Using Switchgrass and Miscanthus as Sustainable Livestock and Poultry Bedding

ONTARIO BIOMASS PRODUCERS CO-OPERATIVE INC.

for a cleaner tomorrow

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The 3 cover photos are courtesy of D. Nott and J. Tost.

Introduction

Warm-season grasses, including switchgrass and miscanthus, are promising new crops in Ontario. These crops can fit well into many farm operations as a means of diversifying farm incomes and markets. Cash crop farmers with marginal land may find growing switchgrass to be an especially effective way to produce a dedicated straw crop for sale. These crops can be grown by livestock farmers as a bedding source and as a supplementary feed in livestock feeding programs. The agronomy of growing and harvesting switchgrass and miscanthus is addressed in two separate manuals [A Comprehensive Guide to Switchgrass Management and Miscanthus Agronomy 2016]. This best management practices (BMP) manual will focus on the use of these grasses as bedding in livestock and poultry operations.

Switchgrass is presently making inroads in commercial dairy operations in Ontario as livestock bedding. Some dairy producers are also using the low potassium switchgrass crop as part of a total mixed ration (TMR) for dry cows and as a physically effective fibre source ("rumen scratch") for lactating dairy cows. By contrast, miscanthus is being successfully scaled up, especially in the southern U.S., mainly as poultry litter, and in Europe is increasing in use as a deep bedding litter for dairy cows. Both grasses are also being used for other bedding applications, including for swine, horses and beef cattle.

Another strong advantage of warm-season grasses is that, once their use as bedding is done, they provide better nutrient availability and contribute to better soil fertility than sand, sawdust or shavings, when they are worked into the soil.

This BMP will provide an overview of the use of these warm-season crops in various bedding market applications, highlighting some of the differentiating characteristics of these grasses and the need for appropriate mechanical conditioning, as well as identifying their strengths and weaknesses compared to alternative bedding products such as wheat straw, wood shavings, sawdust and sand. The focus of this document is on dairy and poultry bedding, as these are among the most demanding bedding categories for developing hygienic bedding.

In general, warm season grasses that are adequately conditioned perform considerably better than cereal straws as bedding in all livestock classes, due to two main features: they are more biologically inert (as they contain less nitrogen) and they have greater fibre strength. Good fibre strength helps evaporate moisture from bedding, which is especially important in poultry operations. Warm season grasses can also provide better comfort to cows and horses than higher-bulk-density materials such as sand, sawdust, pellets or shavings.

Warm-season grasses with adequate conditioning can absorb as much water as woody materials. Conditioned grasses are proving to be less abrasive to the legs of dairy cows than woody bedding materials, which is especially advantageous for preventing hock injuries. However, warm season grass bedding can harbour more bacteria than inorganic bedding, such as deep sand bedding systems used in the dairy sector. Good hygiene management practices will be required to optimize the use of warm-season grasses in livestock bedding applications. Some farmers are using high quality rubber mattresses under cows in combination with a surface layer of warm season grass bedding. This approach appears promising as the rubber mattresses provide good comfort while the thin layer of organic bedding has limited ability to build up harmful bacteria but resolves the hock abrasion problem associated with rubber mattresses.

There are considerable differences in the physical and chemical components between the various materials, which can have an influence on their possible end uses. For livestock bedding, the most positive attributes of warm-season grasses are their good fibre strength, which provides comfort to resting cows in deep bedding systems and resists being trampled down in both ruminant and poultry bedding applications. Producers are also interested in the speed of absorption and total volume of water absorbed per pound of bedding used. Also of equal importance is the desorption of water from the bedding, or how well the bedding evaporates water from the bedding surface to help maintain it in a dry state. The bedding's ability to harbour bacteria and its speed of decomposition have important impacts on animal health, as well as on crop and soil productivity, once the bedding is recycled on fields.

Producers have many factors to weigh when choosing whether to use warm-season grasses or conventional bedding sources. For warm season grasses to successfully compete with traditional bedding sources, they must be conditioned to best meet the needs of the various markets. Conditioning grass has a significant cost, and it appears that the processing requirements will be dependent on both the warm season grass used and the bedding application.

Warm season grasses can be processed into a very fine chop and reassembled into a pellet or crumble to increase the surface area accessible for rapid moisture absorption and good ammonia capture. Finely processed materials may be viable for certain high-value markets such as pet litter or organic poultry production, although the processing cost is very expensive. However, conditioned warm-season grass with high bulk density are not ideally suited to bedding for heavy ruminants such as horses — as they provide modest comfort for resting animals.

There are clear trade-offs involved in terms of optimizing the bedding characteristics for each livestock sector. As well, within a livestock sector, there may be further refinements required. For example, in dairy systems, the optimal bedding choice, conditioning requirements and volumes of use per day may differ considerably for a compost pack barn or a free-stall operation with advanced water or gel-filled mattresses.

This BMP aims to help inform producers about the potential of these grasses while recognizing that further research and farm practice are required to understand how to optimize their use within each sector. Overall warm season grass bedding appears to provide important sustainability advantages for producers in terms of animal comfort, hygiene and body condition while also being a more highly valued soil amendment.

Switchgrass and Miscanthus as Dairy Bedding

Background

Canadian dairy farmers are examining many different strategies to improve production and control costs. Traditionally in Canada, dairy producers used tie-stall barns and bedded animals with straw. In the 1970s, many producers developed larger herds, and free-stall dairy systems became more popular, as herd sizes expanded. The free-stall system led to the development of more diverse bedding options, including widespread use of sand, shavings and straw. Two broad categories of dairy bedding subsequently evolved to provide cow comfort: inorganic beddings (sand and advanced rubber mattresses) and organic sources (larger volumes of straw, sawdust and shavings, used on rubber mats or concrete). The main advantage of inorganic bedding was that the products didn't harbour bacteria as readily as thicker layers of organic bedding. The switch to these newer inorganic bedding products was largely driven by efforts to help control mastitis. The advanced rubber mattresses also helped control the costs of the daily use of larger volumes of organic bedding.

More recently, the increasing size of herds and concerns about the limitations of free-stall systems have led to the development of pack barns. In a pack-barn system, herds are generally larger, and cattle are freely housed on an organic bedding pack. Most commonly, these bedding packs are made of soft wood sawdust. They are most frequently managed as compost pack barns, typically with twice a day disturbance of the pack by tillage. Pack barns are not commonplace in Ontario but are growing in popularity in the Great Lakes region as herd sizes expand and producers become more concerned about cow longevity. The main advantage of pack barns is greater cow comfort, as the animals are much less prone to foot, hock and leg injuries than in other systems. This increased comfort is resulting in greater longevity for the cows in the milking herd. The main concerns of producers using a compost pack barn include limited availability of bedding sources, high bedding costs and increased dust levels in barns.

Warm-season grasses could find a role within each of the three main types of dairy housing systems. Increasing our understanding of the challenges and opportunities of their use within these systems will help better inform producers. Using warm-season grasses as bedding represents a new innovation for dairy farmers that may have impacts on many factors of primary importance but especially cow comfort, disease management and cow longevity in the herd. The various choices of bedding affect daily bedding cost, labour use, capital investments, equipment maintenance costs and the value of dairy manure as a soil amendment. Changes in livestock bedding can have significant impacts on the profitability of the dairy farming enterprise. Considerable analysis may be required to better understand the potential costs, benefits and risks that could be expected with a change in bedding management.

Figure 1. Dairy farmers have reported very good experiences with chopped switchgrass as bedding for dry cows, young stock and calves. It provides good comfort and tends not to be readily broken up and packed down by hoof action compared to cereal straws.

Qualities of a Good Dairy Bedding

- provides a comfortable surface for cows to lay down on
- absorbs fluids to keep the bedding surface dry and cows clean
- absorbs nutrients, ammonia and other odours well
- provides a non-slippery surface that cushions the cow's feet
- is non-abrasive to cow's knees and hock joints
- contains low numbers of environmental mastitis-causing organisms in its raw state
- is readily available at reasonable cost
- is easily stored, applied and removed
- creates little-to-no dust
- is environmentally friendly when spread on land and increases soil organic matter
- when applied as a soil amendment to farmland it provides good nutrient availability and a favourable crop growth response

Cow Comfort

There is increasing interest in cow comfort as a means of increasing daily and lifetime production of milking cows. Of primary importance in choosing a bedding system is the level of comfort it provides cows when they are resting and standing, as well as how abrasive it is to animals getting up and lying down. Larger dairy cows can weigh 600 kg and considerable force is exerted on their body frame, legs and feet when they move. When a cow is resting, blood flows more efficiently through the udder, helping support higher milk production. The more time a cow spends resting, the more inclined it is to high milk production. Typically, a cow should rest for 12–14 hr per day. It is critical to optimize comfort for cows to achieve these long rest period targets. Studies have indicated that for each additional hour a cow rests per day, milk production can increase typically from 1–1.5 litres per day. Most studies indicate that both softer stalls and increased thickness of bedding will help lead to higher milk production.

Figure 2. Adequate quantities of clean bedding help to cushion the animal's feet and to provide greater comfort to animals while resting.

Humans naturally seek out a restful surface to sleep on, which for most of us means finding a good comfortable mattress. What we have learned about mattresses for people is that the more the weight is distributed over the mattress, the more the frame of the body is supported in a natural resting position. A soft mattress under a heavy person will cause too much weight to be concentrated in the centre of the body and a poor night's rest. For a 600-kg cow, the same principles hold true. The more the bedding system envelopes the body and supports it evenly over a larger area, the better. Overall research studies conducted on large ruminants have found an order of comfort of: straw > shavings and sand > rubber mats. In the past 20 years considerable effort has been made to improve the comfort of rubber mats through the creation of rubber mattresses with water or gel filled interiors which greatly improve cow comfort.

Research studies have found two general rules of thumb:

- The higher the bulk density of the bedding generally, the less comfort is provided.
- The thicker the straw, shavings and sand generally, the more comfort is provided.

The bulk density of organic bedding materials will vary considerably, depending on the specific sample taken and the extent the material has been conditioned. It appears that once bedding materials reach >100 kg/m^3 in bulk density, they begin to compromise cow comfort. Sand and straw pellets have a much higher bulk density than herbaceous bedding materials, which tend to be even lower than woody bedding options. The bulk density of cereal straw is generally the lowest among herbaceous materials and is generally about one-third lower than upland switchgrass, when measured at a similar size of grind or length of chop.

Table 1. Approximate Bulk Density of Various Organic and Inorganic Materials

Lower Bulk Density		Higher Bulk Density	
Wheat straw	20–60 kg/m^3	Wood chips	240-520 kg/m^3
Miscanthus	30–75 kg/m^3	Straw pellets	550-600 kg/m^3
Switchgrass	40–90 kg/m^3	Sand	1250-1600 kg/m^3
Wood shavings	50-150 kg/m^3	Concrete	2,400 kg/m^3
Sawdust	200 kg /m^3		

An additional factor to be considered is how well the bedding supports compressive forces. More comfortable bedding materials may be identified within materials of similar bulk densities. It is likely that superior fibre strength properties in a bedding can provide a more even distribution of the weight of the cow, however, this remains to be evaluated. Warm-season grasses such as switchgrass and miscanthus have been under considerable research study for fibre applications such as pulp and paper, and biomass composites (biomass mixed with plastic in applications such as interior door panels of cars). Studies have found that warm-season grasses such as big bluestem, miscanthus and switchgrass possess considerably stronger fibres and resist compressive forces better than cereal crop straws.

Another important consideration is how well the material stays in place. Farmer experience has found that chopped grasses tend to stay in place, as the stem pieces tend to be interwoven. By contrast, wood shavings are flat and readily displaced. This is most notable in horse stalls where shavings are easily displaced by hoof action and require greater stall maintenance.

Figure 3. The pre-chopped material in a large square bale works well for many livestock bedding applications including: deep bedding systems over mats; young stock rearing areas; and calf hutches. The finer a material is chopped the more efficiently it is able to absorb moisture and ammonia. For the material to work well in controlling moisture levels in the bedding pack it should have a sufficiently large specific surface area for both absorption and desorption processes.

Figure 4. For many livestock farmers producing their own switchgrass, hiring a custom square baler with a pre-chopping attachment is a convenient way to create a ready-to-use product. Pre-chopped switchgrass bales will typically have a density 25% higher than cereal straw.

Grasses that have a thicker stem, such as miscanthus or lowland switchgrass, require additional conditioning. Processing the material thoroughly will not only improve comfort and function but help prevent injury from the grasses poking or causing abrasion to cow's udders or legs. Miscanthus (~1-cm-thick stems) must be ground for dairy bedding use rather than simply chopped. Farmers have found ground warm season grasses a soft non-abrasive material on cow hocks. By contrast hock injuries from abrasion is a serious problem from wood shavings use on rubber mats or mattresses. Compared to cereal straws, warm-season grasses tend to have longer, thinner fibres that are better able to resist impacts and maintain their structure upon impact. Cereal straws have been found to possess mainly short fibres that are more conducive to breakage and as such are not very elastic. Elasticity of a bedding material is important, so it does not sag after a brief period of use.

A main problem of bedding is that what is optimal for comfort is not optimal as far as nutrient and ammonia absorption. For example, some horse stable managers like the convenience and cleanliness of pellets. However, European studies have found that loose straw clearly outperforms straw pellets in terms of comfort and longer resting periods for horses. It appears that densified bedding materials may have too high a bulk density to optimize restful sleep for heavy animals. The bulk density of straw pellets can be 10 times that of chopped straw.

The size of the animal affects what it needs to be comfortable. For young dairy calves, most studies indicate straw has proven to be clearly superior to shavings and sand. In winter, straw has proven especially superior as it has much better insulating properties than sand and wood shavings and remains relatively dry. Research has shown that when calves can choose where to lie, they prefer dry bedding. Wet bedding also does not insulate the calf from the cold. If a calf's hair coat is wet, the calf suffers increased heat loss. Studies have found that calves generally grow better and have less scouring events when housed on straw vs. sand or wood shavings.

Warm-season grasses, in all likelihood, can prove to be superior to straw if properly chopped or ground for calves. Switchgrass and miscanthus have higher cellulose contents than wheat straw and will not be as easily trampled by the hooves of animals. The high cellulose content of these grasses is an important factor in their insulating value. The enhanced fibre strength of the grasses will also likely enable them to remain drier under the calves. The fibre strength of the grass materials and their slow decomposition will also help maintain the bedding's original bulk density for a longer period. Farmers report that this also helps and enables grasses to provide better evaporation from the pack. Wheat straw is readily trampled, decomposes quickly and can rapidly form a compressed pack, especially when exposed to moisture. Poultry producers have noted a prominent difference in how the bedding responds to being trampled, when comparing switchgrass or miscanthus with wheat straw use.

Figure 5. The material can be processed by a farmer using a device such as a hammer mill or tub grinder and blown directly into a storage shed. Material from a tub grinder is commonly used directly in deeper bedding application such as dairy cows on rubber mats or for dry cows and young stock. Tub grinders will often produce a less consistent particle length.

Figure 6. For on-farm processing outdoors, a high quality fine chopped material can be produced through a two stage conditioning process. A tractor and tub grinder can be used for chopping and the material then augered to an adjacent tractor and mix mill for fine grinding the material through a 1/4" screen to produce a consistent product.

Bedding Choices and Their Influence on Bacteria and Abrasion

Many producers have switched to inorganic bedding because it generally has lower bacteria counts than organic bedding. Inorganic materials such as sand do not as readily support the growth of environmental pathogens. As such, inorganic materials generally result in lower teat end bacterial counts and lower rates of new infections within herds.

Producers with organic bedding materials can also have low bacteria counts but this generally requires more attention to management. Pathogens may be present before bedding is used by cows as a result of exposure to soil in the field before baling. More commonly, bedding is contaminated by the cow defecating loose faeces on the tail or hocks or tracking manure into the rear of the stall.

The factors that are most conducive to growing bacteria are a high moisture content in the bedding and exposure to manure. Under certain conditions, organic materials can cause a rapid growth of environmental mastitis pathogens, which can multiply to large numbers within 24 hr. The major pathogens associated with bedding materials are the environmental *Streptococci* and coliforms such as *E. coli* and *Klebsiella* spp. In particular, dairy producers should be concerned about using organic materials containing higher levels of potential pathogens that prevent these materials from being an effective barrier to bacterial contamination of teat ends. Organic bedding materials of small particle size can also be problematic, because they can multiply bacteria rapidly and increase teat end exposure to pathogens.

In general, a good indicator of the relative ability of a substrate to grow bacteria is its carbon: nitrogen (C: N) ratio. The higher the N content, the more rapidly the material can heat up, decompose and build up bacterial populations. Table 2 shows the C: N: ratio of various bedding material options.

Table 2. Carbon: Nitrogen Ratio of Bedding Materials

Bedding Option	C:N Ratio
Wheat straw	80:1
Rye straw	100:1
Switchgrass	150:1
Miscanthus	200:1
Sawdust	440:1
Hard wood shavings	550:1
Softwood shavings	650:1

Sand

Many consider sand to be the best bedding material for dairy cows, as it supports very little bacterial growth while at the same time providing a reasonable level of comfort to cows. Sand can be considered to be largely inert and not conducive to most types of bacterial growth. Bacteria counts found in used sand bedding are generally considerably lower than organic bedding materials, which is the primary reason sand has reduced rates of new infections with environmental pathogens.

In addition, herds on sand tend to have the least hock injuries, especially when compared to herds on woody bedding materials or on minimal amounts of organic bedding on rubber mats. However, sand will compress under the weight of cows. Cow movements continually work to turn their beds into a concave form, which requires maintenance to re-form a looser bed to help maintain comfort.

Sand is a poor insulator, which makes it not as comfortable as organic materials in the winter. By contrast, during the warm summer months, the non-insulating aspect of the material allows it to stay cool. Sand reduces heat stress through lower lying temperatures than other bedding materials.

A main problem with sand is that it doesn't work well for manure-handling systems. It settles at the bottom of lagoons and manure collection pits. It can also cause excessive wear on manure-handling equipment. Sand bedding also makes for relatively poor nutrient cycling on farms and is not effective for building up soil fertility and soil organic matter when compared to organic-based bedding systems. Application of used sand bedding to fields often causes severe soil compaction.

Wood Shavings and Sawdust

Wood-based products are also popular organic bedding material choices for dairy producers, although the availability of kiln-dried sawdust and wood shavings can be limited in some areas. Wood products provide reasonably good cow resting comfort and work well in most manure-handling systems. One disadvantage is that sawdust and/or wood shavings can provide an environment for mastitis-causing microorganisms. Bacterial numbers often increase with decreasing particle size. The larger particle size of shavings generally provides the best results among wood-based products. The small particle size of fine sawdust is known to support very rapid growth of bacteria and requires the most attention. These small-sized materials are more likely to cake on the teat skin, resulting in greater opportunities for intramammary infection.

In terms of absorption and desorption, wood products are generally not as effective for bedding as conditioned thin stemmed warm season grass herbaceous materials. The main advantage of woody materials over herbaceous sources such as cereal straw or warm-season grasses is that they are more biologically inert and, as such, do not as easily support bacterial growth. However, for compost pack barns, wood shavings or sawdust have been generally considered the best performing bedding materials. These woody materials have a high lignin content, good surface area-to-volume ratio, low N content and do not readily compact between bedding pack stirrings. Overall, these lignocellulosic materials are resistant to microbial degradation and contribute to a lasting compost material structure.

Another problem with woody residues is that they tend to be the worst performing material in most systems as far as hock injuries when used on mats or mattresses. Hock injuries are the most commonly reported leg injury in Ontario with up to 50% of cows being affected in many herds. Wood fibres can commonly penetrate the cow's hocks when the cow leg is sliding into a resting position or getting up off a surface. The early loss of animals from leg injuries is a challenge of milking herds in Ontario. It is a major economic cost and animal welfare issue that requires more attention by producers.

Figure 7. The quality of woody residue materials sold into the dairy bedding market varies considerably with large differences in particle size present. Injuries can occur as a result of wood splinters piercing the animal's hocks. Wood residues are also abrasive on the hocks especially where thin layers are used over rubber mats and mattresses. The continual exposure of the hocks of the animals to rubbing on the abrasive woody residue cover and mattress can result in a build-up of leg problems in the herd.

Figure 8. Wood shavings are known to be readily displaced by the hoof action of horses in stalls. Dairy producers are also finding that on high quality dairy mattresses, wood shavings tend to pile up and/or be easily swept off the sloping mattresses by the hoof and leg actions of the animal. The abrasion problem on hocks appears to occur due to the lack of organic bedding material being evenly maintained on the abrasive rubber mattresses and the wood fibre material is somewhat abrasive itself.

A secondary problem with wood-based products is that they generally are not very effective soil amendments. Common complaints include that wood-based products acidify soils and are slow to turn over N to the following crop and provide a poor crop response.

Straw

The main advantages of straw are that it is often available on-farm and it makes an excellent manure soil amendment. Straw used for bedding must be clean, dry and free from fungi, yeasts and moulds. Straw used for bedding should not exceed 15% moisture content. Bales with more than 20% moisture content must not be used.

Mechanical shredders condition the straw better, leaving it open and fluffy, which makes an important contribution to keeping cows clean. One strategy to efficiently use straw is applying one-third of the daily quantity in the morning and two-thirds at night, when no cleaning is performed.

Unfortunately, unless managed extremely well, there is generally a higher risk of mastitis occurrence in cows bedded on straw. The high moisture levels of straw will also result in the rapid growth of environmental bacteria in the bedding and contribute to high populations of bacteria on teat ends. Straw bedding contaminated with manure tends to heat up more quickly than other materials. The combination of moisture and manure provides an ideal environment for many pathogens, including those responsible for causing mastitis (*Streptococci* species in particular). Cereals straw are generally the worst performing bedding material group for mastitis problems. By contrast, inorganic materials such as sand do not readily support the growth of environmental pathogens and usually result in lower teat end bacterial counts and lower mastitis infection rates.

Warm-Season Grasses

From a bacterial infection standpoint, both switchgrass and miscanthus appear superior to cereal straw as far as potential for pathogen build-up, due to their lower N content and lower moisture contents. Typically, these warm-season grasses will have ~0.2%–0.4% N harvested as a straw source, while wheat straw will typically be in the 0.8%–1.0% range. Miscanthus and lowland switchgrass tend to have a slightly lower N content than upland switchgrass, due to their high stem content. Warm-season grasses are generally harvested in a very dry state, and typically will be 7%–10% moisture when placed under cows. As well, the grasses tend not to compact and are efficient at evaporating moisture from the pack due to their fibrous structure and hollow stem.

Switchgrass will likely be more readily taken up by dairy farmers with tie-stall and free-stall operations, as it is more easily grown and requires less processing. Switchgrass can simply be pre-chopped while baling to an approximately 7.5-10-cm (3-4 in.) length. The relatively thin stems of upland switchgrass minimize risks of injury to animals. The thin stem walls make it more water absorbing, compared to warm-season grasses with thick stem walls, such as lowland switchgrass or miscanthus, which have less exposed surface area. Another option for producers is to cut the product with a forage harvester to a 1-2" length and bulk store the material. Some farmers are also using a tub grinder to reduce the length of straw to their desired length. Farmers with high quality rubber mattresses in Ontario have started to use ground switchgrass materials (~ ¼-in. length) as a means to minimize hock injuries from animals sliding on the rubber surface. As well, this more finely ground material improves absorption and reduces ammonia formation. Use of modest amounts of ground switchgrass fibre on rubber mattresses appears to be a promising alternative for some farmers.

Figure 9. The Ontario Biomass Producers Cooperative is marketing well conditioned warm season grasses that can optimize the performance of these hygienic bedding materials in dairy and poultry applications.

Ground miscanthus is being used successfully in Europe in bedding packs. It may be a superior bedding product than switchgrass in compost bedding pack applications, as it is generally lower in nitrogen than switchgrass. Miscanthus tends to mainly consist of plant stems that are highly lignified. A European dairy bedding study found miscanthus to have 11.2% acid detergent lignin compared to 6.6% for wheat straw. It appears that given its low N content and higher lignin content, ground miscanthus can perform similarly to woody materials in a bedding pack application. As well ground switchgrass may have a role in compost bedding pack applications.

An additional benefit of warm-season grasses bedding is that, when the material is recycled to the land and incorporated into soils, it provides better nutrient availability and contribute more to soil fertility than sand or wood bedding products.

Good Stall Management

A successful and safe bedding system using appreciable amounts of organic bedding will require a more comprehensive strategy to mitigate against bacterial growth. The stalls should be checked daily, manure scraped and wet spots removed from the stalls. Good management of the stalls will reduce the potential for mastitis outbreaks in herds. Effective stall maintenance will also improve cow comfort. Other ways of reducing the potential for bacterial growth are good ventilation and adequate space for the animals. The dairy ration for the milking herd can also be adjusted to provide consistency of the faeces. The dung pats from a productive milking herd should be firm enough to stand and have a dip in the centre. Dairy producers should avoid pushing their cows with too hot a ration. High productivity can be maintained without heavy concentrate feeding. Cows fed excessively rich diets often will reach a state where they produce thin faeces and become chronically diarrhetic. Milking cows in this state tend to have faeces splattered onto their flanks and udders, and have soiled tails. The loose faeces from these animals can easily contaminate the rest of the herd when cows are crowded together, walking through wet passageways and collecting yards.

Additives to Inhibit Bacterial Growth

One potential strategy to help organic bedding materials reduce their potential to cause mastitis is the use of additives to inhibit bacterial growth. Lime is often used when a clinical mastitis situation occurs in a herd. Hydrated lime is the most popular choice. In free-stall and tie-stall barns, 0.5-1.0 kg (1–2 lb) of hydrated lime is added per stall and has been found to increase the bedding pH and reduce moisture content in the stall. Both *E. coli* and *Streptococci uberis* do not multiply in material above pH 9.5. Dusting stalls daily with lime, before the organic bedding is applied, can be a safe and effective strategy. However, the effect of the added lime is short-lived, and daily application is required.

Conditioning of Bedding Materials to Improve Performance

Various forms of conditioning (chaffing, grinding and densification) of warm season grasses can have very important impacts on the absorptive capacity of the bedding material. Conditioning increases the surface area of the material as well as the amount of accessible carbon. The more the material is conditioned, the more effective its ability to absorb moisture and the greater the total water and ammonia absorbed.

The thick-walled stems of grasses such as miscanthus and lowland switchgrass appear generally inferior to cereal straw and upland switchgrass for both absorptive capacity and ease of use for dairy bedding. Research has also found that cereals selected for improved lodging resistance generally have stems with thicker walls and do not absorb moisture as well as cereals with thinner-walled stems. Cereal crops with thin-walled stems, such as oats, tend to be more efficient at absorbing moisture.

Figure 10. The conditioning of warm season grasses needs to be optimized for each particular livestock and poultry bedding application. The dedusted switchgrass product (left) has the stems split and is cut to a length of ~2-4 cm and the fines removed. This material is ideal for horse bedding as it is a highly comfortable product that creates a low dust and low ammonia environment in the barn. The fine ground switchgrass (right) works very well for high quality mattresses used for milking cows.

Warm-season grasses with thick-walled stems will require more conditioning than cereal straw and upland switchgrass to provide similar water absorption characteristics. The stem walls of miscanthus can often be 1.5–2 mm in thickness, while those of lowland switchgrass are approximately 0.8 mm thick. Stem walls of cereal straws and upland switchgrass are generally 0.6–0.7 mm in width.

Miscanthus contains a high proportion of relatively thick and woody stalks, which makes chopped miscanthus unsuitable for application as bedding material for dairy cows. The same problem is likely to arise from using lowland switchgrass. Thick-stemmed grasses are too coarse for direct use and must be ground for use under dairy cows. A European study found ground miscanthus to perform similarly to chopped wheat straw in a dairy bedding application. However, the ground miscanthus was found to produce less dust in the barn. The low dust may be due to the miscanthus material having a heavier particle weight.

Figure 11. Miscanthus stems tend to be quite thick with typical diameters of 8-12 mm. These stems need to be ground to prevent injury to dairy cows and to improve the surface area for absorption.

The data on the absorptive capacity of various organic bedding materials is quite variable. This is likely due to the great variability in the forms and in the amount the materials are conditioned as well as the soaking times. A general ranking of water-holding capacity from absorption studies appears to be: peat moss > pelleted herbaceous material > finely chopped straw > wheat straw > wood shavings and upland switchgrass > lowland switchgrass and miscanthus. Generally, these materials absorb two to three times their weight in water, with typical ranges for wheat straw of 2.2–3.3 and pine shavings of 2.0–3.0 times their weight. Scientific reports on absorption data from miscanthus and switchgrass is sparse but these grasses tend to have lower water-holding capacity than pine shavings. Few studies are available that have evaluated the water absorption of upland switchgrass or adequately ground products of miscanthus and lowland switchgrass.

The other factor that is of considerable importance is the rate of evaporative water loss from the bedding. Most farmers in Ontario are reporting that switchgrass bedding tends to stay drier under cows than wheat straw. This observation is generally attributed to better water evaporation from the pack. Switchgrass is hollow stemmed, has stronger fibres and is not as easily matted as cereals straw. Studies have generally found that bedding material that is left in a medium-to-longer form tends to evaporate water more rapidly than fine-chopped materials. Overall, there appears to be a need to identify the optimal chop length on warm-season grasses to optimize both absorption properties and desorption (evaporative water loss) from the bedding material.

Producers in Ontario presently are having success in the province in using a roto-cutter to produce pre-chopped switchgrass bales. The pre-chopped and baled product is in a convenient form for producers using deeper bedding systems on rubber mats or concrete. However, a ground switchgrass product processed through a 1/4" screen has been developed by dairy producers in Ontario for use on high quality rubber mattresses.

Figure 12. A newly developed bedding product is fine ground switchgrass that is passed through a 1/4" screen. It is used on rubber mattresses that are typically installed on a 4% slope in free stalls. The fine ground bedding has two major advantages: it is not easily displaced by cows on the sloping mattresses; and it is a soft non-abrasive material.

The primary reason ground switchgrass bedding was developed by producers was to provide a more effective sliding layer between the abrasive rubber cover of the mattress and the cow's skin. The first advantage appears to be the fine ground switchgrass material is much softer to the skin than wood shavings. Wood shavings by comparison are considerable more abrasive and can produce wood splinters that can penetrate cow's hocks. Fine ground switchgrass appears to function in this application similarly to the use of a sock liner in a running shoe to prevent abrasion with the skin. The second major advantage is that the fine ground switchgrass is not as readily displaced by both hoof and sliding leg action. Wood shavings are often swept clean off the rubber mattresses by animal hoof and leg movements. The absence of the organic bedding layer results in the cow hocks having longer periods per day of direct exposure to the abrasive rubber mattresses.

Figure 13. The sliding motion of the cow's legs on the mattresses can be readily seen in this photo. Even though most of the bedding is swept away, the fine ground switchgrass material tends to leave some of the soft ground switchgrass fibre as a layer between the abrasive mattress and the cows skin. Dairy farmers will need to scrape the mattresses of fecal material and to reapply the fine switchgrass bedding twice daily.

Figure 14. A video on fine ground switchgrass bedding use on rubber mattresses for dairy cows is now available on youtube. In the video, Kees Van Esveld of Clinton Ontario highlights how fine ground switchgrass has proven to be an effective solution to the hock abrasion problem he was formerly experiencing with wood shavings use on high quality rubber mattresses. https://www.youtube.com/watch?v=X00C0rhxbdA

Composting in a Bedding Pack

It is worthwhile to further understand the various types of organic bedding forms and how they perform in compost bedding pack applications as well as their impacts on soil fertility and crop production. Composting relies on microorganisms that break down organic matter to produce carbon dioxide, moisture and heat. The composting process is driven by soil microbes, which require a readily available source of carbon to assimilate the nitrogen (N) in the manure. Typically, microorganisms decomposing bedding materials will consume 30 parts of carbon (C) to 1 part of nitrogen (N). If there are insufficient amounts of accessible carbon available, the N in the bedding material can easily be lost to the air as ammonia. A bedding pack with a C: N ratio below 25:1 may decompose quickly, and release significant quantities of ammonia to the air. If ammonia can be smelled in the barn, the C: N ratio is likely below 25:1.

There are detrimental impacts on humans and animals exposed to high ammonia levels in barns. As well, N loss through ammonia represents a loss of N fertility that would otherwise be returned to the farm fields through compost applications for field crop production. If the C: N ratio is too high, the composting process will be very slow. In general, it is preferable to have a mix of organic substrate and manure that results in a C: N ratio of 40–50:1 to minimize ammonia loss. Too much carbon in a compost bedding pack may cause the pack to remain at a low temperature and fail to destroy pathogens. The presence of highly lignified material and large particle sizes of bedding will also impair the composting process as the particle size affects the accessible surface area available for microbes. Thus the farmer needs to understand and manage the sources and quantities of material to be composted, through constant observation.

Cereal straws and corn stalks generally perform poorly in bedding packs, as they decompose rapidly and support high levels of bacterial growth. These materials are also easily trampled, resulting in the pack tending towards an undesirable anaerobic state. Chopped miscanthus has gained favour in Europe due to its excellent fibre strength and low nitrogen content. If switchgrass is to be used successfully in compost bedding packs in Ontario, perhaps the safest way to begin to try to integrate the grass is in low-level blends with woody materials. Research in the U.S. has indicated that a variety of crop residues such as flax shives, soybean stalks and corn cobs can be successfully managed when combined with woody residues. If properly sized to enable effective stirring, both chopped miscanthus and switchgrass can likely play an increasing role in the expansion of compost bedding pack systems in Ontario.

Some general rules of thumb of managing compost bedding packs:

- They require three to four times the amount of bedding of a typical free stall.
- They should be sized per cow to provide a surface area of 7.4–9.2 m^2 (80–100 ft^2) per cow.
- Aeration is essential to incorporate oxygen for aerobic decomposition and to provide a fresh surface for the cows to lie on.
- The pack should be stirred or aerated twice daily to a depth of at least 25-30 cm (10–12 in.) and up to 40-45 cm (16–18 in.).
- Additional media should be added when the pack bed has more than 61% moisture content (if you can't form a ball, the pack is too dry).
- If water droplets appear on the surface of squeezed bedding, the pack is too wet.
- Media at 7%–10% moisture content works better than bedding supplied with a higher initial moisture, as it can absorb more moisture.
- The ideal pack temperature (measured at 30 cm (12 in.) beneath the surface) is 55°C–65°C (hot almost to the point you do not want to touch it).
- The oxygen content of the compost pack should be maintained at 12%–16% to reduce odours and to help enable pack temperatures to reach 55°C.

Switchgrass and Miscanthus for Poultry Bedding

Background

The production of broiler chickens and turkeys is a promising potential opportunity for using switchgrass and miscanthus. With growing consumer interest in antibiotic-free poultry products, some large fast food companies are now offering exclusively antibiotic-free poultry products. Currently 8 of 25 major fast food chains in the U.S. have made the transition to be free of antibiotics.

There are two basic categories of antibiotic-free poultry being developed:

- "without antibiotics, with attributes important to human medicine" (they are allowed to use ionophores)
- "no antibiotics of any kind"

Major fast food chains involved in only offering these two groups of antibiotic-free products include McDonald's, Wendy's, Taco Bell, KFC and Chick-Fil-A. Panera, Chipotle and Subway supply chicken products to consumers in their fast food restaurants that are completely free of antibiotics. The premiums offered to broiler producers for these antibiotic-free products can be approximately 5% above the board price of Ontario.

These changing market dynamics will likely create demand for both more hygienic bedding and higher volumes of bedding required per bird, making the quest to develop more hygienic poultry bedding systems a higher priority than ever. To successfully raise poultry without antibiotics it is of paramount importance to help prevent disease in the first place, and using a hygienically superior bedding product is of paramount importance. To successfully capture this new premium market, broiler producers will also likely need to improve ventilation and adjust stocking density to help prevent disease development.

In Ontario, approximately 200 million broiler chickens are produced every year. This represents approximately 350,000 tonnes of broiler chicken with a commercial value of approximately $800 million per year. As well, Ontario produces about 62,000 tonnes of turkey annually from approximately 6 million birds. Sound management of the poultry bedding used for the large numbers of birds produced in the province is essential to the success of the sector. Typically in Ontario, broilers are managed in large flocks of 15,000 birds in broiler houses that may be 90 m x 12.5 m (300 ft x 40 ft). The birds are grown on cement floors that typically have loose bedding spread to a depth of 4-7.5 cm (1.5–3 in.). In the case of broiler chickens, the birds typically are marketed at ~2.3 kg and produced over a 5–6-week period. Turkeys are marketed over a 10–16-week period in the 5–15-kg range. For broilers, the maximum stocking density for most producers is 31 kg/m^2 (6.35 lb/ft^2). However, barns that demonstrate an ability to operate under higher densities can adopt a density of up to 38 kg/m^2 (7.78 lb/ft^2). In the case of Ontario, all litter must be cleaned out after each flock, prior to the introduction of fresh bedding for the new flock.

For turkeys, the role of bedding in maintaining bird health and performance is even more critical, as the flocks are held for up to 16 weeks and the males on average reach about 15 kg. The longer duration of turkey production and heavier weight of the birds generally make for more difficult litter management conditions.

The overall bedding market is already sizeable within Ontario with an estimated 0.1-.15 kg (0.2–0.3 lb) of bedding used per bird presently. Assuming approximately 0.2-.25 kg (0.4–0.5 lb) of bedding could be required per bird in the future, the overall market in Ontario for broiler bedding could grow up to approximately 45,000 tonnes (100 million lb). With an average cost of $200/tonne this could represent approximately a $9-million bedding market annually for broilers — approximately $10 million if turkeys are included. Overall, producers will weigh a number of factors in choosing a bedding, including price, availability, convenience and performance.

An effective bedding system should:

- efficiently absorb moisture, nutrients and ammonia from bird droppings
- be able to release moisture during periods of ventilation
- create a dry cushion for the resting birds' breast muscle
- form a non-slip dry substrate to minimize leg injuries and help maintain healthy feet
- maintain air quality in the barn by minimizing dust contributions and ammonia
- minimize the conditions conducive to growing harmful disease-causing bacteria or insect populations
- prevent crusting of the surface and cake formation
- reduce odours emitted from the barn to the surrounding community
- dilute the excreta to reduce direct contact with the birds
- enable a good field crop yield response when the litter or composted litter is applied to the field

In addition, effective bedding should:

- optimize comfort by being lightweight, yet firm enough to resist compressive forces and prevent caking when the material gets wet
- optimize absorption/desorption processes by having a sufficiently large specific surface area available
- insulate the birds by being dry and having low thermal conductivity
- have low palatability yet be safe to eat and free of chemicals and moulds
- minimize potential for rapid decomposition, growth of bacteria and ammonia formation by being low in nitrogen
- help prevent moisture build-up by being dry upon arrival and efficient at releasing moisture from the litter (desorption)
- be easy to spread and level

Historically, the main beddings that have been used in Ontario include cereal straws and wood shavings. Some producers have also begun using virgin cardboard. In other districts, coarse sawdust, rice hulls, peanut shells and oat hulls have also been used. Switchgrass and miscanthus have been in use for approximately 2 yr in Ontario and significantly longer in the U.S. These warm-season grasses are being used with success in both turkey and broiler facilities.

Most growers will only make a change if there are significant benefits either in input cost savings or performance benefits realized in their production system. However, in the case of poultry bedding, the growing interest in the new market premiums for antibiotic-free products is a new factor driving producer change. This section of the bedding manual will examine in detail the major issues that affect poultry bedding performance, as well as the particular strengths and weaknesses of switchgrass and miscanthus bedding within the poultry market.

Figure 15. A grow out of 10,000 chicks on chopped miscanthus bedding processed with a tub grinder. Long strands of material will typical rise to the bedding surface as the broilers continually disturb the material. A video on miscanthus and switchgrass use by several innovative Ontario poultry producers is available on youtube at this link: https://www.youtube.com/watch?v=C50m987jy14&feature=youtu.be

Through optimizing bedding management, producers have a promising tool available that may help them realize, in the future, higher market prices through the antibiotic-free poultry market. This review will outline the major factors affecting the effectiveness of bedding and outline possible strategies to more fully optimize the performance of switchgrass and miscanthus as hygienic bedding alternatives.

In this manual, litter is considered the combination of poultry excreta, spilled food, bird feathers and spilled water. Bedding is the material substrate added to the barn floor at the outset of each flock.

Figure 16. Most of the early on-farm studies comparing switchgrass (left) and wood shavings (right) have found similar performance as far as weight gain and feed conversion. On-farm studies have indicated the best results with switchgrass for both absorption and desorption are where the particle size is approximately 2-3 cm. Finer particles sizes will absorb better but lose moisture less effectively (less desorption). A main advantage with switchgrass is it is generally less expensive to source than wood shavings. Some studies indicate there are less problems with foot pad dermatitis with warm season grasses but more detailed assessments are required on optimized warm season grass bedding products.

Moisture Management

Studies on the moisture-holding capacity of various warm-season grasses have shown no strong trends in the absorbency of various bedding materials. Overall, studies indicate that the particle sizing of the grass and its original moisture content appear to be considerably more important for absorption than the specific type of grass used. If the processed materials all have a similar specific surface area and moisture content, then it appears the ability of the bedding to absorb moisture within a 24-hr period is generally similar. A better measure of the effectiveness of bedding is the ability of the material to function to both absorb moisture and release moisture (the desorption process) from the pack over the duration of the flock. As such, 24-hr absorption studies are of little use in judging the merits of one bedding material over another. Of considerably more importance in the difference between materials is their ability to desorb or release water from the bedding material. This property is especially demonstrated when the litter is 4–5 weeks of age at the time when bird stocking density (usually measured in lb/ft^2) and daily excreta production are peaking.

Ideally, the poultry litter should be managed to keep it in an ideal moisture range of 20%–25% or in a satisfactory range of up to 35% in the final weeks of the flock. When moisture content reaches 35%–40%, microbial populations can flourish, which can have important implications for bird health, ammonia and odour formation. When higher moisture content litters reach into the 40%+ range, they will cake and can cause serious problems. By contrast, excessively dry litter will cause the barn to be excessively dusty. Important sources of dust include airborne particles of bird feathers and excreta. A test for assessing moisture content is to squeeze a handful of litter. If the litter adheres tightly and remains in a ball, it is too wet. If it doesn't adhere at all, it is too dry. There should be some adherence of the material if it is in a normal functional range for optimal use as a bedding substrate.

Figure 17. Maintaining dry litter at the peak of a grow-out is very challenging because evaporation rates from dry litter are often insufficient to remove the quantity of water added to the litter daily. Areas near waterers are the most affected by cake formation. Cereal straw is generally the worst performing bedding material for caking as the weak fibres are compressed easily when wetted. Eventually a surface crust forms that increases in both thickness and water content.

Fresh poultry excreta is made up of faeces and urine and has a high moisture content ranging from 55%–83%. The moisture content of the faeces is affected by many factors, including the presence of disease and the proper function of gut flora. Some producers are now feeding whole grains as a means to improve poultry gut function and reduce the moisture content of poultry excreta. Other important sources of moisture include leakage from water lines and improperly maintained or malfunctioning waterers. The bedding should absorb the various sources of moisture and release it back into the air to prevent moisture from continually building up in the litter. The moisture-influencing processes of surface evaporation from the bedding, and water and excreta additions occur at the litter surface. These processes often result in different conditions at the surface compared to the rest of the litter. In time, layers of different moisture contents will form within the litter. Cake eventually results when the litter develops an insufficient capacity to absorb and desorb (release) the moisture from the bedding surface. Maintaining dry litter at the peak of a grow-out is very challenging because evaporation rates from dry litter are often insufficient to remove the quantity of water added to the litter daily.

Once the litter enters into a caking process and the peak of a grow-out has not yet been reached, it is commonly not possible to stop the caking. Caked litter has quite low porosity and tends to dry slowly. Generally, if sufficient time passes during a flock, the cake will increase in depth and the moisture will saturate the litter at 63%–74% moisture. As the moisture begins to peak, the surface will tend to slick over, and serious foot and leg problems can arise. Commonly observed performance differences between litters are in foot and leg problems rather than suboptimal weight gain or feed conversion. More pronounced differences in bird performance on litter of varying quality might be observed in the future if the trend towards antibiotic-free poultry production continues.

Cake Formation

As previously mentioned, the desired goal of the poultry producer is to keep the litter in a friable state with 20%–25% moisture content. In this semi-moist state, it is less prone to be compacted and can dry more readily. If litter is near the optimal moisture content of 25%, the birds' digging/scratching actions will disperse the excreta and mix it into the litter. When in an effective moisture range, the litter commonly will develop a texture that can be described as a moist crumble. If the litter remains friable, the birds can continue to dig and scratch. The constant surface disturbance by the birds can help maintain porosity and help promote drying by exposing the crumbles to ventilation within the barn. It is important to be very attentive to the development of wet litter in the first several weeks of the flock, use sufficient heat and maximize ventilation on sunny afternoons.

Of great importance to the development of a bedding system that does not cake is the ability of a bedding to resist compressive forces, something that differs substantially in various bedding products. When material becomes moist and saturated with nutrients over time, it can begin to decompose and the fibre strength of the material weakens. In the case of wood shavings, it has been observed that wet litter at 30% moisture is more easily compressed than dry litter at 10% moisture. Furthermore, when the litter is compressed at high moisture, it results in improved cohesion between particles and a strong cake formation that is not easily broken up.

Studies on warm-season grasses for compressive forces have been completed to assess their suitability for biocomposites and pulp and paper. They indicate that grasses such as miscanthus and switchgrass have considerably more fibre strength than wheat straw and that overwintering grasses improve strength. Overwintered switchgrass material was found to require double the force of energy of fall-harvested switchgrass crop to be compressed. Testing various forms of bedding that have been exposed to excreta for several weeks would be a useful study to make an effective comparison among bedding options for resistance to compressive forces.

Studies have also found that cake formation is most commonly promoted when particle size is longer than 2.5 cm (1 in.). Longer fibres tend to bridge or matt over on the top of the litter more quickly. Cake eventually results when the litter has an insufficient capacity to absorb or evaporate the moisture from the bedding surface, and the moisture trends up past 40%.

Once well into the process of cake formation, the compressed material will often reach complete saturation. At these high moisture contents, eventually the surface can slick over and result in an increased frequency of leg injuries and food pad dermatitis (FPD).

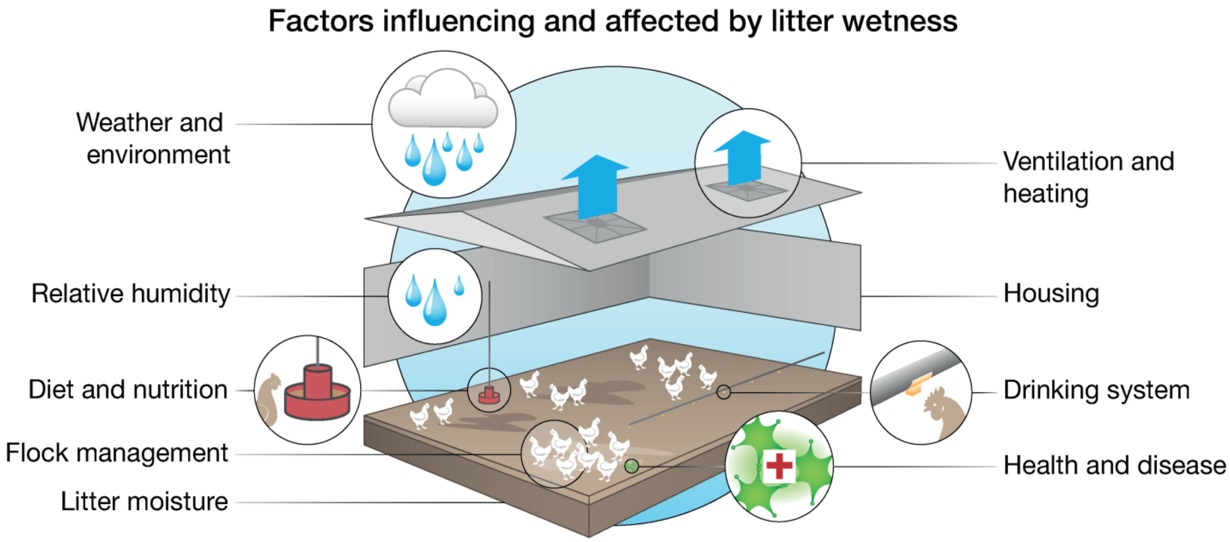

Figure 18. Factors influencing and affected by litter wetness (Dunlop et al. 2016c)

The various factors influencing and affected by the wetness of the litter are presented in Figure 18. Ultimately, moisture has to be vented out of the barn. A comprehensive strategy is required to fully manage the moisture build-up problem in the litter and barn:

- Use ~7.5 cm (3 in.) of bedding of an absorptive bedding material that is not susceptible to be readily compressed when wetted, at the beginning of the flock.
- Use circulation fans to move air within the house. The fans help dry litter by moving warm air off the ceiling and to the floor.
- Use a hot air heat exchanger to reduce energy costs associated with heating the barn to facilitate moisture removal through adequate ventilation.
- Check and manage water systems to prevent leaks.
- Properly powerwash and sanitize the nipple drinker systems to prevent biofilm formation and slow dripping.

- With your nutritionist, assess dietary strategies (such as the inclusion of whole grain feeding) to enhance gut flora and overall bird health to reduce the production of watery faeces.
- Use clay-based drying agents on areas when spills occur.
- Adjust the stocking density if high moisture conditions continue to be present.
- Use well-designed barns with insulated floors and proper wall and ceiling insulation to avoid condensation, as well as a ventilation system that properly mixes and distributes cold air as it enters the barn.

Processing and Spreading the Bedding

Numerous studies have been undertaken in the U.S. on assessing warm-season grasses as poultry litter. One lesson learned from the on-farm studies is that switchgrass had cut materials of varying length when processed using a tub grinder. This was an undesirable feature, as the long strands tend to work themselves to the top of the bedding pack. Long strands can help contribute to matting over and cake formation. A better consistency was found using a roto-chopper, which tends to split the stems along their length.

In Europe it is also more common to see cereal straws dedusted, with fines removed to improve the bedding quality and air quality risks. Of noteworthy importance is that switchgrass chopped to approximately 2.5 cm (1 in.) in length and spread at a 7.5-cm (3-in.) depth generally will hold its volume well. The 2.5-cm (1-in.) long switchgrass particles tend not to flatten as readily as pine shavings. Whereas, if pine shavings are applied at 7.5 cm (3 in.) they will quickly lose one-third of their volume and settle in at 5 cm (2 in.) once birds are introduced. Chopped grasses and wood shavings have quite contrasting shapes, much like a pencil and a plate.

In on-farm trials with switchgrass in the U.S., it was also noted that wood shavings were spread relatively easily as they tend to flow more easily. By contrast, switchgrass is more intertwined and requires a spreading system similar to that used for wheat straw. When handled in bulk, chopped switchgrass can be spread using a rotary rake or hay tedder for more uniform distribution. Producers used to handling cereal straw in poultry barns will generally find their existing methods suitable. It is very important that the grass bedding be uniformly leveled. Variable bedding depth may result in the heights of water drinkers being too low or too high, which may restrict access by baby chicks or cause water spillage if drinkers contact bedding. Uniform distribution of bedding is important for getting birds off to a successful start. To minimize the impact of fines on chicks, extra paper should be spread out and extra feed provided to reduce the risks of chicks consuming fines and starving out.

Figure 19. Poultry litter should be managed to keep it in an ideal moisture range of 20-25%. When in an effective moisture range, the litter commonly will develop a texture that can be described as a moist crumble. If the litter remains friable, the birds can continue to dig and scratch. A constant surface disturbance by the birds can help maintain porosity and help promote drying by exposing the crumbles to ventilation.

Litter Impacts on Ammonia

The quality and quantity of the bedding can also have important impacts on air quality. Optimizing bedding effectiveness may have direct impacts on bird performance, the presence of disease outbreaks and the long-term health of the farm owner and the farm's employees. As well, problematic litter management can cause odour impacts on the surrounding community and create conflicts with nearby residents. Optimizing good bedding management can be a central part of a comprehensive strategy to optimize air quality and minimize odour issues on and off-farm.

Litter is the primary source of odour in meat poultry production. The sources of the odour are varied and can include fresh excreta, the friable litter and the cake containing high moisture. The science of litter odour has not been thoroughly investigated. It is generally understood that litter bedding choices, as well as litter and barn management techniques that maintain dry and friable litter will optimize air quality and minimize odour problems. The use of certain additives used in feed or applied to bedding, such as activated carbon, biochar and zeolite may also impact some specific odourants such as ammonia. Overall, the odour problem seems quite complex and development of a comprehensive strategy is needed to minimize the problem.

Of primary concern to poultry producers is the need to limit ammonia losses and ammonia concentration within the barn. Ammonia represents a major health risk to birds and farm operators. The presence of ammonia also means a loss of N that could be conserved in the bedding and used for crop production.

The main factors affecting ammonia emissions from the litter are:

- increasing litter moisture content
- higher temperatures encouraging ammonia release
- the bioavailability of N in the litter

Nitrogen losses are commonly quite high in the barn. Typically greater than 50% of N excreted by the birds can be lost to the atmosphere prior to litter removal from the barn. Ammonia can be detected by smell in barns when 10–15 ppm of ammonia is present. Ammonia-monitoring devices (e.g., strips and tubes) are useful tools for monitoring ammonia levels in barns. The maximum recommended ammonia concentration in poultry houses in the U.S. is 25 ppm. At this level, discomfort to caretakers is noticeable through eye and nasal irritation. Research examining the negative impact of ammonia exposure has shown approximately a 0.23kg (0.5-lb) reduction in broiler body weight at 7 weeks of age when ammonia exposure increased from 25 to 50 ppm.

Research indicates that materials that are finely chopped, or even compressed, for example, as pellets or crumbles, have an enhanced available surface area to minimize ammonia emissions. Having a sufficient litter depth and using warm-season grasses that are low in N are also very helpful strategies to mitigate ammonia. A large exposed surface area in the bedding will enable more NH3 uptake into the bedding and dilute the N concentration of the litter. In the case of manure studies with straw, NH3 losses are greatest in the order of long straw > chopped straw > straw pellets. Bedding substrates that are relatively high in N such as peanut shells, corn stalks, soybean stalks or wheat straw have much more limited capacity to tie up N in the bedding pack. These bedding materials have proven more susceptible to be quickly decomposed by microbial activity. As a general rule, the higher the N contained in the bedding substrate, the more challenging the ammonia and other odour issues. In the case of warm-season grasses, the more nutrient-rich leaves have been found to decompose 20%–30% faster than the low N stems. Table 3 shows the nitrogen content of various bedding materials.

As will be discussed later, it may be advantageous to separate stems from leaves in dedicated crops such as switchgrass and miscanthus. The stems appear to be a more hygienic choice for producers due to their lower N content. Another main advantage of stems is that they have greater structural strength, making them more difficult to compress and potentially less susceptible to forming cake.

Table 3. Nitrogen (N) Content and Bulk Density of Various Bedding Materials			
Original Bedding Material	**N Content (%)**	**C:N ratio**	**Bulk Density, Loose**
Wood shavings	0.07	650: 1	50–170 kg m^3
Wheat straw	0.75	60–80: 1	20–60 kg/m^3
Switchgrass fall	0.5	100: 1	40–90 kg/m^3
Switchgrass overwintered	0.35	135: 1	40–90 kg/m^3
Miscanthus fall	0.3	150: 1	N/A
Miscanthus overwintered	0.22	200: 1	30–75 kg/m^3

Poultry Diseases

In Ontario, producers are especially challenged and concerned by foot pad dermatitis as it affects their income and ability to use higher stocking densities. Breast blisters are also strongly correlated to the quality of the bedding. Most producers are particularly aware of the need to manage moisture and ammonia levels present in their litter. It is well understood that skin problems such as foot pad lesions, hock burn and breast blisters are associated with higher ammonia levels. Excessively dry bedding can also increase the prevalence of respiratory infections. Many farmers have misting systems to effectively manage this problem.

The impact of bedding on the prevalence of other diseases in broiler production is generally modest, as most producers use antibiotics as part of an overall comprehensive management strategy to prevent health problems from occurring. The growing interest in antibiotic-free poultry will likely create greater interest in strengthening cultural prevention strategies to avoid disease. Disease-preventing vaccines are being used with good success to reduce disease incidence. However, if suboptimal air quality and litter conditions are present, the vaccinated birds will likely have performance challenges, including reduced feed conversion, slower growth rates and high culling rates due to leg injuries. Vaccines can be a useful tool to improve disease incidence, however, efficient bird performance will remain elusive if the environment of the growing birds is not substantially improved. It is of highest importance that a comprehensive strategy is used to improve the growing environment by using adequate quantities of dry hygienic bedding in combination with a well-ventilated facility and appropriate stocking density.

Figure 20. Birds can be assessed for foot or skin lesions that could result when the manure forms a cake and builds up high ammonium levels on the litter surface used by resting birds. Important components of a comprehensive strategy to improve bird performance and to reduce caking potential could include using adequate quantities of conditioned warm season grass bedding and increased barn ventilation to eliminate moisture from the building.

Some types of litter are best avoided if producers are choosing to avoid foot pad dermatitis or choosing to go antibiotic free. For example, hardwood shavings and chopped straw are known to be more prone to developing mould growth. Wheat straw is also known to be susceptible to creating higher moisture litter and early cake formation, and has a high N content that helps promote the growth of biological organisms, including the darkling beetle.

Premium bedding materials have a better chance to optimize bird performance and minimize disease risks. Superior bedding materials are those that are processed to create a large specific surface area, have a low N content, are applied in a dry state and have moderate-to-high resistance to compressive forces. The materials that appear to be the most suitable to meet these requirements on a large scale are softwood shavings and warm-season grasses that have been optimally conditioned.

Optimizing the Quality of Warm-Season Grasses as Poultry Bedding

There are five main ways that the quality of grass bedding can be optimized:

- Process the material to optimize specific surface area to encourage effective absorption and desorption processes.
- Overwinter the material to reduce N content and improve resistance to compressibility.
- Separate the stems from leaves.
- Dedust the product and remove the fines.
- Use warm-season grasses bred for increased stem-to-leaf content to increase the stem-to-leaf ratio in the material.

Process the Material to Optimize Specific Surface Area

From studies with horses and dairy cattle, it is well known that the finer the cereal straw chop, the better the absorption and the lower the ammonia release from the bedding. Studies with cereal straws have also demonstrated that cereals with thinner stem walls, such as oats, absorb moisture more efficiently than modern wheat varieties. The newest wheat cultivars have been selected for thicker stem walls as a trait to improve lodging resistance. In the case of the stem walls of warm-season grasses, the stem wall thickness of upland switchgrass is similar to wheat, while lowland switchgrass types and miscanthus tend to be taller, have fewer stems per m^2 and have both thicker stems and stem walls. Table 4. shows the stem wall thickness of various bedding options.

Table 4. Culm or Stem Wall Thickness of Various Bedding Options

Bedding Source	Thickness
Oats	0.60 mm
Wheat	0.69 mm
Upland switchgrass	0.70 mm
Lowland switchgrass	0.80 mm
Miscanthus	1.3–1.5 mm

To create an adequate surface area for good absorption/desorption, it is essential that the warm season grasses are adequately processed. In the case of upland switchgrass, it appears that chopping the material to a length of 2.5 cm (1 in.) or less provides relatively good performance. Most poultry growers to date in Ontario have used overwintered switchgrass with a pre-chopping attachment on the baler that cuts the material to 5-7.5 cm (2–3 in.) and compresses the material into large square bales. Producers commonly perceive that this overwintered material absorbs moisture better than straw, which tends to have a shiny wax coating. Typically, large square bales of switchgrass will weigh about 10%–15% more than wheat straw. They are commonly shipped in large 0.9 m x 1.2 m x 2.25 m (3 ft x 4 ft x 7.5 ft) bales that fit into a truck with a walking floor.

In the case of lowland switchgrass and miscanthus, it is imperative that the materials are appropriately downsized and conditioned to enable good performance. These tall warm-season grasses have thicker stem walls and, overall, the material appears less absorbing than upland switchgrass. Some efforts are being made to make poultry bedding material even more absorbent by producing crumbles with the materials. New premium cat litters are increasingly being made into a crumble. This intensive conditioning process maximizes the specific surface area available to absorb moisture and ammonia. Densified forms of high-quality bedding could be a viable material for high-value markets such as organic poultry production. Other applications for the crumble material could be as an easily spread, low-dust top dress, applied mid-flock prior to the peak of the grow-out when excreta from the birds are increasing daily. This would likely be most appropriate for the longer grow-out periods associated with ducks and turkeys. The top-dress crumbles may be less disruptive to the flock and create less dust and odour burden or disease risk when mid-flock litter applications are required. This approach might help alleviate the all-too-frequent problem of the litter stratifying with layers of different moisture content when long grow-out periods occur. Top-dressing densified litter mid-flock could also help immediately address a problem with low litter quality that might arise (for example, if inclement weather affects ventilation and evaporation). In general, the technique may not be warranted for most broiler producers that have short cycles of production and good ventilation. Crumbled poultry litters are being marketed in some locations in Europe. For most Ontario broiler producers, their main priority may be sourcing a quality conditioned warm season grass at a reasonable delivered cost.

Overwinter the Material

It is well known that high N levels in crop straws help grow bacteria and accelerate decomposition. Research on warm-season grasses has indicated that the N content of grasses declines when they are overwintered. The N content of switchgrass has been found to typically peak in early summer and then decline through the fall and winter period. Typically, 30% of the above-ground nitrogen is translocated below ground into the crown and roots at fall freeze-up. The later the maturity of the grass, the later this process occurs during the growing season. As well, N can be lost through leaching and loss of leaves.

Overwintering warm-season grasses in Ontario will reduce recovered yields by approximately 15%–20% compared to late-fall harvesting. The main advantages are that the material is very dry at the time of harvest and has improved quality for bedding applications. Approximately 7% of the loss that occurs over winter is through loss of cell solubles. As well, it is known that significant breakage of the grasses can occur overwinter with the main losses being seed heads and leaves. Thus, the N content of both switchgrass and miscanthus is reduced by about one-third through the overwintering process, primarily as a result of the loss of leaves.

The fibrous nature of the plant also increases when the plant is overwintered. The stem component of grasses is highly fibrous. Studies on switchgrass have shown that overwintered switchgrass takes approximately twice as much force to compress as fall-harvested switchgrass does. Thus, there are important differences in compressibility when the grasses are overwintered compared to fall harvesting. For most Ontario poultry producers, choosing an overwintered warm season grass will prove helpful to enhance bedding quality.

Separate the Stems from the Leaves

Technologies are available to separate the stems from the leaves of grasses. This approach may optimize the value chain for warm-season grasses, as stems of grasses have superior characteristics for bedding applications, while leaves may be more suitable for some ruminant livestock feeding applications. The commercial success of this process will be dependent on implementing efficient separation technologies and on the development of markets for the leaves, to make the processing financially viable. On average, the leaves of grasses have 2.5–4 times more N content than the stems. As well, the leaves are much more prone to be easily compressed when they become wet.

A separation process to remove the higher protein leaves from the grasses could make the material more similar to wood shavings in terms of its risk to grow bacteria in the litter. The end-of-season N content of whole plant switchgrass is typically about 0.5% N; for miscanthus, it's about 0.3% N. Miscanthus is typically winter-harvested at a stage when nearly all leaves have naturally dropped and generally has the lowest N content. Table 5 shows the nitrogen content of warm-season grass components at the end of the season.

Table 5. Late fall Nitrogen (N) Content of Warm-Season Grass Components

Processed Bedding Material	N Content
Switchgrass stems	0.30%
Switchgrass leaves	0.74%
Miscanthus stems	0.16%
Miscanthus leaves	0.63%

Thus a separation process could be quite strategic in improving the material in several ways:

- It would enable the bedding material to be mainly stems, which are less conducive to growing bacteria that help support disease and decomposition of the material.
- It would increase the fibre strength of the material and make it less easily compressed.

- It would reduce dust formation as stem particles are heavier than leaves and are less susceptible to be airborne.
- It can enable dedusting of the product and removal of fines.

Dedust the Product and Remove Fines

In the last decade in Europe, dedusting of straws has become increasingly popular as a means to improve the hygienic nature of straw bedding for various livestock markets, including horses, dairy cattle and poultry. Dedusting helps remove sources of airborne particles that can be harmful to the birds and their caretakers. There has been some limited pilot use of dedusted switchgrass in Ontario. Typically, approximately 25% of the material is removed by dedusting and fines removal, primarily the most brittle components of the plant, the leaves and the seed head components. A test of the material removed from the dedusting process found it to be a 0.78% N indicating a high level of leaves were present. The dedusting process has a number of advantages, including reducing the burden of small particles that are easily airborne, reducing the content of leaves and seed head components of the grasses, which are known to be higher in N and have poor fibre strength. It also increases the porosity of the bedding to better enable the litter to absorb small bits of faecal matter. These small particles play an important role in filling in the bedding surface, helping promote the formation of a surface crust. In the case of switchgrass and miscanthus, the process of overwintering, dedusting and fines removal may provide very high-quality litter for producers without any further processing requirements to separate stems from leaves.

Use Improved Warm-Season Grasses

The strategies that have been previously mentioned all have some costs associated with improving the quality of the material for bedding applications. There are also differences between cultivars and species in stem content. In the case of switchgrass, the native ecovars (wild accessions) have approximately

45%–50% stem, and big bluestem has 60%. Research agronomists have found that big bluestem and switchgrass mixtures generally outperform switchgrass monocultures over longer periods. Furthermore, they have better yield stability. Growing big bluestem and switchgrass together in fields and overwintering the grasses may be a good strategy to increase crop quality and harvested product. Plant breeders are also breeding upland switchgrass to have a higher stem content by breeding for reduced tiller number and reduced percentage of vegetative tillers. Thus, new low-cost strategies may be available to producers to deliver a premium warm season grass bedding product that is of significantly better bedding quality than wheat straw, at a marginal increase in cost per tonne of material used.

Cost of Delivered and Processed Bedding Material

Ultimately, livestock producers will be very concerned about the comparative costs of different bedding options and the volumes required to meet their needs. The delivered costs of materials will depend on the volumes delivered, the delivery distance and the amount of processing required. Costs of wheat straw and shavings can vary throughout the province. Wheat straw is least expensive where there is significant wheat acreage and few users (mainly livestock farms and mushroom plants).

Miscanthus is mainly a grass that can be grown in areas of Ontario that do not experience extreme cold. Most of the successful miscanthus growers to date have been located to the south and west of Woodstock, Ontario, and in Prince Edward County. Switchgrass and big bluestem can be grown throughout the province, but these native grasses are mainly targeted for the medium and lower heat unit areas to the north and east of London, Ontario. Pine wood shavings are generally hauled from Northern Ontario milling operations into Southern Ontario.

Processing herbaceous bedding material on farm can be a challenging and dusty job for many smaller broiler and turkey producers. Many poultry farmers have their own straw source. As well, some poultry producers using switchgrass and miscanthus in Ontario are considering growing their own bedding on farm. Thus the actual costs will vary greatly for each individual farm.

In the case of switchgrass, most dedicated producers will aim to sell material at $0.18/kg ($0.08/lb) as a delivered overwintered product in a 0.9 m x 1.2 m x 2.25 m (3 ft x 4 ft x 7.5 ft) bale. More recently, the use of a pre-chopper on the baler has been successfully demonstrated on overwintered switchgrass. This system produces a pre-chopped bale of a 5-7.5 cm (2–3 in.) chop that has approximately a 10% higher density than a standard bale. A pre-chopped 0.9 m x 1.2 m x 2.25 m (3 ft x 4 ft x 7.5 ft) bale can have a delivered cost of approximately $0.20/kg ($0.09/lb). In the case of a dedusted switchgrass product delivered in bags, a rough estimate of the cost may be $0.26/kg ($0.12/lb) in bulk and $0.31/kg ($0.14/lb) in bags. In the case of a crumble, the cost may be as high as $0.32/kg ($0.15/lb) delivered in bulk.

A promising option for very large poultry producers might be to buy a forage harvester and direct chop the material into a 1.9-2.5 cm (0.75–1 in.) length and bulk store it. Local dairy producers ensiling hay crop forage may be equipped to manage the material in a fine-chopped bulk form and could be hired if in reasonable proximity.

Normally warm-season grasses are harvested in the months of March–May when dairy forage harvesting equipment is idle. As the industry expands, the business likely will see custom harvesters become available to on-farm process materials for producers. It is likely that, in the near term, the main market for warm-season grass producers will be in producing a pre-chopped (5-7.5 cm (2–3 in.) long material), over-wintered product in a higher-density bale. This is a relatively modest-cost product that will require no further processing at the farm. For most price-conscious poultry producers, this is likely the most convenient and affordable product to use. Table 6 shows a cost comparison of three delivered bedding materials in Ontario.

Table 6. Cost comparison of three delivered bedding materials in Ontario

Bedding Material	Price	Length of Chop	Weight of Bale
Wheat straw	$0.16/kg ($0.07/lb)	7.5-15 cm (3–6 in.)	360 kg (800 lb)
Switchgrass	$0.18/kg ($0.08/lb)	7.5-15 cm (3–6 in.)	400 kg (900 lb)
Pre-chopped switchgrass	$0.20/kg ($0.09/lb)	5-7.5 cm (2–3 in.)	450 kg (1,000 lb)

Figure 21. Hiring a baler with a roto-cut pre-chop attachment can be a simple and low cost way to produce a chopped material ready for direct on-farm use. It improves user convenience as the dusty chopping job is completed in the field and a dense pre-chopped bale can be delivered to the customer. Long term exposure to dust is a major health risk for producers. Field conditioning biomass for ready-use in the barn is an excellent technique to minimize dust exposure risks to farmers from biomass processing.

Figure 22. The length of the cut available on a pre-chopped bale is continually be reduced by the farm machinery sector. Nominal cuts in the 2.5 cm (1") range are currently being advertised. If these short cut lengths can be realized under field conditions this would largely eliminate any further pre-processing requirements for use in most applications in the poultry sector.

A simple low-cost strategy for applying the material in single-floor barns or ground floors of multi-floor buildings may be through application of a large, square-bale product in a manure spreader. Some producers have purchased a manure spreader that is sized to a desired length of a large bale and has a double beater. When the strings are cut, the bale ideally expands in the spreader to just reach the beaters. Some farmers learn to adjust their bale length to fit their spreaders so they do not overload the beaters with fibre when they are starting with a new bale in the barn. A good even spread is being reported by farmers who drive slowly in a low gear and cover the barn floor in 3–4 straw application passes.

A large single floor barn may only require 1 hr/930 sq. m (10,000 sq. ft) of floor space to uniformly spread the material using the manure spreader method of application. Another time-saving approach being used for farmers is to use their lawnmowers to blow fibre to cover the edge gap that is left by the straw-spreading technique. These two approaches can be used to eliminate hand spreading of bedding. By contrast, spreading baled shaving materials by hand can be a very time-consuming, laborious and dusty job. It may require 6 hr of hand-forking to cover a 930-m^2 (10,000-ft^2) barn area with bales of shavings.

Utilization of Poultry Litter

The volumes of poultry litter produced can be quite large for a poultry enterprise. There are several options to directly utilize the material: manure or compost for field crop production and production of biogas. Producing compost or biogas can be a useful way to add value to this residual product. It also can help reduce odour problems from the farm and eliminate harmful pathogens such as salmonella from entering drinking water supplies.

Poultry Litter as a Soil Amendment

A distinct advantage of using litter composed of grass bedding vs. wood shavings is that it decomposes more rapidly when composted, stockpiled or if directly field-applied as fresh manure. The highly lignified nature of wood shavings and its low N content work together to create a slow microbial decomposition process. Typical lignin levels of softwood shavings would be 30%, while switchgrass and miscanthus are more typically in the 16%–19% range when harvested as mature crops.

Pine wood shavings (C: N ratio of 650:1), when combined with low N manure sources such as beef, horse or dairy manure, has a poor reputation as a soil amendment to enhance crop growth. A main problem is that although the N content of the manure is in theory sufficiently high, the available N for the crop can be lower than anticipated. Often N from the poultry manure can be immobilized by the slowly degrading high C: N wood shavings. In the case of pine shavings, the material is known to acidify soils, which is also detrimental to soils and crop performance.

Thus many producers are opting to compost poultry manure to improve its ability to make nutrients more readily available for crop production. If poultry manure with wood shavings is directly field-applied, farmers often observe that wood shavings remain present in the field several years after a poultry manure application.

Poultry bedding derived from warm-season grasses, by contrast, has a moderately high C: N ratio of 135–200:1 and is a less lignified material. The grasses also have hollow stems, which helps make more surface area available for microbial decomposition in a composting process or when applied to soil. Warm-season grasses generally need a shorter composting period than compost that contains wood shavings. These grasses also tend to create a more aerobic composting process, as the material does not compress as readily as wood shavings. Manure or compost from herbaceous sources will generally provide a more predictable and positive impact on crop production.

A less commonly understood advantage of using warm-season grasses over wood shavings as poultry litter is that over the very long term, the grasses have an advantage in building soil organic matter. Warm-season grasses such as switchgrass and miscanthus are known to contain high levels of phytoliths (plant stones). Typically, grasses will have six times the quantity of phytoliths than woody plant species. Phytoliths are highly resistant to decomposition, are extremely slow to be decomposed and can last for as much as 1,000 years. Thus, growing warm-season grasses may be a promising long-term strategy for slowly but steadily increasing soil carbon. One reason the tall grass prairie zone of North America has the deepest and richest soils in North America is the long-term build-up of phytoliths that help create the high levels of soil organic matter found on prairie soils. Typically, a Midwestern prairie will have nearly double the soil organic matter of a nearby forest soil. Thus, farmers applying warm-season grass litter may be boosting both the potential crop response and making long-term contributions to soil organic matter levels on their farm.

Poultry Litter for Biogas Digesters

Another advantage of using grass bedding over wood shavings as a litter source is that it makes the litter a superior product for use in a biogas digester. The readily digestible parts of plants, known as cellulose and hemicellulose, are higher in grasses than in more lignin-rich wood shavings. Litter composed of warm-season grasses thus creates a higher gas-yielding feedstock for a biogas digester than litter from shavings. The grass litter has a faster rate of passage through the digester compared to wood shavings, due to its less lignified nature. Woody materials are considered a contaminant in a biogas digester.

The best bioenergy strategy for warm-season grasses may be in cascading applications used as:

- a hygienic bedding
- a feedstock for a biogas digester
- a valuable soil amendment when the digestate is field-applied

Conclusion

Given the importance of organic bedding sources (herbaceous and woody materials) to livestock health and well-being it is surprising so little research and technology transfer has been done on developing, optimizing and promoting improved organic bedding sources. This document makes an effort to explain the main traits required for more sustainable organic bedding sources to be developed for livestock and poultry in Ontario. There are three main prerequisites for a high quality organic bedding:

1. It must be low N to minimize:

- the potential for bacterial growth and pre-mature degradation;
- to contribute to efficiently absorbing ammonia.

2. It must have sufficient fibre strength to:

- cushion animals and prevent matting by large ruminants or caking by poultry;
- maintain a high specific surface area that is conducive to moisture absorption and desorption

3. It must be conditioned to optimize the specific surface area that best fits the application to:

- optimize moisture absorption and desorption processes
- optimize nutrient and ammonia absorption

In the case of dairy cattle it appears that switchgrass harvested with a pre-chopper on the baler will provide sufficient specific surface area and fibre strength to be highly useful for most bedding applications on dairy farms. As well this system should work well for beef cattle and most swine applications. Horse owners in Ontario are successfully using a finer chopped dedusted switchgrass product. Dairy farmers that are currently using cereal straw as a bedding source will find few management changes are required to adopt switchgrass as a more hygienic bedding source. Farmers with high quality mattresses and liquid manure systems will most likely prefer a finer ground product that forms a softer layer between the mattress and the animal. Dairy producers with high quality mattresses are experiencing that ground switchgrass is alleviating leg problems they formerly incurred with hock injuries from use of abrasive woody residue materials. The use of high quality rubber mattresses with modest layers of ground switchgrass appears to be a promising new system that can challenge sand based bedding systems for comfort, hygiene and protecting legs from hock injuries. Miscanthus use in dairy bedding systems appears to hold most promise as a compost bedding pack substitute for wood residue packs as it has very low nitrogen. Miscanthus is somewhat more expensive than switchgrass to source in Ontario for most applications currently but production technologies are still evolving for both crops.

For poultry production it appears that both wood shavings and adequately conditioned warm season grasses provide similar performance and that differences between the products in the barn are often modest in recent on-farm trials. An optimized warm season grass bedding product that is conditioned to 2.5 cm length and dedusted with fines removed appears to provide top performance potential. Conditioned switchgrass is clearly superior to cereal straw, which has a relatively high N content and weak fibre strength. The main advantage that warm season grasses appear to have over softwood shavings are that they are less expensive to source on average in southern Ontario. As well many farmers could grow their own bedding or readily access it locally in the future. Wood shavings tend to have variable quality and are shipped in from wood processing facilities from the northern part of the province of Ontario. Another important advantage is the manure quality is improved when it contains no woody residues. For farmers choosing to produce antibiotic free poultry in

Ontario there would be few management changes required to switch from cereal straw bedding to switchgrass bedding and significant animal health benefits will likely be realized. More research is required on optimizing the conditioning of warm season grasses given its potential value for protecting bird health.

For both dairy cattle and poultry production properly conditioned warm season grasses appear to offer significant livestock and poultry health benefits over cereal straw and should be more widely adopted.

Figure 23. A key concept that producers need to understand is that conditioning biomass needs to be optimized for both absorption and desorption processes. Biomass chopped finely will absorb very well but excessive processing will reduce the rate of evaporative water loss. A 2.5 cm (1 in.) average chop length seems to be near the optimal range.

Appendix

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