THE EVALUATION OF FOOD PACKAGING MATERIALS FROM THE STANDPOINT OF PROTECTION AGAINST INSECTS

by
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Signature of professor
in charge of thesis ----------

Signature of author Harold David Rosoff

/

104 Callender Street
Dorchester, Massachusetts
January 15, 1943

Professor Bernard E. Proctor
Supervisor of thesis
Massachusetts Institute of Technology

Dear Sir:

Enclosed herewith is a thesis entitled THE EVALUATION OF FOOD PACKAGING MATERIALS FROM THE STANDPOINT OF PROTECTION AGAINST INSECTS, which I am submitting in partial fulfillment of the requirements for the degree of Bachelor of Science.

Respectfully submitted,

Harold D. Rosoff

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Statement of the Problem

The purpose of the problem was: to test various food packages against several common types of insects to determine if the packages are repellent to these insects. Also, to test various new types of packaging material to determine if they can be used as food containers without danger of insect penetration and subsequent infestation of the food.

Introduction

A. The problem in general.

In order for a package to be a good one it must have several properties; among these are moistureproofness, strength, low cost, eye appeal, etc. However, there is one property which is too often neglected; the property of insect-proofness. By this is meant the property of a package whereby it is repellent to insects which attempt to penetrate it to get at the food within. With the onset of the present war and the subsequent expansion of food shipments to various parts of the world, this problem has become more acute. At the present time a good deal of foods, especially dehydrated foods, are being sent to every section of the globe. This means that the supplies pass through all conditions of temperature, humidity and other variable conditions; also, the supplies, being sent to our armed forces in all kinds of climates, are

susceptible to almost every type of insect known to man. As a result, care must be taken in the selection of a container so that one which is insect repellent is used. The following paper is thus given in an attempt to compare the various containers from that standpoint and to point out the best materials available which may be used.

There is no point in attempting to protect against specific insects because too little is known about many species, especially those in the tropics. However, protection can be had against groups of insects; this is probably adequate. We may group the insects in question as follows: 1. Those infecting the food itself and having little or nothing to do with the container. 2. Insects which are primarily concerned with the container and only secondarily or not at all with the contained food. 3. A few forms which might penetrate considerable thickness of container to get at the food within.

Protection against the first class of insects, practically all of which are beetles, consists primarily in having the food insect-free (eggs included) before it is finally packaged. This is a Food Technology problem to which there are two phases; one, good housekeeping in the producing and packaging plants, so that stored food after processing, before packaging, does not become infested; and, second, rendering the food unattractive to insects, or on the other hand killing them within the package. This is accomplished on the

whole by having the food as dry as possible. Most insects and their eggs would be killed by exposure to 140 degrees F. for about two hours. This is probably an overestimate of the required time, and at higher temperatures the time would drop with great rapidity.

The second problem, that of protecting the packaging material itself is best handled chemically. In the first place, avoid strictly the glues of animal origin and starch or dextrin pastes because these are edible by various insects. This means also the avoidance of starch sized paper or cardboard. On the positive side, it is evident that impregnation with such materials as paraffin would also be a protection. Under such conditions the utilization of slightly toxic materials to protect the box seems advantageous (if used in low enough quantities).

The third category of insects could be handled in essentially the same way as the second, especially if the contained material was so sealed that odors from it would not get out to attract insects.

B. Purpose of the Experiments.

The following experiments were carried out in order to get a comparison between the various common packages as to their relative ability to repel insects and thus conclude what materials may be used or combined to make a container which is insectproof.

3. A Description of the insects used.

Description of the Insects Used.

This section will acquaint the reader with the insects used in the experiments. A description is given of the life history, characteristics and habits.

A. The Rice Weevil (Sitophilus oryza L.)

The rice or black weevil is undoubtedly the most destructive insect pest of stored grain. The name oryza comes from the fact that it was found breeding on rice. It is a small reddish brown beetle, about 1/8th of an inch long, with head prolonged into a long slender snout at the end of which is a pair of stout mandibles or jaws. It is further characterized by being marked on the back with four light reddish or yellowish spots. It is worldwide in distribution being found wherever grain is stored. It prefers a temperate or subtropical climate, but persists in the North in protected situations.

Both adults and larvae feed voraciously on a great variety of grains.

The adult weevil lives on an average from 4-5 months, each female laying between 300 and 400 eggs during this period. Before laying her eggs the female bores a small hole in the grain with her mandibles. When this has been made she turns about and lays in it an egg which she then covers with a gelatinous fluid that seals the hole. The small white fleshy and legless grubs that hatch from the eggs, burrow about inside the kernels and never leave them.

When fully grown these transform to the pupal stage and then into the adult weevil form which bores its way out of the grain. During warm summer weather the egg, larval and pupal stage may be passed in as few as 26 days. It is generally considered that this insect is unable to breed in anything but seed, but it can and does breed in solidified farinaceous material such as macaroni.

B. The Lesser Grain Borer (Rhizopertha dominica F.)

The lesser grain borer, although one of the smallest of the beetles injurious to grain in this country is capable of doing great damage and is rapidly becoming one of our most serious pests. In addition to its destructiveness in stored grain it is not uncommon to find this beetle breeding in flour that has been held in storage for some time. The beetle is a strong flier and spreads with great rapidity from infested grain.

It is now widespread in the Gulf states, and is beginning to show up in farm stored grain in states as far North as Oklahoma and Kansas. Grain samples infested with this beetle are to be found in all large grain centers of the country. It is readily distinguished from other grain pests b y its cylindrical form and small size. It is polished dark brown or black, with a somewhat roughened surface, about 1/8th of an inch long and 1/32nd of an inch wide. It belongs to a family (Bostrichidae) of beetles that have the head turned down under the

thorax and are armed with powerful jaws with which they can cut directly into wood or other tough vegetable material.

Both beetles and larvae cause serious damage in warm climates, attacking a great variety of grains. The females lay from 300 to 500 eggs each, dropping them singly or in clusters in grain. The eggs hatch in a few days, and the small whitish grubs crawl actively out, feeding on the flour produced by the boring of the beetles, or boring directly into grains that have been slightly damaged. They complete their growth either within the grain, or in the grain dust, transform to white pupae, and in time change to adult beetles. The period from egg to adult in summer is said to be a month.

C. The Cadelle beetle (Tenebroides mauritanicus L.)

The Cadelle, one of the best known of the insect pests of stored grain in the U.S., is of worldwide distribution.

The adult insect is an elongate, oblong and flattened, black beetle about one-third of an inch long. The large fleshy larvae of this insect grow to be about 3/4 of an inch long, and have the unfortunate habit of burrowing into the woodwork of grain bins and of remaining there for long periods in enormous numbers, only to come out when fresh grain is placed in the bin.

The Cadelle is one of the longest lived of the insects that attack stored grain; many of the adults live for more than a year and some for nearly two years. The females lay about 1,000 eggs each,

which hatch in from 7 to 10 days into fleshy white larvae with black heads and two horny black points at the ends of their bodies. The development period from egg to adult may be completed in 70 days but is frequently much longer, if conditions are not favorable.

D. The Confused Flour Beetle (Tribolium confusum J.)

This is probably the most important member of the group of insects known as bran bugs.

This small, reddish brown, beetle about 1/8th of an inch long, is generally distributed over the world and is extremely abundant in all parts of the U.S. It is a general feeder on farinaceous foods and is undoubtedly the worst insect pest of prepared cereal foods.

The females, which may live for a year or more, lay on an average 400 to 500 eggs each, dropping them here and there in the flour, grain or other foodstuff. The small white eggs hatch into wormlike larvae, slender, cylindrical, and wiry in appearance. When fully grown they are about 3/16ths of an inch long, and in color are white, tinged with yellow. The development period from egg to adult may be as short as 4 weeks but is usually longer when conditions are unfavorable, and the available food is unsuitable.

E. The Saw-Toothed Grain Beetle (Oryzaephilus surinamensis L.)

The common name of this insect is derived from the peculiar structure of the thorax which bears six saw-tooth-like projections on each side. It is a cosmopolitan pest of stored grain and grain products and is often found in flour mills and warehouses.

The adult beetles may live for more than 3 years, although the average length of life is from 6 to 10 months. The females lay from 45 to 285 eggs each, dropping them loosely among the foodstuff or tucking them away in a crevice in a kernel of grain. The small, slender white eggs hatch in from three to five days. The emerging larvae crawl around freely, feeding as they go. They become fully grown in about two weeks time during summer and then construct delicate cocoon-like coverings by joining together small grains or fragments of foodstuffs with a sticky secretion. Within this pupal cell the larva changes to the pupal stage, which lasts about a week. Development from egg to adult may take place in from 3 to 4 weeks in summer.

F. Indian Meal Moth (Plodia interpunctella Hon.)

This is one of the most troublesome moths that attack stored grain and cereal products. It is now found everywhere. The larvae or worms may completely web over the surface of grains by matting the surface grains together with silken threads. Bagged pop corn,

seed corn and other bagged grains or seed are also attacked, the worms working all through the bag and crawling to the outside to spin their white silken cocoons in which they transform to the pupa and later the adult moth stage. This moth prefers the coarser grades of flour and milled products and is the insect most commonly found in packaged corn meal and other prepared flours.

The female moths lay on an average, about 200 eggs, placing them singly or in groups on the foodstuff. The caterpillars that hatch from the eggs are dirty white in color, with sometimes a greenish or pinkish tint. When fully grown they are about $\frac{1}{2}$ inch long. In summer the period from egg to adult occupies about four weeks.

G. The Larder Beetle (Dermestes lardarius L.)

The larvae of the Larder beetle is very hairy, brown, tapering towards both ends of the body. They feed on animal products of nearly all kinds; feathers, horn, skins, hair, ham, beeswax, bacon, dried Beef and like products.

The Larder beetle is of worldwide distribution.

The adult beetles are about 1/3 inch long, of a very dark brown color, and with a moderately wide yellowish band across the front part of the wing covers. There are six black dots in this band, three on each wing cover, usually arranged in a triangle. The eggs are laid on the food or in sheltered places nearby.

The larvae, on hatching, increase rapidly in size. They feed chiefly near the furface of the infested materials and become full grown (a little over $\frac{1}{2}$ inch long) in 40-50 days. Pupation takes place in the larval skin. The exact number of generations, and some details regarding the length of the stages, are not known.

H. The American Cockroach (Paraplaneta americana L.)

These brown, brownish-black or tan, shiny, flat bodied, foul-smelling insects are well known to almost everyone. They are mainly active at night or in dark basements. Their habits, appearance, bad odor and the probability that they may spread disease make them very objectionable.

They feed on many kinds of material, often becoming annoying in houses by eating the binding or leaves of books or magazines, the paper covering of boxes, various food products in pantries, kitchens, bakeries, restaurants, and like places, and by fouling with their excreta the material over which they run.

This insect is worldwide but is especially abundant in the warmer parts of the world.

The large, brownish-black American roach reaches a length of $1\frac{1}{2}$ inches. The eggs are laid in pod-like or bean-like cases called ootheca. For a number of days before the eggs are deposited, this case may be seen protruding from the abdomen of the female as she moves about. The small roaches hatching from the eggs have much the same appearance as the adults, except that they lack wings. They develop rather slowly,

probably requiring several months, or more, to become full grown. Cockroaches hide in the cracks of buildings during the daytime, and their abundance is much greater than is ordinarily supposed. Sodium fluoride is used as the insectiside and is applied as a powder.

4. Description of the packaging materials tested.

Description of the Packaging Materials Tested.

The purpose of this section is to describe the different packaging materials tested. However, before the descriptions are given, a few pertinent facts should be pointed out.

1. The paper used almost invariably in the manufacture of the containers is the No. 1 Kraft. sheet.

2. The creped paper used is the Kraft sheet which has been creped or has been processed to give it many minute folds. The creping of paper gives it greater strength since the paper must be fully unfolded (or uncreped) before it will break.

3. The term "thermoplastic material" as used below is rather indefinite but simply refers to any substance which is plastic under heat and thus can be used as an adhesive. In many cases asphalt is the thermoplastic material although other substances may be used, e.g., casein.

The materials to be tested are as follows:

1. "Lead foil liner" (Pb foil liner)
2. "Thermophane"
3. "X-Crepe"
4. "Asbestos"
5. "Cartons"
6. "Nylon-glass liner"
7. "Sandpaper - tar"
8. "Egg carton"
9. "Metal liner"

1. Lead Foil liner.

This material consists of four laminations as follows: cellophane on lead foil on asphalt on Kraft paper. The asphalt is the binding agent and the cellophane is a protective coating for the lead foil. The think asphalt layer binds the lead foil to the Kraft paper.

2. Thermophane.

This is a product developed by the Interstate Folding Box Company of Middletown, Ohio. The whole package consists of the inner liner or the Thermophane and the box itself is made of that company's special PROTECTOLITE board.

The liner material is a special multiple-ply sheet, composed of an inner layer of moisture-proof cellophane, an intermediate film of a thermoplastic adhesive medium, with a back of a substantial 30# bleached sulphite paper.

The box or outer carton, as stated above, is made of the Protectolite board which has a photographically opaque black center film. This black center is not asphalt but is a special black dye. A sample of the

Thermophane and the carton are attached.

3. X-Crepe.

X-Crepe paper is made by coating kraft paper with a waterproof cement at a very high temperature. The paper is coated in its flat state, before creping, when the coating can be accurately controlled and laid on the paper in an unbroken film. Likewise, because this coating is applied to the paper before it is creped, the coating is likewise creped and obtains a high degree of flexibility and stretchability which makes it possible for it to retain its protective qualities even after distortion. After being coated, the paper is creped on two intersecting diagonal lines, creating a sheet having a high degree of stretch in every direction, including all the diagonal directions. This diagonally or "X-Creped" paper is then combined with one or more other ply of X-Crepe paper, or to a textile. The X-Creping process imparts the following advantages: (1) A waterproofing coating in an unbroken film of uniform thickness, (2) A coating creped with the paper so that it will stand severe distortion

without rupturing, (3) A combined web that is pliable and that can be stretched and distorted.

X-Crepe can be furnished in single, double or multiple plys. A sample is attached.

4. Asbestos.

This liner consists of asbestos which has been pressed tightly onto a layer of crossing fibers. A sample is attached.

6. Nylon-glass liner.

This consists of a nylon-glass cloth which has been dried and covered with paraffin and pressed between two layers of heavy Kraft paper. The cloth consists of a material composed of a mixture of nylon and glass wool - about 50% each. The cloth is dried and covered with a thick layer of paraffin. A layer of

heavy Kraft paper is placed on each side of the cloth and the three plys are pressed together tightly.

A sample is attached.

7. Sandpaper - tar.

This material consists of three plys; two plys of sandpaper and a thick layer of tar. The sandpaper consists of a very heavy paper with fine sand dispersed evenly on one side of it. The two layers are placed together with a thick layer of molten tar between them and the plys pressed together tightly.

A sample is attached.

8. Egg carton.

This is simply a layer of cardboard with a layer of paraffin on the outside.

A sample is attached.

9. Metal liner.

This is similar to the Lead foil liner. Consists of a layer of cellophane on a layer of metal foil (silver or aluminum) cemented to a layer of kraft paper by a layer of asphalt.

5. Cartons.

This consists of three layers of Kraft paper cemented together by layers of asphalt. The third layer of Kraft paper is cemented to a thick cardboard layer by asphalt. Thus, working from the outside of the package to the inside, the layers are: kraft paper-asphalt-kraft paper-asphalt-kraft paper-asphalt-cardboard.

A sample is attached.

5. Experimental Work

   a. Apparatus

   b. Method of presenting data

Experimental Work.

A. Apparatus.

The method of testing the different materials was simple. Only five pieces of equipment were used; 2 crystallizing dishes, the insects, the packaging material and the incentive--the food used to attract the insects.

The crystallizing dishes were in most cases 2 inches in diameter and 2 inches high. The packaging material was a circle cut out to fit between the dishes, usually about 2 inches in diameter. The number of insects used in any one experiment depended upon the kind of insect, the type of package and the activity of the insect. The incentive was a food used to attract the insect to make it attack the package. In most cases the incentive was grain since most of the beetles were grain beetles.

The method of setting up the experiment was as follows: the two crystallizing dishes were placed with their open ends together and the section of packaging material placed between them in a plane parallel to the ends of the dishes. Since the dishes and the material were of the same diameter, the latter just fit between the two dishes. The insects were placed in one of the dishes and the incentive was placed in the other dish. Thus, the insects, in order to get at the food, had to attack the material. This method was very satisfactory and was used in all the tests.

B. Method of presenting data.

The results obtained will be given according to the packaging materials tested. That is, each material will be given a separate section and under each section the results obtained from the action of each type of insect will be set forth. The descriptions will include a photograph of the result obtained besides other pertinent data. In cases where the material was not attacked there naturally will be no photograph and a negative result will be stated.

The following data will be given with each result:

1. insect used

2. number of insects used

3. length of exposure. This is the time elapsing from the time the test was set up to the time the maximum damage was done and the test stopped.

4. incentive. The food placed in the bottom dish to attract the insect.

5. temperature of test. Usually room temp.

6. area exposed. The area of material exposed to the insects equal to the area of the crystallizing dish. Usually pi square inches or 9.86 square inches.

7. brief description of the damage done.

8. photograph.

6. Results obtained

Results:

1. Results of tests on "LEAD FOIL LINER."

A./ insect . . . . . Confused Flour beetle

number of insects 20-23

length of exp . . . . . 19 days

incentive . . . . . grain

temp . . . . . room (65 deg. F.)

area exposed . . . . . pi square inches

damage . . . . . complete penetration

	front side	rear side
B./	insect	adult Cadelle
	number	4
	length of exp	9 days
	incentive	grain
	temp	room
	area exp	$\frac{1}{4}$ pi square inches
	damage	penetration of the Kraft paper up to asphalt in three areas. No penetration.

C./ insect . . . . . Rice Weevil

number 22-25

length of exp . . . . . 7 days

incentive . . . . . grain

temp . . . . . room

area . . . . . pi square inches

damage . . . . . complete penetration in one place.

D./ insect . . . . . Saw-toothed beetles

number 18

length of exp . . . . . 21 days

incentive . . . . . grain

temp . . . . . room

area exp . . . . . pi square inches

damage . . . . . none

E./ insect . . . . . Larder larvae

number 5

length of exp . . . . . 8 days

incentive . . . . . dried beef

temp . . . . . room

area . . . . . pi square inches

damage . . . . . complete penetration at a large area.

front rear

F./ insect . . . . . Cadelle larvae

number 6

length of exp . . . . . 28 days

incentive . . . . . grain

temp . . . . . room

area . . . . . pi square inches

damage . . . . . none

G./ insect . . . . . Lesser grain borer

number 24

length of exp . . . . . 26 days

incentive . . . . . grain

temp . . . . . 32 deg. C.

area . . . . . pi square inches

damage . . . . . none

H./ insect . . . . . adult Larders

number 7

length of exp . . . . . 10 days

incentive . . . . . dried beef

temp . . . . . room

area . . . . . pi square inches

damage . . . . . none

I./ insect . . . . . Cockroach

number 1

length of exp . . . . . 10 days

incentive . . . . . grain plus dried beef

temp . . . . . room

area . . . . . pi square inches

damage . . . . . none

2. Results of tests on "THERMOPHANE"

A./ insect . . . . . Confused flour beetle

number 23

length of exp . . . . . 50 days

incentive . . . . . grain

temp . . . . . room

area exp . . . . . pi square inches

damage . . . . . attacking around whole periphery and penetration up to cellophane at one place.

B./ insect . . . . . saw-toothed grain beetle

number 17

length of exp . . . . . 27 days

incentive . . . . . grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

C./ insect . . . . . Cadelle larvae

number 7

length of exp . . . . . 28 days

incentive. . . . . grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

D./ insect . . . . . Larder larvae

number 9

length of exp . . . . . 4 days

incentive . . . . . dried beef

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . penetration of liner in one large area.

front rear

E./ insect . . . . . Lesser grain borer

number 25

length of exp . . . . . 26 days

incentive . . . . . grain

temp . . . . . 32 deg. C.

area exposed . . . . . pi square inches

damage . . . . . none

F./ insect . . . . . Rice weevils

number 26

length of exp . . . . . 2 days

incentive . . . . . grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . penetration of liner at one point. Note dark spot on photograph of result.

G./ insect . . . . . Adult Larders

number 6

length of exposure . . . . . 10 days

incentive . . . . . grain and dried beef

temp . . . . . .room

area exp . . . . . .pi square inches

damage . . . . . none

H./ insect . . . . . adult Cadelle

number 8

length of exposure . . . . . 9 days

incentive. . . . . grain

temp . . . . . room

area exposed . . . . . $\frac{1}{4}$ pi square inches

damage . . . . . penetrated sulfide paper up to cellophane.

I./ insect . . . . . adult Larders

number 4

length of exposure . . . . . 10 days

incentive . . . . . dried beef

temp . . . . . room

area exp . . . . . pi square inches

damage . . . . . none

J./ insect . . . . . Cockroach

number 1

length of exposure . . . . . 10 days

incentive. . . . . grain and dried beef

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

3. Results of tests on "X-CREPE"

A./ insect . . . . . Confused flour beetle

number 24

length of exp . . . . . 19 days

incentive . . . . . grain

temp . . . . . room

area exp . . . . . pi square inches

damage . . . . . none

B./ insect . . . . . Larder larvae

number 9

length of exp . . . . . 21 days

incentive . . . . . dried beef

temp . . . . . room

area . . . . . pi square inches

damage . . . . . partial penetration

(about 1/3 deep) at three points.

C./ insect . . . . . Cadelle larvae

number 4

length of exp . . . . . 12 days

incentive . . . . . grain

temp . . . . . room

area exp . . . . . pi square inches

damage . . . . . very slight

attacking of the surface at one area.

D./ insect . . . . . adult Cadelle

number 4

length of exposure . . . . . 19 days

incentive . . . . . grain

temp . . . . . room

area exp . . . . . pi square inches

damage . . . . . none

E./ insect . . . . . Saw-toothed grain beetle

number 19

length of exposure . . . . . 14 days

incentive . . . . . grain

temp . . . . . room

area of exp . . . . . pi square inches

damage . . . . . none

F./ insect . . . . . adult Larders

number 5

length of exposure . . . . . 17 days

incentive . . . . . dried beef

temp . . . . . room

area exp . . . . . pi square inches

damage . . . . . about 1/3 penetration at one area.

G./ insect . . . . . Rice weevils

number 24

length of exposure . . . . . 19 days

incentive . . . . . grain

temp . . . . . room

area exp . . . . . pi square inches

damage . . . . . none

H./ insect . . . . . Lesser grain borer

number 22

length of exposure . . . . . 17 days

incentive . . . . . grain

temp . . . . . 32 deg. C.

area exposed . . . . . pi square inches

damage . . . . . none

I./ insect . . . . . Indian meal moth

number 3

length of exposure . . . . . 19 days

incentive . . . . . .grain

temp . . . . . room

area . . . . . pi square inches

damage . . . . . none

J./ insect . . . . . Cockroach

number 1

length of exposure . . . . . 16 days

incentive . . . . . .grain and dried beef

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . .none

4. Results of tests on "ASBESTOS"

A./ insect . . . . . Confused flour beetle

number 25

length of exposure . . . . . 30 days

incentive . . . . . .grain

temp . . . . . room

area exp . . . . . pi square inches

damage . . . . . none

B./ insect . . . . . adult Cadelle

number 4

length of exposure 20

incentive . . . . . grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

C./ insect . . . . . Saw-toothed grain beetle

number 16

length of exposure . . . . . 23 days

incentive . . . . . grain

temp . . . . . room

area exp . . . . . pi square inches

damage . . . . . none

D./ insect . . . . . Larder Larvae

number 8

length of exposure . . . . . 18 days

incentive . . . . . .dried beef

temp . . . . . room

area . . . . . pi square inches

damage . . . . . none

E./ insect . , ... Rice weevils

number 24

length of exposure . . . . . 22 days

incentive . . . . . .grain

temp . . . . . room

area . . . . . pi square inches

damage . . . . . none

F./ insect . . . . . Cadelle larvae

number 6

length of exp . . . . . 18 days

incentive . . . . . .grain

temp . . . . . room

area . . . . . pi square inches

damage . . . . . none

G./ insect . . . . . Lesser grain borer

number 23

length of exposure . . . . . 22 days

incentive . . . . . grain

temp . . . . . 32 deg. C.

area . . . . . pi square inches

damage . . . . . none

H./ insect . . . . . adult Larders

number 6

length of exposure . . . . . 20 days

incentive . . . . . dried beef

temp . . . . . room

area . . . . . pi square inches

damage . . . . . none

I./ insect . . . . . Cockroach

number 1

length of exposure . . . . . 11 days

incentive . . . . . .grain and dried beef

temp . . . . . room

area . . . . . pi square inches

damage . . . . . none

5. Results of test on "CARTONS"

A./ insect . . . . . confused flour beetle

number 23

length of exposure . . . . . 28 days

incentive . . . . . unknown

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

B./ insect . . . . . Rice weevils

number 25

length of exposure . . . . . .28 days

incentive . . . . . unknown

temp . . . . . .room

area exposed . . . . . .pi square inches

damage . . . . . .none

C./ insect . . . . . Indian meal moth

number 4

length of exposure . . . . . 13 days

incentive . . . . . .unknown

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

D./ insect . . . . . Larder larvae

number 7

length of exposure . . . . . 28 days

incentive . . . . . .unknown

temp . . . . . room

area . . . . . pi square inches

damage . . . . . deep penetration at 3 points but no full penetration. See next page for photograph.

Larder larvae plus "Carton".

E./ insect . . . . . Cadelle larvae

number 4

length of exposure . . . . . 28 days

incentive . . . . . unknown

temp . . . . . .room

area exposed . . . . . .pi square inches

damage . . . . . .deep penetration at two points. Photograph on page 38.

F./ insect . . . . . adult Larders

number 6

length of exposure . . . . . 28 days

incentive . . . . . .unknown

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . partial penetration at two areas. Photograph on page 39.

Cadelle larvae plus "Carton."

Adult Larders plus "Carton."

6. Results of tests on "NYLON-GLASS LINER"

A./ insect . . . . . Confused flour beetle

number 23

length of exposure . . . . . 12 days

incentive . . . . . grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . Rice weevils

B./ insect . . . . . Rice weevils

number 24

length of exposure . . . . . 12 days

incentive . . . . . grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

C./ insect . . . . . Cadelle larvae

number 6

length of exposure . . . . . 12 days

incentive . . . . . grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

D./ insect . . . . . adult Larders

number 5

length of exposure . . . . . 12 days

incentive . . . . . grain and dried beef

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

E./ insect . . . . . Larder larvae

number 8

length of exposure . . . . . 12 days

incentive . . . . . dried beef

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . penetration through top layer of paper and halfway into Nylon-glass liner material.

7. Results of tests on "SANDPAPER-TAR".

A./ insect . . . . . adult Cadelle

number 4

length of exposure . . . . . 14 days

incentive . . . . . grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

B./ insect . . . . . Saw-toothed grain btl.

number 17

length of exposure . . . . . 14 days

incentive . . . . . .grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

C./ insect . . . . . Confused flour beetle

number 24

length of exposure . . . . . 21 days

incentive . . . . . .grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . slight attacking of the top layer of paper. Little damage.

D./ insect . . . . . Cadelle larvae

number 6

length of exposure . . . . . 21 days

incentive . . . . . .grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

E./ insect . . . . . Lesser grain borers

number 20

length of exposure . . . . . 26 days

incentive . . . . . .grain

temp . . . . . 32 deg. C.

area exposed . . . . . .pi square inches

damage . . . . . .none

F./ insect . . . . . .Larder larvae

number 7

length of exposure . . . . . .24 days

incentive . . . . . dried beef

temp . . . . . .room

area exposed . . . . . .pi square inches

damage . . . . . .penetration of top layer of paper up to tar layer on 3 areas of the periphery. Cannot penetrate the tar layer.

G./ insect . . . . . adult Larders

number 4

length of exposure . . . . . 24 days

incentive . . . . . .dried beef

temp . . . . . .room

area exposed . . . . . .pi square inches

damage . . . . . .very slight attacking and penetration of top layer of paper.

H./ insect . . . . . Indian meal moth

number 3

length of exposure . . . . . 19 days

incentive . . . . . .grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

I./ insect . . . . . Cockroach

number 1

length of exposure . . . . . 18 days

incentive . . . . . grain and dried beef

temp . . . . . room

area exposed . . . . . 4 pi square inches

damage . . . . . none

J./ insect . . . . . Rice weevil

number 24

length of exposure . . . . . 21 days

incentive . . . . . .grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . slight scratching of surface at two areas.

8. Results of tests on "EGG CARTON".

A./ insect . . . . . Larder larvae

number 5

length of exposure . . . . . 4 days

incentive . . . . . dried beef

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . complete penetration in one large area.

B./ insect . . . . . Confused flour beetle

number 22

length of exposure . . . . . 10 days

incentive . . . . . grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

C./ insect . . . . . adult Cadelle

number 4

length of exposure . . . . . 15 days

incentive . . . . . grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

D./ insect . . . . . Rice weevils

number 23

length of exposure . . . . . 20 days

incentive . . . . . grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . slight attacking and penetration at two areas.

E./ insect . . . . . Lesser grain borer

number 23

length of exposure . . . . . 26 days

incentive . . . . . grain

temp . . . . . 32 deg. C.

area exposed . . . . . pi square inches

damage . . . . . none

F./ insect . . . . . Cockroach

number 1

length of exposure . . . . . 18 days

incentive . . . . . .grain and dried beef

temp . . . . . .room

area exposed . . . . . 4 pi square inches

damage . . . . . none

G./ insect . . . . . adult Larders

number 4

length of exposure . . . . . 19 days

incentive . . . . . dried beef

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

H./ insect . . . . . Cadelle larvae

number 6

length of exposure . . . . . 15 days

incentive . . . . . .grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

I./ insect . . . . . Saw-toothed grain beetle

number 22

length of exposure . . . . . 17 days

incentive . . . . . .grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

9. Results of tests on "METAL LINER."

A./ insect . . . . . adult Cadelle

number 4

length of exposure . . . . . 13 days

incentive . . . . . .grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

B./ insect . . . . . Saw-toothed grain beetle

number 17

length of exposure . . . . . 16 days

incentive . . . . . grain

temp . . . . . room

area exposed . . . . . .pi square inches

damage . . . . . none

C./ insect . . . . . Confused flour beetle

number 23

length of exposure . . . . . 38 days

incentive . . . . . grain

temp . . . . . .room

area exposed . . . . . pi square inches

damage . . . . . penetration of paper and asphalt layers up to metal layer. No penetration of metal layer.

D./ insect . . . . . Cadelle larvae

number 4

length of exposure . . . . . 41 days

incentive . . . . . grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . none

E./ insect . . . . . Cockroach

number 1

length of exposure . . . . . 18 days

incentive . . . . . .grain and dried beef

temp . . . . . room

area exposed . . . . . 4 pi square inches

damage . . . . . none

F./ insect . . . . . adult Larders

number 5

length of exposure . . . . . 7 days

incentive . . . . . .dried beef

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . complete penetration in two areas.

G./ insect . . . . . Larder larvae

number 6

length of exposure . . . . . 3 days

incentive . . . . . .dried beef

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . penetration in one area.

H./ insect . . . . . Indian meal moth

number 3

length of exposure . . . . . 19 days

incentive . . . . . grain

temp . . . . . .room

area exposed . . . . . pi square inches

damage . . . . . none

I./ insect . . . . . Lesser grain borers

number 22

length of exposure . . . . . 49 days

incentive . . . . . .grain

temp . . . . . 32 deg. C.

area exposed . . . . . pi square inches

damage . . . . . none

J./ insect . . . . . Rice weevils

number 24

length of exposure . . . . . 7 days

incentive . . . . . .grain

temp . . . . . room

area exposed . . . . . pi square inches

damage . . . . . complete penetration of material in one area.

7. Conclusions and Recommendations.

Conclusions:

Each type of packaging material tested will be taken up and briefly discussed.

A./ Lead Foil Liner.

The experiments show that this material is penetrated by the Confused flour beetle (19 days), the Rice Weevil (7 days), the Larder larvae (8 days), and severely attacked by the adult Cadelle beetle (9 days). Obviously, this material is unsuitable as a packaging material. All the insects used in the tests are very common in all parts of the world and the packages are susceptible to almost all of them.

B./ Thermophane.

Results indicate that this material is penetrated by the Confused flour beetle (50 days), severely penetrated by the Larder larvae (4 days), penetrated by the Rice Weevil (2 days) and partially penetrated by the adult Cadelle beetle (9 days).

Again, it is easily seen that this material is very unsatisfactory as a packaging material from the standpoint of insect-proofness.

C./ X-Crepe.

The tests performed show that this material is partially penetrated by the Larder larvae (21 days), very slightly attacked by the Cadelle larvae (12 days), and partially penetrated by the adult Larder beetle (17 days).

This material is fairly good as a packaging agent from the standpoint of being repellent to insects. The results indicate that it is quite improbable that the insects can penetrate it. It is also believed that the reason for the inability of the insects to penetrate X-Crepe is the presence of the tar layers.

4./ Asbestos.

Results show that this material is not attacked or penetrated by any of the insects.

This material is very good as a packaging material from the standpoint of being insect repellent. However, its other characteristics are not known. The Asbestos is very brittle and is easily broken; however, it can be made in all states of plasticity and therefore can probably be used as a food package. Its characteristics as to waterproofness, strength, etc., are not known, but if these are good then it can be safely used.

5./ Cartons.

The tests indicate that these are deeply penetrated by Larder larvae (28 days), deeply penetrated by Cadelle larvae (28 days) and partly penetrated by adult Larders (28 days).

These Cartons seem to be fairly suitable as food packages from the insect standpoint since they were given severe tests and were not penetrated.

Here again, the only deterrent to actual penetration was the presence of the layers of tar.

6. Nylon-Glass liner.

This material is partially penetrated by the Larder larvae.

From the standpoint of being insect repellent this material seems fairly good. However, if given more severe tests, it is quite possible that it might be penetrated by the Larder larvae.

7./ Sandpaper-Tar.

Results show this material to be slightly attacked by the Confused flour beetle (21 days), the paper penetrated by the Larder larvae (24 days), very slightly attacked by the adult Larders (24 days), and very slightly attacked by the Rice weevil (21 days).

This material is very good as a food packaging material from the standpoint of being insect-proof. Although it was slightly attacked, in no case was the tar layer disturbed. Here again the tar was the deterrent to the insects.

8./ Egg carton.

This material was severely penetrated by the Larder larvae (4 days) and slightly attacked by the Rice weevil (20 days).

The Egg carton is not satisfactory as a food container since

it was penetrated.

9./ Metal liner.

This was severely attacked by the Confused flour beetle (38 days), penetrated by the adult Larder beetle (7 days), penetrated by the Larder larvae (3 days), and penetrated by the Rice Weevil (7 days).

Evidently the Metal liner is unsuitable as a container since it was penetrated by three insects.

From the results obtained, the following general conclusions can be obtained:

1. The materials unsuitable as packages from the standpoint of being non-insect repellent are:

   a. Lead Foil liner

   b. Thermophane

   c. Egg carton

   d. metal liner

2. A substantial layer of tar is a good deterrent to insects and the materials including it were all insect repellent. This tar layer should not be confused with the asphalt binder which does not act as a deterrent at all.

3. The materials which may be classified as being fairly suitable as packages are:

   a. X-Crepe

   b. Cartons

   c. Nylon-Glass

The first two of these contain layers of tar.

4. The materials which may be classified as being very suitable as packaging materials from the standpoint of being insect-proof are:

a. Sandpaper-Tar

b. Asbestos

Here again it is noticed that the former of the two contains a heavy layer of tar.

Recommendations:

There are only two packaging materials to be recommended if the container desired is to be safely repellent to insects. These are the "Sandpaper - Tar" and the "Asbestos." If the food is to be shipped to a warm climate, then these are the only packages which can be used with safety. However, if the supplies are sent to cool climates are to places where insects are less frequent and less active, then it is probably adequate to use either the "X-Crepe", the "Cartons" or the "Nylon-Glass".

Before any new packaging material is used for the purpose of shipping foods to any part of the world it should be thoroughly tested not only for its properties of strength, moistureproofness, plasticity, etc., but also for its ability to repel insects. But, unfortunately,

this point has often been overlooked as can be seen from the results of the preceeding experiments.

The problem of insect infestation of foods through packages is an important and costly one, and as our supply routes spread out it will continue to increase.

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