

Kaput® Feral Hog Bait Containing 0.005% Warfarin: An Overview of its Usefulness against Feral Hogs and Safety to Wildlife and Humans

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ABSTRACT: Warfarin has been approved for use in the United States as a rodenticide since 1948. The United States Environmental Protection approved Kaput® Feral Hog Bait (0.005% warfarin) for use as a toxicant to control wild pigs in 2017. The level of warfarin is 80% less than in commercial rodenticide formulations. Since 1994 we have conducted wildlife safety studies examining the potential effects of warfarin on non-target mammals and birds. Over a 25-year period, non-target toxicity research was completed with European ferrets, pied magpies, mallard ducks, bobwhite quail, Norway rats, house mice, and American alligator to assess primary and secondary exposure to warfarin baits. Pen studies were conducted on birds to examine primary exposure to birds feeding on baits ranging in concentration of 0.05% to 0.025% warfarin. Laboratory studies were completed where warfarin baits were fed to rats or prairie dogs and the carcasses presented to ferrets and magpies to simulate wildlife scavenging on carcasses. A low-dose warfarin was presented to Norway rats to simulate spilled Kaput Feral Hog Bait exposure. A low-dose warfarin hog bait reduces wildlife toxicity potential significantly while at the same time is efficacious against wild pigs. Field studies in Texas over three years (2015-2017) showed consistent efficacy of >95% for feral hogs. Daily systematic searches during baiting and post-baiting periods on treatment and control plots showed no non-target effects. In this paper we review studies conducted with warfarin over the past 25 years and the results of our findings.

KEY WORDS: feral hogs, magpies, toxicity, warfarin

INTRODUCTION

Prior to 1948, rodent control in the United States was comprised of a series of acute toxicants, none of which had antidotes. Those included sodium monofluoroacetate (Compound 1080), strychnine, bromethalin, thallium sulphate, red squill (Meehan 1984). Warfarin was developed during the early 1900's and was approved for use as a rodenticide in 1948. Later, in 1954, the drug was approved for use in humans to treat blood clots such as pulmonary embolism and deep vein thrombosis to prevent stroke (Ravina 2011). Today, some 30 million American take warfarin as a drug to prevent blood clots that could induce strokes.

Known as an anticoagulant or blood-thinner, warfarin had the benefit of an antidote (vitamin K1) which can reverse the effects of the compound. Consequently, warfarin quickly replaced many of the acute rodenticides and revolutionized rodent control in the US by providing a product that was efficacious against a broad spectrum of rodents and provided a safety margin of reversing the effects of the chemical in non-target animals (Meehan 1984).

Development of rodenticides and hog toxicants necessitated the need for more information on bait exposure risks to domestic animals and wildlife. The low-risk potential of warfarin was summarized by Poché and Mach (2001) and Baroch (2004).

In 2017, the EPA approved the use of Kaput[®] Feral Hog Bait, containing 0.005% warfarin to control wild pigs. At a low-dose warfarin product the bait was shown to be efficacious both in pen and field studies (Davis 2010, Poché et al 2018, Poché et al 2019).

Results from a series of laboratory, pen, and field studies demonstrated the low risk warfarin poses to non-target animals. The information is presented in the publication.

METHODS

Primary and secondary warfarin toxicity to non-target wildlife were completed on various species to test warfarin bait palatability and the effects of warfarin bait consumption. Here, we include results on mallard ducks (*Anas platyrhynchos*), black-billed magpie (*Pica pica*), bobwhite quail (*Colinus virginianus*), European ferret (*Mustela putorius furo*), Norway rat (*Rattus norvegicus*), house mouse (*Mus musculus*) and American alligator (*Alligator mississippiensis*) that were exposed to warfarin concentrations 2-10 times higher than Kaput[®] Feral Hog Bait.

Mallard duck

In 2008, mallard ducks were exposed to warfarin bait at a concentration of 0.025%, 5 times that of Kaput[®] Feral Hog Bait. The purpose of the study was to determine palatability and consumption of bait and game bird feed in a choice test. This species was selected since it is common throughout North America and is a standard waterfowl model used by the EPA for acute toxicity and avian reproduction studies. Adult mallards (5 male; 5 female) were obtained from a gamebird supplier (Field Trial Game Bird Farm, Wellington, CO) for use in the study.

Our research was performed outdoors in ambient environmental conditions using 10 adult mallards (5 male; 5 female) obtained from a gamebird supplier (Field Trial Gamebird Farm, Wellington, CO) for use in the study. Mallards were group housed in an enclosure approximately 9 m x 9 m, with a covered shelter approximately 1 m x 2 m x 0.5 m available for shade. Water was provided *ad libitum* during the study. In addition, an artificial plastic pond was made available and the water was replaced when dirty.

In a choice test mallard ducks were provided 2 kg commercial game bird feed

and 2 kg warfarin bait in separate feed containers. Paraffin bait blocks, containing 0.025% warfarin, were cut into 16 pieces to make it easier for mallards to consume. Furthermore, this smaller bait size also simulated potential bait spillage by feral hogs under actual-use field conditions. The bait and poultry feed were provided to all mallards for 14 days during acclimation to the pen. The amount of warfarin bait and commercial game bird feed consumed was recorded every 2 days of the exposure period. Throughout the test, metal trays were placed under feed containers to retrieve any spilled diet. Spilled feed and bait was collected and added to the appropriate feed for consumption estimates. Feed presented to ducks was protected from rain and wind. Ducks were examined twice daily for signs of exposure to the bait and to ensure feed and water was always present. Diet consumption was measured to nearest g.

A no-choice test was conducted with mallard ducks. Birds were group housed and presented 4 kg of warfarin bait. The wax bait was ground into a powder to make it as easy as possible for mallards to consume the product. The bait was presented to mallards for 7 days. Warfarin bait consumption was weighed every 2 days during the no-choice test.

At the conclusion of the choice and no-choice tests, ducks were presented with commercial game bird feed for 14 days and were examined twice daily for signs of exposure to the bait and to ensure feed and water was always present.

Black-billed Magpie

Laboratory research on magpies was reported by Poché and Mach (2001). Two separated secondary toxicity studies were conducted in 1997. Norway rats were fed a 0.05% warfarin diet until each expired. The carcasses were presented to individually caged magpies (7 males, 7 females) for 5

consecutive days, rat remains removed, and ferrets observed for 22 days post-exposure.

Bobwhite Quail

A choice study using bobwhite quail was completed in 2010. Quail were offered Kaput® Combo Bait Mini Blocks containing 0.025% warfarin and game bird feed in separate feeder trays. The bait was crushed into a fine consistency to enable quail to consume the product. Trays contained 750 g of either the bait or bird feed. Twenty male and 20 female quail were conditioned to the 10 x 10 m pen for two weeks then presented the bait and game bird diet for 14 days. After the exposure period quail were observed for 14 days.

In 2018, a study to determine palatability and consumption of Kaput® Feral Hog Bait by bobwhite quail was tested using 40 individuals (20 M, 20 F). Treatment and control groups were comprised of 10 quail of each sex. Quail were housed in separate covered outdoor enclosures approximately 5 m x 6 m and 3.3 m x 3.3 m for treatment and control groups, respectively. Both pens were provided with structures for shade. Water was provided *ad libitum* during all periods of the study.

This study was initially designed to be a 30-day no-choice test. During the first three days of bait (Kaput® Feral Hog Bait) exposure treatment birds were offered bait exclusively, while control birds were administered challenge diet. Consumption by treatment birds was notably low; therefore, the study was changed to a choice test to reduce the potential for starvation. For the remaining 27-day bait exposure period, the treatment group was offered both bait and game bird feed, whereas the control group was only exclusively offered non-toxic bird feed. The bait was ground into a granular consistency to replicate the physical form of the commercial feed. Feeders holding the bait and feed were placed on separate metal

trays inside the quail enclosure. Spilled feed was collected and added to the appropriate feed for consumption estimates. Consumption of the bait and game bird feed were recorded approximately daily to the nearest 0.1 g, and feed was replenished *ad libitum*. The position of the bait and feed were reversed daily to reduce the potential for feeder position bias. Bait acceptance was calculated using comparison between warfarin bait and commercial game bird feed consumption. Any quail that died during testing was necropsied and the liver and muscle tissue analyzed by Colorado State University for warfarin residue.

Post-exposure observations were made completion of the choice test. The bait was removed from the treatment group and replaced only with game bird feed. During the post-exposure period, quail were observed approximately two times daily for signs of anticoagulant poisoning, and to ensure feed and water were always present.

European ferrets

The details of this study were reported by Poché and Mach (2001). Research conducted during 1996 and 1997 involved the use of black-tailed prairie dogs (*Cynomys ludovicianus*) presented with 0.05% warfarin gain bait for five days. The carcasses from warfarin-treated animals were presented to individually caged European ferrets, 11males and 11 females for seven consecutive days. Ferret consumption of the carcasses was recorded daily to the nearest g. After the 7 days ferrets were given ferret chow and observed for 21 days post-exposure.

Norway Rat

During field trials evaluating the performance of the hog bait, small rodent species were observed near feeder stations primarily during nocturnal hours. To test if Kaput® Feral Hog Bait was palatable to

small rodent species, we exposed feral hog bait and the EPA Challenge Diet (EPA 1991b) to Norway rats during nocturnal hours (approximately (1700-0700 h). We weighed feed consumption and recorded any observable symptoms of warfarin effects.

Two treatment groups and no control group were used for this study. The Kaput® Feral Hog Bait and challenge diet were offered to the treatment group rats in separate cups on opposite sides at the front of the cage during the nocturnal exposure period. After presentation of the bait and challenge diet, lights in the laboratory study room remained until the next morning. All treatment groups received 4 bait blocks, totaling approximately 40 g. The water was replenished *ad libitum* before each presentation to its respective amount, and challenge diet was offered at 40 g each day. Cups were identical in type and size. Feed cups were placed so that they were equidistant from walls, shelter, and water source so that there was no clear advantage to either container position. Throughout the study, paper plates were placed under rat cages to retrieve any spilled diet. Any spilled diet was collected and added to the appropriate feed dish for consumption estimates. At the end of the 10-day nocturnal exposure period, the bait was removed, and maintenance diet was provided *ad libitum* during the 5-day post-exposure observation period. Daily consumption of the bait and challenge diet was recorded during the exposure period for all surviving animals or until death. Diet fouled by urine or feces was replaced daily with fresh diet.

House Mouse

Kaput® Feral Hog Bait was presented to house mice in a choice test. There were 3 treatment groups (T1, T2, and T3) was comprised of 9-10 mice (4-5 males, 5 females) group housed in 6 cages. The bait and challenge diet were offered to the

treatment group mice in separate cups on opposite sides at the front of the cage during the exposure period. All treatment groups received 4 bait blocks, totaling approximately 40 g bait. The bait was replenished *ad libitum* before each presentation to its respective amount, and challenge diet was offered at 40 g each day. Cups were identical in type and size. The positions of the bait and challenge diet were not be reversed daily to better imitate field conditions. Feed cups were placed so that they were equidistant from walls, shelter, and water source so that there was no clear advantage to either container position. At the end of the 10-day nocturnal exposure period (1600-0700 h), the bait was removed, and challenge diet was provided *ad libitum* during the 5-day post-exposure observation period. Daily consumption was recorded during the exposure period for all surviving animals or until death. challenge diet fouled by urine or feces was replaced daily with fresh diet.

On Day 0 of exposure, paper towels were placed under the cages in place of wood shavings and were used for the remainder of the test. Paper plates were then placed on top of the paper towels to retrieve any spilled diet. Both paper towels and plates were replaced at least once a week during the exposure and post-exposure periods. Spilled diet was collected added to the appropriate feed dish. Diet fouled by either urine or feces was replaced with fresh TS or challenge diet. At the end of the 5-day post-exposure period, all survivors within treatment groups were euthanized by asphyxiation with CO₂ gas.

American Alligator

To determine if secondary toxicity of warfarin poses a threat to alligators, we fed warfarin-killed rats to American alligators in a 2008 study. This study simulated an alligator consuming a warfarin-effected feral hog or scavenging on a recently killed hog.

Alligators were obtained from Colorado Gators, Mosca, Colorado. The animals were transported to Genesis Labs by the owners of Colorado Gators, kept in plastic boxes with tape around the muzzle. Five alligators were used for the study.

Alligators ranged in length from 1.3 to 1.5 m in length and were singularly housed in a 2-meter diameter circular metal enclosure with 0.8 m sides. One end of the tank was maintained approximately 15 cm above the floor such the tilt allowed for the animal to be completely submerged in water is so desired. Water was replaced weekly and the tanks were routinely rinsed and vacuumed to ensure a clean housing environment. One-third to one half of the enclosure had a plastic container with bricks inside to prevent floating. Each was covered with a rubber mat to allow for a dry area such that gators could bask outside the water at will. The ambient air temperature in the study room ranged between 24 and 32°C, and water temperature within the tanks was within 1°C of the ambient air.

Laboratory rats (*Rattus norvegicus*) were obtained from Harlan-Sprague Dawley (Indianapolis, IN). Rats had unique identification numbers, housed in individual cages, and provided food and water provided *ad libitum* during a 7-day acclimation period. At the end of the acclimations period, rats were exclusively provided 0.025% warfarin bait (5 times the concentration of Kaput® Feral Hog Bait) with no alternative diet. Daily consumption of the bait was recorded for each rat to the nearest 0.1 g until the individual expired. Each deceased, warfarin-inundated rat was placed into a labelled sealed container and stored in a freezer at -20° C until used in the study. Data obtained from each rat included total g of bait consumed, the number of mg of warfarin consumed, mg/kg warfarin eaten, and the approximate number of LD₅₀ of warfarin ingested.

Rats were selected for presentation to alligators the evening before feeding. The frozen rats were placed in a lab sink overnight for thawing. On the morning before offering the rats to the gators, the rats were placed in warm water to simulate natural body temperature. Alligators were each presented with an entire rat weekly during the first three weeks of the study. Rats were placed into the tanks near the head of the gators. Four alligators were fed rats killed by warfarin bait consumption, and the 5th alligator was given rats that had not received any bait. For weeks 4 and 5 rats were skinned, the entrails (intestines, liver, heart, lungs, and other internal organs) placed in porcine hard gelatin capsules (Torpac, Fairfield, NJ, size# 07, 24 mL (1.5 oz)) capsules, and the carcass cut into 4-5 parcels depending on the size of the rat. The gators were each presented with all parts of a partitioned rat. During the 3-wk post-treatment observation period, alligators were fed Gator Chow (Fish Foods, Grand Junction, Colorado). Throughout the post-exposure period, each alligator was presented with approximately 250 g of pellets every 3-4 days until the study was terminated.

The alligators were monitored a minimum of twice daily for general observations during the exposure and post-exposure periods. The reptiles were visually examined for possible effects of anticoagulant intoxication: lethargy, bruising, bleeding, or general discomfort. In addition, blood was drawn from each alligator, with one individual having blood drawn a second time one week later. A 22-gauge needle (about 5 cm in length) was used to draw blood from the underside of the tail, midway between the anus and tip of the tail. Blood was collected in ethylenediaminetetraacetic acid (EDTA) tubes to prevent clotting. The blood was centrifuged to separate out the plasma which was then transferred into glass vials.

Samples were frozen at -20° C from the day of collection and defrosted before analysis.

Hog Feeder Development

A key to delivery of a toxicant to hogs is excluding non-target wildlife and domestic animals from baits. Campbell et al (2012) tested an Australian hog feeder (HogHopperTM) and had good results excluding non-target wildlife with the exception of raccoons (*Procyon lotor*).

A similar designed feeder with heavier gage metal, increased weight, and internal and external modifications was tested and used in 2017. This feeder known as the HogStopper® was good at keep wildlife from accessing bait (Poche et al 2019b).

Field Testing Warfarin Bait Formulations

Experimental Use Permits (EUP) were obtained from the EPA and field efficacy studies conducted during 2015-2017 near Amarillo, Texas. The initial 0.005% warfarin bait was an extruded wax product containing a fat-soluble dye. That bait was evaluated in 2015 with the methods and results reported by Poché et al (2018).

Additional field efficacy evaluations were conducted in 2016 and 2017, when corn formulations were used, both at 0.005% warfarin (Franckowiak et al 2019). These studies were performed in areas about 50 miles east of Plainview, Texas.

RESULTS

Mallard ducks

The warfarin bait consumption by mallard ducks was 5.5% of total food intake. During the choice test, 640 g of warfarin bait was consumed over the 14-day exposure period, compared to 10,946 of game bird feed. Consumption of warfarin bait peaked on Day 4 of exposure (Table 1).

Table 1. Consumption (g) of Warfarin Bait and Game Bird Feed by Mallard Ducks During a Choice Test, 2008.

Feed Type	Day 2	Day 4	Day 6	Day 8	Day 10	Day 12	Day 14	Total
0.025% Warfarin bait	34	376	32	68	102	2	26	640
Game Bird Feed	202	1,690	1,276	1,968	1,970	1,928	1,912	10,946

During the no-choice test a total of 1,330 g of bait was consumed, averaging 19 g per duck/day (0.475 g warfarin per duck/day). The paraffin in the bait served more as a repellent as ducks were observed attempting to feed alternative food, such as grass within and outside the pen. Behavioral avoidance of the warfarin bait, because of the wax, resulted in the no-choice test being terminated to prevent duck starvation.

The ducks were monitored for two weeks upon completion of both testing regiments. During that 14-day period, 13.258 kg of feed was consumed. This amounted to 94.7 g per duck/day. No symptoms of warfarin bait consumption were observed during the study.

Black-billed Magpie

The secondary toxicity study conducted by Poché and Mach (2001) simulated rats consuming 0.05% warfarin bait (10 times the concentration of that in Kaput® Feral Hog Bait) then fed to magpies. The results demonstrated no effects of warfarin in scavenger bird. The EPA (1991) cited that warfarin is virtually nontoxic to game birds. Because of low residue levels in the carcasses of feral hogs, these data demonstrate a low risk of warfarin to magpies.

Bobwhite quail

In the 2010 study during the exposure period, total consumption of the combined game bird feed and warfarin bait was 4,812.4

g. Of the total, 534 g of Kaput® was consumed (11%). The treatment group consumed an average of 2.0 g of bait per bird daily which amounted to 0.5 mg warfarin. None of the birds in the treatment group died or showed signs of toxicity to warfarin.

The 2018 study using Kaput® Feral Hog Bait, resulted in quail consumption by the treatment group of 6.6% of the total diet. Consumption of the bait (713.9 g) by the treatment group was significantly lower than the alternative diet (10,057.4 g; $U = 0$, $P < 0.001$). We found no significant differences ($U=103$, $P = 0.36$) in consumption of the challenge diet between the treatment and control groups (11,0378 g). The treatment group averaged a daily feed rate of 1.4 g of the TS per bird/day (which averaged 0.007 mg per bird/day of warfarin) and 19.6 g of the challenge diet per bird per day. The control group averaged 20.4g of challenge diet per bird per day. We found no differences in body weight ($F_{3,75}$, $P = 0.122$) as a function of study group (treatment, control) or study period (acclimation, post-exposure).

One mortality occurred during the exposure period. During the necropsy, blue dye was noted in the enlarged bile duct and the gizzard; the gizzard was soft and had paste-like texture, and full of bait. Liver and muscle tissue samples were collected and analyzed. Liver residue analysis exhibited a warfarin concentration of 17.1 ng/g (0.0171 mg/kg). Muscle tissue residue analysis was below the limit of detection. According to Erickson and Urban (2004) the LD₅₀ for

warfarin in bobwhite is >2,150 mg/kg and the LC₅₀ is 625 ppm, confirming mortality was not the result of warfarin.

All remaining birds at the end of the post-exposure observation period appeared healthy and displayed no internal or external signs of anticoagulant poisoning. At the conclusion of the post-exposure observation period, all quail in the treatment group were euthanized and necropsied. No internal or external signs of anticoagulant poisoning or lesions were found in any of the quail.

European Ferret

The 28-day secondary study conducted in 1996 with warfarin-killed rats showed no effects on ferrets (Poché and Mach 2001). A second study completed in

1997 had similar results. This suggests little potential risk to carnivores from feeding on Kaput®-killed hogs.

Norway rats

Kaput® Feral Hog Bait acceptance by the treatment groups 1 and 2 were 4.7% and 3.3%, respectively (Table 2). This indicated poor palatability to rodents. Treatment groups did not differ in bait consumption ($t_{18}=1.03$, $P = 0.32$) or challenge diet consumption ($t_{18}=-1.13$, $P = 0.28$) during the exposure period. For all rats, weights were 274.0 g and 295.6 g for pre-exposure and post-exposure periods, respectively. We found no significant differences in weight as a function of treatment group and study period ($F_{3,36} = 0.52$, $P = 0.67$).

Table 2: Feed Consumption and Warfarin Bait Acceptance by Norway Rats During a Nocturnal Choice Test, 2018.

Treatment Group	Exposure Period		
	Challenge Diet Consumption (g)	Warfarin bait Consumption (g)	Warfarin Bait Acceptance (%)
T1	1646.0	81.9	4.7
T2	1837.8	62.1	3.3
T1 and T2	3483.8	144.0	4.0

Of the 20 rats exposed to bait for 10 days, no mortality was observed throughout the exposure and post-exposure periods. In addition, we observed no symptoms as a result of warfarin bait consumption.

House Mice

Two female mice from T3 found dead during this study (2 of 29 mice). Both mice were necropsied and had signs of warfarin intoxication. Blue dye was also present in the subcutaneous fat of the mice. Before expiring, one mouse was hyporeactive, while

the other was found dead with no prior signs of warfarin effects. The remaining 27 mice exposed to bait for 10 days did not show signs of warfarin effects during the exposure or post-exposure periods.

American Alligator

Norway rats fed 0.025% warfarin bait began exhibiting symptoms of anticoagulant intoxication on day 5 of bait exposure, with the first mortality on day 6. The last rat succumbed to the bait on day 13. Norway rat

carcasses were presented to alligators the day following the last rat mortality.

During the first presentation (week 1), two alligators consumed their entire rats by the end of the day. During the second week later after the second presentation, none of the treatment gators consumed the entire rat. When presented rats in week 3, two alligators consumed the entire rat. For weeks 4 and 5, when skinned rats with the entrails were fed to alligators, the entire rat was consumed by each animal, with the exception of gator 4 in week 5 that had only 6 grams of rat tissue remaining.

For weeks 4 and 5, the all treatment gators quickly consumed the two gelatin capsules containing the internal organs and gastrointestinal tract within a minute after presentation. The smaller portions of rat carcass were eaten within 30 minutes after placed into the tank.

Feeder Development

Over a 3-year period a satisfactory feeder was designed to exclude non-target animals from accessing bait in studies from northern Texas. Table 3 presents results as reported by Poché et al (2019b)

Table 3: Results of Nontarget Wildlife Activity Near Commercial Hog Feeders and HogStopper® During Field Studies in North Texas (Poché et al 2019b)

SPECIES	2016 (commercial)		2017 (HogStopper®)	
	Feeder Visits ¹	Feeder Entry ²	Feeder Visits	Feeder Entry
Raccoon	164	10	153	0
Deer	33	0	178	0
Turkey	43	0	25	0
Rat/Mouse	38	0	24	1

¹ Non-target species on camera near or at feeder.

² Feeder door lifted by wildlife in attempt to access contents.

³ Mouse likely entered feeder when hogs lifted guillotine doors.

Field Studies Testing Warfarin Bait Formulations

With all three years of field trials, efficacy surpassed EPA's minimum of 70% (EPA 1991b). Table 4 gives a summary of those data. After extensive carcass

searching over the three-year period, no non-target fatalities were observed. For details see Poche et al (2018) and Franckowiak (2019).

Table 4: Summary Results of Kaput Feral Hog Bait Efficacy over a 3-year Period of Field Testing.

Efficacy Based on:	2015 ¹	2016 ²	2017 ²
Trail Camera counts	98.5%	93.7%	94.7%
Bait Consumption (kg/wk)	97.8%	96.9%	88%

¹ Poché et al (2018); ² Franckowiak et al (2019)

DISCUSSION

Our study presents data generated from a combination of laboratory, pen, and field research conducted to assess potential non-target risk of a low-dose warfarin bait (Kaput® Feral Hog Bait). Before the development of the HogStopper® in north Texas access to feeders by non-target wildlife exclusion was a challenge. Refinement of the design in a guillotine feeder was effective at keeping wildlife and domestic animals away from the bait.

An important consideration in toxicology has to do with the concept “dose makes the poison”, formulated by Paracelsus some 500 years ago (Frank and Ottoboni 2011). It has become the foundation of toxicology in that all things are poisonous depending on the dose administered. It means that any substance can produce harmful effects, including water and oxygen, and is linked to the amount taken in. Warfarin is an example: it can save humans

from fatal strokes, or kill rats and pigs, depending on the dose.

The Kaput® Feral Hog Bait contains a blue tracer dye that is fat soluble and becomes visible after the consumption of approximately 250 grams of bait (Poché et al 2018). Should a hunter harvest a feral hog which has consumed the warfarin bait, a necropsy reveals the internal and subcutaneous blue color in the fat.

A report by Guillory (1985) referenced President Dwight D. Eisenhower had a heart attack in 1955, Physicians gave him 35 mg/kg of warfarin to prevent blood clots. Of the 30 million American on warfarin today, the daily dose ranges from 1 to 20 mg/day. Should there be an accidental overdose, vitamin k can be administered to reverse the effects of the drug.

As with most mammals fed warfarin baits, 95% of the residues bind in the liver and the half-life in plasma is approximately 42 hours (Meehan 1984). During pen and field studies

conducted with Kaput®, warfarin residues recovered from livers of wild pigs killed with warfarin from using 0.005% warfarin and pen research using 0.01% bait averaged 3.69 and 3.11 ug/g, respectively (Poché et al 2018; Poché et al 2019a).

During the 2015-2017 field efficacy trials, no non-target species were recovered dead nor showed signs of exposure to low-dose warfarin bait (Poché et al., 2018; Franckowiak et al. 2019). Supporting data to substantiate those claims are presented in Table 5.

Table 5. Summary of Wildlife Species Studies Using Warfarin Baits, Concentration of the Baits, Year of Study, and Results.

SPECIES	YEAR OF STUDY	CONCENTRATION %	MORTALITY
Mallard Duck	2008	0.025%	0 of 20
Pied Magpie	1997	0.050%	0 of 7
Bobwhite Quail	1992, 2018	0.005%	0 of 20
European Ferret	1996, 1997	0.05%	0 of 12
Norway Rat	2018	0.005%	0 of 20
House Mouse	2018	0.005%	2 of 29
American Alligator	2008	0.025%	0 of 4

Toxicants can play an important role in feral hog control. Of major concern are secondary toxicity to non-target animals and alerting humans to avoid consumption of feral hog meat. The potential risk is very low because of the blue dye incorporated in the bait and the low residues from the 0.005% warfarin concentration in the product. The

overall risk assessment conducted by the EPA rated Kaput Feral Bait as a Toxicity Category IV pesticide, which is the least restrictive of regulated products and is determines as “practically non-toxic and not an irritant” (EPA 2019). This is an important consideration in the use of any pesticide.

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