Insect Repellent Activity of Fatty Acid Derivatives

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Introduction

Although the property of certain chemicals to repel insects has long been recognized, the fundamental principles involving such activity are not as yet clearly understood. It is well known that repellency has little in common with lethal properties and that chemicals possessing a high degree of repellency for insects are frequently non-toxic to the insects and also that toxic substances are often attractive to them. Repellent propties and insecticidal activity are, therefore, separate and distinct functions and it does not follow that a compound possessing one of these properties possesses the other. Bunker and Hurschfelder[1] and later Mail[2] made a study of the repellent activities of a large number of organic compounds in an attempt to correlate insecticidal activity with chemical constitutions.

The field for insect repellents has been rather generally limited to their use in various lotions, creams and solutions for human use. There exists, however, a large potential use for repellents in the agricultural field if cheap and highly effective repellents can be developed. Many insecticides, particularly those used for leaf eating insects, depend upon a certain amount of damage to the plant before a sufficient quantity of the insecticide is consumed to be effective. They are, of course, rather generally applied as a protective measure which often reduces the plant injury to a minimum. In the life cycle of some insects the adult deposits eggs in the bud or other tender portions of the plant where the further development of the bud or plant part serves as a protection to the eggs until they are hatched. A serious amount of damage may be done by these insects before an insecticide can be effective against them. If the plant was sprayed with a repellent, the adult insect would avoid contact with it, and this cycle with its subsequent damage would be avoided. For this purpose the repellent could be either absorbed upon an inert dust or upon a solid insecticide, such as lead arsenate, or it could be applied in the form of a spray. The method of application chosen would, of course, depend upon the particular problem at hand. This method of insect control depends upon the development of highly repellent compounds which can be produced at nominal costs.

It is the object of this paper to study the repellent properties of a number of fatty acid derivatives and to correlate repellent activity with the particular functional group or groups present.

Method of Conducting Repellent Tests

The test insect used throughout this investigation, unless specially noted, was the common house fly, Musca domestica. This insect is extremely difficult to repel, since it is continuously moving about in search of food. The flies were reared under carefully controlled laboratory conditions.

The test flies, numbering from three to four hundred, were confined in a wood cage (19.5″ high, 9.5″ wide, and 14.5″ long) surrounded with 16 mesh copper wire screening on the two broad sides of the cage. The cage was equipped with a trap door for the introduction of food, water and the test samples. Bait attractants for the test work were made by spreading two grams of diastatic malt extract (Fleischmann) in the center of a seven centimeter filter paper so that an even, thin film covered the paper leaving a one-quarter inch margin around the circumference. The coated paper was baked for eighteen hours at 37°C. in order to dry the malt film. Upon removal from the oven, one drop of the test chemical was placed upon the malt film and spread as evenly as possible over the surface. Three or four chemically treated malt papers were usually included in each test along with an untreated malt paper which served as a control. The papers were pinned to the inside screened surface of the cage in such a manner that the light fell on the rear or untreated surface of the paper. The natural tendency of the flies in the cage was to be attracted to the malt extract as a source of food. The repellent properties of the test chemical were measured by its ability to protect the malt extract from attack by the flies. The degree of repellency of the various compounds tested is derived from counts of the number of flies feeding on the treated malt surfaces compared to the number feeding upon the untreated surface. It was observed that the usual response of the flies to the introduction of the malt papers was a mass migration. After depletion of the food upon the control, the flies moved to the paper containing the chemical possessing the least repellent properties, then to the next least repellent and so on. Counts of the number of flies feeding on the test samples were made fifteen minutes after the introduction of the papers into the cage, and all counts thereafter were made at thirty-minute intervals for a period of three hours or more.

Repellent Action of Some Fatty Acid Derivatives

The repellent activities of some derivatives of lauric acid are shown in Table I. Each cage contains three to four hundred flies. The table shows the results obtained when an untreated malt paper was placed into the cage along with a malt paper treated with the chemical designated in the table.

TABLE I.—THE REPELLENT ACTIVITIES OF LAURIC ACID AND SOME OF ITS DERIVATIVES
(Musca domestica)

Time Min.	Laurone		Lauraldehyde		Dodecyl Amine		Dodecyl Alcohol		Lauronitrile (L,ho+T)		Lauric Acid	
	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated
15	27	14	107	19	80	0	19	0	59	0	19	14
45	24	19	110	14	10	0	19	1	30	0	19	2
75	15	10	74	52	6	6	20	0	31	0	20	5
105	12	16	87	48	3	14	18	0	16	0	18	9
135	10	12	102	29	1	16	17	0	28	0	17	4
165	9	8	......	......	0	12	13	0	9	0	13	1
195	5	6	......	......	......	....	......	....	10	0	......	....
225	9	2	......	......	......	....	......	....	......	....	......	....
Total	111	87	480	162	100	48	106	1	183	0	106	35

The results tabulated in Table I show that lauric acid possesses little repellent activity. Laurone, lauraldehyde, and dodecyl amine possess little, if any, repellent action. Lauronitrile and dodecyl alcohol are both highly repellent. These results indicate that the fatty alcohols and nitriles possess a degree of repellency not found in the other derivatives investigated.

It was decided to determine the repellent activities of a number of fatty alcohols and fatty nitriles in order to determine the relationship between chain length and repellent action in any given homologous series. Table II shows the repellent properties of a number of higher alcohols.

TABLE II.—REPELLENT PROPERTIES OF SOME HIGHER ALCOHOLS

(Musca domestica)

Time Min.	Control	Octyl	Dodecyl	Hexadecyl	Control	Decyl	Undecyl	Undecenyl
15	63	27	9	48	61	3	1	0
45	39	20	0	54	54	1	0	2
75	17	12	0	31	18	2	0	0
105	15	8	0	18	19	0	0	0
135	17	6	0	14	14	0	1	0
Total	151	73	9	165	166	6	2	2
	Cage 1				Cage 2			

In Table II, and in all the following tables, the samples should be referred to the nearest preceding control. The results with the higher alcohols tabulated in Table II show that decyl, undecyl, undecenyl and dodecyl alcohols are highly repellent. Octyl alcohol is only mildly repellent and hexadecyl alcohol is not repellent. Repellent activity in the alcohol series is, therefore, a function of the chain length, and the optimum chain length is from ten to possibly thirteen carbon atoms inclusive.

A very detailed study was made of the repellent properties of the aliphatic nitriles in order to obtain the relationship which exists between the chain length of the nitrile and its repellent action. The results obtained are shown in Table III.

nitriles are not active. One very interesting observation in connection with these results is that the lower nitriles, which possess very objectional odors to humans, are not repellent. Lauronitrile possesses only a mild odor and tridecylonitrile is essentially without odor. This indicates that there is no connection between repellency for insects and odors as observed by humans.

The repellent action of several of these derivatives was compared to that of oil of citronella in order to ascertain their degree of repellent activity as compared with a substance of recognized repellent action. Table IV shows the repellent activity of lauronitrile, undecylonitrile and tridecylonitrile as compared to that of oil of citronella for Musca domestica and Table V for the common green bottle blowfly (Lucilia sericata).

TABLE IV.—REPELLENT ACTION OF OIL OF CITRONELLA, UNDECYLONITRILE, LAURONITRILE AND TRIDECYLONITRILE FOR MUSCA DOMESTICA

Time Min.	Control	Oil of Citronella	Undecylo-nitrile	Lauro-nitrile	Tridecylo-nitrile
15	36	6	0	0	0
45	39	4	0	0	0
75	57	11	0	0	0
105	41	9	0	0	0
135	49	7	0	0	0
165	47	19	0	0	0
195	31	11	0	0	0
Total	300	67	0	0	0

TABLE V.—REPELLENT ACTION OF LAURONITRILE AND OIL OF CITRONELLA FOR THE COMMON GREEN BOTTLE BLOWFLY

(Lucilia sericata)

Time Min.	Control	Lauronitrile	Oil of Citronella
15	40	4	0
45	48	4	1
75	46	6	8
105	30	3	10
135	17	6	19
165	5	3	20
195	5	5	24
225	4	6	26
Total	195	37	108

TABLE III.—REPELLENT ACTIVITIES OF ALIPHATIC NITRILES

(Musca domestica)

CAGE 1

Time Min.	Control	Aceto. C_2	Propio. C_3	Butyro. C_4	Valero. C_5	Enantho. C_7
15	55	28	39	12	42	48
45	49	26	24	30	33	44
75	20	31	13	19	12	17
105	17	26	12	14	8	9
135	7	20	5	10	4	7
165	4	4	4	5	5	6
Total	152	135	97	90	104	131

Cage 2

Time Min.	Control	Caprylo. C_8	Lauro. C_{12}	Tridecylo. C_{13}	Pentadecylo. C_{15}	Margaro. C_{17}
15	28	1	0	1	21	23
45	15	7	0	0	18	20
75	18	10	0	0	9	29
105	9	10	0	0	5	14
135	12	12	0	0	6	10
165	5	10	0	0	3	8
Total	87	50	0	1	62	104

Cage 3

Time Min.	Control	Capro. C_6	Pelargono. C_9	Capri. C_{10}	Undecylo. C_{11} (sat.)	Undecyleno. C_{11} (unsat.)
15	39	26	0	0	0	0
45	42	29	0	0	0	0
75	14	26	5	3	0	0
105	20	15	6	0	1	0
135	17	12	10	0	0	0
165	9	8	6	5	0	0
Total	141	116	27	8	1	0

An examination of the data presented in Table III shows that the lower nitriles, containing nine or less carbon atoms, possess very little repellent activity. Tridecylonitrile is highly repellent, but pentadecylonitrile is only mildly repellent indicating that the higher

The results shown in Table IV and V indicate undecylonitrile, lauronitrile and tridecylonitrile to be significantly more repellent to flies than oil of citronella.

Table VI shows the repellent activity of dodecyl alcohol as compared to oil of citronella.

TABLE VI.—REPELLENT ACTION OF DODECYL ALCOHOL AND OIL OF CITRONELLA FOR MUSCA DOMESTICA

Time Min.	Control	Dodecyl Alcohol	Oil of Citronella
15	61	1	0
45	67	0	0
75	40	0	0
105	36	1	3
135	31	0	3
165	25	0	4
195	15	0	5
225	13	0	4
Total	288	2	19

The results shown in Table VI indicate dodecyl alcohol to be more repellent than oil of citronella for Musca domestica.

Toxicity of Lauronitrile

The toxicity tests were performed under carefully controlled conditions. Six rats were fed 0.25 cc. samples each by means of a stomach tube. No ill effects were observed immediately following the administration or during the ten days following.

A slight inflammation was observed upon the ears of rabbits treated with 2 cc. of a 10% alcoholic solution. This disappeared the following day and the ears remained normal during a two week period. Application of 1.5 cc. of a 10% alcoholic solution to the skin on the underside of the forearm of two human subjects produced no ill effects.

A rabbit's eyes were treated with 1.5 cc. of undiluted lauronitrile by means of an eye dropper. No ill effects of any kind were observed.

From the results of the toxicity tests, it was decided that lauronitrile is not toxic either when applied externally or administered orally.

Future Work

A larger scale investigation of the use of lauronitrile as a repellent for insects upon cattle, dogs and other animals is now being conducted. During the present season extensive tests have been undertaken upon the effectiveness of lauronitrile as a repellent for insects upon agricultural crops. The results of this work will be reported at a later date.

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Summary

(1) The repellent activity of a number of fatty acid derivatives for flies has been studied. It was found that certain higher alcohols: decyl, undecyl, undecenyl, and dodecyl alcohols are highly repellent and that aliphatic nitriles containing from ten to fourteen carbon atoms possess high repellent activity for the insects tested.

(2) Undecylonitrile, lauronitrile, tridecylonitrile and dodecyl alcohol are more repellent for flies than oil of citronella under the test conditions.

(3) Lauronitrile is non-toxic both when applied externally or administered orally.

LITERATURE CITED

(1) Bunker, C. W. and Hurschfelder, A. D., Am. J. Trop. Med., 5, pp. 359 (1925).
(2) Mail, C. A., Montana State Coll. Agri. Bull., pp. 288 (1934).

Abstracts

Oils and Fats

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Yield differences in oil milling. Magne Sethne. *Kgl. Norske Videnskab. Selskaba. Skrifter 1939,* No. 3, 150 pp. (Pub. 1940). Three equations are given for calcg. the theoretical oil yield, the factory loss and the cake yield; from the analyses of the raw material and corresponding oil cake. The analytical results and data given are from 5 yrs. of investigations on copra and peanuts. The discrepancy between sampling at the ship and at the mill were insignificant during the 5 yrs. Analytical methods for both raw materials and cake were investigated. The influence of drying, grinding with sand, choice of solvents, method of volatilizing solvent and drying ext. and extn. after HCl treatment on the oil detn. are given. The HCl treated samples were extd. with Et_2O and with petrol. ether; these gave results which were 0.34-0.87% higher than the non-HCl treated samples. Lowest results were by extn. with petrol. ether; these were 0.17-0.50% less than with Et_2O extn. Benzine, benzol, CCl_4, C_2HCl_3 and CS_2 extd. 0.20-0.80% more oil from copra than Et_2O. The oil extd. from peanuts by Et_2O and benzine was practically the same while benzol extd. 0.10-0.32% more. Influence of temp. and time when drying in vacuum, in ordinary oven and in atm. of CO_2 and an indirect moisture detn. were evaluated. The indirect method, calcn. indirectly from the amt. of oil and residue from the oil detn., gave the most plausible results. These were higher on the raw products and lower on cake than by the direct methods. The differences between the theoretical and actual factory yield, oil yield and cake yield were given graphically and in tables and were compared with the data from other reports. In an attempt to explain the losses, the author investigated the oil detns. and balance. Development of free fat acids during processing may have some effect. An appreciable portion of the free fat acids remains in the cake and are not quantitatively extd. in the oil detn. The oil extd. during analysis differed in content of P and N compds. from that com. pressed out. An equation for this influence was given. Water balance calcn. and investigations indicated that there was less factory loss when the indirect method of analysis was used. An equation for the effect of analytical error was presented. There are 43 references. (*Chem. Abs.*)

Composition of cottonseeds.. 4. Lipase of germinated seed. H. S. Olcott and T. D. Fontaine. *J. Am. Chem. Soc. 63,* 825-7 (1941). Dormant cottonseeds contain no lipase. Lipolytic activity develops during germination. Concurrently, total lipids decrease and free fatty acids increase. The germinated cottonseed lipase is effected in the pH range 6 to 9 (opt. 7 to 8). $CaCl_2$ activates the enzyme, particularly in alkaline solns. The effects of several other reagents on its activity are described.

Grapefruit yields textile oil. *News bulletin—Natl. Farm Chemurgic Council 2,* 22-3 (1941).

The determination of fat in the presence of free fatty acids. I. The Mojonnier test of mix-