Fumigants & Pheromones

Digital Newsletter Delivered by Insects Limited, Inc. *Issue 177*

Organic Fumigation Using Either CO2 or Nitrogen

Patrick Kelley, BCE
President of Insects Limited

One of the many data points that has drastically changed over the past 20 years is the sheer amount of organic food that is consumed in the world today.

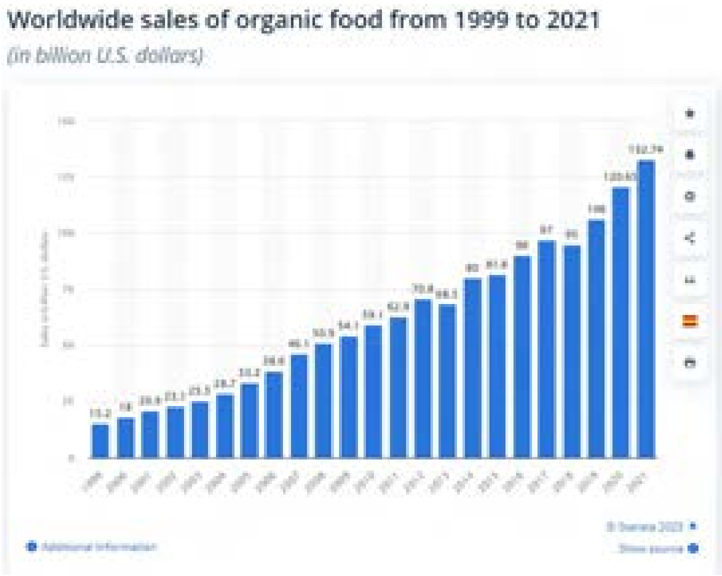
In the United States, the retail sales of organic food rose from 10 billion in 2001 to 55 billion in 2020. On a global scale, organic food sales rose from 15 billion in 1999 up to 132 billion in 2021.

There is no argument that more and more consumers are demanding organic foods and that the market must react to fulfill this demand.

This article is one in a series that are based on presentations given at the 14th Stored Product Protection Conference hosted by Insects Limited and held at Purdue University on June 14 & 15, 2023. The 2-Day conference that focused on protecting our food and cherished belongings from pests had 140 people attend from 6 continents and 24 different countries. This presentation given by Insects Limited president Patrick Kelley covered the pros, cons and stumbling blocks of using carbon dioxide (CO²) or nitrogen as organic fumigants on organic food products.

From a pest standpoint, the nature of organic foods is adherently more at risk to pest attack than a non-organic equivalent. Organic foods are checked by governments and by certifying organizations to verify that no prohibited substances (E.g., common pesticides) encounter the soil, the crop, or the finished food product.

An important aspect of whether we can use carbon dioxide or nitrogen as a treatment is whether the organic certifying organizations allow their use. The National List of Allowed and Prohibited Substances identifies substances that may and may not be used in organic crop and livestock production. It also lists the substances that may be used in or on processed organic products.



The retail sales of organic food has risen dramatically over the past two decades. Image from https://www.statista.com/statistics/273090/worldwide-sales-of-organic-foods-since-1999/

In general, synthetic substances are prohibited unless specifically allowed and non-synthetic substances are allowed unless specifically prohibited:

https://www.ams.usda.gov/rules-regulations/national-list-allowed-and-prohibited-substances.

Currently, non-synthetic, oil-free grades of nitrogen are allowed as organic treatments as well as synthetic, man-made (anthropogenic) carbon dioxide.

Organic operations are certified by private, foreign, or state entities that have been accredited by USDA.

Carbon Dioxide

Carbon dioxide (CO^2) is one of the more commonly found gases on earth, but it has also been identified as a gas that has an indirect effect on the ozone layer in the stratosphere when excessive levels are emitted on earth. The amount of carbon dioxide used to treat pest infestations, though, is minuscule compared to the quantities produced in the air-sea gas exchange or through other industrial uses such as the generation of electric power.

Hypercarbia, a word meaning elevated levels of carbon dioxide, is what kills insects and rodents when fumigating with CO^2. Oxygen deprivation (anoxia) in CO^2 treatments leads to an increase in mortality rates, but it is desiccation, or dehydration due to increased respiration which specifically accounts for physiological death of pests.

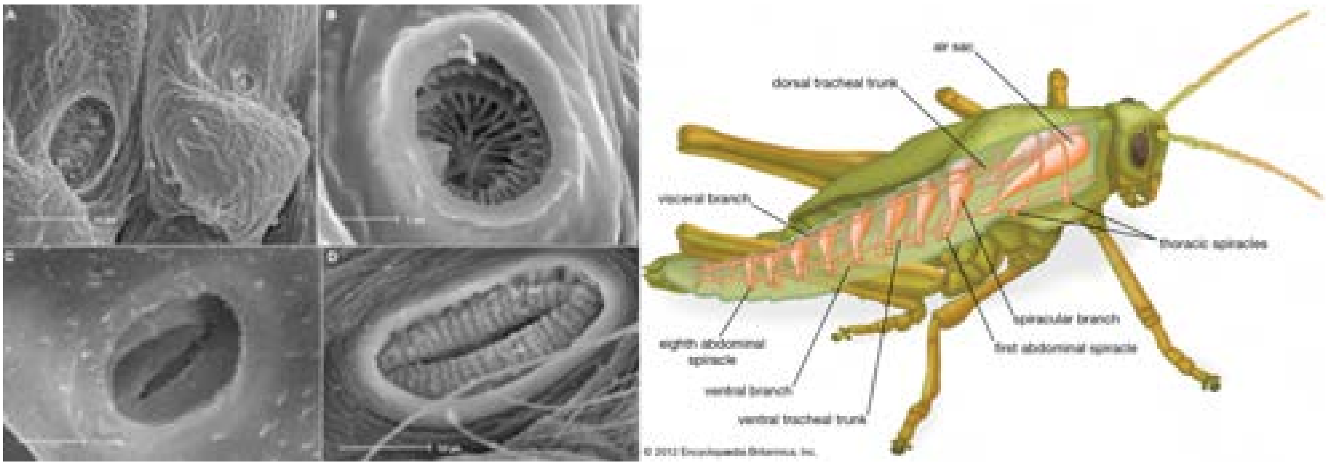
Increased levels of carbon dioxide cause insect spiracles to remain open as the insect's body tells it to get rid of excess CO^2. The open spiracles cause the insect to lose valuable water molecules and eventually leads to the insect dying from dehydration and desiccation. Image copyright: Insects Limited, Inc.

The effects of CO^2 on the respiration of insects are significant. A 2% increase of carbon dioxide causes an increase of 50% in the breathing rate of insects. A 5% increase of CO^2 causes an increase of 300% in the breathing rate of insects.

% Increase of Respiration Caused by CO²

- 2% CO² causes an increase of 50% in the breathing rate of insects
- 5% CO² causes an increase of 300% in the breathing rate of insects

The means that increased respiration leads to the death of the insects can be explained by examining the way that insects breathe. Unlike mammals, insects do not breathe through their mouths, but instead through tiny holes in their exoskeletons. These tiny holes, called spiracles, open when the insect wants to take in oxygen but also open when the insect wants to get rid of waste carbon dioxide. The spiracles remain shut at all other times to retain water molecules in the insect's body.



Spiracles of wood-boring beetles observed under SEM. Lyctus linearis (Goeze): A. Abdomen extremity of the larva with the last two spiracles; B. Penultimate abdominal spiracle; C. adult abdominal spiracle; D. Trichoferus holosericeus (Rossi), larval thoracic spiracle. From Chiappini, Elisabetta & Aldini, Rinaldo. (2011). Morphological and physiological adaptations of wood-boring beetle larvae in timber. Journal of Entomological and Acarological Research, Ser. II. 43. 47-59. 10.4081/jear.2011.47. and The respiratory system of an insect, including spiracles. Encyclopedia Britannica (2012)

Increases in CO² cause the spiracles to remain open as the insect's body tells it to get rid of excess CO². Unfortunately for the insect and fortunate for those of us trying to eliminate a pest insect problem, the wide-open spiracles allow the valuable water molecules to escape from the insect's body and the insect eventually dies of desiccation and dehydration. At this same time, high CO² levels and lower oxygen levels prevent the insect from any energy gain. CO² poisoning and suffocation can also be playing a role in speeding up the insect's death.

The recommended times that a CO² treatment takes varies greatly depending on where you are getting your information. The cylinderized CO² product "IGI Carbon Dioxide Powered by Liphatech" lists the following on their pesticide label, **"For storage and structural fumigation, dosage rates vary from 60% atmosphere to 88% atmosphere. Treatment times vary from 24 hours to 4 days. Do not fumigate if temperature is less than 40ºF. Structure should be as gas tight as possible before treatment. Maintain as near as 60% ±10% CO2 as possible."**

The time frame on the pesticide label for IGI Carbon Dioxide Powered by Liphatech above is much shorter than what is recommended on some well-respected museum websites or in several museum-based scientific papers on CO² treatment.

MuseumPests.net, a great resource for all pest issues found in museums says this about treatment time: ***"Treatment time is typically four-weeks in the 'kill zone' range: 4.8% - 8.2% oxygen, 60% CO² at 20-29ºC (68-84ºF). Updated methods show that treatment times can be reduced by increasing the initial CO² to 80% within the first five days. From this point on, 14 days are necessary to kill all species. During this period it is imperative that the CO² does not fall below 60% and temperatures do not fall below 80º F."***

The reason for the differences in exposure time might have to do with relative humidity (RH). When cylinder-based carbon dioxide is used in a treatment, it is a dry gas with no water molecules. Pumping large amounts of carbon dioxide into an enclosure can quickly drop the RH % to levels of 10% or even lower. When treating dried-food goods or grains, lower RH levels do not have negative consequences on the food products. The dried-foods and grains often have initial internal RH percentages in the teens and the food has a chance to rebound to a normal level after the treatment. The same is not true when treating museum objects. A drastic drop in RH can negatively and permanently affect a museum object. Museum conservators and curators generally try to keep valued collections as environmentally stable as possible and as close to an RH of 50% as possible. Considering the difficult task that museum professionals have of attempting to keep objects in the same condition 500+ years from now as they are today, makes this standard a bit easier to understand. The 50% RH during a museum fumigation that uses CO² is often achieved with humidifiers pumping moisture into the enclosure throughout the duration of the treatment. Since desiccation and dehydration are the factors killing the insects, the higher RH for museum objects during treatment is likely keeping the insects alive longer. This may explain why longer times (*3 - 4 weeks*) are recommended and needed for museum treatments with CO² while only 1 - 4 days are specified on the IGI Carbon Dioxide Powered by Liphatech label for food and grains.

One of the drawbacks of a carbon dioxide treatment is that it is difficult to contain this active gas molecule and retain the levels needed to kill insects. The oxygen in ambient air on the outside of the treatment enclosure is actively trying to get inside. For these reasons, entire-structure carbon dioxide fumigation is not cost effective and not recommended unless significant investment is made into specifically modifying the structure to make it gas impermeable. Standard polyethylene sheeting (<6mm thick) will not suffice as a barrier as it only slows the egression of CO² and the ingress of oxygen. Eventually CO² levels drop below what is needed to kill insects using standard polyethylene. HDPE, Nylon, EVOH or multi-layered plastic and foil barrier films are a better option to contain CO² and keep oxygen from entering the treatment area.

Nitrogen

When nitrogen is being used as the treatment gas, it works much differently on the insect than carbon dioxide does. Where carbon dioxide is killing insects through desiccation, dehydration and carbon dioxide poisoning (hypercarbia), nitrogen is killing insects through suffocation alone by creating an anoxic environment. While carbon dioxide levels only need to be at 60% - 80% to be effective, the level of nitrogen needs to be near a level of >99.7% which translates to <0.3% oxygen. *Some recent research suggests that levels of 1% oxygen are satisfactory to kill insects in certain situations.* The nitrogen being introduced forces the oxygen out of the fumigation enclosure. Standard breathing air is made up of 78% nitrogen, 21% oxygen, 0.04% CO² and 0.96% other gases (mostly argon). The job of the fumigator is to force the 21% oxygen in the breathing air out of that enclosure to an acceptably low level and keep it out for at least a 3-week period.

The reason it takes so long to suffocate an insect (Humans would suffocate within minutes at oxygen levels of 5%) is that as soon as oxygen levels begin to dip, insects stop moving, they close their breathing spiracles, and they retain any oxygen that they previously had in their system. Since they are not moving, they are not using energy and thus only use incrementally small amounts of oxygen.It can take up to a full 3 weeks before insects use up the oxygen supplies that they hold within their bodies prior to suffocation. The most inactive stages of insect, the pupal and egg stage, tend to live the longest under low levels of oxygen.

After using nitrogen to flush out the oxygen in breathing air, and holding those low levels (<0.3%), insects will finally suffocate after 3 weeks. Image copyright: InsectsLimited, Inc.

When performing Anoxic treatments, different styles of enclosures can be used. The company Hanwell makes prefabricated Anoxic Storage Solutions for use with oxygen scavengers. Iron shavings that make up the scavengers chemically react with oxygen molecules, consuming the oxygen. The end-product after the reaction is iron oxide (rust).

As stated above, whenever considering a carbon dioxide or anoxic treatment, the type of barrier material used in the enclosure is of the utmost importance. CO^2 and oxygen have extremely small, active gas molecules that are not easily contained. Hanwell's enclosures use a multi-layered foil barrier that can be heat-sealed to keep oxygen out after the existing oxygen has been consumed. Soft-sided enclosures (GrainPro, Maheu Fumigation Bubble, Heritage Packaging, etc.) use PVC plastics to contain the gas molecules, while hard-sided permanent chambers (Vacudyne Inc., etc.) use metal walls with sealable doors to contain the gas. If using standard polyethylene, a thickness of >6 mils is necessary.

Costs for the different enclosures can vary greatly. Smaller Hanwell enclosures can be purchased for slightly over $100 USD, larger, custom soft-sided enclosures can be made for ~$20,000 USD while a permanent, metal, hard-sided chamber may run ~$200,000. USD.

It is important to evaluate what you will be creating a modified atmosphere for, when planning your organic fumigation. You will need to ask yourself what space you will be using, what resources (electricity, temperature controls, etc.) are available in that space and what budget that you have prior to deciding. The need for organic fumigations has risen dramatically over the past decade. Effective solutions are out there if you consider all these parameters.

Both soft-sided mobile and hard-sided permanent fumigation chambers can be used when performing organic fumigations with carbon dioxide or nitrogen. Shown here are GrainPro's cocoon on the left and QVS Vacuum Fumigation Chamber on the right.

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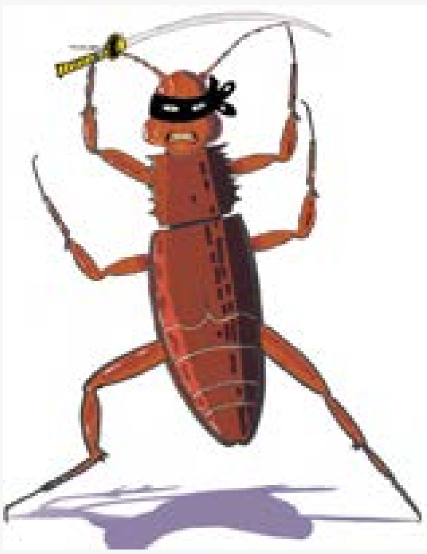
Saw-toothed Grain Beetle - The Ninja of Stored Product Pests



Saw-toothed grain beetles can have "ninja-like" skills too enter food packaging Image copyright Insects Limited

In the quiet corners of our warehouses, homes and pantries, a stealthy insect with ninja-like qualities lurks – the saw-toothed grain beetle (*Oryzaephilus surinamensis*).

Minuscule in size, this pesky pest can slip undetected into the tightest of food containers and climb right up on the smoothest glass surfaces on its way to cause considerable damage to our food supplies and provoke frustration among homeowners and food processors alike.

We can almost imagine it doing cartwheels and leaping across tall buildings on its trek to get inside our food packages.

Let's look into the fascinating world of saw-toothed grain beetles, exploring their characteristics, habits, and how to combat their unwelcome presence.

1. A Tiny Intruder: Identifying the Saw-Toothed Grain Beetle

Measuring between 2.5 to 3 mm in length, this reddish-brown beetle derives its name from the six saw-like projections along each side of its thorax.

These distinctive serrations make it easy to differentiate from other pantry pests like the flour beetle.

Having a profile of less than half a millimeter, this stealthy insect can slip right through many types seals or small perforations of food packaging on its way to decimate the food product within.

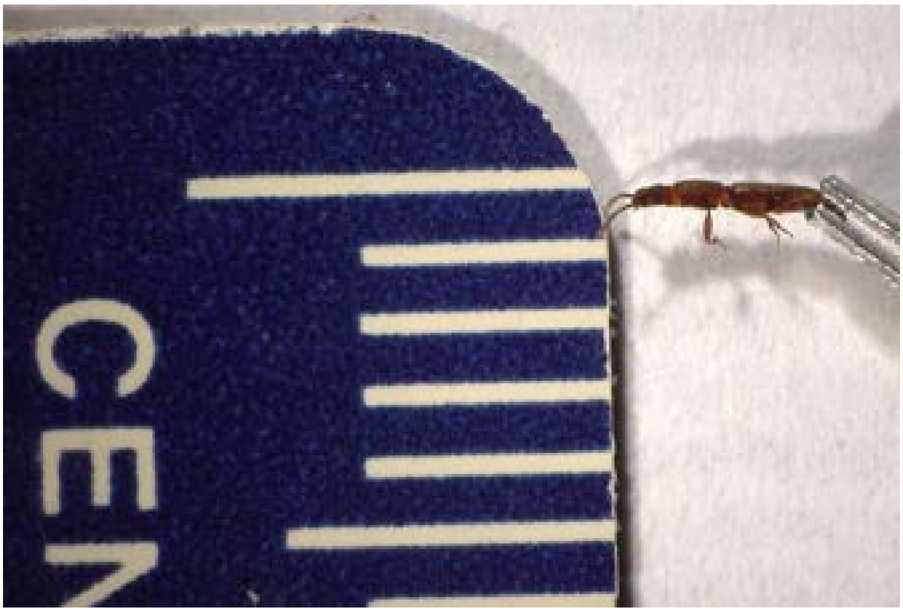
A saw-toothed grain beetle on a US Penny. Image: Patrick Kelley, Insects Limited.

The distinct saw-like protrusions on the thorax of the adult saw-toothed grain beetle makes it easy to distinguish from other stored product beetles except the look-alike merchant grain beetle. Photo credit: Samantha Kiever, Insects Limited

2. The Silent Invader: Life Cycle and Reproduction

Understanding the life cycle of these tiny invaders is crucial in effectively combating them.

The saw-toothed grain beetle silently undergoes a complete metamorphosis, consisting of four stages: egg, larva, pupa, and adult. Under optimal conditions, the life cycle can be completed in as little as 30 days, allowing the population to grow rapidly.



Having a profile of less than half a millimeter, this stealthy insect can slip right through many types of food packaging to decimate the food product within. Photo credit: Patrick Kelley, Insects Limited

Females can lay up to 300 eggs, depositing them within cracks and crevices near food sources.

The eggs hatch into tiny white larvae that actively feed on the foodstuff, leaving behind a telltale sign of infestation – a fine powder-like frass.

3. Sneaky Behavior: Infestation Signs and Damage

The presence of saw-toothed grain beetles is often detected through the holes they chew into food packages and the powdery residue they leave behind. Their thin profile allows them to slip right around the cardboard flaps in boxes of pasta and rice. Since they are excellent climbers, they can easily migrate between packages, spreading infestations rapidly.

Infested food can be rendered inedible and contaminated with beetle parts and excrement. Additionally, their presence in food processing facilities can lead to financial losses and damage the reputation of businesses.

4. Pantry Pirates: Preferred Habitats

Saw-toothed grain beetles are highly adaptable and can be found in various food products stored in pantries, kitchens, and food processing facilities. They are particularly attracted to grains, cereals, flour, pasta, rice, dried fruits, nuts, pet food, and other dry foodstuffs. They have been known to use the cracks in concrete floors of food warehouses to travel from one pallet of food to another. They thrive in tight spaces and in warm temperatures.

5. Preventive Measures: Keeping Saw-Toothed Grain Beetles at Bay

Preventing an infestation is always preferable to combating one. Here are some practical tips to minimize the risk of saw-toothed grain beetle invasions:

- Inspect and clean food storage areas regularly.
- Store food in airtight containers made of glass, metal, or heavy-duty plastic.
- Rotate food supplies to ensure older items are used first.
- Dispose of infested items promptly and seal them in plastic bags before discarding.
- Keep a vigilant eye on new food products brought into your home.

6. Eradicating Infestations: Integrated Pest Management

If an infestation is already underway, Integrated Pest Management (IPM) practices can help control the population while minimizing environmental impact. IPM for saw-toothed grain beetles begins with a good monitoring program. Their ability to maneuver and climb also means that most sticky glue traps and pitfall traps do not work to trap them. Extensive research done at Insects Limited's R&D Laboratory has found that the All Beetle Trap with Gel Attractant is the best trapping method available to monitor this elusive pest. IPM may involve physical control, such as removing infested products, freezing or heating infested items to kill beetles and larvae.

In severe cases, chemical treatments, such as diatomaceous earth or pyrethrin-based insecticides, could be used.

Conclusion

As invisible invaders, saw-toothed grain beetles pose a significant threat to our food supplies and storage areas. Their ninja-like abilities to sneak into, maneuver around and infiltrate our food products can be infuriating and expensive.

By understanding their biology and behavior and implementing preventive measures, we can better protect our homes and businesses from these tiny but formidable pantry pests.

Stay vigilant, monitor, and act promptly, for even the smallest beetle can cause the biggest of problems.

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Spotted Lanternfly and Tree of Heaven: The Invasive Duo Threatening US Agriculture

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In the world of IPM, we're always reminded to **"Start with the insect first!"**

Today, our focus is on the Spotted Lanternfly (SLF), a devastating invasive pest threatening the heart of US farming. But this story features not one, but two invaders - the second being the SLF's preferred host, the Tree of Heaven.

Figure 1. Spotted lanternfly, Photo Credit: Lawrence Barringer Pennsylvania Department of Agriculture, bugwood.org

The Invaders and Their Impact

Both the Spotted Lanternfly and the Tree of Heaven hail from China. The tree was brought over as an ornamental plant in the 1780s and has since grown aggressively across the country. The lanternfly was first detected in Pennsylvania in 2014. Today, these two invaders stand as a formidable threat to American agriculture. The lanternfly uses the Tree of Heaven as a favorite host, making this duo a challenging adversary for farmers and regulators alike.

Destructive Feeding Habits

As sap suckers, Spotted Lanternflies can severely impact over 70 plant species. The As sap suckers, Spotted Lanternflies can severely impact over 70 plant species. The insect weakens plants, hampers their growth, and reduces yield. Adding to the assault, the lanternfly excretes a sugary substance, honeydew, encouraging sooty mold growth and often causing premature plant death.

Figure 2. Spotted lanternfly life stages, Photo Credit: Iowa Department of Natural Resources

A Threat to Key Industries

The Spotted Lanternfly's choice of host plants places vital sectors of the US economy in its crosshairs. Grape, apple, and hops industries stand on the front line of this invasion. Additionally, hardwood timber species, including oak and walnut, are threatened, which could lead to considerable economic repercussions.

Tackling the Threat

The battle against the Spotted Lanternfly and the Tree of Heaven necessitates a strategic approach. Implementing quarantine measures and promoting public awareness are key components of this strategy. Citizens are also encouraged to report sightings, destroy egg masses, and cut down Tree of Heaven when possible.

Figure 3. Tree of heaven in an urban environment, Photo Credit: A. Smith, ODNR Division of Forestry

A Ray of Hope

While this invasive duo is spreading, there is a ray of hope. Scientists are exploring potential biological controls, including predators, parasites, and diseases that may naturally curb these species in their native habitats.

The fight against the Spotted Lanternfly and the Tree of Heaven is not only about safeguarding our economy; it's also about preserving the integrity of our ecosystems. If you spot either of these invasive species, please report it to your local extension service or the Department of Agriculture. Your actions could be a deciding factor in this struggle. As we face the dual threats of the Spotted Lanternfly and the Tree of Heaven, our mantra must evolve: "Start with the pest first!" becomes our new guiding principle.

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Big News: Insects Limited, Inc. is Moving to a Brand New Location!

To our valued customers, vendors, and partners:

We are thrilled to share some exciting news that marks a significant milestone in our journey at Insects Limited, Inc.

Today, we are delighted to announce that we are moving to a brand new, state-of-the-art facility that will serve as our new home and the epicenter of our continued growth.

Our new location represents not just a physical move, but a leap forward in our commitment to providing you with the best in stored product protection solutions. You can view updates on our progress page.

Here's what you can expect from this exciting development:

Progress Photos and Virtual Facility Tour: We understand that you are eager to see our new home. In the coming weeks, we will keep you informed with progress photos as we create this space into a cutting-edge hub for innovation. And stay tuned for an invitation to join us for a virtual tour of the facility, where you can witness firsthand the impressive capabilities of our new space.

Enhanced Service for You: Our move to this new location is all about improving our services for you. With upgraded facilities and expanded resources, we are poised to serve you better than ever before. Expect increased capacity and more efficient processes.

Our Commitment to Excellence: At Insects Limited, Inc. our mission has always been to advance the stored product protection industry through science, education, innovation, and the delivery of quality products. This move is a testament to our commitment to this mission, and it reflects our unwavering dedication to providing you with the most effective solutions in the market.

Exciting Times Ahead: We are genuinely excited about the future and the endless possibilities our new location brings. Our vision is to continue our successful partnerships with all of you while exploring new horizons and pushing the boundaries of what is possible in our industry.

As we embark on this exciting journey, we want to express our sincere gratitude for your continued support and partnership. Without you, this significant milestone would not be possible.

In the weeks to come, we will keep you updated with more details about our move and the various ways it will positively impact our collaboration.

Thank you for being a valued part of the Insects Limited. Inc. community. We look forward to sharing this journey with you and delivering on our promise of excellence in stored product protection.

Watch Progress Video

Here's to the future and the many successes it holds!