The Use of Sodium Nitrite ($NaNO_2$) Utilizing a Targeted Feeder/Dispenser System for the Control of Feral Swine

This technical assessment is in conjunction with the use of WPF's patented Feeder as specified in United States Patent 10,034,454 (Issued July 31, 2018)

PROBLEM STATEMENT

The production of an integrated feeder system which allows for the successful eradication of feral hogs while protecting non-targeted species, maintain effective delivery of a toxin, and ensure a safe environmental outcome has been pursued from a variety of strategies for many years.

The feeder system as specified in the above noted patent uses unformulated sodium nitrite ($NaNO_2$) as the agent to control feral swine. The use of $NaNO_2$ has been identified for a number of decades as an effective agent (toxin) for the use in the control of feral hogs [1,2,3]. The designed feeder, dispenser, and toxic feed establishes an integrated delivery system which allows for an effective concentration of the toxin targeting only feral hogs while protecting both humans and the environment. This assessment does not review the safety features of the WPF Feeder for protecting against non-target species, design for dispensing, and simplicity of operation for use. These engineering/mechanical design features are reviewed extensively within the patent application.

ASSESSMENT SUMMARY

1. By using a chemical compound as sodium nitrite (unformulated) in this delivery feeder and dispenser system, it allows for a straightforward analysis of the compound not being impacted by a stabilizing formulation/agent. This strategy is significantly different from the approach of using a microencapsulated compound (stabilizing formulation) or a chemical structure which has not been fully characterized.
2. The chemistry of sodium nitrite has been well characterized for its stability in dry conditions (stable salt) and its natural degradation pattern when exposed to moisture, air, and high temperatures. Although microencapsulation provides an effective protection (in essence a time-release mechanism), it produces a potentially unsafe element by ensuring chemical stability and impacting non-target species if released.
3. The use of a specific targeted feed and designed feeding device selects for only feral hogs to be exposed to the sodium nitrite. The dispensing mechanism (sodium nitrite in a specially designed childproof container) allows for maintaining the stability of the compound by minimizing exposure to moisture.

4. The delivery of the sodium nitrite allows for a known concentration of the toxin and an assessment of worst case scenarios which show minimal to no risk to humans or non-target animals.
5. By using a compound ($NaNO_2$) which degrades into natural elements as part of the nitrogen cycle, it provides a safe alternative to man-made agents for use as toxin bait for wild hogs.

The summary assessment is supported through the following documentation.

CONCERN

In addition to significant financial costs and damages, feral swine act as reservoirs for viral, bacterial and parasitic organisms that can be transmissible to both domestic animals and humans [(4)]. In our current environment of dealing with a pandemic viral infection, the seriousness/reality of viral transmission has escalated. Pseudorabies virus (PRV), Classical Swine Fever Virus (CSFV), and Porcine Reproductive and Respiratory Syndrome Virus (PRRS) are commonly found in feral swine tissue samples and can cause devastating economic losses to domestic swine operations [(5)]. As the wild hog population continues to exponentially increase and interactions with human inevitable occur more often, the probability of zoonotic disease transmission increases [(4)].

In an article published for CAES News in 2014 (Feral hogs eating away at farmers' land), "feral hogs may be prime prey for hunters, but to Georgia farmers they're the ultimate predator. They destroy farmland, eat away at a farmer's crops and drastically reduce potential profits."

CONTROL EFFORTS

Efforts to manage the growth of the wild pig population have fallen short, but researchers from the University of Georgia are testing new data-gathering tools that will help guide future control measures. The study appears in the Journal of Wildlife Research and is available online at http://www.publish.csiro.au/WR/WR16204. Co-authors on this study are John Kilgo and Mark A. Vukovich, USDA Forest Service, Southern Research Station; and Fred L. Cunningham, USDA Animal and Plant Health Inspection Service, Wildlife Services, National Wildlife Research Center, Mississippi Field Station.

Over the past decades, several strategies including trapping, recreational hunting, aerial hunting and baiting have resulted in minimal reductions of feral swine populations. These methods have proven insufficient given the rise in total population occupied by feral swine within the United States.

Warfarin, an anticoagulant that is often utilized at a low dosage to treat thrombosis in humans, has been evaluated for its efficacy in an effort to lower feral swine populations. Warfarin was first approved by the EPA in 1952 for its use as a rodenticide (EPA, 1991). In Feb. 2017, the State of Texas commenced a Warfarin Program to eradicate feral Swine and was ceased shortly thereafter the result of multiple parties/special interest groups raising concerns on a number of levels[(13)]. The manufacturer withdrew the registration of their warfarin-based product out of concerns of a protracted legal process[(14)].

Compound 1080 (sodium fluoroacetate) has also been evaluated in highly populated areas of feral swine resulting in a 73% decline in observed populations. Although success had been achieved using sodium fluoroacetate, the United States of America banned Compound 1080 from general pest control in 1989, limiting its use to livestock protection collars (EPA, 1995) because of its toxicity to both humans and animals.

Due to the known high level of toxicity of sodium nitrite to swine (*Sus scrofa*), its use has been pursued in Australia to control feral pigs and wild boar[7,8]. The sodium nitrite induces methemoglobinemia in swine, i.e. it reduces the amount of oxygen that is released from hemoglobin, so the animal will feel faint and pass out, and then die in a humane manner after first being rendered unconscious [9].

Dr. VerCauteren NWRS (USDA) said the solution isn't as simple as sprinkling sodium nitrite on the ground and sitting back and watching your feral swine problem disappear. Sodium nitrite breaks down quickly in the environment when moisture is present, and the taste is so disgusting that hogs and other creatures wouldn't be likely to ingest enough to harm them. [12]

Waiting for a solution led WPF to explore an alternative approach utilizing sodium nitrite.

Chemistry of Sodium Nitrite

Sodium nitrite is obtained by the reaction of sodium nitrate and lead.

$$NaNO_3+Pb=NaNO_2+PbO.$$

Sodium nitrite is an inorganic compound with the chemical formula $NaNO_2$. It is a white to slightly yellowish crystalline powder that is very soluble in water and is hygroscopic (absorbs moisture from the air). As is well known, sodium nitrite is used as a preservative in human foods.

It is soluble in water, and an aqueous solution is alkaline because of nitrate hydrolysis. In an acidic solution, the main performance is oxidation. Sodium nitrite can be placed in the air with the oxygen reaction, and gradually produce sodium nitrate: $NaNO_2+1/2O_2=NaNO_3$.

Nitrite is much more reactive when compared to nitrate. Nitrous acid, HNO_2, has a pKa of 3.3, so when nitrite is dissolved in water, it is found mainly as the nitrite anion, NO_2. The nitrite ion, once reduced to act as the nitrosating/nitrosylating agent in cured meats, can occur through several pathways involving endogenous compounds and added ingredients. Temperature, pH, endogenous compounds, and other added ingredients can contribute to the reduction of nitrite to nitric oxide. Two molecules of nitrous acid can form water and the anhydride of nitrous acid, dinitrogen trioxide (N_2O_3) during dissociation. This is the rate-determining step in the production of nitric oxide from nitrite.

The stability of sodium nitrite is also demonstrated by its use in analytical chemistry testing[6]. A review of several articles on method development indicate the importance that once the sodium nitrite is dispensed into solution, the degradation process is controlled by keeping the solution on ice. The solution to be used must be used the day of preparation to ensure testing quality. These methods are covered within the EPA test methods (Method 1686).

Although not directly a factor to this specific application, sodium nitrite is reported to be photo-oxidized (decomposes in light) with a half-life of 82.3 days. Half-life is simply a calculation to the time required for any specified property (e.g. the concentration) to decrease by half.

The general chemistry of sodium nitrite is that in a dry contained enclosure, the compound is stable. Once the compound is exposed to moisture/humidity, the compound decomposes into sodium, nitrous acid, and hydroxide ions.

"The problem is when we take sodium nitrite out of a container, it pulls moisture out of the air and loses its lethal properties," said Glen Gentry, project investigator and resident coordinator at LSU's AgCenter – Bob R. Jones-Idlewild Research Station. "It quickly starts turning into sodium nitrate and becomes ineffective at killing the hogs."(10)

In work completed by Dr. Glen Gentry's team, in 2016, the lethal dose (LD_{90}) of sodium nitrite was determined to be 4.5 grams per 22.7 kg pig (50 lb)(10).

Assessment of Sodium Nitrite using WPF's Feeder (Patent No. 10,034,454)

A literature review of this subject reflects the multiple strategies and approaches that have been attempted during the past decade. The Federal government has invested a significant amount of research money and time. Each of these approaches have focused on a single element of the concerns – toxin, stability, non-target animals, safety, environment. The development of this integrated approach – WPF Feeder, Dispenser, and feed/toxin – has covered each of the concerns.

When the WPF Feeder/Dispenser integrated solution is deployed, approximately 11.3 grams of $NaNO_2$ is delivered. Along with the $NaNO_2$, approximately 1.2 kilograms of pig feed, and 11 grams of the taste masking agent (malic acid) are dispensed into the feeding trough (approximately 2.5 pounds) to allow the pig to feed.

With these as the variables, the sodium nitrite is now exposed to the air and moisture (not only from the environment but also the saliva as a result of feeding). As noted from the general chemistry review, once the compound ($NaNO_2$) is exposed to moisture, the properties of hygroscopic and water soluble place the compound into a less stable condition. From studies conducted, the hog will consume the 2.5 pounds of feed/masking agent/Sodium nitrite in an extremely short period of time. This will ensure minimal degradation of the sodium nitrite to maintain its intended effectiveness. Additional aliquoting (dispensing) of feed will not occur until the hog backs out of the feeder and then re-enters. It could be speculated that from the dispensed sodium nitrite a scenario in which unconsumed sodium nitrite may appear on the mouth/nostril region of the hog.

Since the sodium nitrite is 0.9% of the feed mix (1145 grams of pig feed, 11 grams of Sodium nitrite, and 11 grams of malic acid (masking agent)), the amount of sodium nitrite on the outside of the pig would be minimal. If you assume 5 grams of feed 'on the pig', this would be an amount of 0.05 grams of $NaNO_2$. The estimated lethal dose for humans has been determined to be 2.6 grams.

In addition, it is a safe assumption to consider that the mixture would be moist. Therefore the sodium nitrite is now in an unstable condition and degradation from the environmental conditions would continue. Under these conditions, the concern of residual sodium nitrite would be minimal.

As reviewed, the USDA APHIS, working with associated institutions, continue to pursue an encapsulation/micro-encapsulation solution (formulation) utilizing $NaNO_2$ combined with corn gluten meal protein and a peanut-based substance (oil) to achieve a stable formula. The efforts have been on-going for a number of years and included prior field trials (Jan 2018) with unintended consequences – non-target species (birds) exposure and accidental deaths (several hundred birds [(11)]. The studies continue to pursue a solution (conducted more tests/field trials) while, at the same time, having to develop a delivery system that is not only an effective delivery mechanism but also precludes non-target species access. At the time of this review, the efforts have not achieved the desired result such that the investigators have intimated the hardware solution should not be deployed in areas where bears may be present out of concern for non-target exposure – inability to utilize an apparatus to ensure a bear is not able to gain access to the contents.

USDA APHIS has struggled with shelf life challenges as well as $NaNO_2$ breakdown and thus the need to increase the amount of $NaNO_2$ to ensure effectiveness. The concern being that in solving one problem potentially creating another problem – increased risk for non-target exposure to a lethal dose.

Upon a wild hog ingesting $NaNO_2$, studies have been reported by Dr. Gentry's team with regards to the effect and outcome to the hog[(10)]. These studies have shown that the half-life (amount of time for a compound to decrease to half of its original value) of sodium nitrite in pigs to be between 29 and 62 minutes, meaning degradation of the sodium nitrite occurs rapidly. Data from research trials have indicated that nitrite levels in thigh muscle, liver and small intestine samples collected between one and seven days post- death from pigs poisoned with sodium nitrite were less than 100 parts per million for the amounts tested. This concentration is less than 200 parts per million, which is considered safe for human consumption, according to the U.S. Food and Drug Administration[(10)]. This outcome utilizing unformulated sodium nitrite addresses concerns which were raised from the Texas studies using warfarin as the poison. It is recommended that wild hogs which succumb to death by way of any toxin should be discarded preferably by an appropriate waste disposal company.

Based on WPF Dispenser's design, the remaining sodium nitrite remains stable, sealed (childproof container in a secured enclosure) from exposure.

Environmental Review/Nitrogen Cycle

Ammonia, nitrite and nitrate are the common ionic forms of inorganic nitrogen in ecosystems. These ions can be present naturally, as part of the nitrogen cycle, as a result of atmospheric deposition, nitrogen fixation by bacteria and biological decay of organic matter. Hence nitrite occurs naturally in soil and putrefaction processes caused by oxygen-free conditions convert nitrites in soil into nitrogen gas or into gaseous compounds such as nitrous oxide or nitric oxide. In addition, bacteria of the genus *Nitrobacter* oxidise nitrites to nitrates, which are reduced to nitrogen by anaerobic bacteria in soil and sediment.

Due to the water solubility of sodium nitrite, this means that if any sodium nitrite does fall out of a feeder the compound will be leached into the soil by rain. Consequently, sodium nitrite does not accumulate in the soil, as some pesticides might or if protected by encapsulation.

Research from Australia has determined that sodium nitrite does not pose a significant hazard to the environment. As stated, this is because it is highly water-soluble, which results in hydrolysis of the sodium nitrite into sodium, nitrous acid and hydroxide ions, which do not accumulate in the environment. The risk of unintentional poisoning is, therefore, reduced or eliminated.

Review

WPF has developed a Toxin Dispenser for Wild Pig Delivery System (patent-pending) integrated with their patented Feeder. This integrated solution (Feeder/Dispenser) is able to utilize commercial feed i.e. corn with sodium nitrite (in a powder form factor – commercially available) coupled with a masking agent (in a powder form factor – commercially available). The sodium nitrite and masking agent are inserted (child-proof sealed bottles) into the Dispenser and ready for use upon activation. There is no need to develop a bait formulation or encapsulate/micro-encapsulate to ensure effectiveness and shelf life. None of these components are blended, mixed or combined together. The solution utilizes mechanics and physics to make available an effective and safe solution for the eradication of feral swine.

References

1. Sodium Nitrite Toxic Bait for Feral Swine - USDA APHIS, www. aphis.usda.gov › publications › wildlife damage.

2. Sodium Nitrite: A Potential Toxicant in the Fight Against Invasive Wild Pig. Nri.tamu.edu>blog>January

3. Revenge of the Wild Pigs Goes Toxic. www. agweb.com › article › revenge-of-the-wild-pigs-goe...

4. Brown, V, R. Bowen, A. Bosco-Lauth. (2018). Zoonotic pathogens from feral swine that pose a significant threat to public health. Transbound Emerg Dis. 65: 649– 659.

5. Witmer, G., R. Sanders, and A. Taft. (2003). Feral Swine: Are they a disease threat to livestock in the United States. Digital Commons at University of Nebraska:316–roberso325.

6. EPA-821-R-01-005 January 2001 Method 1686 Nitrate/Nitrite-N in Water and Biosolids by Manual Colorimetry Draft January 2001 U.S. Environmental Protection Agency Office of Water Office of Science and Technology Engineering and Analysis Division 1200 Pennsylvania Ave., NW Washington, DC 20460

7. Lapidge, Steven; Wishart, J.; Smith, M.; Staples, L. (2009). "Is America Ready for a Humane Feral Pig Toxicant?". Proceedings of the 13th Wildlife Damage Management Conference: 49–59.

8. Cowled, B. D.; Lapidge, S. J.; Humphrys, S.; Staples, L. (2008). "Nitrite Salts as Poisons in Baits for Omnivores". International Patent WO/2008/104028.

9. Porter, S.; Kuchel, T. (2010). Assessing the humaneness and efficacy of a new feral pig bait in domestic pigs. Study PC0409 (PDF). Canberra, South Australia: Veterinary Services Division, Institute of Medical and Veterinary Science. p. 11.

10. Battling Feral Swine Research Aims at Safe, Effective Control. Louisiana Agriculture, Winter 2016

11. APHIS Wildlife Services Conducts First Field Trial of Feral Swine Toxic Bait: Plans Modifications to Mitigate Hazards to Non-Target Species. June 2018. USDA APHIS Stakeholder Information.

12. Poison Bait to be Tested in War on Wild Hogs. Aon Magazine, by Mike Bolton, February 1,

2018.

13. Feral Hog Poison Proves Divisive Issue in Texas, Texas Outdoor Digest, by Will Leschper Mar 3, 2017, Source: https:/texasoutdoordigest.com/hunting/hog/feral-hog-poison-proves-divisive-issue-in-texas/

14. Kaput Feral Hog Bait Won't Be Coming to Texas After All, Texas Outdoor Digest, by Will Leschper, Apr 25, 2017, Source: https:texasoutdoordigest.com/hunting/hog/kaput-feral-hog-bait-wont-be-coming-to-texas-after all.

This review/assessment has been completed by Dr. Gregory Gibb (www.greggibbconsulting.com). He is a graduate of Ohio State University and has over 30 years of industrial experience in the biological sciences with a specific focus on microbiology. He is a resident of Evans, GA (greg@greggibbconsulting.com). This review is not intended to be comprehensive to all of the details of design to the WPF Feeder or examine all strategies that have been executed to control wild hogs.