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European starling feeding activity on repellent treated crops and pellets

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ABSTRACT

The varied diet of European starlings (*Sturnus vulgaris* L.) can present challenges when working with starlings in experimental testing and holding situations and should be taken into account when testing repellents applied to food. Our purpose was to evaluate an anthraquinone-based repellent (Arkion Life Sciences, New Castle, DE, USA; active ingredient 50% 9,10-anthraquinone; hereafter anthraquinone) and SucraShield™ (Natural Forces, Davidson, NC, USA; active ingredient 40% sucrose octanoate esters) repellent for non-lethal protection of specialty crops (i.e., fruit, sweet corn) and grains. Our objectives were to evaluate (1) laboratory efficacy of anthraquinone applied topically to blueberries and sweet corn, (2) laboratory efficacy of anthraquinone applied to two pellet matrices, and (3) laboratory efficacy of SucraShield™ as a chemical repellent for European starlings. We found that anthraquinone was not an effective repellent for blueberries or sweet corn, although consumption of each matrix varied potentially due to sucrose content. Anthraquinone was an effective repellent on CU Bird Carrier pellets with 6275 ppm needed to achieve 80% repellency, whereas up to 35,000 ppm anthraquinone was not effective when the anthraquinone was not topically applied. SucraShield was not an effective repellent for starlings and in fact increased consumption of CU Bird Carrier as concentration increased.

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1. Introduction

While some animals including birds of prey and tropical frugivores (Meserve, 1977) are able to maintain a relatively constant diet throughout the year, many species utilize more plastic food consumption strategies. The European starling (*Sturnus vulgaris* L.) is one example of a species whose diet changes widely throughout the year. Gut contents of European starlings show that they consume a variety of plant (e.g. seed and fruit) and animal (e.g. earthworm, snail, insect) species in varying ratios depending on season (Taitt, 1973; Feare, 1984; Fischl and Caccamise, 1987). Authors attribute the European starlings' ability to thrive in so many varied habitats to this ability to change their diet to accommodate what is locally available (Taitt, 1973).

European starlings are known for taking advantage of these flexible feeding habits to thrive in areas where birds with a more specialized diet cannot. This has made European starlings well suited to cause damage to agriculture crops and feed lots in the U.S., Europe and Australia (Stickley et al., 1976; Dolbeer et al., 1978; Wright, 1982; Mason et al., 1985; Summers, 1985; Glahn and Otis, 1986; Feare, 1992; Bentz et al., 2007), and damage can be extensive when starlings congregate in large foraging flocks (Shwiff et al., 2012). Bird damage to blueberry crops from species including European starlings, American robin (*Turdus migratorius* L.) and common grackle (*Quiscalus quiscula* L.) in 1989 were estimated at $8.5 million based on survey results (Avery et al., 1992). Starlings are also known to damage sweet corn and in cage trials consumed 40% more sweet corn than red-winged blackbirds (*Agelaius phoeniceus* L.; Woronecki et al., 1988). Repellent-based methods to reduce economic damage from starlings to crop and livestock production have been evaluated, but most are not considered economically effective against starlings (Avery, 1992). Anthraquinone-based

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products used as seed treatments have been successfully tested with several species of birds including Canada geese (*Branta canadensis* L.), sandhill cranes (*Grus canadensis* L.), red-winged blackbirds, and common grackles (Blackwell et al., 2001; Werner et al., 2009, 2011a,b). Limited testing with European starlings was conducted by Poche (1998) which showed that starlings detect anthraquinone at 150 ppm on grain baits but higher doses were required to achieve repellency. Anthraquinone has been shown to cause post-ingestional distress in birds that often leads to vomiting (Avery et al., 1997). SucraShield™ (Natural Forces, Davidson, NC, USA; active ingredient 40% sucrose octanoate esters) is marketed as a sugar-based insecticide and has not been previously evaluated for avian repellency. However, sugars specifically sucrose sugars are known to repel certain species of birds including European starlings (Martinez del Rio et al., 1988 Martinez del Rio, 1990).

Although in Europe there has been a recent population decline of European (common) starling populations, and they have been listed as a species of highest conservation concern (Freeman et al., 2007; Eglington and Pearce-Higgins, 2012), they still flock and cause damage in agriculture crops and feed lots due to their gregarious nature. An improved understanding of starling behavior and effective means to present repellents to starlings will benefit agricultural producers and the avian community. Our purpose was to evaluate an anthraquinone-based repellent (Arkion Life Sciences, New Castle, DE, USA; active ingredient 50% 9,10-anthraquinone; hereafter anthraquinone) and SucraShield for non-lethal protection of specialty crops (i.e., fruit, sweet corn) and grains. Our objectives were to evaluate (1) laboratory efficacy of anthraquinone applied topically to blueberries and sweet corn, (2) laboratory efficacy of anthraquinone applied to two pellet matrices, and (3) laboratory efficacy of SucraShield as a chemical repellent for European starlings. The capture, care, and use of all birds associated with our repellent efficacy studies were approved by the Animal Care and Use Committee of the United States Department of Agriculture's (USDA) National Wildlife Research Center (NWRC Studies QA-1740, 1901, S.J. Werner-Study Director, QA-1748, J.C. Carlson-Study Director).

2. Methods

2.1. Facilities, maintenance and diets

European starling feeding experiments were conducted at the USDA, NWRC in Fort Collins, CO, USA. In total, we used 301 European starlings for laboratory efficacy and preference experiments. We provided water *ad libitum* to all birds throughout testing and maintained all starlings in 4.9 × 2.4 × 2.4-m cages (40–50 birds/cage) within a wire mesh-sided building for ≥2 weeks prior to our experiments (i.e., for quarantine, holding). Starling experiments were conducted in individual cages (0.9 × 1.8 × 0.9 m) within a wire mesh-sided building. We provided all birds free access to grit and maintenance diet during quarantine and holding. The maintenance diet consisted of Layena® poultry pellets (Purina Mills, St. Louis Mo, USA).

2.2. Feeding experiments

Between April 2010 and December 2012, we conducted four laboratory efficacy experiments to establish concentration–response relationships for European starlings offered blueberries, sweet corn, 16% Poultry Layer Complete (Ranch-Way Feeds, Fort Collins, CO, USA), and CU Bird Carrier (CUBC, Purina Mills, Gray Summit, MO, USA) treated with anthraquinone. We conducted one laboratory efficacy experiment to establish a concentration–response relationship for European starlings offered CUBC treated with SucraShield™ (Table 1). Our laboratory efficacy experiments included concentration–response experiments and preference experiments (Table 1). All starlings acclimated within individual cages for five days (Wednesday–Sunday) prior to each of the feeding experiments.

2.2.1. Concentration response

Subsequent to the acclimation period, concentration–response experiments included a 3-day pre-test (untreated food; Monday–Wednesday) and a 1-day test (repellent-treated food; Thursday). Concentration levels were selected based on a combination of the end-use formulation proposed by the company and maximum levels that we were able to apply to test diets and still have the potential to meet residue requirements for ripening crops (i.e. blueberry and sweet corn). Food consumption (±0.1 g) was measured the day subsequent to each of the pre-test and test days of each experiment. We conducted residue analyses of the 16% Poultry Layer Complete, and CUBC anthraquinone treatments (Table 1).

During the acclimation period, one food bowl that held untreated food (20 blueberries, 75 g of 16% poultry pellets, or 75 g CUBC) was presented on the north side of the cage at 0800, daily. Starlings were only offered untreated blueberries from 8 to noon and were subsequently offered maintenance diet (*ad libitum*) after 4 h. During the pre-test, one bowl of untreated food was presented on the north side of the cage. Starlings were only offered untreated blueberries from 8 to noon and were subsequently offered maintenance diet (*ad libitum*) after 4 h. Birds were ranked based upon pre-test consumption of untreated food and assigned to treatment groups such that each group was similarly populated with birds that exhibited high-low daily consumption. We then randomly

Table 1
Summary of European starling (*Sturnus vulgaris*) testing at the National Wildlife Research Center, Fort Collins, Colorado, USA.

Commodity	Repellent tested	Test type	Number of treatment groups	Concentrations tested	Residues (ppm)	(*n*) per treatment
Blueberry	Anthraquinone	Concentration response	5	0.1%, 0.2%, 0.3%, 0.4%, 0.5%	n/a	10
Blueberry	Anthraquinone	Preference	1	0.3%	n/a	10
Sweet corn	Anthraquinone	Concentration response/ preference	6	0.1%, 0.25%, 0.5%, 0.75%, 1.0%, 2.0%	327, 429, 700, 1574, 2770, 4805	11
16% Poultry Pellets	Anthraquinone	Concentration response	6	0.25%, 0.5%, 1.0%, 2.0%, 3.0% and 4.0%	1920, 3580, 7870, 14,800, 23,300, 35,000	9
16% Poultry pellets	Anthraquinone	Preference	1	0.25%	1920	11
CUBC	Anthraquinone	Concentration response	4	0.5%, 1.0%, 2.0%, 4.0%	5130, 10,100, 20,500, 33,300	11
CUBC	SucraShield	Concentration response	5	0.25%, 0.5%, 0.75%, 1.0%, 2.0%	n/a	11
CUBC	SucraShield	Preference	1	1.0%	n/a	11

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