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Repellency of Chemical Compounds to Stored Product Insect Pests
A Review of Literature

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1. INTRODUCTION and FUNCTION of this Study [1)]

Dried and processed foodstuffs, drugs and various other storeable commodities are increasingly packaged or bagged in different sorts of wrapping materials the world over, especially in the industrialized countries. The aim of this packaging is not only to compile the products but also to protect them against stored product pest infestation and adverse environmental conditions. Living organisms, mainly the stored product insects, mites and microorganisms, are the major source of destruction of stored commodities.

Wrapped or bagged goods are transported to different countries all over the world with international trade. Sanitary measures, handling techniques and the environmental conditions vary greatly from country to country. It is, therefore, essential that packages of stored goods should be efficient enough to withstand poor sanitation and handling techniques as well as extreme infestation pressures of stored product pests, especially in the tropical and subtropical parts of the world. The protection of these goods against pest infestation is a matter of great concern to manufacturers, wholesalers, marketers and consumers throughout the world.

Packaged goods are infested either by invadors which grain entry into the products through structural weakness or by penetrators that are capable of boring through almost any packaging material except glass (143,144,160). The infestation of these commodities may, however, also occur before or during processing and packaging at the factories. Attack of invadors may be avoided by perfectly sealing the products in poreless wrapping materials. Protection of packaged foodstuffs against

1) This research project "Investigations for Protection of Packaged Foodstuffs against Infestation of Stored Product Insect Pests" was subsidized by funds allotted by the "Arbeitskreis Industrielle Forschungsvereinigungen e.V."(AIF) to Dr. R. Wohlgemuth, Director of the Stored Products Protection Institute of the Biological Research Centre for Agriculture and Forestry, Berlin-Dahlem, Federal Republic of Germany.

infestation of penetrating insects is only possible, however, if the wrapping materials are mechanically resistant to the penetrators. Moreover, the odour of the packaged products may attract the stored product pests if the packages are not sufficiently impervious to air (73,152).

Mechanical resistance of various different kinds of packaging materials against a broad spectrum of stored product insects have been amply investigated (11,36,37,48,56,57,82,86, 113,137,146,162). According to these comprehensive experimental studies the structural resistance of different types of wrapping materials vary greatly, however, none of the materials tested was absolutely insect-proof to all the stored product insect species under various environmental conditions. Efficient sealing of seams and seals as well as non-porous wrapping materials are essential for the protection of packaged commodities against invadors, microorganisms and unfavourable environmental factors (40).

Packaged dried and processed foodstuffs and other storeable goods may, additionally, be protected through chemical compounds. However, the use of insecticides in the protection of stored goods against attack from storage pests is not especially safe due to their toxicity and the acute residual problems (30,83,87,88,147). Highland et al. (84) indicated that application of chemicals to packages is useless if the packages are not efficiently insect-proof.

Application of insecticides to control various kinds of serious pests, infact, can not be absolutely eliminated. However, they may only be applied if their use is in reality indispensable. Furthermore, in the case where insecticides are applied their influence on beneficial insects - parasites and predators - and their effect directly on man as well as domestic animals should be comprehensively investigated. Likewise, their consequences on the ecosystems as a whole should be thoroughly examined (18,19,76,138,139,140). Moreover, a big difficulty which arises through the use of non-specific toxicants

is the development of insecticide resistant strains of pests (46,93).

Pest infestation may be controlled with various other devices. Levinson (115) assessed the possible utilization of insectistatics and pheromones for control of stored product pest infestation. Various antifeedant compounds, which prevent the feeding of pests on a treated material without necessarily killing or repelling them (164,165), have also been investigated to save stored commodities from the storage pests (117, 118). As these compounds leave beneficial animals, parasites and predators of pests undisturbed they may be reliably applied in pest control.

Similarly, experimental studies have also been carried out to protect packaged goods against infestation of stored product pests through specific insect repellent chemical compounds. Repellent is defined as a chemical compound which causes insects to make oriented movements away from its source (43). Control of pests by means of different chemical repellents may easily be introduced into an integrated pest control program because the ecosystems are left relatively undisturbed.

Comprehensive experimental studies on repellency of various chemical compounds to a wide spectrum of blood-sucking and irritating arthropod species, especially various species of the insects, were carried out during and after the second world war to protect man from attacks by these pests. A voluminous literature on the laboratory research and practical application of different compounds is available in this field of pest control. This literature has been amply surveyed (29, 41,42,101,127,155,159).

Evaluations to find out the efficient stored product insect chemical repellents have been carried out by various different authors during the last three decades. A large number of chemical compounds have been assessed on their repulsive

effect on these insect pests, and a number of publications exist in the area of pest control. However, a comprehensive survey of the literature pertaining to the experimental and practical knowledge of stored product insect repellents has yet to be conducted. In this paper, therefore, the literature is reviewed to reveal the present level of the knowledge concerning the laboratory and practical trials on chemical repellents of storage pests. Likewise, the future prospects of laboratory research as well as practical application of chemical repellents in control of infesting pests will be discussed.

2. SYNTHETIC CHEMICAL REPELLENTS for Stored Product Insect Pests

A previous literature review (48) pertaining to destruction of packaged products by these pests revealed that package infestation can be prevented through insect repellent chemical compounds. According to these studies, infestation of cadelle larvae, Tenebroides mauritanicus L., - one of the most effective penetrators of packages - , might be checked for a period of more than 50 days with 3,5-dinitro-2-methylphenol and for somewhat shorter period with some other chemical compounds. Frings (49,50,51) and Frings and Neal (52) evaluated repellency of ammonium and potassium salts on american cockroach, Periplaneta americana L., meal worm, Tenebrio molitor L., and on larvae of T. mauritanicus.

Chamberlain and Hoskins (34) investigated repelling effect of various chemical compounds on T. mauritanicus larvae; T. molitor larvae; granary weevil adults, Sitophilus granarius L.; dampwood termite, Zootermopsis angusticollis Hagen and Z. nevadensis Hagen and drywood termite, Kalotermes minor Hagen. The following compounds showed a repellent effect on these insect pests: copper sulphate; trichlorophenol; chlorohydroquinone; hexachlorocyclohexane; DDT; nitroiodobenzene; terpineol; benzil; quinoline; 3,5-dinitro-2-methylphenol; morpholine; diphenylamine; phenothiazine; acetic acid or trichloro-

acetic acid; ß,ß-dithiocyanodiethyl ether and ß-butoxy-ß-thiocyanodiethyl ether; coumarin and thiocoumarin. Moreover, this study indicated that relatively non volatile essential oils were not noticeably repellent. Toxicity was in some cases associated with repellency but not in all. Wolcott (163) assessed various chemical repellents for protection of wood against termite infestation.

Termite, the most serious pest of wood, wooden structures and crops in the tropics and subtropics, besides stored product insect pest, is a very destructive pest of various wrapping materials which are commonly used for the packaging of different kinds of foodstuffs and other stored commodities (12, 13,14,54,55,151).

Laboratory evaluations (4,5) on repellent effect of 984 chemical compounds on adults from mixed culture containing confused flour beetle Tribolium confusum Duv. and red flour beetle, T. castaneum (Hbst.) demonstrated that the following compounds have $\geq$60 % repellent effect on the insect tested: 3-chloro-N,N-diethylbenzamide; diallyester-1,4-cyclohexanedicarboxylic acid; 2,4-dinitrophenyl phenylether; propylester N,N-diisopropylglutaramic acid; 2,3,5,6-tetrachlorophenol; N-pentylphthalimide; cyclohexylester-1-piperidineacetic acid; alpha, alpha, alpha-trifluoro-2-nitro-4-methylaniline; N-propylphthalimide, N-hexylsuccinimide; N-octylsuccinimide; N-ethylphthalimide; sec-butyl N,N-diethylsuccinamate; 4-tolyl benzoate; and N-methylphthalimide.

N-octylsuccinimide, N-propylphthalimide and N-hexylsuccinimide proved to be the most efficient repellent of all the chemical compounds tested. Repellency of N-pentylphthalimide to various species of genus Tribolium was also confirmed by Swank et al. (154).

Larvae of black carpet beetle, Attagenus piceus (Oliv.) were repelled by paradichlorobenzene (10). Permethrin showed a repulsive action against larvae and adults of the black carpet beetle, A. megatoma (F.); furniture beetle, Anthrenus

flavipes Le Conte; webbing clothes moth, Tineola biselliella (Hummel) and against adults of T. castaneum (23,25,28,32,33, 45,107). Blow (17) stated repelling effect of this compound on german cockroach, Blattella germanica (L.). Bry et al. (24, 26,27) evaluated repellency of some more chemical compounds on A. megatoma and T. confusum. These studies also indicated that phenolic compounds or those compounds which contain a benzodioxide (methylenedioxyphenyl)ring system might have strong repellent effect on various insects. Likewise, a strong repellency of phenolic compounds to adult T. confusum was narrated by Gillenwater et al.(61). Moreower, phenols which might be prepared with commercially available inexpensive raw materials, have been applied as protectants against housefly and wood borers (103,104), and some of the compound showed a good repellent effect for 6 months. Further, investigation with such compounds are essential to devise efficacious repellents for stored product insect pests.

Twenty-one of 24 alkynyl esters of mandelic acid (-hydroxybenzene-acetic acid), - evaluated on their repulsive action against adult T. confusum, - demonstrated 60 % effect on this pest. Some of the compounds studies even revealed 80% repellency for 2 months (64). The following chemicals were evaluated as repellents for this insect by Gillenwater and McDonald (62): 3-acetyl-2-(2,6-dimethyl-5-heptenyl)-4,4-dimethyloxazolidine; 1-(m-chlorobenzoyl)-3-pipecoline; 1-(3-methylphenoxy)-2-pipecoline and N,N-dipentyl-2-methylbenzamide. Guy et al. (75) tested the repellency of 90 chemical compounds against adult T. castaneum. Fourteen of the 90 chemicals tested showed >80 % and 19 compounds demonstrated >60 % repellent effect on this species of stored product insects. N-butylsulfenyl N,N-dimethyldithiocarbamate (peroxycarbamic acid, dimethyltrithiobutyl ester) even demonstrated about 95 % repellency.

Experimental studies with esters of mandelic acid (-hydroxybenzene-acetic acid) demonstrated that 12 of the 29 compounds tested have a strong repellent effect on adult T. confusum. Similarly, 16 of the 36 amides derived from heterocyclic

amines showed >60 % repellency to this serious stored product insect pest. According to these laboratory evaluations 1-(1-oxotetradecyl)piperidine was the most efficient chemical repellent of all the compounds tested (122,123). Huge (95) stated the repellency of methyl and propyl esters of 4-hydrobenzoic acid on larvae and adults of T. mauritanicus; sawtoothed grain beetle, Oryzaephilus surinamensis (L.); T. confusum and Indian meal moth, Plodia interpunctella (Hbn.).

Büchel (29) explained repellency of 2-hydroxyethyl-N-octyl sulfide, 3-chloropropyl-N-octylsulfoxide to cockroaches and N-acetyl-1,2,3,4-tetrahydrochinoline, 2,2,4-trimethyl-1,3-pentadiol and 3-benzylmercaptopropionitril as common repellent for insects. Toxicity and repellency of different chemical compounds was also studied by McDonald et al. (121) on adult T. confusum. These evaluations demonstrated repelling effect of diethyl phosphate ester with o-tolylglyoxylonitrile oxime and (5-benzyl-3-furyl)methyl 2,2-dimethyl-3-(2-methylpropenyl) cyclopropanecarboxylate on the stored product insect species tested. In accordance with the tests these compounds were too toxic at a high rate of application. Therefore, the evaluation of repellency was only possible at a low rate of application.

Goodhue and Tissol (68) and Goodhue and Howell (66) investigated about 200 compounds for their repellent effect, especially, on Periplaneta americana, and sometimes, however, the effect of the compounds was also evaluated on oriental cockroach, Blatta orientalis L. and Blattella germanica. The following chemicals proved repellent to these vermin: 5-chloro-4-amino-2,6-dimethyl-pyrimidine; butadiene-furfural copolymer; tert-butylsulfenyl thiocyanate; iso-propylsulfenylpiperidine; O-ethyl-S-tert-butylsulfenyl xanthate; O-ethyl-S-tert-butyl-thiosulfenyl xanthate; N,N-dimethyl-tert-butylsulfenyl dithiocarbamate; 1,2,3,4-tetrachlorobutane; Acetophenone and cumene isopropyl peroxide. Organic peroxides and butadiene furfural copolymer showed the highest repellent effect on the cockroaches. The later chemical agent proved quite stable.

Mathlein (120) revealed repelling effect of 2-hydroxyethyl-n-octyl sulfide, di-n-propyl isosinchomeronate, 3-chloropropyl-n-octyl sulphoxide, N-octyl bicycloheptene dicarboxamide and di-n-butyl succinate on adults of Tribolium destructor; T. castaneum; Australian spider beetle, Ptinus tectus Boield.; drugstore beetle, Stegobium paniceum (L.); Oryzaephilus surinamensis and rust-red grain beetle, Cryptolestes ferrugineus (Steph.) and on larvae of T. destructor; Attagenus piceus and Cadra cautella (Walker). These studies also showed that the longterm effect of the chemical agents was strongly influenced by environmental factors, i.e. temperature, relative humidity and light. These chemical compounds also repelled various species of disease-carrying arthropods (66,67,68).

Khan (106,107) and Khan and Wohlgemuth (108) tested 39 chemical compounds on their repellent effect against adult T. castaneum. Diethyltoluamide, N,N-diethyl-3-methylbenzamide, dimethylphthalate, hendecenoic acid, phthalic acid dimethyl ester and pyrethrum showed $\geq$90 % repellent effect. Tert-butyl-2,4,5-trichlorophenylcarbonate, benzoic acid benzyl ester, lindane and permethrin revealed more than $\geq$80 % repellency. Mandelic acid ethyl ester, tetramethrin and benzoic acid showed about 60 % repelling action on this pest.

The evaluations on broad spectrum of repellency of various compounds showed that diethyltoluamide, N,N-diethyl-3-methylbenzamide, dimethylphthalate, hendecenoic acid, tert-butyl-2,4,5-trichlorophenylcarbonate, benzoic acid benzyl ester and phthalic acid dimethyl ester have a high repellent effect on the following species of storage pests: cigarette beetle, Lasioderma serricorne (L.); merchant grain beetle, Oryzaephilus mercator (Fauv.); Oryzaephilus surinamensis; lesser grain borer, Rhizopertha dominica (F.); S. granarius; St. paniceum; T. castaneum, T. confusum, T. destructor; T. madens (Charpentier); Tenebrio molitor; khapra beetle, Trogoderma granarium (Everts) and Plodia interpunctella.

The effect of different chemical compounds varied not only

from species to species but it also varied on different developmental stages of the same species. In general, the repellency of a chemical agent was higher on adult insects than on the larvae of the same species of the pests (106,107,120). The effect lasted longer on filter paper than on plastic foils(106).

According to these studies, diethyltoluamide was the most efficient repellent for various species of storage pests. However, the lasting effect of this chemical agent was not longer than 3 to 4 weeks.

Diethyltoluamide also demonstrated a strong repellent effect on broad spectrum of blood-sucking and irritating insect species (1,58,59,71,72,77,99,149,150). Jones and Jacobson (100) extracted diethyltoluamide from pink bollworm moth, Pectinophora gossypiella (Saunders). According to these studies, this compound occurs in fairly large amount in female adults and to a much lesser degree in female pupae. However, it is completely absent in female larvae and in all stages of the male insects. Its function in the life of the insect is still unknown. It may be supposed that this compound functions as repellent to certain natural enemies of this insect.

Synthetic pyrethrins plus piperonyl butoxide as longterm repellent for protection of packaged foodstuffs against infestation of wide spectrum of stored product pests have been amply evaluated elsewhere (2,3,8,9,20,21,22,38,39,44,69,70,81, 110,113,114,116,128,129,130,131). Pyrethrins have long been known to have low mammalian toxicity. They are, therefore, relatively safe and suitable for use in protection of packaged commodities from storage pests. The effectiveness of synergized pyrethrins may be extended by microcapsulation, as with insecticide Sectrol^{TM}(15). Methoxychlor and dichlorovos also showed repellency to stored product insects (78).

Heat-sealed pouches of glassine paper that was laminated with adhesive plus synthesized pyrethrins to aluminium foil and either polyethylene or an isomere filled with cocoa mix were protected against infestation of various stored product

pests even up to one year (85). Synthetic pyrethrins as an efficient repellent to broad spectrum of storage pest species was also described by Jones and Sylvester (101). Control of these pests with piperonyl butoxide and pyrethrins dust and various other chemical compounds was explained by Laudani(112) and Wilbur (161). Moreover, synthetic pyrethroids, silica gel and carbaryl have shown a longterm effect against various species of storage pests (79,88,111,119,158). The residues of piperonyl butoxide and pyrethrins might be determined with the methods explained by Blinn et al. (16), Chazin (35) and Miller and Tweet (125).

Chemical materials applied to various packages may penetrate the treated surface and contaminate the packaged commodities (30,87). The penetration of applied chemicals can be lessened or checked by the use of various layers, kraft paper, saran-coated paper or grease-proof paper, between the treated surface and the packged commodities (80,89,90).

3. PLANT PRODUCTS as REPELLENTS for Stored Product Insect Pests

Pyrethrum, debris, nicotine, oil of citronella and various other plant extracts have been used for a long time as repellent against different species of insects, especially against blood-sucking and irritating insects (53,74,91,92,94, 126). Extensive laboratory investigation on repelling effect of 390 extracts of different species of plants against Japanese beetle, Popillia japonica (Newman), were carried out by Metzger and Grant (124). According to these studies, 56 of the 390 products repelled this insect. Pierpont (132) evaluated the effect of some more plant products on this pest. Experimental and practical knowledge of plant products repellent to insects, especially disease-carrying insects, has been explained in detail by Dethier (41,42), Jacobson (96,97) and Jones and Sylvester (101).

Repellent effect of pyrethrum on various different species of storage pests has been demonstrated by many authors,

cited earlier in the paper. This compound functions not only as a repellent to the pest but at higher concentration it has also an insecticidal effect.

Neem tree, Azadirachta indica A., demonstrated antifeedant effect on various species of insect pests (60,65,102,109, 142,153). This tree has also shown repellent and antifeedant effect on locusts (31,133,134,135). Khan (unpublished), too, found the antifeedant effect of neem kernel extracts on adult Rhizopertha dominica, one of the most serious stored product pests.

Qadri (136) investigated repellent effect of kernel extracts of soapnut, Sapindus trifoliatus L., shikai, Acacia concinna Dc., custard apple, Anona squamosa Linn. and neem against adult rice weevils, Sitophilus oryzae L. and T. castaneum. Repellency of custard apple, neem and shikai extracts was relatively higher to these storage pests in comparison with soapnut extracts. The two former plant extracts also showed antifeedant effect on these pests.

Repellency of neem, Melia azadirachta (L.), ak, Calotropis procera Ait., and gardinia, Gardinia jasminoides Ellis to adult T. castaneum, Rh. dominica and Trogoderma granarium was studied by Jilany and Malik (98). According to these experiments, neem extracts have stronger repellent effect on the pests than the other two plant products. Moreover, the kernel extracts were more effective in comparison with leave, flower and fruit extracts. Similar results were also obtained by Roomi and Atiquiddin (141), Saramma and Verma (145) and Teotia and Tiwari (156) on the effect of Melia azadirachta on various species of stored product pests. Repeseed, Brassica napus L., extract, too, revealed repellency to adult T. castaneum and T. confusum (47).

4. CONCLUSIONS

These studies revealed that chemical compounds repellent to blood-sucking and irritating insects may have a repellent

effect on stored product insects. There are still large number of synthetic chemical agents and plant products repellent to disease-carrying insects. Most of the compounds are non-toxic. It may be appropriate to carry on further investigations into the repellency of these compounds to storage pests. The most efficient repellent of these pests can be practically used in the control of stored product infestation.

Investigations into repellent effect of various compounds on disease-carrying insects (42,148,157) and on different storage insect pests (61,64,106) indicated that certain chemical categories have an efficient repelling effect on these vermin. Further studies to find specific chemical categories repellent to the insects have to carried out. Knowledge of such chemical categories may be beneficial for the discovery and manufacture of more effective repellents.

Many authors, mentioned in the paper, have evaluated repellent effect of phenolic compounds, esters of mandelic acid, amides of heterocyclic amines and various plant products, neem and rapeseed extracts as well as many other plant product explained in the literature, on various species of stored product pests. These substances are relatively non-toxic and they can be prepared easily from commercially available and inexpensive raw materials. Further investigation have to be made to evaluated the repellency of such compounds to storage pests. The compounds having efficient repellent effect on the insects may be practically applied in the control of storage infestation.

Olfactory repellency of a repellent agent is due to its high volatility. Chamberlain and Hoskins (34) showed that non volatile essential oils were not noticeably repellent to various insect species. Likewise, Mathlein (120) explained that repellenteffect of a compound is decreased if its volatility is reduced. Therefore, the repellency of a chemical agent can not be prolonged by decreasing its volatility with stabilizers. Practical application of chemical compounds which have a strong

immediate repellency but no longterm repellency is also possible if packaged commodities are sprayed with definite dosage rates of the compounds at regular intervals. Anonymous (6, 7) and Gillenwater and McDonald (63) indicated that slow release insecticides dispensers are an efficient method for providing longterm reservoirs of insecticides, repellents, attractants and many other pest-control chemical compounds. These methods may be used to prolong repellency of various chemical compounds which show a high immediate repellent effect but no longterm effect.

The effectiveness of chemical agents vary not only with species but also with the various developmental stages of the same species. Moreover, the effect of a compound is influenced by environmental factors. The action of a compound also varied on different types of wrapping materials. It is, therefore, important to consider all these factors when conducting future investigation.

5. SCHLUSSFOLGERUNGEN

Die Untersuchungen ergaben, daß chemische Verbindungen, die auf blutsaugende und lästige Insekten abstoßend wirken, auch für Vorratsschädlinge repellierend sein können. Es sind noch eine ganze Reihe von weiteren synthetischen Stoffen und pflanzlichen Produkten bekannt, die krankheitsübertragende Insekten abstoßen. Die meisten dieser Verbindungen sind nicht toxisch. Es erscheint daher sinnvoll, auch diese Verbindungen auf ihre Wirkung gegenüber Vorratsschädlingen zu untersuchen, in der Hoffnung, die wirkungsvollsten im Vorratsschutz einsetzen zu können.

Die Untersuchungen an krankheitsübertragenden und vorratsschädlichen Insekten lassen den Schluß zu, daß die Repellentwirkung an bestimmte chemische Gruppen gebunden ist. Weitere Untersuchungen sollen dazu dienen, solche repellierende Strukturen zu finden. Viele in der vorliegenden Arbeit erwähnten Autoren haben die Repellentwirkung von Phenolverbindungen,

Estern der Mandelsäure, Amiden der heterozyklischen Amine und verschiedener Pflanzenprodukte wie Neem und Rapssaatextrakten an Vorratsschädlingen getestet. Die Substanzen sind wenig toxisch und können leicht aus billig käuflichem Rohmaterial hergestellt werden.

Mathlein (120) stellte eine Beziehung zwischen Dampfdruck und Repellentwirkung fest, wonach mit abnehmendem Dampfdruck auch die Wirksamkeit abnimmt. Nicht-flüchtige Öle haben keinen merklichen Repellenteffekt (34). Daher kann die Dauerwirkung nicht verbessert werden, indem man durch Komplexbildung den Dampfdruck der wirksamen Substanz vermindert. Für die Praxis könnten jedoch Repellenzien, deren Nachteil nur in einer zu geringen Dauerwirkung liegt, durch wiederholtes Besprühen der Packung in geeignetem zeitlichem Abstand anwendbar sein. Auch mechanische Verdampfersysteme, die über lange Zeit geringe Mengen des Wirkstoffes in die Atmosphäre abgeben, können diese Schwierigkeiten überwinden (6,7,63).

Die Repellentwirkung einer Substanz ist nicht nur artspezifisch, sondern - bei der gleichen Art - auch vom Entwicklungsstadium abhängig. Auch die Umweltverhältnisse sowie die Art des Verpackungsmaterials können die Wirkung beeinflussen. Alle diese Faktoren müssen daher bei zukünftigen Untersuchungen berücksichtigt werden.

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7. LITERATURE

1. Altman, R., Smith, C.N. 1955: Investigations for protection against mosquitoes in Alaska. J. Econ. Entomol. 48: 67-72.
2. Anonymous, 1949: Insect repellent for textile bag fabrics. North-west Miller 240: 8a
3. Anonymous, 1957: Impregnation of sacking. Pest. Infest. Res., p. 20.
4. Anonymous, 1959: Laboratory evaluation of promising compounds as repellents to flour beetles, Tribolium spp. USDA AMS (Ser.) MRR 324, 46 pp.
5. Anonymous, 1964: Supplement I to laboratory evaluation of promising compounds as repellents to flour beetles, Tribolium spp. USDA AMS (Ser.) MRR 324. 46 pp.
6. Anonymous, 1974: Piperonyl butoxide and pyrethrins in the adhesive of cellophane-polyolefin two-ply bags. Fed. Register 39(210): 382245.
7. Anonymous, 1975: Controlled release insecticides. Soap/ Cosmet./Chem. spec. 51: 44, 46, 48, 96.
8. Arnold, K.A. 1955: Insect repellent coating for multiwall paper bags. Techn. Assoc. Pulp. Pap. Ind. (Tappi) 38: 326-328.
9. Arnold, K.A. 1955: Insect repellency in multiwalls. (Bags treated with non-toxic pyrenone in surface coating are found completely resistant to insect penetration). Mod. Packag. 28: 120-121, 194, 196.
10. Arnold, J.W. 1957: Toxicity and repellency of paradichlorobenzene to larvae of the black carpet beetle. J. Econ. Entomol. 50: 469-471.
11. Batth, S.S. 1970: Insect penetration of aluminium-foil packages. J. Econ. Entomol. 63: 653-655.
12. Becker, G. 1962: Schäden an Kunststoffen durch Tiere. Z. angew. Zool. 49: 95-109.

13. Becker, G. 1963: Die Widerstandsfähigkeit von Kunststoffen gegen Termiten. Materialprüf. 5: 218-232.

14. Becker, G., v. Seydlitz-Kurzbach, E. 1972: Widerstandsfähigkeit von Kunststoff-Folien gegen Termiten, Schaben und Heimchen. Material u. Organismen 7: 161-176.

15. Bennet, G.W., Lund, R.D. 1976: Evaluation of encapsulated pyrethrins (Sectrol™) for german cockroach and cat flea control. Pyrethrum Post 14: 68-71.

16. Blinn, R.C., Dorner, R.W., Gunther, F.A. 1959: Comparative residual behaviour of pyrethrins and piperonyl butoxide on wheat. J. Econ. Entomol. 52: 703-704.

17. Blow, P.D. 1978: Laboratory evaluation of pyrethrin against cockroaches and rust-red flour beetle. Int. Biodeterior. Bull. 14: 71-76.

18. Bosch, Van den, R., Stern, V.M. 1962: The integration of chemical and biological control of arthropod pests. Ann. Rev. Entomol. 7: 367-386.

19. Bovey, P. 1959: Aktuelle Probleme der Schädlingsbekämpfung. Schweiz. Landwirtsch. Monatsh. 37: 325-339.

20. Brooke, J.P. 1960: Results of laboratory and field experiments using food packaging materials coated with pyrethrins and piperonylbutoxide. Verh. Int. Kongr. Ent. (Wien) II: 291-296.

21. Brooke, J.P. 1961: The treatment of food packaging materials with pyrethrins and piperonyl butoxide for the protection of packaged products from insect infestation - A review of recent work. Pyrethrum Post 6: 14-22.

22. Brooke, J.P., Lomax, P.H. 1967: Protection of packaged food from insects. Pyrethrum Post 9: 36-39.

23. Bry, R.E., Boatright, R.E., Lang, J.H., Simonaitis, R.A. 1979: Pyrethrin sprays effective against fabric pests. Soap/Cosmet. Chem. Spec. 55: 42-45.

24. Bry, R.E., Jurd, L., Lang, J.H., Boatright, R.E. 1978: Moth proofing: Candidate repellents against black carpet beetle larvae (Coleoptera: Dermestidae). J. Georgia Entomol. Soc. 13: 63-66.

25. Bry, R.E., Lang, J.H. 1976: Durability of FMC 33297 in moth proofing tests: Biological afficacy against larvae of the black carpet beetle (Coleoptera: Dermestidae). J. Georgia Entomol. Soc. 11: 4-9.

26. Bry, R.E., Lang, J.H., Boatright, R.E. 1973: Candidate repellents for moth proofing: Preliminary investigations with black carpet beetle larvae (Coleoptera: Dermestidae). J. Georgia Entomol. Soc. 8: 306-309.

27. Bry, R.E., Lang, J.H., McDonald, L.L. 1972: Surfactants as protectants of woolen fabric against black carpet beetle larvae damage. J. Georgia Entomol. Soc. 7: 196-204.

28. Bry, R.E., Simonaitis, R.A., Lang, J.H., Boatright, R.E. 1976: Durability of FMC 33297 in moth proofing. Soap/ Cosmet./Chem. Spec. 52: 31-33, 98.

29. Büchel, K.H. 1970: Insekten-Repellents. Chemie der Pflanzenschutz- und Schädlingsbekämpfungsmittel 1: 487-496.

30. Butterfield, D.E., Parkin, E.A., Gale, M.M. 1949: The transfer of DDT to foodstuffs from impregnated sacks. J. Soc. Chem. Indust. 68: 310-313.

31. Butterworth, J.H., Morgan, E.D. 1968: Investigation of locust feeding inhibition of the seeds of the neem tree, Azadirachta indica. J. Insect Physiol. 17: 969-977.

32. Carter, S.W., Duffield, P.A. 1976: A preliminary evaluation of the pyrethroid NRDC 143 as an industrial moth proofer. J. Text. Inst. 67: 77-81.

33. Carter, S.W., Duffield, P.A. 1977: Moth proofing with permethrins during drying. J. Text. Inst. 68: 330-334.

34. Chamberlain, W.F., Hoskins, W.M. 1949: The toxicity and repellency of organic chemicals towards termites and their use in termite proofing food packages. Hilgardia 19: 285-307.

35. Chazin, J.D. 1969: Qualitative gas liquid chromatographic analysis for piperonyl butoxide in insect repellent treated paper. Techn. Assoc. Pulp. Pap. Ind. (Tappi) 52: 414-418.

36. Cline, L.D. 1978: Penetration of seven common flexible packaging materials by larvae and adults of eleven species of stored-product insects. J. Econ. Entomol. 71: 726-729.

37. Cotton, R.T. 1944: Protection of stored and dried processed foods and seed supplies from insect attack. J. Econ. Entomol. 37: 380-384.

38. Cotton, R.T., Frankenfeld, J.C., Strickland, W.B. 1949: Insect-proofing cotton bags. US Dept. Agric. Bull. Ent. Plant. quarant. Circ. E-783: 1-4.

39. Cotton, R.T., Frankenfeld, J.C., Strickland, W.B. 1949: Insect-repellent cotton bags (Treatments of cloth with new non-toxic insecticides shows great promise). Mod. Packag. 23: 126-127.

40. Curran, T.D. 1976: Seal quality measurement. Mod. Packag. 49: 30-34.

41. Dethier, V.G. 1947: Chemical insect attractants and repellents. The Blakiston Co., Philadelphia, pp. 289.

42. Dethier, V.G. 1956: Repellents. Ann. Rev. Entomol. 1: 181-202.

43. Dethier, V.G., Browne, L.B., Smith, C.N. 1960: The designation of chemicals in terms of the responses they elicit from insects. J. Econ. Entomol. 53: 134-136.

44. Dove, W.E., Schroeder, H.O. 1955: Protection of stored grain with sprays of pyrethrins-piperonyl butoxide emulsion. J. Agr. Food. Chem. 3: 932-936.

45. Duffield, P.A. 1977: Moth proofing permethrin. Pestic. Sci. 8: 279-283.

46. Dyte, C.E. 1972. Resistance to synthetic juvenile hormone in a strain of the flour beetle, Tribolium castaneum. Nature 238: 48-49.

47. Ediz, S.H., Davis, G.R.F. 1980: Repellency of rapeseed extracts to adults of Tribolium castaneum and Tribolium confusum (Coleoptera: Tenebrionidae). Can. Entomol. 112: 971-974.

48. Essig, E.O., Hoskins, W.M., Kinsley, E.G., Michelbacher, A.E., Smith, R.F. 1943: A report on penetration of packaging materials by insects. J. Econ. Entomol. 36: 822-829.

49. Frings, H. 1945: Gustatory rejection thresholds for larvae of the cecropia moth, Samia cecropia (Linn.). Biol. Bull. 88: 37-43.

50. Frings, H. 1946: Gustatory thresholds for sucrose and electrolytes for the cockroach, Periplaneta americana (Linn.). J. exp. Zool. 102: 23-50.

51. Frings, H. 1948: Inorganic salts as repellents for package penetrating insects. J. Econ. Entomol. 41: 413-416.

52. Frings, H., Neal, B.R.O. 1946: The loci and thresholds of contact chemoreceptors in females of the horsefly Tabanus sulcifrons Macqu. J. Exp. Zool. 103: 61-80.

53. Galun, R. 1975: Protection of livestock from Tsetse bites by means of repellent. Pyrethrum Post 13: 2-4.

54. Gay, F.J., Wetherly, A.H. 1962: Laboratory studies of termites resistance. IV. The Termite resistance of plastics. Commonwealth Sci. and Ind. Res. Org., Div. Entomol.,Techn. Pap. No. 5: 31 pp.

55. Gay, F.J., Wetherly, A.H. 1969: Laboratory studies of termite resistance. V. The Termite resistance of plastics. Div. Entomol., CSIRO, Melbourne, Techn. Pap. No. 10: 49 pp.

56. Gerhardt, P.D., Kindgren, D.L. 1954: Penetration of various packaging films by common stored-product insects. J. Econ. Entomol. 47: 282-287.

57. Gerhardt, P.D., Kindgren, D.L. 1955: Penetration of additional packaging films by stored-product insects. J. Econ. Entomol. 48: 108-109.

58. Gertler, S.I., Gouck, H.K., Gilbert, I.H. 1962: N-alkyltoluamides in cloth as repellent for mosquitoes, ticks and chiggers. J. Econ. Entomol. 55: 451-452.

59. Gilbert, I.H., Gouck, H.K., Smith, C.N. 1955: New mosquito repellents. J. Econ. Entomol. 48: 741-743.

60. Gill, J.S. 1972: Studies on insect feeding deterrents with special reference to the fruit extracts of the neem tree Azadirachta indica A. Juss. Ph. D. Thesis, University London.

61. Gillenwater, H.B., Jurd, L., McDonald, L.L. 1980: Repellency of several phenolic compounds to adult Tribolium confusum. J. Georgia Entomol. Soc. 15: 168-175.

62. Gillenwater, H.B., McDonald, L.L. 1975: Repellency of nineteen candidate compounds to adult Tribolium confusum. J. Georgia Entomol. Soc. 10: 151-155.

63. Gillenwater, H.B., McDonald, L.L. 1977: Toxicity, repellency and attractancy of slow-release insecticide dispensers. J. Georgia Entomol. Soc. 12: 261-267.

64. Gillenwater, H.B., McGovern, T.P., McDonald, L.L. 1981: Repellent for adult Tribolium confusum: Alkynyl mandelates. J. Georgia Entomol. Soc. 16: 106-112.

65. Girish, G.K., Jain, S.K. 1974: Studies on the efficacy of neem seed kernel powder against stored grain pests. Bull. Grain Techn. 12: 226-228.

66. Goodhue, L.D., Howell, D.E. 1960: Repellents and attractants in pest control operations. Pest Control 28: 44, 46, 48, 50.

67. Goodhue, L.D., Stansbury, R.E. 1953: Some new fly repellents from laboratory screening tests. J. Econ. Entomol. 46: 982-985.

68. Goodhue, L.D., Tissol, C.L. 1952: Determining the repellent action of chemicals to the american cockroach. J. Econ. Entomol. 45: 133-134.

69. Goodwin-Bailey, K.F., Brooke, J.P. 1957: The treatment of wrapping materials for foodstuffs with pyrethrins and piperonyl butoxide for protection against insect infestation. Verh. Int. Pflanzenschutz Kongr. (Hamburg) 4: 1761-1767.

70. Goodwin-Bailey, K.F., Holborn, J.M. 1952: Laboratory and field experiments with pyrethrins/piperonyl butoxide powders for the protection of grain. Pyrethrum Post 2: 7-17.

71. Gouck, H.K., Gilbert, I.H. 1955: Field tests with tick repellents in 1954. J. Econ. Entomol. 48: 499-500.

72. Green, N. 1958: Synthesis of carboxy-labelled ^{14}C-N,N-diethyl-m-toluamide, an insect repellent. J. Econ. Entomol. 51: 707-710.

73. Groves, M.C. 1972: Pest infestation of the flexible package. Australian Packag. 20: 21.

74. Guy, N.G., Dietz, H.F. 1939: Further investigations with Japanes beetle repellents. J. Econ. Entomol. 32: 248-252.

75. Guy, R.H., Highland, H.A., Metts, C.E. 1970: Repellency of selected compounds to Tribolium castaneum. J. Econ. Entomol. 63: 1847-1850.

76. Hagen, K.S., Smith, R.F., 1958: Chemical and biological methods of pest control. Agr. Chem. 13: 30-32, 89-92.

77. Hall, S.A., Green, N., Beroza, M. 1957: Insect repellents and attractants. J. Agr. Food Chem. 5: 663-667, 669.

78. Harein, P.K., Gillenwater, H.B., Jay, E.G. 1970: Dichlorvos: Methods of dispensing, estimates of concentration in air, and toxicity to stored product insects. J. Econ. Entomol. 63: 1263-1268.

79. Highland, H.A. 1967: Resistance to insect penetration of carbaryl-coated kraft bags. J. Econ. Entomol. 60: 451-452.

80. Highland, H.A. 1975: The use of chemicals in processing and packaging of stored-products to prevent infestation. Proc. Int. Working Conf. Stored Prod. Ent. (Savannah) 1: 254-260.

81. Highland, H.A. 1977: Chemical treatments and construction features used for insect resistance. Package Development and Systems 7: 36-38.

82. Highland, H.A. 1978: Insect resistance of food packages. A review. J. Food Processing Preservation 2: 123-130.

83. Highland, H.A., Byrd, R.V., Secreast, M. 1968: Effect of ethylene vinyl acetate on the migration of piperonyl butoxide from coatings of synergized pyrethrins of kraft paper. USDA ARS 51-28: 10 pp.

84. Highland, H.A., Davis, D.F., Marzke, F.O. 1964: Insect-proofing multiwall bags. Mod. Packag. 37: 133-134, 136-138, 195.

85. Highland, H.A., Cline, L.D., Simonaitis, R.A. 1977: Insect-resistant food pouches made from laminates treated with synergized pyrethrins. J. Econ. Entomol. 70: 483-485.

86. Highland, H.A., Jay, E.G. 1965: An insect resistant film. Mod. Packag. 38: 205-206, 282.

87. Highland, H.A., Jay, E.G., Phillips, M. Davis, D.F. 1966: The migration of piperonyl butoxide from treated multiwall bags into four commodities. J. Econ. Entomol. 59: 543-545.

88. Highland, H.A., Merritt, P.H., 1973: Synthetic pyrethroids as package treatments to prevent insect penetration. J. Econ. Entomol. 66: 540-542.

89. Highland, H.A., Secreast, M. Merritt, P.H. 1968: Polyvinylidene-coated kraft paper as an insecticide barrier in insect-resistant packages for food. J. Econ. Entomol. 61: 1459-1460.

90. Highland, H.A., Secreast, M., Merritt, P.H. 1970: Packaging materials as barriers to piperonyl butoxide migration. J. Econ. Entomol. 63: 7-10.

91. Holden, J.R., Findlay, G.M. 1944: Pyrethrum as a Tsetse fly repellent, human experiments. Trans. Roy. Soc. Trop. Med. Hyg. 38: 199-204.

92. Hornby, H.E., French, M.H. 1943: Introduction to the study of the Tsetse-fly repellents in the field of veterinary science. Roy. Soc. Trop. Med. Hyg. 37: 41-54.

93. Hoskins, W.M., Gordon, H.T. 1965: Arthropod resistance to chemicals. Ann. Rev. Entomol. 1: 89-122.

94. Howell, D.E., Fenton, F.A. 1944: The repellency of a pyrethrinthiocyanate oil spray to flies attacking cattle. J. Econ. Entomol. 37: 677-680.

95. Huge, T.L. 1959: Bars insects from packages. Food Eng. 31: 62-63.

96. Jacobson, M. 1959: Insecticides from plants. A review of literature (1941-1953). USDA Handbook 154: 299 pp.

97. Jacobson, M. 1966: Chemical insect attractants and repellents. Ann. Rev. Entomol. 11: 403-422.

98. Jilani, G., Malik, M.M. 1973: Studies on neem plant as repellent against stored product insects. Pakistan J. Sci. Ind. Res. 16: 251-254.

99. Johnson, H.L., Skinner, W.A., Maibach, H. J., Pearson, T. R. 1967: Repellent activity and physical properties of ring-substituted N,N-diethylbenzamides. J. Econ. Entomol. 60: 173-176.

100. Jones, W.A., Jacobson, M. 1968: Isolation of N,N-diethyl-m-toluamide (deet) from female pink bollworm moths. Science 159: 99.

101. Jones, G.D.G., Sylvester, N.K. 1966: Pyrethrum as an insect repellent. Part 1. Literature review. Pyrethrum Post 8: 38-41.

102. Joshi, B.G., Ramaprasad, G. 1975: Neem kernel as an anti-feedant against tabacco caterpiller (Spodoptera litura F.). Phytoparasitica 3: 59-61.

103. Jurd, L., Bultman, J.D. 1977: Use of dibutylbenzylphenol as a wood preservative. US Patent 4029818.

104. Jurd, L., Fye, R.L., Morgan, J. 1979: New types of insect chemosterilants. Benzylphenols and benzyl-1,3-benzodioxole derivatives as additives to house fly diet. J. Agr. Food Chem. 27: 1007-1016.

105. Kenan, R.H. 1959: Insect repellent treatments for packaging applications. Manuf. Confectioner 39:43-45.

106. Khan, M.A. 1981: Repellents für vorratsschädliche Insekten. Anz. Schädlingskde., Pflanzenschutz, Umweltschutz 54: 70-77.

107. Khan, M.A. 1982: Further investigation on repellency of chemical compounds to stored product insect pests. J. Stored Prod. Res. (In press.).

108. Khan, M.A., Wohlgemuth, R. 1980: Diäthyltoluamid als Repellent gegen Vorratsschädlinge. Anz. Schädlingskde, Pflanzenschutz, Umweltschutz 53: 126-127.

109. Ladd, T.L., Jacobson, M., Buriff, C.R. 1978: Japanese beetles: extracts from neem tree seeds as feeding deterrents. J. Econ. Entomol. 71: 810-813.

110. Langbridge, D.M. 1970a: The protection of packaged foods from insect attack (Trials using pyrethrum, synergized pyrethrins and carbaryl as paper coatings). Pyrethrum Post 10: 6-9, 14.

111. Langbridge, D.M. 1970b: Treatment of paper to protect packaged food from insect attack. Austral. Food Manuf. 40: 40, 42, 44, 46, 48.

112. Laudani, H. 1953: Control of stored product and household insects. A review of some research at the USDA, Savannah, Georgia Laboratory. Proc. Ann. Mtg. Chem. Spec. Mfr. S. Ass. 40: 117-120.

113. Laudani, H., Davis, D.F. 1955: The status of federal research on the development of insect-resistant packages. J. Techn. Assoc. Pulp Pap. Ind. (Tappi) 38: 322-326.

114. Laudani, H., Swank, G.R. 1954: A laboratory apparatus for determining repellency of Pyrethrum when applied on grain. J. Econ. Entomol. 47: 1104-1107.

115. Levinson, H.Z. 1974: Possibilities of using insectistatics and pheromones in the control of stored product pests. EPPO Bull. 4: 391-416.

116. Lomax, P.H. 1972: Die Behandlung von Verpackungen aus Karton zur Bekämpfung von Insektenbefall. Verpackungsrundschau (Sonderausgabe): 34-36.

117. Loschiavo, S.R. 1969: Effects of the antifeeding compound AC-24055 (4'-(3,3-Dimethyl-1-triazeno) acetanilide) on the survival development and reproduction of some stored-product insects. J. Econ. Entomol. 62: 102-107.

118. Loschiavo, S.R. 1970: 4'-(3,3-dimethyl-1-triazeno) acetanilide to protect packaged cereals against stored product pests. Food Technol. 24: 181-185.

119. Mallis, A., Esterlin, W.E., Miller, A.C. 1961: Keeping german cockroaches out of beer cases. Pest Control 29: 32-35.

120. Mathlein, R. 1967: Laboratory trials with chemical repellents against stored-product pests. Meddn. St. Växtsk. Anst. 13: 446-468.

121. McDonald, L.L., Guy, R.H., Speirs, R.D. 1970: Preliminary evaluations of new candidate materials as toxicants, repellents and attractants against stored-product insects. USDA MKTG, Res. Rep. 882: 1-8.

122. McGovern, T.P., Gillenwater, H.B., McDonald, L.L. 1977: Repellents for adult Tribolium confusum: Mandelates. J. Georgia Entomol. Soc. 12: 79-84.

123. McGovern, T.P., Gillenwater, H.B., McDonald, L.L. 1979: Repellents for adult Tribolium confusum: Amides of three heterocyclic amines. J. Georgia Entomol. Soc. 14: 166-174.

124. Metzger, F.W., Grant, D.H. 1932: Repellency to the Japanese beetle of extracts made from plants immune to attack. USDA Techn. Bull. 299: 21 pp.

125. Miller, W.K., Tweet, O. 1967: Determination of piperonyl butoxide by gas chromatography. J. Agr. Food Chem. 15: 931-934.

126. Morgan, E. 1940: The tropical grass Melinus multiflora as a preventive against malaria and tropical diseases. J. Trop. Med. Hyg. 43: 179.

127. Painter, R.R. 1967: Repellents. In "Pest Control", ed. W. W. Kilgore and R.L. Doutt. 267-283. New York, Academic Press 477 pp.

128. Parkin, E.A. 1961: The potantialities of pyrethrum in the bag storage of grain. Trop. Stored Prod. Inf. 3: 77-81.

129. Parkin, E.A., Scott, E.I.C. 1959: Repellency tests with wrapping papers. Pest Infest. Res. 25.

130. Parkin, E.A., Scott, E.I.C. 1960: Repellency tests with wrapping paper. Pest Infest. Res. 35.

131. Parkin, E.A., Warman, A.T. 1962: Repellency tests with wrapping papers. Tests with flour beetles. Tests woolly bears. Pest Infest. Res. 36-37.

132. Pierpont, R.L. 1939: Japanese beetle control tests on american elm trees in Delaware. J. Econ. Entomol. 32: 253-255.

133. Pradhan, S., Jotwani, M.G., Rai, B.K. 1963: The repellent properties of some neem products. Bull. Reg. Lab. Jammu I: 149-151.

134. Pradhan, S., Jotwani, M.G. 1968: Neem as an insect deterrent. Chem. Age India: 19: 756-759.

135. Pradhan, S., Jotwani, M.G. 1971: Neem kernel as antifeedant for locust. Sneha-Sandesh 13: 1-5.

136. Qadri, S.H.H. 1973: Some new indigenous plant repellents for storage pests. Pesticides 7: 18-19, 22.

137. Rao, K.M., Jacon, S.A., Mohan, M.G. 1972: Resistance of flexible packaging materials to some important pests of stored products. Ind. J. Entomol. 34: 94-101.

138. Rinvay, E. 1964: The influence of man on insect ecology in arid zones. Ann Rev. Entomol. 9: 41-62.

139. Ripper, W.E. 1956: Effect of pesticides on ballance of arthropod populations. Ann. Rev. Entomol. 1: 403-438.

140. Ripper, W.E., Greenslade, R.M., Hartley, G.S. 1951: Selective insecticides and biological control. J. Econ. Entomol. 44: 448-458.

141. Roomi, M.W., Atiquiddin, M. 1977: Observations on the repellency of neem plant, Melia azadirachta L., on some stored-grain pests from Pakistan. Z. angew. Ent. 84: 124-129.

142. Ruscoe, C.N.E. 1972: Growth disruption effects of an insect antifeedant. Nature New Biol. 236: 159-160.

143. Sacharow, S. 1970: Food packaging in developing nations. Part I. Food Eng. 42: 80-81.

144. Sacharow, S. 1972: Modern flexpacks demand bacterial and insect protection. Gordian 72: 219-220.

145. Saramma, P.U., Verma, A.N. 1971: Efficacy of some plant products and Magnesium carbonate as protectants of wheat seed against attack of Trogoderma granarium. Bull Grain. Technol. 9: 207-210.

146. Schmidt, H.-U. 1979: Die mechanische Widerstandsfähigkeit von Packstoffen (Folien) gegen den Getreidekapuziner (Rhizopertha dominica F.), den Brotkäfer (Stegobium paniceum L.), den Rotbraunen Reismehlkäfer (Tribolium castaneum Hbst.) und die Larven der Dörrobstmotte (Plodia interpunctella Hbn.). Material und Organismen 14: 241-258.

147. Schreiber, A.A., McClellan, D.B. 1952: Determination of insecticide residues. Analyt. Chem. 24: 1194-1195.

148. Sherman, J.L. 1966: Development of a systemic insect repellent. J. Am. Med. Assoc. 196: 256-258.

149. Skinner, W.A., Crawford, H.T., Skidmore, D., Maibach, H.I. 1977: Tropical mosquito repellents X: 2-oxazolidones. J. Pharm. Sci. 66: 587-589.

150. Skinner, W.A., Crawford, H.T., Rutledge, L.C., Maussa, M.A. 1979: Tropical mosquitos repellents XI: Carbamates derived from N,N-disubstituted diamines. J. Pharm. Sci. 68: 390-391.

151. Snyder, T.E. 1955: Termite attack on plastics and fabrics. Pest Control 23: 48-56.

152. Spangler, H.G. 1965: Reactions of the larvae of Khapra beetle and Trogoderma parabile to certain food substances and organic compounds. J. Econ. Entomol. 58: 212-218.

153. Steets, R. 1975: Die Wirkung von Rohextrakten aus den Meliaceen Azadirachta indica und Melia azederach auf verschiedene Insektenarten. Z. angew. Ent. 77: 306-312.

154. Swank, G.R., Davis, D.F., Gertler, S.I. 1957: N-pentylphthalimide as a repellent for possible use on insect resistant packaging. J. Econ. Entomol. 50: 515-516.

155. Sylvester, N.K., Weaving, A.J.S. 1967: Pyrethrum as an insect repellent. Part III: A study of the resistance of Pyrethrins films, when applied in three types of formulation, as insect repellents to human skin. Pyrethrum Post 9: 8-14.

156. Teotia, T.P.S., Tiwari, G.C. 1971: Dharek drups and leaves as protectants against Sitotroga cerealella Oliv. infesting wheat seeds. Bull. Grain. Techn. 9: 7-12.

157. Travis, B.V., Morton, F.A., Jones, H.A., Robinson, J.H. 1949: The more effective mosquito repellents tested at the Orlando, Fla., laboratory, 1942-1947. J. Econ. Entomol. 42: 686-694.

158. Watters, F.L. 1966: Protection of packaged food from insect infestation by the use of silica gel. J. Econ. Entomol. 59: 146-149.

159. Weaving, A.J.S., Sylvester, N.K. 1967: Pyrethrum as an insect repellent, part III: A laboratory technique for its evaluation as a mosquito repellent, and the influence of formulation on persistence. Pyrethrum Post 9: 31-35.

160. Weidner, H. 1962: Die Bedeutung der Verpackung im Vorratsschutz gegen Insekten. Süßwaren 6: 1074-1087.

161. Wilbur, D.A. 1952: Effectiveness of dust containing piperonyl butoxide and pyrethrins in protecting wheat against insects. J. Econ. Entomol. 45: 913-920.

162. Wohlgemuth, R. 1979: Protection of stored foodstuffs against insect infestation by packaging. Chem. Ind. No.5, 330-334.

163. Wolcott, G.N. 1947: The permanence of termite repellents. J. Econ. Entomol. 40: 124-129.

164. Wright, D.P. 1963: Antifeeding compounds for insect control. Advan. Chem Ser. 41: 56-63.

165. Wright, D.P. 1967: Antifeedants. In "Pest Control", ed. W.W. Kilgore and R.L. Doutt, pp. 287-293, New York, Academic Press, 477 pp.