, utility tractors with underslung mufflers and exhaust pipes can pump carbon monoxide directly into your workers’ breathing zone. Only use tractors with vertical exhausts during setting.

Preharvest Preparation

The most important safety work you can do on your farm is preseason preparation. The old saying, “An ounce of prevention is worth a pound of cure,” is certainly applicable here. Doing what is necessary to create a safe workplace will help you avoid many in-season injuries that cost time and money.

Prior to hanging tobacco, carefully inspect the rails (and all related structural members) of your barns for cracks and damage, and be sure they are not loose, since broken or loose rails or related structures are a major cause of falls while hanging tobacco. Needless to say, these falls can be extremely serious and can result in broken necks, permanent paralysis, or death. Do not assume that the rails and related members are in the same condition they were last year. Look them over carefully and repair or replace rails and related members with even a small amount of weakness. Make sure they are securely attached. Look for locations where ladders or steps can be efficiently added to the barn to reduce the amount of climbing around on the rails, especially in very large barns that have become more common in burley tobacco production. To date, no workable personal fall protection systems have been developed for conventional burley tobacco barns, so the condition of the rails and related members are crucial in protecting workers. This cannot be emphasized enough.

Check the barn for bee or wasp nests, especially around and under eaves. Tobacco housing activities can disturb bees and wasps and result in painful stings for workers. Safely remove any known nesting areas. Long-distance, quick knockdown insecticides work well to reduce the chance of stings.

Inspect wagons and other equipment used during harvest. For wagons, inspect the deck itself, look for cracked or broken floorboards or other wooden parts, and make sure that the rear rack is sound and secure. Check the running gear, including rims, tires, and tire pressures. The last thing you want in the middle of harvest is to have a wagon go down from some sort of failure. A breakdown on the road while transporting a load of tobacco is even more dangerous. If you pull more than one wagon at a time, the hitch on the rear of the leading wagon must be in good condition, since it is pulling the wagon behind it. You should have safety hitch pins (pins with retainers so they cannot pop out) for all your wagons. You should have a bright and clean SMV emblem on all wagons, especially the rear-most wagon if pulled in tandem. Don’t leave safety issues to chance.

Before dropping sticks from your Hi-Boy or other machine, make sure the machine itself is in good working condition, especially steering systems and wheels/tires that could lead to a failure or loss of control if they malfunction. Make sure you have safe, comfortable accommodations for the riders. Just because you’ve always done it this way does not mean improvements cannot be made. Does the machine have sturdy, comfortable seats that don’t wobble or do anything else that could lead to a