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Methyl anthranilate as pig repellent: Effects on the feeding behavior and production performance

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Abstract Preventing pigs such as wild pigs (*Sus scrofa*) from accessing the farm can be blocked by installing fences or repellent to make them feel reluctant to access the farm. Most wild pigs were captured to prevent crop damage and incidence of African swine fever (ASF). Still, there is a limit to capturing them due to the rapid population growth. A study was conducted using "To Nature" repellent with an active ingredient of Methyl anthranilate (MA) to assess the effectiveness of MA as a pig repellent and determine its effect on feeding behavior and production performance. A total of eight female pigs [(Landrace x Yorkshire) x Duroc] were randomly arranged and used in the experiment for five weeks. Each treatment was replicated four times, having one pig in every replication. The feeders' position with MA repellent was shifted weekly with a ratio of 0.25% and mixed with 10kg of feed. The number of approaches of pigs to the feeder was monitored daily using a full HD CCTV 5-megapixel camera. A significantly lower number of approaches, feed intake, and total time spent feeding in the feeding trough was recorded from the feeder with MA repellent mixed in the diet. Regression analysis revealed a positive relationship in the feeding behavior of pigs in the feeder mixed with MA repellent in the diet. Therefore, 0.25% MA repellent can be used as pig repellent without adverse effects on the production performance of growing pigs.

Keywords: animal welfare, feeding avoidance, feeding approach, growth performance, pig repellent

1. Introduction

Wild pigs (*Sus scrofa* Linnaeus, 1758), also known as feral hogs, feral swine, invasive wild pigs, or wild boar, are among the most invasive species, causing significant damage to natural environments and agricultural resources (Lowe et al 2000; Pimentel 2007; Anderson et al 2016; Snow et al 2021). The rapid population growth of wild pigs has caused significant damage to the agricultural industry. However, wild pigs can be blocked from accessing the farm by installing fences or repellents that pigs feel reluctant to access around the farm. In South Korea, the crop damage caused by harmful animals is increasing, and the damage caused by wild pigs is the most severe, worth 6,509 million won (USD 4,552,687.50) in 2018 (MEHADS 2022). Most wild pigs were captured to prevent crop damage and incidence of African swine fever (MAFRA 2021), and even attacked people (Yon 2019). According to the Ministry of Environment, 50,412 heads of wild pigs were captured in 2018, but there is a limit to capturing them due to the rapid population growth (MEHADS 2022).

The National Institute of Biological Resources in South Korea reported that the inhabitation density of wild pigs has steadily increased over the last five years, growing from 4.3 wild pigs per 100 hectares in 2014 to 5.2 in 2018. The reduction in crop damage caused by wild pigs can be achieved by utilizing toxic baits. Toxic baits are being developed and utilized with invasive wild pigs in Australia (Lapidge et al 2012) and New Zealand (Shapiro et al 2016). Moreover, several chemical deterrents containing methyl anthranilate are registered as bird repellents in the USA and have been shown to repel depredating birds on various crops (Curtis et al 1994; Avery et al 1995; Werner and Avery 2017).

Methyl anthranilate (MA), a plant spice extract found naturally in grapes and strawberries, has long been used in the food processing industry to prepare edible flavors and additives (Li et al 2020). Methyl anthranilate is extensively used to make ingestive stimuli taste aversive in visually mediated passive-avoidance learning studies in domestic chicks, *Gallus gallus domesticus* (Marples and Roper 1997). In addition, methyl anthranilate has been used as a bird repellent for crop protection (Avery et al 1995; Cummings et al 1995). Several studies have assessed the effectiveness of MA formulations as avian feeding deterrents. However, no information was published online using MA as pig repellent determining feeding avoidance. Feeding avoidance of a repellent would be advantageous, potentially reducing the

number of pigs approached from visiting the farm treated with repellent.

Feeding is an important behavior that can be measured in various ways when considering a group of pigs. The exploratory behavior of swine is related to their desire for movement and feeding (Zhuchaev et al 2020). This includes keeping track of the amount of food consumed, the amount of time spent eating, and the frequency with which the animals' head is in the feeding trough (Alameer et al 2020). Unlike actual consummatory behavior, animals will also visit the feeding area without ingesting feed, which is classified as a non-nutritive visit (NNV) (Miller et al 2019; Weary et al 2009). Different approaches can be used to prevent wild animals from entering the farm and prevent them from eating crops, cereals, and other staple food. This can be controlled by mechanical, biological, and chemical methods (Kaur et al 2020). However, these methods are either too costly or not eco-friendly. Hence, our study aimed to assess the effectiveness of Methyl anthranilate as a pig repellent and evaluate its effect on feeding behavior and production performance.

2. Materials and Methods

2.1. Ethical approval

The pigs in the experiment were managed and cared for according to good animal husbandry practices. The Institutional Animal Care and Use Committee (IACUC), Sunchon National University, reviewed and approved the methodology (SCNU IACUC-2022-02).

2.2. Experimental animal, design, and housing

The feeding behavior and production performance of eight female growing pigs were explored in this study. As an alternative to wild pigs, the crossbreed [(Landrace x Yorkshire) x Duroc] was used in this experiment as part of the preliminary investigation. The experiment was conducted at the experimental swine farm of Sunchon National University. The feeding behavior of pigs was observed for one week in 24 hours using the CCTV camera to monitor the pigs' activity. After the one-week adaptation period, experimental animals were randomly distributed in a separate experimental pig pen and raised in a controlled housing environment for five weeks. Each treatment was replicated four times, having one pig in every replication.

The experimental pig was raised separately in a pig pen with a measurement of 3 x 3m with one feeder for the control, while 3 x 6m in the treatment pigs with two feeders were installed in the pig pen and placed 3.0m apart, and each feeder was labeled as with and without repellent in the diet (Figure 1). The pigs were raised in the monitored growing house with concrete flooring, good ventilation, an average housing environment of 21.38 °C, and the relative humidity varied from 35.30 to 58 % (mean: 44 %), ammonia (NH_3) level of 1.97 ppm.

The housing temperature was determined using eight-bit Smart Sensors (model: SMT-75, Seoul, South Korea). The NH_3 concentration was quantified by installing a sensor-NH_3 3E 100 SE (City of Technology, Bonn, Germany) and positioned inside the pig house at the height of 1.90m at a range of 0-50 ppm (Mun et al 2020). The humidity inside the pig house was determined using a digital hygrometer (Electronic Digital Hygrometer HTC-1, Jinggoal International Ltd., Guangdong, China). A data logger system (CR10X data logger, Campbell Scientific Inc., Edmonton, AB, Canada) was connected to all measuring devices to record data every hour (Jeong et al 2020).

All lights were switched during the experiment, which lasted five weeks, from February 25-April 01, 2022. A full HD CCTV 5-megapixel camera was installed to monitor the pigs feeding behavior. The camera was placed on an elevating bracket about 2.8 meters off the ground, pointing downward to get a top view of the pen (Li et al 2020).

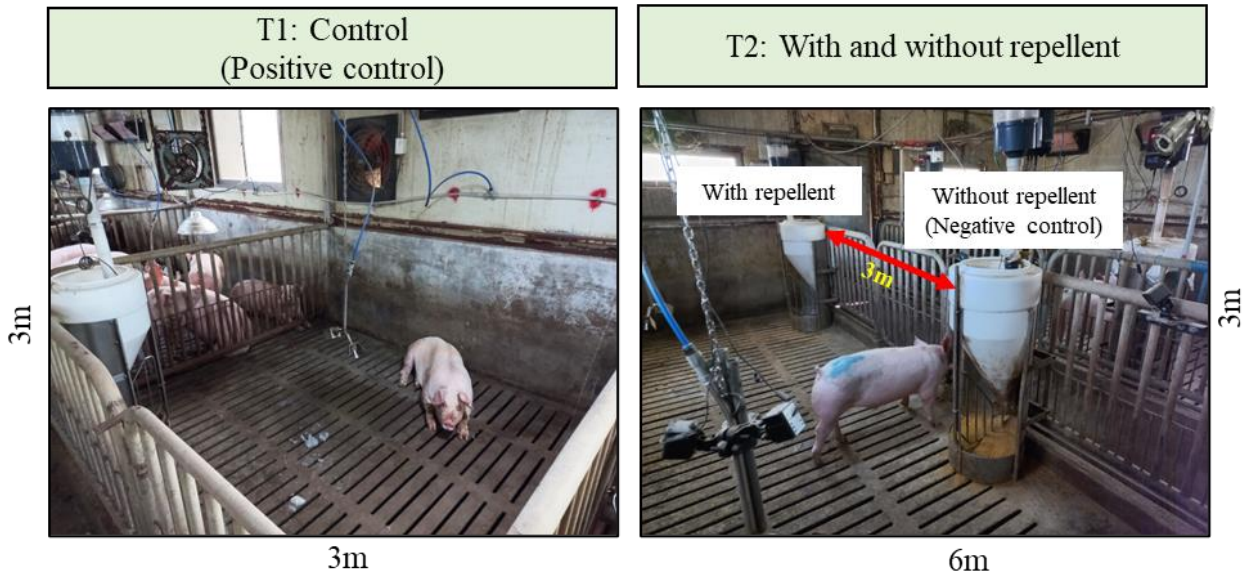

Figure 1 The experimental pigs were raised in their respective pig pen.

2.3. Real-time monitoring of feeding behavior

During the adaptation period, the activities of pigs were monitored 24 hours a week to evaluate pigs feeding time. Alameer et al (2020) conducted a study on pigs' behavior monitoring using a deep learning method. The authors reported that pigs spend very low amounts of time eating from 06:00–07:00 am and become more active after 09:30 am. However, based on the 24 hours a week activity monitoring using the CCTV camera, the experimental pigs in our study are more active from 07:00-09:00 am and at 02:00-4:00 pm.

In this study, a single and highly trained observer monitored the pigs feeding behavior daily from 07:00-09:00 am and 02:00-04:00 pm to obtain a more reliable result. As the observations focused on feeding-related behaviors, the experimental animal was considered feeding when the pig's head was inside a feeding trough (Miller et al 2019).

2.4. Experimental treatment and feeding management

The "To Nature" repellent with an active ingredient of Methyl anthranilate (45%), a product of Jeonjin Biopharmaceuticals, was mixed into the feed at 0.25% from weeks 1-5 to assess the effectiveness of the product (Table 1). In the treatment animals, the feeders assignment of feed mixed with repellent was shifted weekly. The positive control refers to pigs raised in a pig pen with no MA repellent mixed into the diet throughout the experimental trial. In contrast, the negative control refers to pigs raised in the pig pen with two feeders, one feeder was assigned with repellent (treatment), and the other feeder was without repellent (negative control). In this experiment, the feed mixed with repellent was only prepared once at week 1, and the same feed was given for the subsequent weeks. The pigs were fed *ad libitum* with a commercial grower ration from weeks 1 to 4 and gradually shifted to a finisher ration in week 5. Clean and fresh drinking water was also provided.

2.5. Data collection on the growth performance

The initial weight of the pig was taken at the start of the study using an electronic digital weighing scale. Moreover, feed intake (FI), body weight gain (BWG), and feed conversion ratio (FCR) were measured. The feed intake was determined by offering a weighted amount of feed and weighing the remaining feed every morning (Ampode and Mendoza, 2022). The pigs were weighed individually every week to determine their weekly body weight gain. The feed conversion ratio was determined by calculating the total FI divided by the BWG (Eladia and Ampode 2021).

2.6. Statistical Analysis

The number of approaches was analyzed using the paired-sample T-test, and the data were expressed as mean ± standard deviation (SD). The growth performance data were subjected to a One-way Analysis of Variance (ANOVA) test using the Statistical Package of Social Science software (IBM SPSS Statistics 21). The results with significant differences are further compared using Tukey's Honest Significant Difference (HSD), and the differences were statistically assessed at $P < 0.05$. To correlate the relationship between the number of approaches and feed intake, linear and quadratic regression analyses were performed using the SPSS and Sigma Plot software.

Table 1 The inclusion rate of the "To Nature" repellent.

Week	Inclusion Rate (Repellent: Feeds)	Percentage (%)
1	25 ml (0.025L): 10 kilograms	0.25
2	25 ml (0.025 L): 10 kilograms	0.25
3	25 ml (0.025 L): 10 kilograms	0.25
4	25 ml (0.025 L): 10 kilograms	0.25
5	25 ml (0.025 L): 10 kilograms	0.25

3. Results and Discussion

3.1. Feeding behavior

The "To Nature" repellent with an active ingredient of methyl anthranilate (MA) was used in this experiment to assess its effectiveness as a pig repellent and determine its effect on pigs feeding behavior. To the best of the authors' knowledge, this is the first study using "To Nature" as a pig repellent. The data shows that even if the position of the assigned feeder with repellent was shifted weekly, a significantly lower number of approaches were recorded in the feeder with MA repellent compared to the feeder without repellent mixed in the diet (Figure 2). The mean values of the number of approaches of pigs mixed with and without "To Nature" repellent are 10.27 and 25.89, respectively. These findings could positively impact the agricultural sector because the crop damage caused by wild pigs is a major problem.

The total number of hours spent feeding in the feeder with repellent is significantly lower than the feeder without repellent mixed in the diet (Figure 3). The mean values showed that pigs only spent 36 minutes in the feeder with repellent, while 271 minutes were spent in the feeder without repellent. The average daily time spent feeding (ADTSF) of pigs recorded was 5 minutes in the feeder with repellent and 38 minutes in the feeder without repellent mixed into the diet.

The feed avoidance of pigs to the feeder with repellent mixed in the diet might be due to the olfactory repellent effect. These findings are similar to the report of Kaur et al (2020), who studied the behavior responses and histological changes in sense organs of house rats exposed to Methyl anthranilate at 2.5% under the ethovision video tracking system. The researchers reported that after MA treatments, the rats only moved on untreated sides, and their mobility in untreated zones reduced significantly. However, after several days, the rats entered the treated zone but were not up to the end of the site. Therefore, the increase in the number of approaches and feed intake in our study in week

5 indicates that pigs had become accustomed to the repellent, and it will no longer be bothersome.

Linear regression analysis revealed a positive relationship between the number of approaches and feed intake in the feeder with repellent mixed into the diet (Figure 4 and 5). This observation implied that the pigs tend to avert the feed with repellent and when the number of approaches increases, the amount of feed intake also increases. In contrast, quadratic regression analysis between the number of approaches and the feed intake of pigs in the feeder without repellent mixed into the diet was not consistently correlated with the number of approaches and the amount of feed intake. Although the number of approaches to the feeder with repellent from weeks 1-4 were documented, no feed intake was recorded. It means that pigs only explored the area, which is classified as a non-nutritive visit (NNV). Animals are thought to perform NNVs where food is available in their environment, and if the feed is not palatable, they will look for other areas where feed is available (Day et al 1998; Svensson and Jensen 2007; Weary et al 2009; Miller et al 2019).

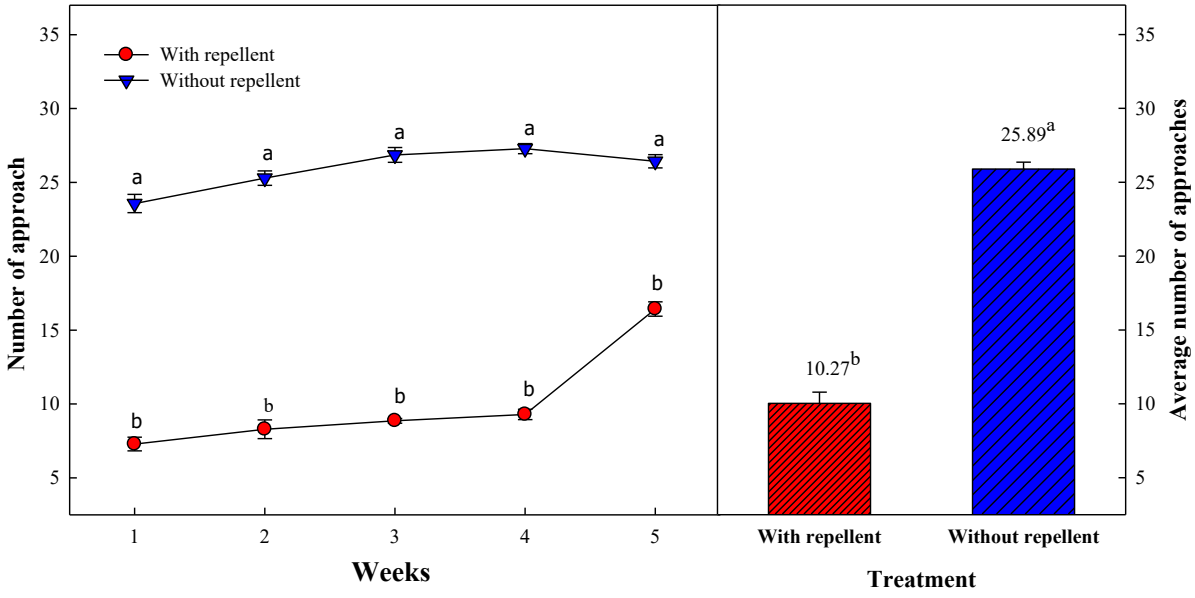

Figure 2 The average number of approaches of pigs in the feeder with and without repellent in the diet.

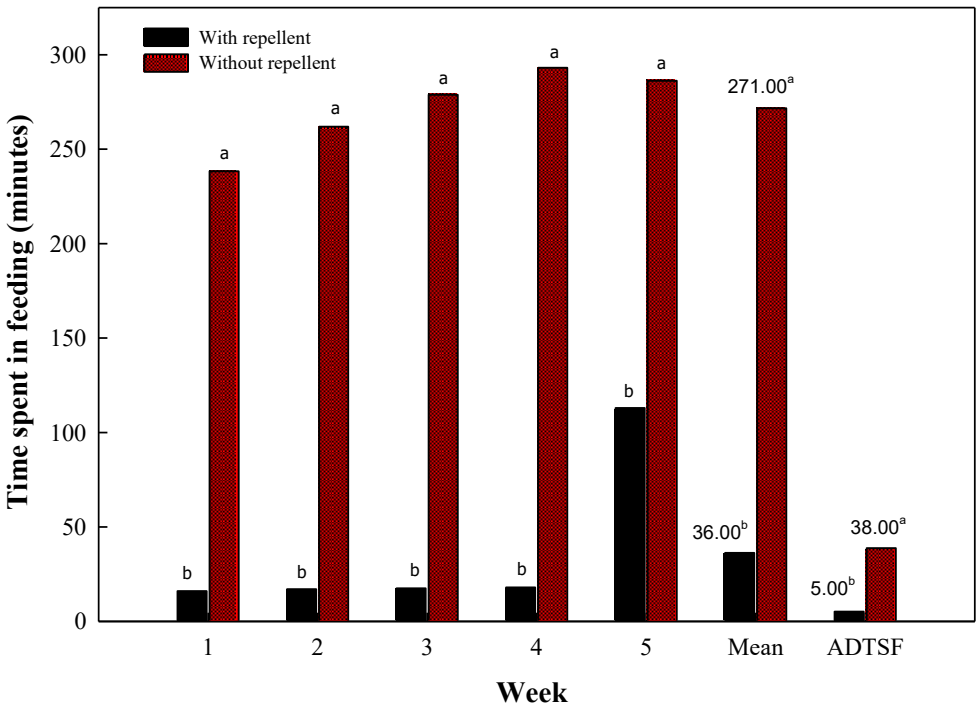

Figure 3 The average time spent eating in the feeder with and without repellent in the diet.

3.2. Growth Performance

The initial weight of pigs in positive and negative control was not significantly different, with 58.40kg and 59.45kg, respectively. However, significant differences were observed in the feed intake of pigs from weeks 1 – 5, where the feeder with repellent mixed into the diet was significantly lower feed intake than the feeder without repellent. The cumulative feed intake of pigs in the positive (control) and negative control was statistically comparable. At the same time, the feeder with MA repellent in the diet got the lowest feed intake and was statistically different between treatments.

A significant effect ($P < 0.001$) was observed on the cumulative feed intake of pigs from weeks 1 to 5. The data shows that from weeks 1-4, pigs did not eat the feed with 0.25% MA repellent and preferred to eat at the feeder without repellent (negative control) (Table 2). The cumulative feed intake, average daily feed intake, and feed conversion ratio of pigs in positive and negative control from weeks 1 to 5 are statistically comparable. Likewise, the feeder with repellent showed the lowest ($P < 0.001$).

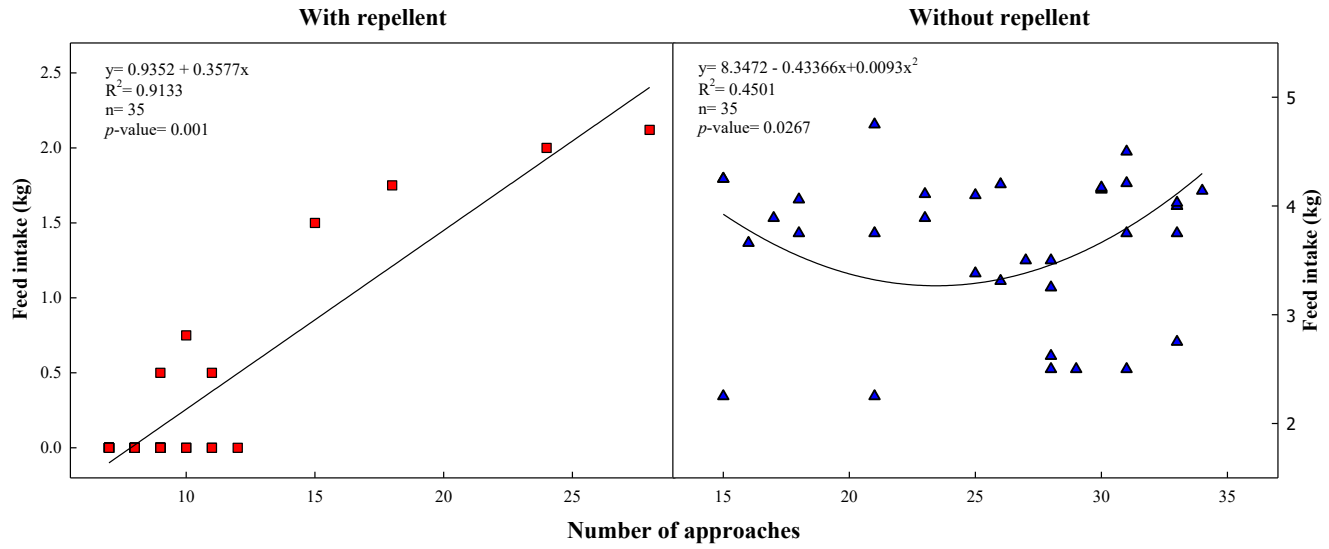

Figure 4 Relationship between the number of approaches and feed intake of pigs with and without repellent in the diet.

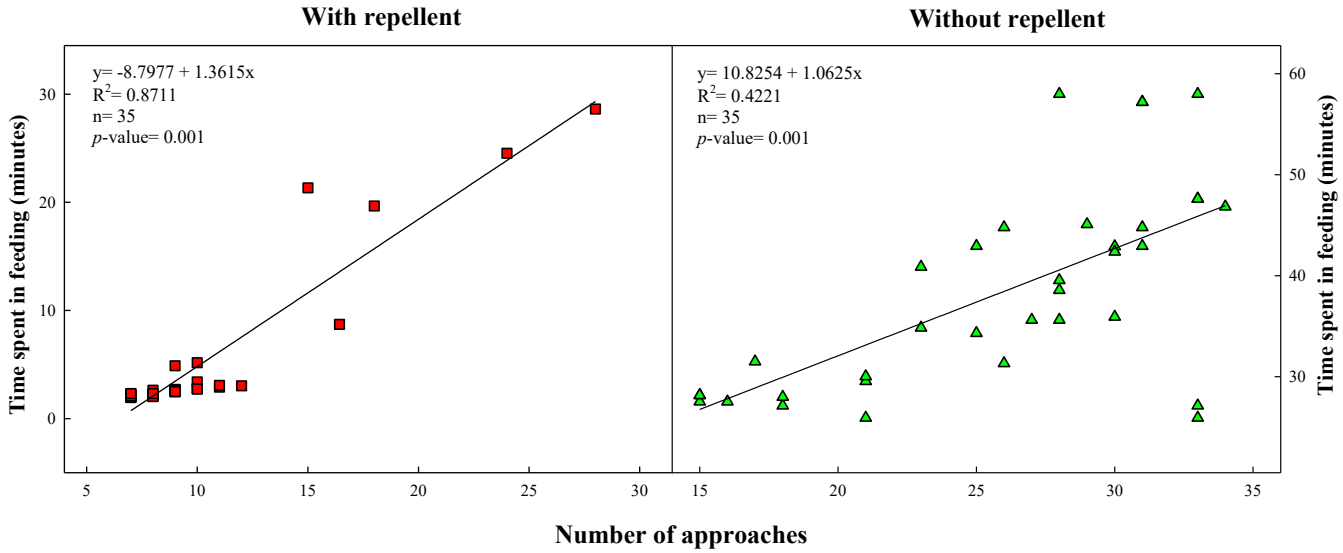

Figure 5 Relationship between the number of approaches and time spent eating in the feeder with and without repellent in the diet.

Although statistical differences were observed in the feed intake, the data revealed no significant differences in pigs' body weight gain. The cumulative body weight gain of pigs in the positive and negative control is 43.93kg and 46.03kg, respectively. This implies that MA repellent is non-toxic and has no adverse effect on pig production performance. This is because MA is a natural compound mainly obtained from concord grapes (*Vitisla brusca* L.) (Sun et al 2011), and it is a monocyclic aromatic amine (Kaur et al 2020). Furthermore, MA is a GRAS-listed (generally recognized as safe) food flavoring (Belant et al 1997; Jenner et al 1964; Code of Federal Regulations 1998).

Table 2 The average effects of Methyl anthranilate on the growth performance of pigs (per pig in kg).

Parameters	Control	TREATMENTS		Total#	*SEM*	*P-value*
		With repellent	Without repellent			
Week 1 (0.25% repellent)						
Initial Weight	58.40	-	59.45	59.45	0.384	0.188
Body Weight Gain	8.68	-	8.89	8.89	0.523	0.860
Feed Intake	26.53[a]	0.00[b]	28.09[a]	28.09	3.901	0.001
Average Daily Feed Intake	3.79[a]	0.00[b]	4.01[a]	4.01	0.557	0.001
Feed Conversion Ratio	3.06	-	3.16	3.16	0.095	0.648
Week 2 (0.25% repellent)						
Body Weight Gain	8.55	-	10.38	10.38	0.707	0.221
Feed Intake	25.50[b]	0.00[c]	28.50[a]	28.50	3.860	0.001
Average Daily Feed Intake	3.64[b]	0.00[c]	4.07[a]	4.07	0.551	0.001
Feed Conversion Ratio	2.98	-	2.75	2.75	0.156	0.515
Week 3 (0.25% repellent)						
Body Weight Gain	8.85	-	9.33	9.33	0.537	0.692
Feed Intake	26.13[a]	0.00[b]	24.84[a]	24.84	3.628	0.001
Average Daily Feed Intake	3.73[a]	0.00[b]	3.55[a]	3.55	0.518	0.001
Feed Conversion Ratio	2.95	-	2.66	2.66	0.149	0.363
Week 4 (0.25% repellent)						
Body Weight Gain	9.25	-	8.61	8.61	0.354	0.860
Feed Intake	26.98[a]	0.00[b]	29.03[a]	29.03	4.000	0.001
Average Daily Feed Intake	3.85[a]	0.00[b]	4.15[a]	4.15	0.571	0.001
Feed Conversion Ratio	2.92	-	3.37	3.37	0.179	0.237
Week 5 (0.25% repellent)						
Body Weight Gain	8.60	-	8.83	8.83	0.476	0.834
Feed Intake	25.56a	9.13c	17.38b	26.51	2.033	0.001
Average Daily Feed Intake	36.5a	1.30c	2.48b	3.78	0.290	0.001
Feed Conversion Ratio	2.97a	1.03c	1.97b	3.00	0.258	0.001
Mean *(Week 1 - 5)*						
Body Weight Gain	43.93	-	46.03	46.03	0.569	0.055
Feed Intake	130.68[a]	9.13[b]	127.84[a]	136.97	17.09	0.00
Average Daily Feed Intake	3.73[a]	0.26[b]	3.65[a]	3.91	0.488	0.001
Feed Conversion Ratio	2.98[a]	0.21[b]	2.78[a]	2.99	0.383	0.001

Control: positive control without repellent in the diet throughout the experiment; With repellent: Feed mixed with "To Nature" repellent; Without repellent: negative control where the feeder was installed in one pig pen together with the feeder with repellent; -: The same pig and value in the without repellent (negative control); #: is the sum of the data from with and without repellent.

The positive effect of Methyl anthranilate as a pig repellent confirms the findings of many researchers who reported that viable plant-based repellents with an active ingredient of methyl anthranilate are effective against rodents (Singla and Kaur 2014; Bala and Babbar, 2019). Similarly, Mason and Clark (1995) reported that MA acts as an active component in commercial products that prevent crop loss and damage caused by birds. Marples and Roper (1997) testified that the response of MA odor in chicks has a discriminative stimulus in taste-avoidance learning. Furthermore, repellents were used to manipulate animal behavior and are considered a communication device that sends a signal from which the animal extracts a message and excites the primary defense mechanisms causing food rejection (Bala and Babbar, 2019). It was also reported by Mason et al (1989) that repellent can be visual, gustatory, olfactory, acoustic, chemicals, or a mixture of these characteristics. The feed avoidance and the decrease in the feed intake of pigs in the diet mixed with MA repellent confirm the report of Mason et al (1991). They reported that MA concentrations as feed additives significantly reduced the feed consumption of birds.

4. Conclusions

Including 0.25% methyl anthranilate as a repellent effectively avoids pig feeding. Non-nutritive visits were recorded in the feeder with MA repellent, and linear regression analysis revealed a positive relationship in the

feeding behavior of pigs on the number of approaches, feed intake, and total time spent in feeding. Further, MA repellent is safe and eco-friendly with no adverse effect on the growth performance of pigs. In conclusion, the "To Nature" repellent with an active ingredient of Methyl anthranilate can be used as a pig repellent to deter feeding, and the efficacy of the repellent could last 28 days or more. Field experiments using wild pigs and determining the feeding behavior and production performance using the deep learning method are recommended.

Conflict of Interest

The authors declare no conflict of interest.

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