Fostering Academia Industry Collaboration in Food Safety & Quality

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Pest Control in Food Industry

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Chapter 1

The importance of pest control in food industry:

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This book preface describes the importance of pest control in food industry. The damaging influence of pests on safety of products and workers are clarified. Food handler must be aware of the specific hazards associated with food pests and how they can be controlled to ensure safe food production. A food pest is an animal that lives in or on our food. Pests can easily contaminate food because they carry microorganisms, which cause serious health risk for the consumers. Pests can also contaminate food with hairs, droppings, urine and eggs. Food may be also contaminated with pests' dead bodies. Pests in food industry including insects, rodents, birds and other animals that can cause contamination of the raw materials and food products, and thus may contribute to the spread of diseases that can jeopardize the health of consumers. Pest control in food industry is necessary to prevent spreading of diseases and contamination of materials and products. Pest control is a legal duty of every company. To comply with legal regulations, companies have to make a great effort to achieve good reputation to customers and markets that can be easily lost due to information related to pest infestation and food poisoning. A food pest can damage cables, pipes, machines by nibbling, in which it causes great damage resulting in fire or flooding in the food premises, and a great loss of money. Food premises are attractive to pests because of the presence of foods, the availability of warmth and moist conditions as it forms a harbourage place to them. Pests can be brought into premises in raw materials, packaging, containers, vehicles, but all the possibility that can bring pests in food premises must be carefully checked and controlled to prevent the contamination of food by such pests. Food

handler must do regular inspection of food premises to ensure that they are pest-free. They have the responsibility to learn about pests and pest's control, and to learn how they can check premises and report any sign of pests' presence, such as pest infestation, any defects as holes, damage of walls, windows, and cables or any droppings and urine.

Pest control is one of the main prerequisite programs that come before the implementation of any other food safety system and must be introduced before the application of any further safety systems including HACCP.

This book handles materials related to pest control, concept and importance of pest control in food industry, control measures, the most important species and the effects of certain pests in food industry, and the application of integrated pest management program in food industry.

Good Manufacturing Practices (GMP) has assured that foods are produced under hygienic conditions to prevent or at least minimize microbiological, chemical and physical hazards.

Pest control is an essential part of GMP in food processing, starting from hygiene to the production of safe food. Establishing procedures for pest control is an important component of GMP. The pests of primary interest for food industry are insects and rodents whom are responsible for spreading of diseases through foods. Birds sometimes may become a problem in food production and may cause potential public health hazards.

The reasons for the application of pest control in food industry can be considered in two aspects, depending on whether the pests are active in the primary production, in farms, or in food processing sector. If there

are some health problems in animal farms, further processing of raw materials that comes from this farm must be controlled or even stopped because of the potential impact of pathogenic bacteria that can cause health problems, and sometimes even death of humans.

Fulfilling standards, technical and technological regulations in the area of food safety is important not only in the processing sector, but also on the level of primary production and markets.

Often, pest control is considered as critical control points of HACCP which is not accurate. For food safety system that is applied in any food production process, pest control is not a production process, only instruments in which the risk of pests and their impact on production are to be eliminated or reduced to an acceptable level.

In certain situations, presence of pests (e.g. in food storage) may be considered critical control point, and pest management may become a method for their monitoring and control. Pest control must always be seen as one of the basic prerequisites program that must be fulfilled in the entire production chain, not just in certain places that are potentially more exposed to pest presence.

Pest control in farms is regulated by the application of good agricultural practices (GAP) as well as some bio-security programs. The purpose of applying these standards is to minimize the presence of pests to an acceptable level or to eliminate their presence.

This is a more flexible approach to pest control than at the food processing level, since not all activities on farms can fully controlled.

Food manufacturers must have an effective pest control system in place; food premises must have good hygiene practices including pest's control to prevent contamination, waste of food, and spread of diseases.

Chapter 2

Pest Control in Food Processing: Concepts, Safety and Regulations:

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This chapter focuses on improving the knowledge on the following topics:

- Concept and importance of pest control in food processing.
- Food safety towards pest attack and invasion.
- Legislation of pest control in food processing and facilities.

2.1. Concept and importance of pest control in food processing:

Pest control is defined as actions aimed to reduce or eradicate pests (macro-organisms), including in particular: flies, cockroaches, mice and rats, as well as weevils and other insects that can infest food products.
Despite that pest control is a main challenge along the entire food chain for the impact on various economic and safety aspects, but it becomes more important in food processing facilities where the abundance of food (raw, processed, unpacked, and packed), ideal environmental conditions (moisture and temperature), extended business hours and various harbourage sites create conducive conditions that allow pest infestations to thrive.

The presence of pests in any food handling premises is unacceptable. Pests pose a series of risks include:

- Contamination of work surfaces and foodstuff.
- The spread of diseases (pathogens are transferred from the gut or external surface of the pest).
- Damage to food packaging and containers and, for a longer extent, the property.
- Adverse public opinion and loss of reputation.
- Prosecution and closure of the food factory.

Food factories and food-related facilities are complicated and with large structures of many locations and environments differently vulnerable to insect infestation. In regard of the pest control, they could in general be differently classified based on various criteria, such as:

- Function (food processing, mill, warehouse, and food stores).
- Commodity (cereals, animal, vegetal-based materials, spices).
- Product type and degree of processing (raw material, ingredient, half-products, final products, packed, unpacked products, human food or pet food).
- Equipment, structure type (new vs. old, construction materials).
- Geographic location (urban vs. countryside) and surrounding landscape.

The complicated structure of different food facilities make generalizations about pest management in these facilities very difficult and the impact of pest attack of different intensity and consequences.

Moreover, facility conditions can change over time because of seasonal fluctuations, changes in physical structure and management, and other variables.

The implementation of a pest management program in food facilities requires the understanding of all of the food facility structures and operations, the taxonomy, behaviour, ecology, and biology of pest species and the effective use of monitoring and management tools available.

2.1.1. Food processing and pest control management:

Pest control has to be taken into account in each step of the food processing chain, from the raw material production, till the food service. In particular, the following steps need to be taken into account:

- Primary production (farms and breeding): there are main differences on the pest's risks depending on the agricultural and breeding practices.
- Post-harvest (cereals, grains, agricultural products) and post-slaughter procedures and storage.
- Transport (raw materials, ingredients from foreign, overseas countries): boats, trains, containers, trucks, up to the processing food factory.
- Storage raw materials (in the facility).
- Food processing premises including packaging.
- Storage of processed (packed and unpacked) products.
- Transport of processed foods (from food factory to the buyer location).
- Buyer location (shop, warehouse etc.): storage, selling rooms, consumer houses, or food service, restaurants

Each of these steps could be at risk of biological contamination and pests attach depending on a series of variables and factors. Each food commodity during its process chain could be subjected to specific pest invasion and specific actions needs to be developed.

In food processing factories, pests can invade and attack facilities, foods and they often accumulate in pots, pans or dishes or on window sills. Main risk of pests occurs where foods are stored either temporarily or for a long time.

Pest control cannot be effectively accomplished unless and until proper cleaning has been done. If pests are present, they must be controlled before any sanitizing step as they will re-contaminate any surface that may have been sanitized. Cleaning and sanitisation have to be applied according to GMP and regulated procedures and pest management programmes should be applied to prevent, as far as practicable, the introduction of pests into the site and to reduce the conditions that may encourage their presence. The application of integrated pest management (IPM) strategies that integrate food safety practices, now allows avoiding the use of the widely applied chemicals of pest control.

The presence of pests could have an effect on the quality and safety of food commodities. Therefore, IPM programs must focus on prevention, detection, and early elimination of problems with the goals to prevent insects from entering the facility, to keep insect populations from increasing or becoming established in the production stream, to suppress insects where prevention has been unsuccessful, and to monitor the environment.

In most food facilities, the goal is to have zero insect activity. However, in majority of the cases, this cannot be achieved and effective thresholds are needed. They should be adjustable, targeted, and serve as upper boundary limits to indicate a successful program. IPM programs should aim to prevent insects from reaching threshold levels and triggering an increase in intensity or change in response when limits are exceeded.

2.1.2. Processed food products and pest control:

In general, almost all dried and partially-dehydrated food products are susceptible to pest's infestation, and among others, cereal products (flour, cake mix, rice, crackers, corn, cookies), seeds (dried beans), nuts, chocolate, dried fruits; spices; powdered milk and cured meats.

A stored food product may become infested at the processing plant or warehouse, during transport, at the store, or right in the home. Food products kept on shelves for long periods are particularly susceptible to infestation, but more in general foods of any age can become infested.

Stored food insects are capable of penetrating unopened paper, thin cardboard, and plastic, foil, or wrapped packages. Pests can damage packed products, chew their way into packages or crawl in through folds and seams.

Packed foods can have a different vulnerability to pest attack, being those made of paper, and natural tissues easier to be destroyed. Metal and glass packaging provide a substantial protection of the foods unless casual, unpredictable fractures and holes are present that allow insects, in particular to penetrate into the food. However, common plastic materials (polyethylene, polypropylene and polyester) could be penetrated by various pests. Insects that are able to penetrate plastic and multi-layered packaging materials are named as "true" penetrators and include among others *R. dominica* and *L. serricorne*. In particular, adults of the rice weevil, *Sitophilus oryzae* (L.), the grain borer, *Rhyzoperthadominica* (F.) and the cigarette beetle, *Lasiodermaserricorne* (F.) are able to penetrate different packaging materials with higher capacity at decreasing thickness of the material.

By contrast, common stored-product insects and other pests penetrate packaged food through existing holes or openings/imperfections at

seals and considered as “invaders”.

Insects in food product packages begin to multiply and then spread to the rest of the place and products.

2.1.3. Types of Food Facilities:

Each food-related facility has its own unique risks for attracting pests and this implies that staff and pest management professionals have to adhere and apply different standards and rules to comply with their control.

Two main food facilities can be identified based on their pest control needs:

Dry or Low-Moisture Food Facilities:

This category includes all dry-food processing facilities and products of a dry nature that can produce airborne materials like flour mills, feed mills and seed and bean processing, rice mills, confectionary or candy production, mix plants.

In general, food facilities that are dealing with low moisture foods and ingredients are susceptible to pests that can survive for long periods without easy access to water, such as beetles, rodents and birds. In addition, other pests can be attracted by these facilities depending on the nature of the material being processed. Dry-food facilities face a unique challenge as dust from production that can accumulate along ducts, electrical panels and in cracks and crevices that can be difficult to remove by cleaning alone. The use of compressed air to clean layers of dust could further scatter and disperse them in the air and throughout the facility. Dust can also disperse insect eggs or adult insects and this conventionally used cleaning procedure could further spread the infestation reducing its cleaning-up effectiveness.

Alternative methods should be used in these facilities to collect dust and insect eggs/adult insects without spreading any mess or infestation throughout the facility include vacuuming method.

Wet or Liquid-Food Facilities:

This category of facilities includes, factories with beverage plants, bottling plants, breweries, canning facilities, dairies and wineries among others. They are characterised in general for their high levels of moisture in the environment that could support pests that need water to thrive, such as cockroaches and flies. In these facilities, wet clean-up procedures are also typically used to sanitize equipment that can contribute to an increased pest presence and a proper water and drainage management systems need to be implemented to control the waste water generated in these processes. Additionally, the use of air curtains can help preventing the entry of flying insects.

Among food facilities also those related to retail and service have to be included. They also present a specific characteristic that deals with storage of food (fresh or processed) and its preparation.

As regards, food retail, grocery stores, food shops and supermarkets are facilities with different array of settings and vary greatly in size. A variety of pests, such as cockroaches, flies, rodents and the occasional bird or squirrel can be attracted to food retail locations while some pests that infest could be location dependent. They can manage and sell un-packed (fruit, vegetables, meat) and packed foods, and this needs to be properly taken into account. The retail facilities have to be taken into account not only the safety issues related to the contamination of the products they sell, but also the negative impact on business's reputation when consumers and buyers are aware of pest presence and therefore impact profits. These facilities should implement prevention controls

such as air curtains and door sweeps, which can help deter the entry of small flying insects.

On the other hand, restaurants and other food service facilities face main issues of pest presence as it impacts the safety of the food and dishes contaminated but also the reputation and business as just one pest-related incident can lead to hefty fines from health departments and temporary or, in more severe cases, permanent closure. Main concern for food service operators are among others cockroaches, flies, rodents and ants and stringent preventive controls, including a strong pest management program with regular inspections to prevent potential contamination has to be set and developed.

2.2. Food Safety:

Pests are in general a main concern for food facility directors for various aspects that deals with safety. Apart from the infestation, they can cause additional damages that in turn may impair microbial status of foods and facilities. In particular, insects could alter temperature, moisture/ humidity level and micro-flora of the infested commodity through their metabolism and multiplication.

Main efforts should be made to prevent insects or insect parts in finished products. The presence of live insects or insect contamination (body parts, faecal material, etc.) in finished products is unacceptable and may make food unsuitable for consumption.

Pests in general are vectors of several diseases that may endanger human or animal health. For instance, various insects detected in stored-products are contaminated by enterococci, reservoirs for potentially virulent and antibiotic resistant genes.

Main safety issues for foods and humans are due to birds, including pigeons, sparrows, starlings, seagulls, crows, swallows. Of these, the

three non-native species, pigeons, sparrows and starlings, are responsible for the majority of bird problems at food establishments as they have adapted extremely well to man-made environments and they have become extremely resourceful at exploiting sources of any available food, water, and shelter.

Pest birds carry and transmit a large number of animal diseases including diseases of humans, poultry, and other birds and animals. Pigeons, starlings, and sparrows have been reported to transmit over sixty diseases such as pigeon Ornithosis, encephalitis, Newcastle disease, Histoplasmosis, Cryptococococcosis, toxoplasmosis, pseudo-tuberculosis, pigeon Coccidiosis and Salmonellosis.

Bird droppings deface and accelerate deterioration of buildings, parking lot light fixtures, signs, equipment and other features in facilities and landscape. Bird droppings could produce flies, airborne contaminants, fungus spores and detestable odors. Ectoparasites of pest birds include chewing lice, fleas, ticks, biting flies and mites, some of which can enter bird infested buildings and bite people. These arthropods can themselves inadvertently become food contaminants and adulterants. At food facilities, bird infestations should be treated with the same degree of concern and urgency as rodent problems.

Integrated control programs must take care of rodent as pests because they consume human food and contaminate it with its faeces and urine and also they contaminate food, physically and microbiologically. They spread of diseases, such as *Salmonella* spp., *Listeria* spp., *Escherichia coli*, *Cryptosporidium parvum*, *Leptospira* spp., Hantaviruses, Bubonic plague and Toxoplasmosis.

Another safety aspect of pest contamination and invasion is related to the release in the air and more in general in the environment of

molecules via saliva, faeces and shedding body parts that may induce severe allergenic reaction.
Exposure to certain pests, such as mice, dust and insects, can cause allergies, especially for young people.

2.3. EU and international legislation:

2.3.1. Food processing and premises:

Pest control legislation in general refers to the broader requirement for food safety. However, specific aspects along with the standards and accepted practiced need to be considered and regulated.
In EU and around the world, several laws and regulations have been issued to allow food professional and business to deal with the management of pest control in food processing and along the whole food chain.

...1. Europe:

The General Food Lawis defined as a requirement for the traceability and responsibility for withdrawal and recall of contaminated food on food operators (*Regulation (EC) No 178/2002*, Articles 18 and 19). This includes importers, producers, processors, manufacturers and distributors and traceability systems must be implemented at all stages of production, processing and distribution. A rapid alert system across member states for when there is a risk to human health or the environment in relation to food or food contact material (Art. 50).
Food hygiene in EU is regulated by the *Regulation (EC) No 852/2004 on the Hygiene of Foodstuffs*. This contains general clauses that give broad guidelines for operating while some specific articles set some rules to prevent animals and pests from causing contamination.

- Primary producers (categorised according to the animal and

plant sector) and related operations (e.g. transport, storage and handling: they have a general requirement to protect food from contamination by taking the appropriate and adequate measures. This includes taking into account further processing that the products will undergo. They also have to apply measures to store and handle hazardous substances and waste in a way that prevents contamination.

- Record keeping:

All effects on food safety should be documented, from pests on the farm until the product reaches the consumers.

- Food premises:

The location and design of the building should ensure that the safety and quality of the food products are ensured and protected from pests as well.

- Food waste: as in general,

The presence of residues of non-industrial materials and residues in the factory or in the vicinity attracts pests and sheltering them, it is necessary to put these waste in appropriate containers and close them very well and then dispose them quickly is also very important.

- Handling and storage of food stuffs:

Raw materials must be protected from contamination from its arrival and through all stages of manufacturing until they reach the consumers.

- Food business operators are to ensure that staff are supervised and trained in food hygiene.

In addition to this check list in UK, the UK Food Standards Agency (FSA) provides a checklist to help small food producers comply with food safety law and pest control. The British Pest Control Association (www.bcpa.org.uk) contributes with professionals to support food

producers in the management of the application of EU and national regulations.

...2. US legislation:

Food and Drug Administration (FDA) is responsible in US for federal legislation in the food sector. The Code of Federal Regulations for Food and Drugs specifies the measures to be taken by food manufacturers and the parts relating to buildings and facilities indicates pest control rules, including the maintenance of plant and grounds to protect against food contamination (removal of litter, waste and weeds that can attract or harbour pests), draining of areas that can cause food-borne contamination or pest breeding; hygienic design and construction of plants to enable sanitary operations for food manufacturing and maintenance; traceability and storage of pesticides and other chemicals; no pests are allowed in any area of the food plant; disposal of rubbish and any of all to minimise the attraction of pests.

In addition, the Food Code, jointly issued by FDA, the Centres for Disease Control and Prevention (CDC) of the US Department of Health and Human Services and the Food Safety and Inspection Service of the US Department of Agriculture (USDA), indicates some guidelines for pest control in food premises including:

Maintenance of buildings and verification of the absence of pests inside by conducting periodic inspections of incoming and outgoing materials and then use of appropriate methods to combat them and remove dead individuals by appropriate methods.

..1. Environmental protection:

The use of chemicals against pests in farms also introduces additional costs for food processors.The main aspects related to the chemicals used are:

- Which chemicals are allowed to be used in food production and storage?
- Which chemicals can be used on food processing premises?
- Limits of the chemical residue in food.
- How to handle, store and apply pesticides in various situations to prevent contamination by biocide chemicals or the pests themselves.

Allowed types of pesticides in the food chain and for general pest control on premises are evaluated and regulated by various government agencies.

- EU: pest control products are regulated by the EU Bio-cidal Products Regulation (Regulation (EU) 528/2012) covering various groups of products aimed to protect people and animals from harmful microorganisms and pests (e.g. disinfectants, pest control products, and preservatives).
- UK: The Health and Safety Executive (HSE) regulates use of pesticides. In this country acts also the Control of Pesticides Regulations (COPR), an older UK national scheme, covering various pest control products.
- US: the continual monitoring and assessment of biocide chemicals to determine if they are safe to be used is under the control of the Environmental Protection Agency (EPA). The US Department of Agriculture analyses pesticide residues in plant products, meat and dairy products, while the Food and Drug Administration (FDA) collects data on residues in processed/ cooked food. This applies both to produced food products and to the imports products. The EPA determines tolerances and

possible risk from exposure to pesticides from multiple sources: food, water, residential and other non-occupational sources.

Chapter 3

Inspection and Auditing of Pests:

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This chapter provides basic knowledge on how to inspect and audit pests and where and the importance of pest inspection and audition in the control process and its success. Tools of inspection are also discussed.

Inspections and audits can be provided to fulfill a number of different requirements, including:

1. Field biologist inspections designed to satisfy auditors' requirements.

2. Additional inspections to supplement existing arrangements.

3. Audits to assess current pest control measures and compliance to specification.

4. Audits to assess "pest status".

5. A useful addition to any series of audits is a quantitative measure of improvement.

3.1. Inspection:

Searching the pest individuals or groups outside and inside the structure. Try to find the rest of places, breeding sites, sites of food

resources and hiding places of pests. This will take place based on finding the pests themselves, its feces, its exuvia (molting cuticle in insects) and sign of feedings and damage. This finding will help in controlling pests while they are outside and before entering buildings. Understanding pest's biology, preferences and behavior is of great important in the inspection process.

3.1.1. Flies inspection:

The outside breeding areas of flies including pet and fresh manure, rotting fruits and vegetables, garbage and damp garbage, decaying organic materials. Inside breeding areas are: trash cans, dirty diapers and rotten foods … etc. The flies rest at sunny surfaces in daytime and under eaves at night.

3.1.2. Ant inspection:

They nest in moist areas outdoors and indoors as well. The possible outdoor nesting sites are firewood piles, under yard debris, in electrical and utility boxes, dirt mounds in the yard and under the structure siding. Indoor, they nest the moist areas like bathrooms and kitchens. It also prefers behind and under electrical equipment, sinks and cabinets, behind wallpaper, in cracks and crevices, and around walls.

3.1.3. Cockroach inspection:

They are nocturnal; it is best inspected at night. They prefer moist-dark areas like bathrooms and kitchens. They look like ants in their places of presence especially indoors. They can be inspected also by the faecesthey leave behind and by the egg cases (called oothecae).

3.1.4. Rodent inspection:

The best time of inspection is at dusk or just after dark. Dust can be used to follow the rodent pathway, because tail drags of rats can be seen in dusty areas. Baby powder or flour can be used for this task. Signs used for rodent inspection are gnawing, fecal pellets and tracks.

3.1.5. Stored Product Pests (SPP) inspection:

Inspection of the materials in the store is the first and basic step. Flight activity, signs of feeding, damage, smell and web formation all are signs for SPP inspection. Some examples of inspection signs for most common SPP are mentioned here. Grain weevils noticed on walls must be breeding in whole grains or on compressed food debris in cracks and crevices. Webbing is an indication of moth infestation. The first sign of mite presence is a fine dust layer on the surface of goods. The minty smell is an indication of the flour mite.

3.2. Tools of inspection:

Inspection of pests takes place by the monitoring process. Different tools can perform such monitoring, such as:

Traps and detectors: whether light, pheromone and food-attractants traps are used. These tools used to determine the time of pest arrival and subsequently the size of pest population. They are generally used for flying pests.

Non-toxic baits used for rodents' inspection in order not to harm non-target animals.

Tracking dust: dusts are used to detect the presence of rodents and for following up the rodent pathway.

Chapter 4

Methods of Pest Control in Food Industry:

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This chapter deals with the control methods used against pests related to food industry. These are preventive, chemical and non-chemical methods.

Any pest control approach includes exclusion, restriction and destruction of the pest. The most important is to exclude pests from entering the buildings mainly by physical barriers. Once the pests succeed in entering, restriction and destruction means should be taken to maintain pest-free conditions. Restriction means creates unfavorable conditions that retard pest harboring and breeding. Destruction methods include all methods help in reducing pest populations to an acceptable level. Any pest control approach consists of one or more of the following control methods: preventive, chemical and non-chemical methods.

4.1. Preventive methods:

The preventive methods are considered the core of the IPM in food industry. It prevents pests from getting closer, enter, damage and disturb the food facilities, workers and the materials used. The building location, design and accessories are important factors in pest attack and pest control.

4.1.1. Building design:

1. **Pest requirements:** Three things inside buildings attract the pests; these are food, warmth and shelter. These attractants must be kept out of pest reach.

2. **Location:** There are sites that attract pests more than others, such as water collection sites, waste collection sites etc.
3. **Choice of vegetation:** some vegetation attracts certain pests and may others repel it.
4. **Water:** standing water may attract pests that need it as breeding site like mosquitoes. Rats populate in the presence of water. Therefore, that good drainage of land is required.

5. **Lighting:** both location and type of light are important. Regarding light type, some insects attracted to UV light, others to infrared light …etc., so type of lighting determines the attractiveness of the site mainly to flying pests. Furthermore, site of lighting is also important, minimum amount of lighting is physically attached to the building is the recommendation.

The use and distribution of more than one small bulb is better than using a single large bulb because the heat is more distributed in the case of small bulbs. Moreover, lighting must not promote birds nesting and must repel insects.

6. **Building perimeter:**

The lower edges of the walls of the buildings should be tilted to allow the water to be discharged away from the building and surrounded by an area of concrete to prevent the growth of the grass near the walls.

7. **Waste areas:**

The waste areas should be kept at least 10 meters away from the buildings so that the buildings remain inaccessible to insects.

8. **Ancillary buildings:**

Continuous cleaning rounds should be carried out around the compounds such as sub-stations to remove the accumulated tree leaves and wastes to prevent exploitation of insects and mice.

9. **Building color schemes:**

The color of the buildings plays a role in attracting pests, especially the insects, so the colors must be undesirable to insects such as dark blue and green.

10. **Building structure:**

The areas between the walls are made of concrete so that the rats cannot dig and enter the buildings, and the floors are smooth and free of cracks and possible use of promising materials such as epoxy-resin.

11. **Services:**

Gas and water pipes and electrical cables must be well sealed where it passes through walls in order not to harbor the pests especially the rodents. Vertical and horizontal ducts may facilitate the insect and rodents movement between floors and from site to site of the floor. Attention must be taken to protect the drains not to fracture to prevent rats from gaining access to cavities of the walls.

12. **Flooring:**

All joints must be sealed very well in order not to allow rodents access to floor cavities and thereby to other building areas. Wastes should be easily removed and this will be achieved by ensuring smooth surfaces especially under equipment. Drainage channels should be sufficiently wide to accommodate expected flow volumes. Ensuring suitable floor surface slope to the floor drains is necessary.

13. **Doorways:**

Exit doors should be made of materials not allowed rodents to gnaw. In addition, doors should be fit and self-closing. Gaps below doors should be smallest and not allowing pest entry. Outside doors must not be like curtain doors, rubber flap-back doors ….etc., because they are not well sealed and allows pest entry.

14. **Windows:**

Windows must be covered with fine mesh to prevent flying insects from entry, windows ledges must design not to allow birds roosts.

15. **Warehousing:**

Pests can enter through the loading bays because doors are left open for a relatively long time during loading and unloading of vehicles, or because of the in-adequate barriers. Packaging material and general waste are often attractive to pests because it is almost compacted in proximity to loading bays. Damage to the fabric of the building is likely because of the continuous use of such areas, therefore, continuous maintenance of these areas is reducing pest invasion. Goods must be stored on racking to be kept off the floor; this will help in good cleaning and easy pest inspection. Good stock rotation methods should be enforced. Returned goods must be kept in their own quarantine place away from packaging and finished goods.

4.1.2. Hygiene:

Effective hygiene is necessary to reduce pest threat. Wet cleaning is promoting pest activity. The following hygiene instructions will lead to less pests and less damage, these are: get rid of poor hygiene to reduce

pest attraction, identifying the hygiene shortfalls by regular inspections for the high risk areas, avoiding factors that attract pests, keeping storage areas at best conditions, maintain in-use and out-use equipment clean and at continuous inspection, and avoiding the availability of water and food resources to the pests.

4.1.3. Waste management:

Location of waste collection places must be far away from buildings, waste bins must be covered tightly and continuously.

4.1.4. Environmental management:

Vegetation around buildings should include plants of a minimum leaf, fruit and seed shedding. Never leave tree branches to touch buildings in order not to form a bridge for crawling insects like ants to enter the buildings. The ground cover must not be dense in order not to provide cover for rodents to harbor under. Never let plants to climb the walls; it harbors pests and forms a route for pest entry as well.

4.2. Chemical control:

4.2.1. Preface: Chemicals are one of the most important methods of pest control. These chemicals could be organic or inorganic, natural or synthetic and called pesticides. Besides these pesticides, there are other chemicals of great importance and promising in IPM programs, including:

Hormones: it secretes inside the insect body, it controls the molting process in insects during its development, and these hormones are becoming manufactured in factories to be used in insect control.

Pheromones: the most important is the sex pheromones, used in insects to attract the other sex. Pheromones are also becoming manufactured in factories.

Furthermore, there are another chemicals being used in pest control but of less important, these are chemo-sterilants, repellants, attractants and anti-metabolites.

4.2.2. Pesticides:

Pesticide is any chemical or mixture of chemicals that aimed to control, prevent, destruct, repel, and reduce any living organism considered as pest. The name of the pesticide is associated with the pest name it is fighting; Acaricide against acari, Avicide against birds, Insecticide against insect...etc.

Chemical control must be the last choice to be used against pests, and if obliged; the safe ones are most preferred.

Pesticides used to control pests in food premises can be grouped- according to pest type- into:

4.2.2.1. Insecticides:

Used to control flies, ants, cockroaches and stored product insects. It can be classified- according to the way they enter the insect body- to: stomach poisons, contact poisons and respiratory poisons. Moreover, it can be classified according to the origin or the chemical composition to:

1. **Inorganic insecticides:** including:

    a. Arsenicals: mainly used in baits
    b. Flourines: mainly used in baits
    c. Inorganic phosphorous: aluminum phosphide used against insects and zinc phosphide used against rodents
2. **Naturally occurring organics:** including oils and insecticides of plant origin (botanicals)
    a. Oils: especially the petroleum oils that can be mixed with baits against pests
    b. Botanicals: like rotenone (from Deriss plant) and nicotine (from tobacco), mainly can be used against insects and acari
3. **Synthetic organics:** includes -based on the chemical composition- the following:
    a. Organo-chlorines
    b. Organophosphates
    c. Carbamates
    d. Synthetic pyrethroids
    e. Miscellaneous compounds

4.2.2.2. Acaricides:

Acaricides can be classified into the following groups:

1. **Inorganic sulfur:** it is of low cost and low toxic to non-target animals
2. **Organic sulfur compounds:** consists of diphenyl group and chlor, effective against acari with least toxic to beneficials

3. **Formamidines:** effective against acari mainly against the egg stage
4. **Carbamates:** it contains oxime group in its composition
5. **Organophosphates:** especially the systemic aliphatic organophosphates and the phenyl derivatives
6. **Pyrethroids:** few are available against acari because they are not systemic, so the few that act as contact poisons and that goes through the digestive system

4.2.2.3. Rodenticides:

It can be divided into two main groups:

1. **Poisonous gases (fumigants):**
    a. Sodium cyanide that can be used in stores and in the field, available as powder.
    b. Aluminum phosphide that also can be used in stores and in the field, available in pellets, tablets, sachets and strips formulation.
2. **Stomach poisons:** generally used in baits with food and attractant materials
    a. Inorganic phosphorous: like elemental phosphorous and zinc phosphide
    b. Anticoagulants: like coumarines (warfarin and coumatetralyl) and indandiones anticoagulants (pindone and diphacinone)
    c. Organochlorines: used as tracking powder
    d. Organophosphates
    e. Organic fluoro compounds: in pellets and poisoned grains
    f. Urea-Thiourea derivatives

g. Pyrimidin derivatives
h. Sterol derivatives: in poisoned grains
i. Thalium derivatives: in poisoned grains or paste

...3 Aviticides:

Repellants are the main approach for bird control. The birds will stay away from such repellants. These are chemical, visual, physical and auditory bird deterrents.

Chemical deterrents: range from:

A. sticky gels.

B. liquid sprays that taste bad.

C. fogging systems.

4.3. Non-chemical methods:

4.3.1. Preface: Pest control includes also actions alternative to the conventional ones based on chemicals and fumigants (methyl bromide and phosphine). Consumer concerns about un-safety issues, environmental impact and risks of the development of resistance to chemical of insects are leading to identify and apply alternative approaches and methodologies. Moreover, in some cases, non-chemical pest control methods can be used also to complement the conventional chemical tools and improve the effectiveness of the pest control action.

These include, among others, mechanical, physical and biological methods.

4.3.1.1. Mechanical methods:

Mechanical methods are only partly effective in pest control but can be applied in combination within a correct Pest Control Management.

These include some physical barriers against insect and pest contamination of the food commodities and food industry

environments. Air curtains protect against insect and dust entry into food establishments and could reduce cold air loss in refrigerated facilities. Air curtains, more effective if the area being protected is under positive air pressure, can be used for personnel doors and entrances large enough for loading trucks or for the passage of large equipment and be complemented by downward-directed fan that sweeps air across the door opening.

4.3.1.2. Physical methods:

The control of pests and insects by physical methods include different types of traps (probe and pheromone traps), manipulation of physical environment, mechanical methods, physical removal, abrasive and inert dusts, light and ionizing radiations and dielectric heating (microwaves, radio frequency).

4.3.1.2.1. Insect light traps:

They use a high-voltage, low amperage current on a conducting grid located in front of a quasi-ultraviolet irradiation source. Flies are attracted by the light source, where they are electrocuted. Some light traps contain a "black light," effective at night, and a "blue light," which is effective in the daytime.

They may be installed to manage and monitor some flying insects and used to complement the protection against certain insects (e.g. Indian meal moths, fruit flies, etc.).

For high effectiveness of this method light traps in food processing plants and warehouses should be installed and placed according to manufacturer's instructions and in compliance with any regulatory policies and guidelines in various location at some distance of the entrances, doors and windows as well as inside the food plant order to

protect both the entrance and path that insects may follow to the processing areas.

Light traps should be placed to maximize insect capture without interfering with facility operations, being visible from the exterior and being likely to attract insects to open food.

4.3.1.2.2. Sticky Traps:

These traps are made of sticky flypaper, pieces of waterproofed cord, or flat pieces of plastic covered with a slow-drying adhesive. They are unspecific and can catch a wide variety of flying insects while some sticky traps contain pheromones so that a specific insect species can be caught.

These traps can be combined with low-voltage light traps to stun at first the insects, which then fall down onto the glue board. This action limit the production of insect fragments and reduces the bug zapping sound generated by the electrocution traps.

4.3.1.2.3. Microwaves and radio frequency methods:

Microwaves are electromagnetic waves with wavelengths ranging from as long as 1 m to as short as 1 mm, or equivalently, with frequencies between 300 MHz (0.3 GHz) and 300 GHz. Radio frequency engineering is based on the use of waves of higher frequency 1 GHz (30 cm), and the upper around 100 GHz (3 mm).

They are energy waves travelling at the light speed rate, reflected by metals, transmitted through electrically neutral materials (e.g. glass, most plastics, ceramics and paper) whilst absorbed by electrically charged materials. Biological materials when exposed to microwaves radiation absorb an amount of energy, which depends on the dielectric characteristics of the material that, in turn, depend on chemical composition and in particular on moisture content. When dry

foodstuffs containing insects are heated, the insects are heated up to lethal temperature because they have higher water content in comparison with the foodstuff which is either left unaffected or gets slightly heated.

Microwave treatments represent, thus, an interesting alternative to chemical methods to kill insects in grain and dry/low moisture commodities (e.g. seeds and grains) as their application do not leave any undesirable residues and thus might be very effective for controlling insect infestation compared to other available methods. The achieved disinfection is recognised as safe and competitive in comparison with fumigation as it avoids environmental pollution. Additional advantages over other pest control methods include the control of all developmental stages of storage pests; short time treatment, increased susceptibility of treated insect to the other stress (e.g. controlled and cold atmosphere); preservation of the product quality; automation of the process.

Microwave methods for disinfestations purposes can be applied in continuous processes and treat large quantities of products in a short time. Process parameters require a specific optimisation to achieve an effective disinfection of insects, without any commodity damage. Critical factors that can affect the microwave heat transfer behaviour are thickness, geometry, and the dielectric properties of the food along with plant aspects including the uniformity of electromagnetic field, cavity effects and workload or product interaction.

Efficient disinfection by microwaves has been observed in tree nuts and pistachios, spices, leaves and exotic fruits. Microwaves have been also experimented in combination with other pest control methods

(irradiation, cold storage) thereby higher disinfection efficiency was observed.

Other potential application fields are the control of insects (quarantine) and mites in stored foods and dried fruits. Mites could also produce allergens with potential impact on food industry workers, consumers and human pets (cats and dogs) health.

Radiofrequency dielectric heating has been applied to control postharvest insects (i.e. fifth-instar orange worm larvae) in nuts (almonds, walnuts, hazelnuts) maintaining the quality of the product.

Some studies evidenced also the potential of additional positive side-effects of the use of both microwave and radio frequency energy for insect disinfection on the food product as the process can also determine enzymes and microbial inactivation, thereby an increased shelf-life and safety of the product can be achieved.

4.3.1.2.4. Inert dusts:

Milled diatomaceous earth can also be used to control insects. The microscopic particles of the diatom shell produced by milling have an easy path to penetrate the insects' wax coating whenever contact is made, causing moisture depletion and death. When shell particles enter the body cavity, they could also interfere with digestion, reproduction and respiration.

4.3.1.3. Biological methods:

Integrated pest management (IPM) programs could include also biological control. Among others, the most widely used biological control schemes for the control of phytophagous insects is the development and incorporation of host plant resistance achieved by the use of plant species that are known to be refractory to attack (e.g. incorporation of gene splicing, recombinant DNA manipulation). Other

approaches include the use of viruses, fungi, and bacteria to produce diseases in specific pests and of growth regulators, hormones, and pheromones that can influence sexual activity, primarily those aimed to sterilize male pests.

Growth regulators that interrupt the life cycle of insects and prevent their development in the pupal stage have been evaluated to control mosquitoes, fleas, and other insects.

Pheromone Traps

Pheromones are chemical substances emitted by insects to communicate with others and to induce a certain behavioural response of the same species. They have different names depending on the exploited effect. The aggregation (acting on both sex insects) and sex (only acting on male insects) attractant pheromones have become important tools for monitoring and controlling agricultural pest populations and complement pest control strategies. In general, pheromones are unsaturated esters, alcohols, and aldehydes, and species specificity is governed by the identity of the different components of the pheromone blend and by their relative proportions in the mixture. Over 1600 pheromones and sex attractants has been defined in the past four decades.

Pheromones traps can be used in pest management for detection and monitoring, mass trapping and mating disruption in the insects.

Natural and synthetic sex attractant pheromones lure male insects into sticky traps where they become permanently trapped and die. Sex pheromones can be also used in chamber traps where the insects are caught. Some include also a plastic funnel leading into the reception chamber, which contains an insecticide strip.

Innovative products are based on microencapsulated pheromones that provide a slow chemical release over a long period of time.

Abbreviations:

GMP- Good Manufacturing Practices

HACCP-Hazard Analysis and Critical Control Points

FSA- Food Standards Agency

IPM- Integrated Pest Management

FDA- Food and Drug Administration

CDC- Centres for Disease Control and Prevention

USDA- United States Department of Agriculture

HSE- The Health and Safety Executive

COPR-Control of Pesticides Regulations

EPA- Environmental Protection Agency

SOPs-Standard Operating Procedures

FSMA-Food Safety Modernization Act

GFSI- Global Food Safety Initiative

SPP- Stored Product Pests

DNA-Deoxyribonucleic acid

DDT-Dichloro Diphenyl Trichloroethane

BPCA/RSPH-Best Pharmaceuticals for Children Act/Royal Society for Public Health

NVQ-National Vocational Qualifications

SLA- Service Level Agreement

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