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(Research Article)

The palatability and efficacy of boric acid gel baits on cockroaches

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Abstract

The present study is aimed at producing cockroach insecticide gel bait.

The cockroach insecticide gel bait comprises of a stomach toxicity component (boric acid), phagostimulants (sucrose and starch), thickening stabilizers (carboxylmethyl cellulose and alginic acid), a preservative (sodium benzoate), a moisturizer (glycerol) and water.

Seven products were made, with varying concentrations of boric acid. 0.05g of carboxylmethyl cellulose was dissolved in 2.0g of glycerol with stirring for 30mins, 0.75g of alginic acid was also added to the mixture with stirring for about 10mins, water was added in drops for complete dissolution of the mixture, 1.5g of soluble starch, 2.0g of sucrose and 0.05g of sodium benzoate were added and stirred vigorously, then different concentrations of boric acid (0.01g, 0.10g, 0.15g, 0.20g, 0.25g, 0.30g, 0.50g), were added to the seven samples respectively.

The effectiveness of the gel bait was found to increase with increase in concentration of boric acid.

The insecticide gel bait has some advantages over other insecticide formulations, in that it does not pose threat to human health and also to the environment.

The gel bait can be placed in sensitive areas (in kitchens close to food, plates, and water cans), where most formulations cannot be placed or sprayed.

Keywords: Boric acid; Cockroach; Gel bait; Palatability; Insecticide; Pest control

1. Introduction

Cockroaches are known to carry certain fungi, viruses and bacteria, which cause specific diseases in humans. Additionally, cockroaches produce allergens that can induce asthma. Worldwide, approximately 300 million people suffer from asthma. More than 250,000 deaths per year are attributed to asthma and this number is expected to increase by approximately 20% over the next decade (WHO 2006).

The urbanization of people around the world, from rural communities into large crowded cities, has been blamed for some of the increased occurrences of asthma. This may be due to increased exposure to pest cockroach allergens. Because of the risk they pose to human health, cockroaches are considered a serious urban pest. Cockroaches that live in close association with humans are considered the worst pest. Those mostly encountered are the German, Brown banded, Oriental and American cockroaches.

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1.1. Motivation of work

Cockroach control is commonly accomplished with the use of insecticides. With repeated application of an insecticide, insecticide resistance becomes an issue. Consequently, new insecticides must be tested to combat the resistance. Insecticides are available in a number of formulations, such as sprays, dusts, and more recently, gel baits. Each formulation has positive and negative attributes.

With sprays, there is increased insecticide exposure to humans as well as environmental degradation of the insecticide due to heat or moisture. Dust can have a long residual, but can become airborne and will dump if exposed to too much moisture. Gel baits, which are increasingly relied upon for cockroach control, can be used in sensitive areas where other formulations cannot be used, and limit the amount of insecticides in the environment. However, some cockroach strains have developed an aversion to some of the ingredients in gel baits; therefore, their matrices must be altered to overcome the aversion.

1.2. Aims and objectives

Determination of the oral toxicity of boric acid in different concentrations against cockroaches.

Evaluation of the palatability of boric acid incorporated into food baits against cockroaches.

2. Literature review

Four hundred million years ago, 150 million years before dinosaurs appeared, the first arthropods (springtails, spiders, and scorpions) were roaming the earth. Cockroaches entered the fossil record 300-360 million years ago and have remained nearly unchanged in appearance (Bletchley 1920, Appel 1995, Rust et al. 1995, Copeland 2003, Kendall 2005). Of the more than 4,000 described species of cockroaches that currently inhabit the earth (Bell 1984, Mabbett 2004) just a few are considered pests.

All cockroaches are hemimetabolous. They undergo three life stages: egg, nymph, and adult. Cockroach "eggs are enclosed in an ootheca which can be carried by the gravid female for a few hours and then dropped or glued to a surface or the ootheca can be carried until nymphal hatch (Mullins and Cochran 1987). Nymphs are similar in appearance to adults but are wingless. Nymphal development is punctuated by molts; the final molt ending in adulthood. Incubation time of Oothecae and nymphal development are both temperature and nutrient dependent, with warmer temperatures increasing the rate of development.

2.1. Pest status

Pest cockroaches are those that live and breed in and around human structures (Cornwell 1976). Their "natural habitat" is outdoors and it is the fault of humans that pest cockroaches exist. "We encourage them to come indoors" by providing them with an environment similar to their "natural habitat".

Once inside, these cockroaches are considered pests for both aesthetic and health reasons. Four primary pest species are German cockroach, Brownbanded cockroach, Oriental cockroach, and American cockroach (Whitney et al.1967, Cornwell 1968, Reierson et al. 1979, Darr et al. 1998, Carpinera 2004). Pest cockroaches are divided into two groups, domestic and peridomestic cockroaches, based upon where they live and breed. Domestic cockroaches are found mostly indoors while peridomestic cockroaches can be found outdoors as well as indoors.

2.1.1. German cockroach

Distribution

Originating in Asia (Atkinson et al. 1990, Appel 1495). The German cockroach has a worldwide distribution and is considered to be "one of the worst insect pests" (Blatchley 1920) in heated structures (Cornwell 1968, Ross and Mullins 1995). Cornwell (1968) attributed its distribution to human commerce and war, suggesting that the German cockroach stowed away with humans as they traversed the globe.

Habitat and ecology

German cockroaches prefer a "warm, moist environment" (Cornwell 1968) where they have "daily access to water" (Barcay 2004). This includes houses, apartments, restaurants, supermarkets, food processing plants, motor vehicles, as well as naval and cruise ships (Cornwell 1968, Barcay 2004, Metzger 1995). Kitchen areas are often preferred harborage sites and large aggregations have been located around refrigerators, stoves, and trashcans (Appel 1995). In heavy infestations, German cockroaches are found throughout structures and are rarely found living outdoors (Cornwell 1968, Appel 1995).

2.1.2. *Brownbanded cockroach*

Distribution

Brownbanded cockroaches are believed to have originated in Africa (Atkinson et al. 1990). First discovered in Florida in 1903, it has since been found throughout the continental United States as well as tropical and subtropical regions of the World (Blatchley 1920, Cornwell 1968, Atkinson et al. 1990, Barcay 2004). Brownbanded cockroaches' distribution is attributed to its tendency to hide in and attach eggs to furniture with subsequent movement of humans (Cornwell1968, Pest management 1989, Rust et al. 1995, Barcay 2004).

Habitat and ecology

Brownbanded cockroaches inhabit "homes, apartments, hotel, and hospital rooms" more than "stores, restaurants, and kitchens" (Pest Management 1989). They are only found outdoors in Africa (Cornwell 1968). Brownbanded cockroach water requirement is much lower than that of German Cockroaches, and preferring warm, 27°C, and dry areas. These factors allow them to infest diverse locations within a building such as bedrooms, shelves, spaces behind pictures, ceiling voids, light fixtures, electronics, and inside all types of furniture (Cornwell 1968, Pinto 1988, Barcay 2004, Capinera 2004).

2.1.3. *American cockroach*

Distribution

The American cockroach originated in Africa (Cornwell 1968, Roth 1982, Atkinson et al. 1990). Its spread from Africa was greatly aided by commerce, as this cockroach is the most common one found in ships (Blatchley 1920, Cornwell 1968, Barcay 2004). It "has been introduced to most countries of the world" and is widely distributed in tropical and subtropical regions (Blatchley 1920, Cornwell 1968, Bell 1984). The American cockroach lives outdoors in tropical and subtropical regions and indoors in temperate regions (Bell 1984).

Habitat and ecology

The American cockroach is most commonly associated with sewer systems but can be found under leaf debris, woodpiles, mulch, dumps, latrines, palm trees, shed, and alleys (Cornwell 1968, Roth 1982, Barcay 2004). They can also occur in greenhouses where they will feast on young plants (Blatchley 1920). The American cockroach will move indoors. Once inside it is associated with basements and areas where food is prepared or stored (Cornwell 1968, Barcay 2004). This can include restaurants, grocery stores, bakeries, as well as factories, hospitals, hotels and zoos (Cornwell 1968, Barcay 2004). They are active at temperatures of >= 21°C and temperatures < 6°C will kill them. However, it has been reported that active American cockroaches have been found in trash heaps that were covered with snow (Barcay 2004).

2.1.4. *Oriental cockroach*

Distribution

Described as "the most noisome and disagreeable insects" (Blatchley 1920). The oriental cockroach is believed to have originated in north Africa and spread by means of commerce (Cornwell 1968). The oriental cockroach is found in 20 of the 48 contiguous states, but not in Florida or most of the rest of the southeastern United States. They can be found in two South American countries, Chile and Argentina (Cornwell 1968), and in more temperate regions of the world.

Habitat and ecology

Oriental cockroaches are located in and around structures, prefer cooler temperatures, and are most active at 20-29°C (Cornwell 1968). Outdoors, they gravitate to areas in the shade such as under leaf debris, stones, and tree bark as well as in lumber and trash piles (Cornwell 1968, Pest Management 1995). Oriental cockroaches are relatively cold tolerant and can survive at 2°C for more than 42 days (le Patourel 1993). The oriental cockroach can move indoors by way of laundry, food packaging, and gaps around doors, windows, or pipes, and cracks in the foundation (Thomas and Robinson 1986, Pest Management 1995, Barcay 2004). Indoors-they prefer moist, damp, cool areas such as crawl spaces and basements (Blatchley 1920, Pest Management 1995, Barcay 2004). They are also found in warmer areas such as wall and porch voids (Thomas and Robinson 1986, Pest Management 1995) as well as around "radiators, ovens, and hot-water pipes" (Cornwell 1968). The Oriental cockroach can use garbage chutes, electrical conduits, and plumbing to move from lower areas of a structure to upper levels (Pest Management 1995).

2.2. Control methods

Cockroach pests need to be controlled because of the risks they pose to human health. Most insecticides used to control cockroaches disrupt insect nervous systems; others can interfere with the cuticle and even interrupt the process of molting into adulthood. Consideration of insecticidal mode of action is important when trying to control cockroaches.

2.2.1. Synthetic insecticides

After World War II, synthetic insecticides were developed extensively to control insect pests, such as cockroaches. There are varieties of modes of action of the numerous synthetic insecticides, but some are explained below:

Sodium channel

Sodium channels are voltage gated and when stimulated to open they allow the influx of sodium ions, which can cause excitatory reactions in the nervous system. Pyrethroids are synthetic versions of naturally occurring pyrethrin insecticides. Pyrethroids are some of the most common insecticides and there are a large number of them including allethrin, cyfluthrin, lambda-cyhalothrin, delthmethrin and permethrin. They function as sodium channel agonists, binding to the channel and causing neuron-excitation, which results in rigid paralysis. There are two generations of pyrethroids. Type 1 pyrethroids do not contain an alpha cyano group, they have a fast knockdown, but little residual activity. Type II has an alpha-cyano group, a slower knockdown, and longer residual (Barcay et al. 2004, Yu 2007).

Oxidiazine, which includes the active ingredient indoxacarb, is a relatively new insecticide that functions at the sodium channel as an antagonist. It binds to the sodium channel, holding it closed, which results in flaccid paralysis. Indoxacarb is called a pro-insecticide because it is relatively inert until ingested. Once inside the insect, it is metabolized to its toxic form N-decarbomethoxyllated metabolite (DCJW) (Yu 2007).

Dichloro-Diphenyl-Trichloroethane (DDT), an organochlorine, functions at the sodium channel as an agonist. It binds to the channel and causes neuron-excitation resulting in rigid paralysis. It was first synthesized in 1874; however, its insecticidal activity was not discovered until about 1940 (Cornwell 1976, Yu 2007). Both a dust and a spray formulation were used extensively during and after World War II, for control of everything from body lice to mosquitoes (Cornwell 1976). However, not all organochlorines act on the sodium channels.

Chloride channels

Chloride channels are ligand gated and located in the central nervous system (CNS) as well as the peripheral nervous system (PNS). When stimulated, they open to allow chloride ions to enter and cause neuron-inhibition. The chloride channels open when glutamate in the PNS or r-aminobutyric acid (GABA) in the central nervous system binds to the postsynaptic neuron. Cyclodiene as antagonists bind to the channel and prevent chloride ions from entering, resulting in neuron-excitation and rigid paralysis. Phenylpyrazole, which includes the active ingredient fipronil, is also a chloride channel antagonist. It binds to the postsynaptic neuron preventing the influx of chloride ions. This causes an over-stimulation of the nervous system and rigid paralysis. However, Avermectins, such as abamectin and emamectin benzoate, act as chloride channel agonists. They bind to the channel and prevent it from closing. This allows chloride ions to flow into the cell and results in neuron-inhibition and flaccid paralysis (Yu 2007). Avermectins are microbial lactones; however, not all insecticides in this class work on chloride channels.

2.2.2. Natural insecticides

Natural insecticides are the oldest insecticides used for insect control. They have been used for well over a century (Reierson 1995). Prior to World War II, they were used extensively for cockroach control (Cornwell 1976). These were inorganic materials, such as boric acid, diatomaceous earth, arsenic, phosphorus and sodium fluoride, as well as organic materials such as pyrethrins made from crushed dried chrysanthemum flowers (Cornwell 1976, Ebeling 1995, Barcay 2004). These materials were mixed with food to make baits or used as dust. Inorganics can have long residuals and low resistance, but can also be slow acting (Bennett et al. 1988).

Both boric acid and diatomaceous earth act as cuticle disrupters. They are abrasive and absorptive to the insect cuticle. This has the effect of causing the insect to desiccate due to water loss. Phosphorus is an acetyl cholinesterase inhibitor while arsenic and sodium fluoride affect production.

Use of natural insecticide dusts greatly decreased with the development of synthetic insecticide "sprays, fogs, and aerosols" which were less labour intensive and had a faster speed of action (Ebeling 1995). With the onset of resistance to synthetic insecticides, dust regained some popularity.

2.3. Formulations

Insecticides are dispersed by a variety of formulations and one insecticide (active ingredient) can be used in more than one type of formulation. Each type of formulation has both positive and negative qualities. Therefore, consideration should be taken when deciding which formulation to use in a given environment.

2.3.1. Wettable powders

Wettable powders (WP) consist of an active ingredient adhered to a diluent with a wetting agent which are then suspended in water (Yu 2007). It is sprayed into surfaces or injected into harborages (Koehler et al. 1995, Barcay 2004). Wettable powders generally have good residual, especially on porous surfaces. However, they tend to leave a visible residue on dark coloured materials.

2.3.2. Emulsifiable concentrates (EC)

Emulsifiable concentrates (EC) consist of the active ingredient, a solvent, and a surfactant mixed with water. Like WPs, ECs can be sprayed onto surfaces or into harborages. Unlike WPs, they do not stain surfaces. In addition, they do not adhere well on non-porous surfaces like "stainless steel and ceramic tile" and are absorbed by porous surfaces. They can become unstable when applied on materials with a high pH (Barcay 2004) performing best on finished wood, vinyl tile and porcelain (Koehler et al. 1995).

2.3.3. Microencapsulation

Microencapsulates consist of an active ingredient surrounded, or encapsulated, by plastic. The active ingredient is released over time. These insecticides generally have low odor and a long residual activity. While mortality can be observed within a few hours, it can require a couple of days for initial mortality. Since release is slow and over time, cockroaches may be exposed to sub-lethal doses, thereby decreasing the time required for insecticide resistance to develop (Koehler et al. 1995, Barcay 2004).

2.3.4. Dusts

One of the oldest formulations for delivering insecticide is dust. A dust often used in cracks and crevices (Yu 2007). They have a low odor and a long residual. They can also be used round electrical outlets and equipment (Koehler et al. 1995).

2.3.5. Baits

One of the more important formulations for cockroach control is baits. Baits have been used for more than a century and Blatchley (1920) described a bait made from phosphorus paste, which contained "sweetened flour paste" and 1-2% phosphorus, which was to be spread on "paper or cardboard and placed in the runways of the roaches" However, it was not until the early 1980s that cockroach gel baits were seriously considered for cockroach control. Gel baits consist of an active ingredient, a feeding stimulant, and a carrier (Yu 2007). Gel baits can be used in sensitive areas where other formulations are prohibited while reducing the amount of insecticide placed in the environment. Proper gel baits placement is important, since gel baits must often compete with other food sources. Additionally, use of other insecticides, especially repellants, on or around gel baits can affect control.

2.4. Resistance

A large number of neurotoxic insecticides were used for cockroach control, as the pest has a considerable ability to develop resistance to a variety of chemical insecticides (Cochran 1989 and 1995b; Scott et al., Rust and Reierson 1991, Rust et al. 1993, Holbrook et al. 1999, Espinosa-Islas et al. 2002 and Rahayu et al. 2012). The toxicity of some new neurotoxic insecticides is either very limited (i.e., neonicotinoids) or not well established (i.e., phenylpyrazole) against cockroaches in Egypt.

Boric acid (H3BO3) has been used as an insecticide since 1948 (See et al. 2010). It was the standard chemical used for the control of some pests until the chlorinated hydrocarbon pesticides became available (Lal and Srivastava 1950). Moreover it is not classified as carcinogen or skin irritant (Langford et al.). One advantage of using boric acid is that it destroys the cellular lining of the foregut. This effect induces death to the insects by starvation and the cockroaches have difficulty to show resistance to boric acid (Cochran 1995b).

A phenylpyrazole insecticide, fipronil discovered by Bayer Crop Science in 1987, and introduced in 1993 as a form of solid (e.g., insect bait), liquid spray, or as a granular product (Anonymous 2000), and registered in the U.S in 1996 (Ware 2000, and Jeong Lee et al. 2010). It controls cockroaches, mosquitoes, ticks, and fleas at both larval and adult stages (Chanton et al. 2002). Fipronil interferes with the aminobutyric acid (GABA) channel, where it disrupts normal nerve influx transmission (e.g., passage of Chloride ions). This causes excessive neural excitation, paralysis, and finally insect death (Gaut et al. 1998). Fipronil gel baits have been widely used to control German cockroaches in America since several years due to German cockroach resistance to several insecticides and fipronil gel bait is considered safer in application than other treatment methods (Ahmed and Suliyat 2011).

A neonicotinoid insecticide, imidacloprid belonging to the chloronicotinyl compounds. It was first proposed in 1991. It exerts toxic effects after oral ingestion; it is also suitable for use in bait formulations (Nasirian 2007). The main factor of chloronicotinyl being favourable is their low affinity to vertebrates compared to insect nicotinic receptors. They have high selectivity; have a quick knock down effect and long residual activity. Worldwide, it is considered to be one of the insecticides used in the largest volume (COX 2001). Fipronil and imidacloprid gel baits completely killed the German cockroaches under laboratory conditions in the ingested bait method.

Poisoned baits, in the last two decades, have largely displaced other formulations for controlling cockroaches and pests (Anaclerio and Molinari 2012). The poisoned baits are much less translocatable, so it is less hazardous than the spray formulations (Gore and Schal 2004). So the tested insecticides used as bait are safer and environmentally friendly than insecticides sprays.

2.5. Recipe sample

Table 1 Emulsion bait formulation (Anna, 1998)

Ingredients	Function	Range (% by weight)
Active ingredient	Active	0.25 - 50%
Fatty acids	Diluents	1.0 - 5.0%
Carbohydrate source	Food	20.0 - 30.0%
Glycerin or sorbitol	Solvent	20.0 - 30.0%
Protein source	Food	4.0 - 7.0%
Vegetable protein source	Food	0 - 5%
Modified methylcellulose	Gel agent	0.3 - 0.6%
Linked polyacrylic Cross acid polymer	Gel agent	0.1 - 0.8%
Odor masking agent	Masking agent	0.4 - 0.6%
Inorganic base	pH adjuster	0.35 - 0.70%
Starch	Thickener	1.0-7.5%
Anti-microbial agent	Preservative	0.05-0.85%

Table 2 Composition of gel for blattella germanica bait

Composition	Chicken Liver Gel	Cow Blood Gel	Cockroach Feces Gel	Honey - Banana Gal
Fipronil	0.03%	0.03%	0.03%	0.03%
Gelling agent	0.75%	0.75%	0.75%	0.75%
Cane sugar	30%	30%	30%	30%
Carrageenan	2%	2%	2%	2%

Dimethyl sulfoxide	0.05%	0.05%	0.05%	0.05%
Chicken liver powder	5%	-	-	-
Cow blood powder attractant	-	5%	-	-
Cockroach feces powder attractant	-	-	5%	-
Honey-banana food scent attractant	-	-	5%	-
Biocide	0.5%	-	-	-
Propylene glycol	5%	-	-	-
Sorbitol (70% WW)	10%	-	-	-
Water	53.33%	53.33%	53.33%	53.33%

Structure of Boric Acid

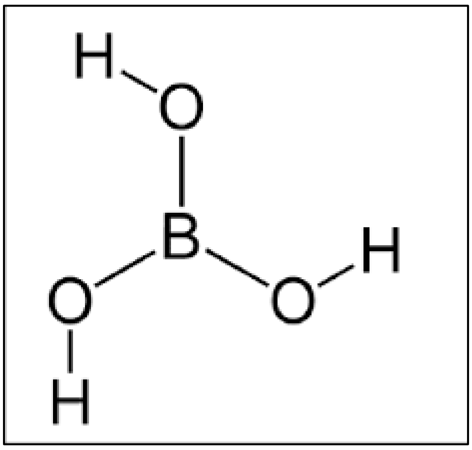

Figure 1 Structure of Boric Acid

3. Materials and methods

3.1. Materials

The materials used include Beakers, Spatula, Manual stirrer, Wash can, Electronic scale, Cockroaches, and Cockroach cage.

3.2. Reagents used

- Boric acid: Active ingredient
- Carboxylmethyl cellulose: Thickener
- Alginic acid: Gelling agent
- Soluble starch: Attractant
- Sucrose: Food
- Sodium benzoate: Preservative
- Glycerol: Solvent
- Distilled water: Co-solvent

3.3. Reagents collection

The reagents were procured from Elisco scientific, Laboratory Chemicals and reagents, hospital and dental materials store in L12 No13 shop Ogbete main market Enugu.

3.4. Insect collection

Different species of cockroaches were collected by handpicking, from kitchens, cupboards, and close to septic tanks.

3.5. Cage construction

The cages were constructed with rectangular cartons, tiny holed nets, gums, and masking tapes.

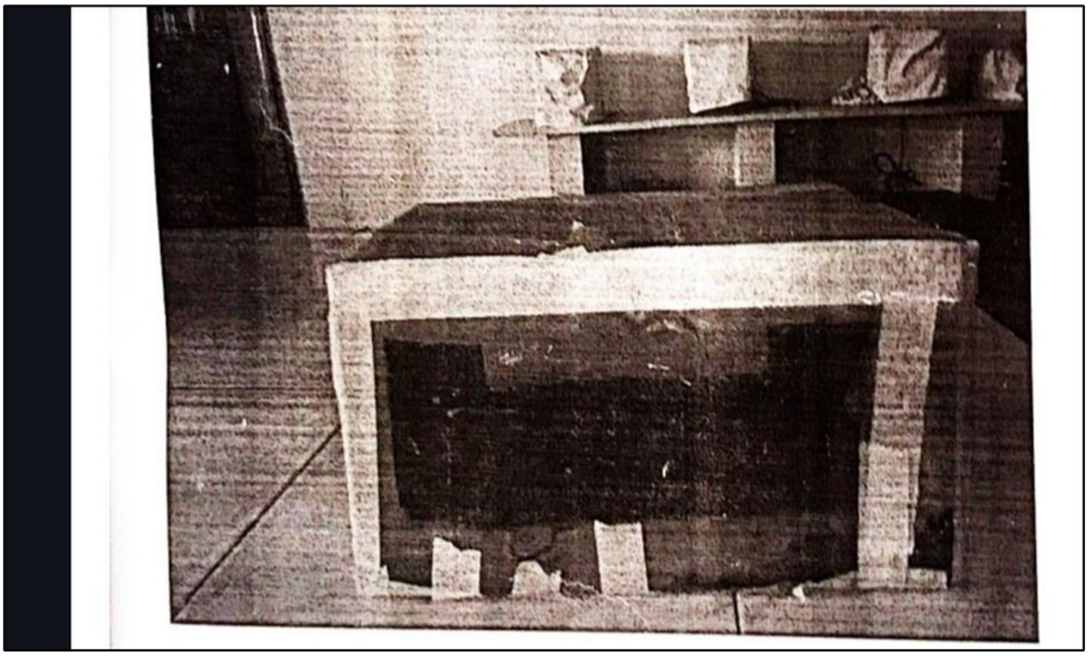

Figure 2 Images of cages constructed

Figure 3 different samples of cages constructed using rectangular cartons (Chicken and Indomie cartons)

3.6. Sample preparation

3.6.1. Calculation

Converting the ingredients in % by weight into grams before weighing.

%COMPOSITION X 10g FOR

First set of sample preparation:

- Boric acid: 0.1/100 x 10g = 0.01g
- Boric acid: 1.0/100 x 10g = 0.10g
- Boric acid: 1.5/100 x 10g = 0.15g
- Alginic acid: 7.5/100 x 10g = 0.75g
- Carboxylmethyl cellulose: 0.5/100 x 10g = 0.05g
- Sodium benzoate: 0.5/100 x 10g = 0.05g
- Sucrose: 20/100 x 10g = 2.00g
- Starch: 15/100 x 10g = 1.5g
- Glycerol: 20/100 x 10g = 2.00g

Second set of sample preparation:

The same 10g was used, only the percentage compositions of boric acid were varied:

- Boric acid: 2/100 x 10g = 0.20g
- Boric acid: 2.5/100 x 10g = 0.25g
- Boric acid: 3.0/100 x 10g = 0.30g

Third set sample preparation:

The percentage composition of boric acid was changed again:

- Boric acid: 5/100 x 10.5g = 0.5g

Fourth sample preparation:

50g was considered:

- Boric acid: 5/100 x 50g = 2.5g
- Alginic acid: 7.5/100 x 50g = 3.75g
- Sodium benzoate: 0.5/100 x 50g = 0.25g
- Carboxylmethyl cellulose: 0.5/100 x 50g = 0.25g
- Glycerol: 20/100 x 50g = 10g
- Sucrose: 20/100 x 50g = 10g
- Starch: 15/100 x 50g = 7.5g

3.6.2. *General preparatory methods for making the insecticide gel bait*

The various reagents were measured out using an electronic scale into different beakers. Carboxylmethyl cellulose was dissolved in glycerol, dispersed for 30 minutes by stirring. Alginic acid was added to the mixture and stirred for at least 10 minutes, adding water to fully dissolve the two gelling agents. The soluble starch, sucrose, sodium benzoate, and boric acid were added into the mixture, and stirred until a homogeneous gel was formed.

3.7. Testing of sample

Table 3 Variation of concentration of H3BO3 used and the number of cockroaches

Set Of Sample	**First Set**			**Second Set**			**Third Set**
Cage No	1	2	3	4	5	6	7
No of Cockroaches	5	13	11	5	12	9	16
Mass of Boric Acid Used	0.01g	0.10g	0.15g	0.20g	0.25g	0.30g	0.50g

3.8. Readings

The following readings were taken on the insecticide gel bait to determine its effectiveness. The readings were taken from the last sample prepared.

The density:

- Weight of 60ml syringe = 35.93g
- Weight of syringe + sample = 77.76g
- Weight of sample = 77.76g - 35.93g = 41.83g
- Volume of sample = 35ml
- Density = Mass/volume = 41.83/35ml = 1.1951g/ml

THE pH:

The pH of the insecticide gel bait is = 3.01

3.9. Product sample

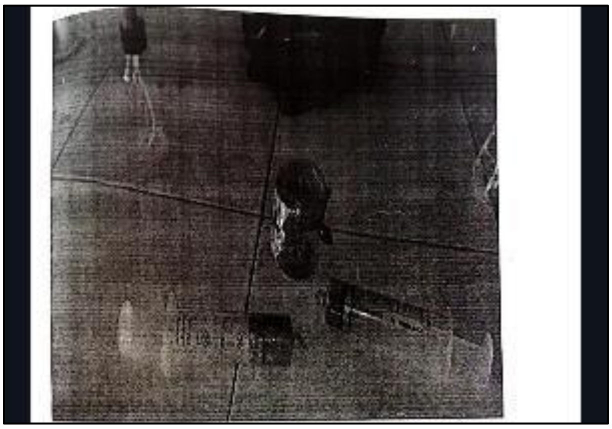

Figure 4 sample of insecticide gel baits produced.

4. Results

Different insecticide gel baits were made with different masses of boric acid and were placed in different cages containing cockroaches, in order to ascertain palatability and also the efficacy of the gel baits by checking how the insecticide gel baits were consumed and the death rate of the cockroaches.

Table 4 variation of concentration of h3bo3 with death of cockroaches

No Of Cockroaches		5	13	11	5	12	9	16
Mass of Boric Acid		0.01g	0.10g	0.15g	0.20g	0.25g	0.3g	0.5g
pH		3.14	3.09	3.07	3.06	3.05	3.04	3.01
Density (g/ml)		1.1617	1.1767	1.850	1.1933	1.2017	1.2100	1.1951
Color		Brown	Brown	Brown	Brown	Brown	Brown	Brown
No of Deaths and Days	First Day	0	0	0	0	0	0	4
	Second Day	0	0	0	0	0	0	5
	Third Day	0	0	0	0	2	2	3
	Fourth Day	0	1	2	0	1	2	3
	Fifth Day	0	0	0	1	4	1	1

5. Discussion

From the table above, it was observed that the concentrations of 0.01g, 0.10g, 0.15g, 0.20g of the insecticide gel baits were palatable but their efficacy was low, due to the low death rate.

With an increment of the concentration of boric acid to 0.25g and 0.3g, it was observed that the insecticides palatability was good enough, and the cockroaches started dying as from the third day of gel placement. When the concentration of boric acid was increased to 0.5g, it was observed that the insecticides palatability was good, and also the death rates and day was improved. The efficacy of this gel bait appeared to be the best of all the gel baits produced.

6. Conclusion

Insecticides can be formulated in different forms, but great care must be exercised to minimize risks to human health, during application. The method used in placement of this insecticide gel does not contaminate our homes, as it can be swept out, when it is no longer useful. Insecticide gel bait production and usage should be encouraged in Nigeria, to reduce the population of pests and minimize pollution on humans and our environment.

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